TOPICAL REPORT

Reporting Period Start Date: July, 2001

Reporting Period End Date: December, 2002

Principal Authors: Wayne Place, Chuck Ladd, TC Howard

Date Report was issued: December, 2002

DOE Award Number: DE-FC26-99FT40645

Name and Address of submitting organization:

Synergetic, Inc.
122 Cox Avenue
Raleigh, NC 27605
919 832-4011
919 247-3372

DISCLAIMER:

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United State Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Refernces herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

ABSTRACT

SYNERGETICS, INC., is in the process of designing, developing, and testing an air handling duct system that integrates the air duct with the cornice trim of interior spaces. The device has the advantage that the normal thermal losses from ducts into unconditioned attics and crawl spaces can be totally eliminated by bringing the ducts internal to the conditioned space. The following report details work conducted in the second budget period to develop the Cornice Duct System into a viable product for use in a variety of residential or small commercial building settings. A full-scale prototype has been fabricated and tested in a laboratory test building. Based on the results of that testing, the prototype design has been refined, fabricated, installed, and extensively tested in a residential laboratory house. The testing indicates that the device gives substantially superior performance to a standard air distribution system in terms of energy performance and thermal comfort. A patent has been submitted, refined based on feedback from the patent office, and resubmitted. Additional refinements to the design will lead to additional claims being added to the patent in the near future. Designs are being finalized for a refined version that will be fabricated and tested in the same residential laboratory house. Work is expected to be complete on this project in April of 2003.

INTRODUCTION:

Current residential construction in the United States is based overwhelmingly on wood framing. This system is very efficient structurally and very economical to build. However, the system was developed before the advent of central heating and cooling. As a consequence, the system never had a provision for thermal air distribution. The "patch" to the system has been to run ducts through unconditioned attics and crawlspaces, where 30 to 40% of the energy can be lost before the air arrives at the conditioned space. These losses could be eliminated by bring the air distribution ducts internal to the thermal envelope of the residence. Typical commercial methods for dealing with this problem, such as hiding the ducts above a hung ceiling, have not proven to be aesthetically acceptable in the residential market. The current project is directed at developing a product that will be aesthetically compatible with residential visual standards, while keeping the ducts internal to the conditioned space.

EXECUTIVE SUMMARY

Good progress is being made on all tasks.

Based on lessons learned in the fabrication and testing of the device, significant refinements have been made to the design of the Cornice Duct to improve both the quality and economy of the device. A version of the device embodying these refinements will be fabricated and tested. The refinements to the design are being incorporated into the final version of the patent.

Some tasks are a few months behind schedule and a no-cost extension to April 2003 has been requested.

PROJECT ACCOMPLISHMENTS AND STATUS (ON A TASK-BY-TASK BASIS):

In the following narrative:

Each task in the contract statement of work is stated in normal text, followed by

an explanation of progress on, and the status of, that task in italic text.

Task 2.1 – Component Fabrication

Based on the design and manufacturing techniques developed in Budget Period 1, the Recipient shall fabricate all full-scale prototype components necessary for installation of a complete Cornice Duct System in the Laboratory House.

This task has been completed.

Task 2.2 – System Installation

The Recipient shall install a complete Cornice Duct System and related HVAC equipment in the laboratory house. The layout of the Cornice Duct System shall allow the system to be tested under different configurations, including 1) Duct runs around the perimeters of the house, and 2) a more centralized configuration that minimizes overall duct length. The Recipient shall balance the system for each test configuration to insure that the air distribution conforms to the design dictates. The recipient shall install test instrumentation in the laboratory house to carry out the testing protocol developed in budget period 1. Instrumentation shall include, but not be limited to:

- Instruments for each room in the laboratory house to acquire air distribution, temperature, and acoustic data.
- Instrumentation of the heat pump and air handling fans to acquire electricity consumption data.
- Installation of exterior weather data acquisition sensors to monitor temperature, humidity, and wind velocity at periodic intervals.

The laboratory house shall be equipped with an instrumented, conventional-duct HVAC system to allow comparison with the Cornice Duct System.

The recipient shall conduct all check-out, calibration, shake down, and related activities necessary to prepare for testing performed under Task 2.3.

This task is complete, except for the acoustic data.

Action Item for DOE:

The acoustic data referred to above has not been taken. The Recipient is now of the opinion that normal human hearing is adequate to make this acoustic assessment and the Recipient is hereby requesting that the acoustic data be dropped as a requirement of this project.

Task 2.3 – Full-Scale Prototype System Testing

The Recipient shall conduct testing of the laboratory house HVAC systems that incorporate the conventional duct system and the Cornice Duct System in accordance with the approved testing protocol developed in Task 1.4.

This work has been underway since April 2002 and will be complete by the end of April 2003.

Action Item for DOE:

This work is behind schedule by a few months. The Recipient would like to request a no-cost extension of the contract until the end of April 2003 in order to complete this work.

Experiments

The following is a brief summary of the experiments that have been performed to date at the test house. Testing is still in progress and a detailed report including the raw data will be compiled upon test completion.

Introduction

Before the end of the heating season (during February and early March of 2002), several observations were made in the house:

- 1. As predicted based on the previous experiments, substantial amounts of air are being delivered to all parts of the network in the test house.*
- 2. Delivering air on multiple sides of a room appears to be counterproductive, creating a tendency for conditioned air to collide at the center of the room. When the air is being delivered horizontally across the ceiling (from the openings at the front/top of the Cornice Ducts), the air collides at the center of the room and then descends on the heads of the occupants. In contrast, air delivery on one side appears to be smoother and more effective, leading to a greater level of human comfort.*
- 3. The surfaces of the ducts are fairly warm in the vicinity of the heat pump, indicating that a fair amount of the heat is conducting through the walls of the duct and is being delivered to the space by radiant and convective transfer from the surfaces of the ducts. This suggests the desirability of minimizing the length of duct runs. Of course, minimizing duct runs also has economic advantages.*
- 4. At the ends of duct runs, the heat degradation is apparent, with air being delivered at a perceptibly reduced temperature. This effect is most pronounced at the ends of the long runs, but it is even observable within a single room when the conditioned air is being delivered to the room by the duct on the outside wall of the room. Again, this suggests the desirability of minimizing the length of duct runs.*

Items 2, 3, and 4 above were addressed by limiting the output flow of the cornice duct system to only one wall for each room. The flow pattern used for these experiments is shown in the following drawing.

Figure 1 - cornice duct flow arrangement

Power measurement testing

Power measurement testing involved alternately operating the conventional and cornice duct systems at a set temperature while measuring the environmental conditions both inside and outside the test house. Power consumption was measured using kilowatt-hour meters installed on the HVAC compressor and fan (one meter each) and verified using the utility installed kilowatt-hour meter. Environmental conditions were measured inside the test house using the standard HVAC thermostat, with local temperature and humidity sensors, and with air velocity meters. Environmental data for external conditions was collected from the National Weather Service (WS Form F-6, local climatological data from the Raleigh-Durham Intl. Airport) and from the NC State Solar Center, which is less than half a mile from the laboratory house. Cooling system power consumption data was collected from 23 April until 26 September 2002 and has been completed. Data is still being collected for the heating system power consumption tests. That data collection will continue until a total of one year of performance data has been collected.

The cooling system power consumption tests are summarized in the charts on the next page. The power use for these tests was compared to the degree-days of cooling for the testing period. These comparisons show a substantial and consistent energy savings for the cornice duct system versus the conventional ducting. The energy use per day for the tests has been included but this data varies based on external environmental conditions during the test and is therefore not an indication of the relative efficiencies of the two systems.

Note: Cooling degree-days are notorious for being skewed by solar gains and internal heat sources in the building. However, the impact of these factors was kept to a minimum, because we have a laboratory house with no occupants to generate internal heat loading and because windows were kept fairly well shaded to avoid large inputs of solar heat. Therefore, normalizing the data based on cooling degree-days can be argued to have validity in this experimental situation.

Room temperature testing

The temperature was measured in various locations in a single room in the test house. These tests were started on 26 June 2002 and are still in progress. The results of the completed tests are summarized in the chart below. The variance of temperature between sensors in the test room never exceeded 1 degree F (the sensors are accurate to ± 0.1 degree F). A variety of arrays of temperature sensors were used. The highest standard deviations of temperatures were observed during the two tests where the sensors were distributed at different heights in the room (the tests starting on 2 July and 13 July). In these tests, as expected, the highest reading sensor (T02) was located physically higher than the other three sensors.

Air velocity measurements

Air velocity was measured using a handheld air velocity meter. Conventional system air velocity measurements were taken at each register and at the return air intake. Air velocity measurements for the cornice duct system were taken at the return air register for comparison with the conventional system. Measurements were also taken at the outlets of the cornice ducts and qualitatively assessed to be satisfactory. The air velocity data indicates a consistent quantity of air is delivered for both systems to all rooms in the test house. It was also observed that the difference in sensed air velocities across the spaces was lower with the cornice duct system than with the conventional system.

List of test instrumentation

Power: Amprobe model # WH2VIA1P3W kilowatt-hour meters (2).

*Air velocity: Alnor model RVA rotation vane anemometer.
Bacharach Flo-Rite air velocity meter.*

*Temperature: Dickson Model TX-120 temperature and humidity meter/logger.
Dickson Model SX-100 temperature meter/loggers (3).*

Task 2.4 – Computer Modeling.

The Recipient shall conduct Computational Fluid Dynamic modeling of the room air distribution provided by the Cornice Duct System in each configuration tested in the laboratory house (e.g., perimeter supply and central supply). Modeling of the room air distribution provided by the conventional duct system (e.g., grills and diffusers) shall also be conducted. This modeling is intended to yield graphical depictions of the air velocity and temperature distributions produced by the Cornice Duct and conventional duct systems for comparison. Modeling shall be conducted for at least two rooms of the laboratory house. Modeling of the air flow within specific components of the cornice duct system (e.g., at a corner) shall also be conducted.

After extensive investigation and assessment, the Recipient does not believe that this is the most productive approach to advancing understanding of this system. More rapid and economical insights can be generated by expanding the experiment studies. This opinion has been reinforced by John Van Osdal of NETL. Of particular concern to the Recipient is fabricating and testing recent design advances that have emerged from the experimental tests and from the experience of fabricating the ducts for the laboratory house.

Action Item for DOE:

Recipient has requested that the \$45K originally allocated for software acquisition for Task 2.4 – Computer Modeling be made available for fabricating, installing, and testing advanced versions of the Cornice Duct that have emerged out of the experience of the last two years. This request has been made to Kelly MacDonald and William Haslebacher and they have given verbal approval, conditional on the fact that it will be a no-cost revision to the contract. The money would be spent on extrusions for the new version of the

Cornice Duct and on labor for installation, experimental testing, and evaluation. The precise distribution of labor among Synergetics personnel, technicians, consultants, and subcontractors is not known at this time. However, the recipient wants to emphasize that this work is particularly crucial to moving the product more rapidly toward market viability and action will be taken in the very near future to initiate the fabrication of extrusion dies. (See next section for more details on the new design.)

Task 2.5 – Product Evaluation

The recipient shall evaluate all data acquired in Task 2.3 with regards to performance and cost of the Cornice Duct System and with regards to any design or manufacturing refinements necessary to improve the system and make it commercially available.

The Recipient shall develop design guidelines, specifications, and cost projections for the Cornice Duct System derived from the work set forth in this proposal.

The Recipient shall develop detailed architectural information on an assortment of Cornice Duct System profiles and details for a variety of residential applications. The residential applications shall include application of the Cornice Duct System to ranch, raised ranch, split level, and multistory house styles. Connection of the air handling unit(s) shall be considered and described.

The Recipient shall compile the design guidelines, cost projections, specifications, architectural information, and ~~modeling~~ experimental results, in formats that can be used to present the Cornice Duct System to potential installers and manufacturers and at industry conferences.

This work is underway and will be completed by the end of April 2003.

Many refinements have been made to the original design of the Cornice Duct and those refinements are being finalized for fabrication at this time. These refinements are also being described for incorporation into the patent. In the process, specifications and cost projections are being developed. Among the changes being made in the device are the following:

- 1. The openings for air are redesigned so that they are not visible to any persons anywhere in the occupied space, regardless of how far away from the ducts they are standing. This will enhance the visual appearance of the product.*
- 2. The openings for air are configured to enhance laminar flow across the ceiling, since this appears to be the most promising method of achieving good thermal comfort and minimal system cost.*
- 3. The controls for the openings have been redesigned to eliminate the need for the costly fabrication operation of punching and also to eliminate the high tolerances required to assure alignment of punched openings.*
- 4. The design has been simplified in terms of the number of parts and in terms of the procedures for assembly. These simplifications will apply to*

both the ducts and the corner boxes. The latter will be totally eliminated from the basic version of the system.

- 5. Lighting has been incorporated into the Cornice Duct.*
- 6. A version has been generated that is strong enough to use as a shelf. For economy reasons, this device will probably most often be used on only one side of the room. In this arrangement, it will no longer be perceived as a cornice. In the light of that fact, the salability of the device may be enhanced by mounting the device lower on the wall and promoting it as decorative shelf. Mounting it lower on the wall also enhances the performance of lighting incorporated into the device, since the light source will be further from the ceiling, thereby allowing more uniform distribution of light on the ceiling and reducing the severity of the angle of the light incident on the ceiling, which is problematical in highlighting flaws in the ceiling.*

Efforts are currently underway to identify a set of houses to be used as the illustrative examples for the design guidelines.

We have been in touch with Phil Spartz of the California Energy Commission, who is interested in using the Cornice Duct in some of their demonstration houses. This seems like a good opportunity to accelerate the process of adoption.

We are having conversations with Arun Vohra about doing an article and presentation for the next ASHRAE conference.