



# **SIMPLE, LOW-COST "CLOSED-LOOP INTELLIGENT PROGRAMMABLE CONTROL" FOR SINGLE-PHASE AC ASYNCHRONOUS INDUCTION MOTORS IN HVAC&R SYSTEMS USING "OPTICAL/GRAPHICAL PROGRAMMING"**

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*Market Assessment*

*Prepared for*

U.S. Department of Energy  
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by

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# EXECUTIVE SUMMARY

## Introduction

The subject technology, **Simple, Low-Cost “Closed-Loop Intelligent Programmable Control” for Single-Phase AC Asynchronous Induction Motors in HVAC&R Systems Using “Optical/Graphical Programming”**, is designed to offer increased control of electric motors, enabling them to be used in a continuous variable-speed capacity. The technology can be retrofit for older systems or used in original equipment, dramatically increasing the efficiency and functionality of the furnaces, heat pumps, and air conditioners (HVAC) units.

## Technology Overview

Over the past 20 years, more than 85 million air conditioners and heat pumps were produced for use in the U.S., many of which were manufactured with single-phase electric motors. Indeed, electric motors account for as much as 50 percent of the total energy consumed in the U.S. Due to the design and operation of the single-phase, fixed-speed motor, however, much of this energy is not used efficiently. The use of variable speed motors in the HVAC industry has improved the efficiency of the units while reducing audible noise and improving the air quality. However, most efforts have used new motors along with digital controls, resulting in complex systems with unit-specific designs to make the new motor and new controls compatible.

The subject technology offers a new approach to the problem. The **Closed-Loop Intelligent Programmable Control** utilizes a simple, generic system to drive single-phase motors and several other types of HVAC designs. Early tests using the Optical/Graphical Programmed Encoder (OPE) have shown reductions in air-conditioner motor electricity consumption from 20 to 60 percent versus single-speed operation.

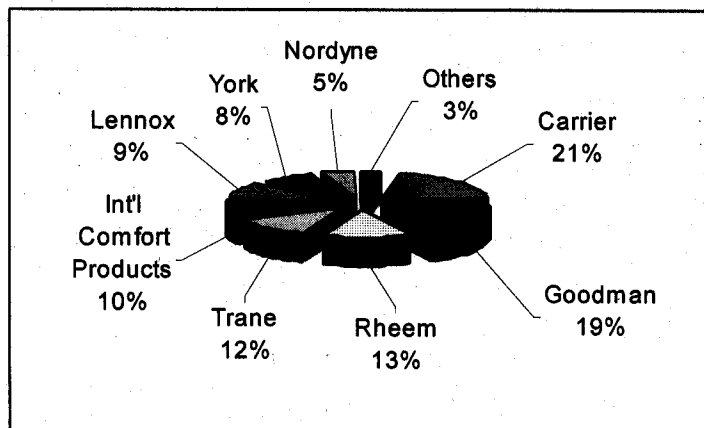
## Market Overview

The HVAC market is characterized by the following features:

- In 1999, sales of fixed-speed blower fans exceeded 8 million units and continues to increase.
- From 1998 through 2000, annual shipments of HVAC systems have exceeded 6 million.
- Stricter efficiency standards from the U.S. DOE to be implemented by 2006 will benefit variable-speed technologies.

### SHARE-OF-MARKET PICTURE FOR 1997

**ACs/HEAT PUMPS (UNITARY) 5,359,858**



Source: APPLIANCE MAGAZINE, SEPTEMBER 1998

Most of the HVAC industry experts, manufacturers, distributors, and contractors interviewed for this market assessment expressed significant interest in the performance claims of the subject technology. In particular, three of the top seven HVAC manufacturers in the industry expressed serious interest in learning more about the technology, while an industry engineering group offered to test the technology.

According to the research, a variable-speed motor technology that can provide greater energy efficiency with more

reliability and at a lesser cost than existing variable-speed units should be well received by the industry. Further, it is anticipated that distributors and contractors will follow the lead of the HVAC manufacturers. At the same time, it is clear that HVAC manufacturers will consider implementation of a new technology only after extensive and conclusive field testing has demonstrated its capabilities.

## Barriers and Opportunities to Market Entry

Barriers include:

- acceptance by the industry;
- concerns about retrofit compatibility; and
- competition with existing technology.

Market opportunities include:

- testing opportunity;
- significant industry interest;
- growth in the HVAC industry; and
- shift to more energy-efficient HVAC units.

## Conclusion

The high sales of HVAC units in the past – and the forecasts of a sustained market over the next few years – demonstrate a considerable opportunity for the subject technology. The U.S. DOE has also increased minimum efficiency standards that will be in place by 2006. These factors working in parallel could help open the market to the subject technology as manufacturers seek to develop more energy-efficient units at a lower cost.



The general opinion of the industry seems to be that the market is ready for new technology, demonstrated by increased sales of diverse energy-efficient systems. However, with new technology comes the burden of proving efficiency and reliability claims. It seems that acceptance of the subject technology can be attained, but this can only be accomplished by demonstrating the reliability and effectiveness of the subject technology through testing procedures.

Research for this assessment found possible assistance to aid in the testing process. An independent engineering company expressed interest in testing the subject technology in their facility. In addition, upon verification of the test results, two and possibly three major HVAC manufacturers have stated they will be interested in seriously considering implementation of the technology in their systems.

## Introduction

Single-phase alternating current (AC) motors are used in numerous residential products, including furnaces, heat pumps, and air conditioners (HVAC). HVAC motors are primary targets for improved operation and efficiency, as most are fixed speed and among the greatest consumers of electricity in a home.

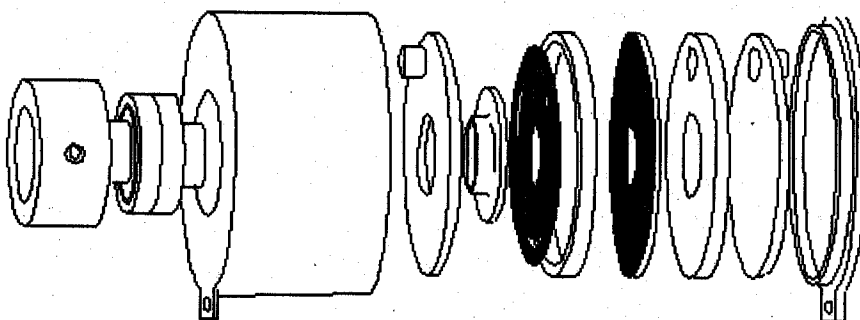
Using variable-speed instead of fixed-speed motors reduces energy consumption and noise while improving air quality and comfort. Most efforts to implement these new systems focus on the use of digital controls with new motors. These efforts produce the desired outcome, but with undesirable side effects. Also, these new motors and controllers are generally unit specific, typically utilized only in new systems, and often much more complex and costly than the original AC units replaced.

The subject technology, **Simple, Low-Cost "Closed-Loop Intelligent Programmable Control" for Single-Phase AC Asynchronous Induction Motors in HVAC&R Systems Using "Optical/Graphical Programming,"** is an innovation designed to increase the energy efficiency of HVAC systems by providing simple, generic, variable-speed control to several types of motors, including single-phase AC motors. According to the developer, Opto Generic Devices, Inc., this technology increases energy efficiency and can be fitted for older systems or used in original equipment.

## Technology Overview

The emphasis to produce more energy-efficient systems is now at the forefront of most HVAC manufacturers' research and development activities. The subject technology, **Closed-Loop Intelligent Programmable Control**, offers a simple control solution that could be easily integrated into any new system or retrofit into existing HVAC units.

**Figure 1: Optical/Graphical Programmed Encoder**



Source: Opto Generic Devices, Inc.

The control function is processed by means of the Optical/Graphical Programmed Encoder (OPE). The OPE can perform data computation, analyze complex math algorithms, and solve equations and functions without using



current computing techniques. The encoder functions much like an intelligent sensor with an embedded digital micro or digital signal processor, but does not need or use any micros, software, look-up tables, digital clocks, etc., to execute its motion-control programs. The technology offers a simple single package that uses motion data and produces a direct compatible signal. The encoder relies on three processes for its control function:

### Input Data

Converts analog motion into analog electromagnetic data (radiant energy) that is directly input, clocked, or moved into the Motion Processing Unit (MPU) via direct connection to the shaft motion.

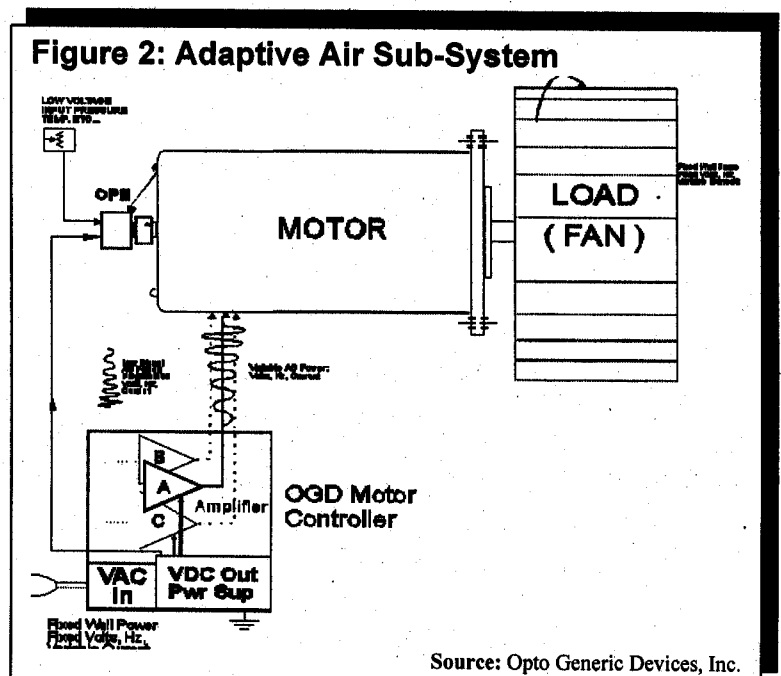
### Process Data

Graphical programs interact directly with the radiant energy by modulation or mixing the analog shaft motion with the graphically programmed instructions, creating dynamic real-time electromagnetic signals that are clocked or co-processed by the shaft's movement.

### Output Results

The MPU converts the modulation real-time electromagnetic data directly into real-time electric signals (digital or analog), which can be directly amplified without conversion to high power for direct use by the analog motor, which converts it back to analog motion.

This method of motor control is not limited to single-phase AC induction motors, but it has been chosen to power the variable air-moving fan sub-system used in HVAC units. The subject technology is a combination of several products to create an Adaptive Air Sub-System, capable of dynamically adjusting



air flow to air temperature or other external-control parameters. Initial lab prototypes have shown reductions of 20 to 60 percent in electricity consumption versus single-speed operation.

The complete Adaptive Air Sub-System is made up of five elements:

1. programmed Encoder that generates the control and feedback signals;
2. variable direct current (DC) rail power supply; converts AC wall power to DC;
3. analog power driver/amplifier, a simple, low-frequency "dumb" amplifier;
4. single-phase AC induction motor; and
5. forward-curve "squirrel cage" blower and housing.

The complete Adaptive Air Sub-System should fit into the same physical dimensions of an equivalent fixed-speed system and can be a drop-in replacement. The system could be a retrofit for existing HVAC units or integrated into original equipment.

Conventional technology currently utilizes digital motor control to operate the new variable-speed HVAC systems. This technology has proven to be effective in increasing efficiency, reducing audible noise, and improving air quality and comfort. However, due to the complexity of these systems, reliability can be somewhat questionable, and the cost is often double or triple that of a typical single-speed system. In contrast, the **Closed-Loop Intelligent Programmable Control** technology represents a simple, generic alternative to the current variable-speed technology at a price within 30 percent of an equivalent fixed air blower. Without having to replace the entire unit, the benefits of variable-speed technology may be available with significant savings.

## Market Environment

### Market Overview

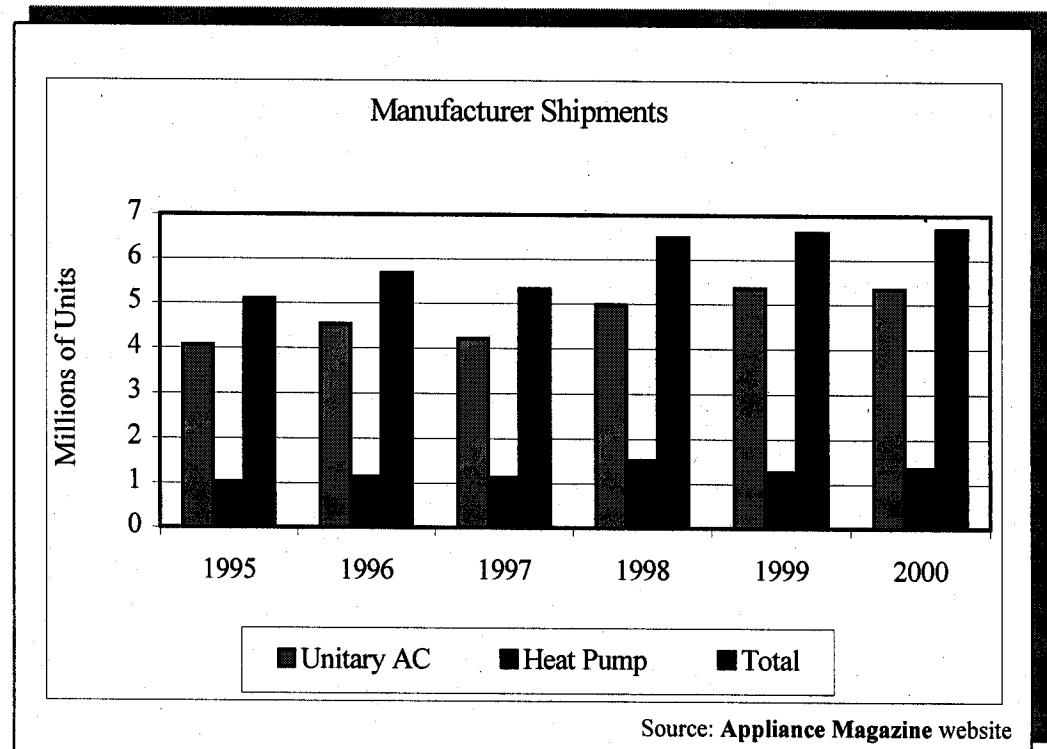
The residential HVAC market is a multi-billion dollar industry dominated by a few manufacturers controlling over 90 percent of the total market share in the U.S. These market shares are shown in the Executive Summary.

Sales of HVAC units continue to rise. Figure 3 below illustrates that manufacturer shipments of central air conditioners and heat pumps have exceeded 5 million units every year since 1995, with this figure topping 6 million units for each of the last 3 years. In a



recent **Appliance Magazine** article describing industry forecasts, the Gas Appliance Manufacturers Association (GAMA) projects a continuing increase in the HVAC market for the period 2000 to 2004. These projections are driven primarily by the GAMA members' perception of market forces including: the future general economy, estimates of single-family housing starts, selection of equipment with increased efficiency during home improvements and commercial up grades, world and national fuel pricing, and replacement/modernization projections.

Reuben Autry, President of GAMA, confirmed the industry's forecasts that shipments should be up 2.28 percent in 2000, 2.63 percent in 2001, and 3.8 percent in 2002. However, while replacement activity will keep HVAC equipment shipments very close to last year's record levels in 2000, 3 consecutive record years will have significantly reduced the number of old units at risk of failure, thereby limiting replacement opportunities for competing systems that require a complete new furnace. This development could actually improve the upgrade replacement market opportunities for the OPE system, as someone who has recently purchased a new system is more likely to upgrade rather than buy another new system.



Even with replacement opportunities possibly diminishing in the next few years, retrofit opportunities should still be strong as consumers look for more energy-efficient systems.

In 1999, U.S. sales of fixed-speed blower fans in the HVAC industry were more than eight million units, representing market potential in the hundreds of millions of dollars. Perhaps the greatest indicator for retrofit technology is the 85 million air conditioners and heat pumps that have been produced for use in the U.S. over the past 20 years. The subject technology offers a viable alternative to a new fixed-speed system, with all the benefits of variable-speed operation and at a significantly lower price.

The average price for a very typical 2 ½ ton, single-speed HVAC unit is approximately \$1,200 to \$2,000. The more efficient multi-speed units range from \$2,500 to \$3,500, and the variable-speed units sell as high as \$5,000. However, the price for only the blower unit (the unit to be replaced by the proposed retrofit adaptive air sub-system) is significantly lower by approximately \$250 for the single-speed systems and up to \$500 for the top-end variable-speed systems. According to Opto Generic Devices, Inc., the proposed sub-system will be offered at a cost within 30 percent of the single-speed price. This would offer the benefits and increased efficiency of 20 to 60 percent over single-speed units. At this price, there would also be savings of up to 10 to 50 percent over current multi-speed units.

The record sales of HVAC units over the past few years indicate an extremely active market, and the projections for the next few years show continued record sales. The market potential for the subject technology seems to be significant in the Original Equipment Manufacturer (OEM) markets if the HVAC manufacturers appear interested in the technology and are willing to implement its use in their energy-efficient HVAC units.

### **Industry Interviews**

In an effort to further define the subject technology's market potential, interviews were conducted with a number of HVAC industry representatives. Leaders in HVAC research and design, representatives with major governing organizations, top manufacturers and with regional and local distributors were questioned to determine how the technology might be received and what barriers and opportunities it might encounter.

**Dr. Jeff Haberl**, Associate Professor of HVAC design and efficiency in the School of Architecture at Texas A&M University, along with **Dr. Dennis O'Neil**, also with Texas A&M University, stated that the market is crowded with variable-speed technologies. Both agree the subject technology will have to prove its effectiveness and reliability, but



if this can be done satisfactorily, acceptance is very possible. Although companies currently offer retrofit systems, none would be priced as low or offer a simple, generic replacement like the subject technology. The price of the system would be the key to breaking into the market due to existing products that offer many of the same benefits.

**Dr. Warren Heffington**, an Associate Professor conducting research in energy-efficient HVAC equipment in the Mechanical Engineering Department at Texas A&M University and also serving as Director of the Industrial Assessment Center, expressed some of the same opinions as Haberl. Heffington believes the subject technology is a good idea, but agrees the awardee will have to prove the system's performance and reliability. He did not balk at the energy-savings claims of 20 to 60 percent, but stated he would like to see test data to confirm these claims. Heffington expressed doubts about the possibility of entering the market through contractors, but did suggest that if tests and demonstrations can verify the product's reliability, manufacturers would likely be interested, and then the contractors will follow.

**Steve Szymurski**, Director of Research for the Air Conditioning and Refrigeration Institute (ARI), the HVAC industry's governing body, expressed doubts regarding the retrofit application for the technology. Szymurski sees possible compatibility problems with the different components associated with the various types of systems now available on the market. **Craig Becker**, a residential Sales Manager with Trane, also noted these potential compatibility issues. He indicated, however, that if the motor control functions as the awardee claims, Trane and probably other manufacturers will be interested.

**Bruce Hunn**, Technology Director for the American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc. (ASHRAE), explained that a market does exist for retrofit technology and that some manufacturers currently offer such service, but cost and dependability are the limiting factors. Hunn was uncertain how the awardee should proceed to move the **Closed-Loop Intelligent Programmable Control** into the marketplace, but he expressed confidence it will be accepted if its capabilities can be satisfactorily proven.

**Glenn Friedman**, Technical Manager for the Air Conditioner Contractors of America (ACCA), parted from the other interviewees and expressed doubts about the technology. He believes that even if the **Closed-Loop Intelligent Programmable Control's** claims can be verified, it will have a difficult time penetrating the current market, because existing variable-speed technologies are not likely to be pushed out of the market easily.

Representatives from the manufacturing industry showed interest in the subject technology, especially with new Department of Energy (DOE) efficiency standards looming in the next five years. Most HVAC manufacturers currently offer variable-speed technology, but due to a mandated 12 Savings Energy Efficiency Rating (SEER) efficiency rating mandated by the U.S. DOE for implementation by 2006, lower-priced alternatives would be greatly beneficial. Due to the historically high price of variable-speed units, manufacturers are greatly interested in a lower-priced, variable-speed technology, especially if efficiency and reliability claims are proven.

Specifically, **Bill Farris**, Residential Product Manager for Outside Systems for York International Corporation, and **Bob Kowynia**, Sales Director for Lennox Industries, Inc., stated that their respective companies would be interested in evaluating the subject technology and subsequently adopting it if the evaluations are positive. Additionally, **Travis Manning**, Control Specialist for Hannasch Electric-Magnum Engineering, which designs industrial and residential HVAC systems, sees great potential for the subject technology, not only in the HVAC industry, but also in any industry that requires electric-motor control. Manning was another interviewee who expressed interest in testing the **Closed-Loop Intelligent Programmable Control** technology in their facility.

Regional and local distributors generally mirrored the opinions of the HVAC manufacturers. Distributors have seen a large increase in sales of more energy-efficient systems. **Neil Henderson**, Service Manager for REC Industries, and **J. D. Rudd**, Service Manager for JC Innovative Services, suggested this increase can be attributed to higher energy costs and the extra savings associated with the units. Informing the public of the benefits of these more efficient systems has also been a key factor with increasing popularity, according to **Leslie Davis**, Sales Manager of Houston Area Distribution for American Standard. **Dennis Onowen**, Inside Trade Specialist with Trane, stated that increased sales of more efficient HVAC units is mainly due to increased efforts to inform the public of the possible savings. All of these contacts agreed, however, that even more variable-speed units would be sold if they were not typically 25 to 50 percent more expensive.

When questioned regarding the reliability and overall opinion of the new variable-speed units, distributors were for the most part complimentary of the subject technology, with the exception of its price. **Gilbert Lavender**, President and Owner of Lavco AC, and **Curtis Powell**, Service Representative for Barkers Heating and Cooling, Inc., also expressed concern regarding the digital control systems for these units. The complex

nature of the digital controls and circuits are inherently more problematic than the more simple, single-speed alternatives. Lavender and Powell seemed interested in a simple, variable-speed control, but made it clear that all manufacturers require repairs to be made with original manufactured replacement parts.

## Competitive Environment

While there do not appear to be any technologies on the market today that offer substantially the same type of motor control and retrofit capabilities as the subject technology, other variable-speed HVAC systems are available. Older, single-phase units have also been converted to variable speed without having to replace the entire HVAC system. These systems are identified and described below, together with a comparison between them and the subject technology.

### Pulse Width Modulation (PWM)

A large majority of variable-speed systems operate by PWM control systems. As discussed in a 1997 article by I. Panahi in *Energy Design News*, a digital system is used to generate PWM signals. A microprocessor contains approximate value look-up tables that estimate the speed of the motor for given conditions. These values are used to calculate what type of PWM signal should be used to drive the motor at the determined speed. The PWM systems then send digital power pulses to an analog motor. The electric motor must convert, transform, and smooth the switched digital power pulses into a continuous analog electric signal.

**Advantages of PWM over OPE** — The main advantage of a system controlled by PWM is its acceptance in the HVAC industry as a relatively efficient way to obtain variable speed. While Opto Generic Devices, Inc., has an extensive and excellent record, the Optical Programming in the encoder to date has a limited history. Results from the limited installations are very positive, but more testing must occur to gain acceptance from the manufacturers and the industry in general.

**Advantages of OPE over PWM** — The main advantage that the proposed OPE has over PWM technology is the very method by which the PWM control functions. Panahi's article in *Energy Design News* illustrates the difference in these two methods. The PWM microprocessor contains approximate look-up tables that estimate what signal should be used to drive the motor at the determined speed. Because approximate values are used to estimate motor speed, the PWM signal could be inaccurate. This inaccuracy reduces the efficiency of the motor and the fan's airflow effectiveness. In contrast, the

OPE control offers continuously variable speed, or continuously adaptive airflow, matching optimum motor efficiency to the HVAC current conditions.

Another major advantage of the OPE is the simple, generic nature of the control system. A PWM system is very complex, increasing the number of components necessary to offer the variable-speed control. The additional components are more prone to malfunction, which could in turn, lead to increased costs. PWM control systems also require the motor to be fitted to the PWM system. A PWM system may also require the motor to be re-engineered, at an increase in cost, to handle high voltage, high frequency, transient signals (often necessitating an inverter-duty motor). PWM is a series of high-speed, high-power, digital voltage pulses that use varying duty cycles (on/off times) that must be absorbed and averaged by the motor into varying voltage and current levels. The OPE system, on the other hand, is analog, which means it can be easily adapted to control any type of electric motor to re-create a smooth analog sine wave.

### **Electronically Commutated Motor (ECM)**

An article by M. Valenti in *Mechanical Engineering* describes the programmable ECM as a brushless DC permanent-magnet motor that uses electronic controls to operate the motor. The efficiency of the system derives from its ability to adjust to temperatures. When the air temperature is low, the motor is run at less than full capacity, which conserves energy. When the temperature increases, the motor speed will also increase. Because the motor adjusts to temperature, its efficiency can increase up to 20 percent over typical motors.

**Advantages of ECM over OPE** — The only major advantage of an ECM system over an OPE system is that ECM systems are already used in the HVAC industry. These systems have been proven to function very efficiently and are accepted by the industry. However, the ECM system suffers from some of the same problems associated with PWM systems. In particular, it uses a DC motor, and if any part of the system malfunctions, the motor will not – and cannot – operate in a back-up or fixed-speed mode.

**Advantages of OPE over ECM** — One major advantage of an OPE system over an ECM system is illustrated in a 1998 article by Z. Yu in *Appliance Manufacturer*. This article notes that ECM systems must specifically use a DC motor, whereas the OPE system can use any motor. This difference could increase repair costs for ECM systems, while the OPE system has the flexibility to be used with whichever motor results in the best overall system value.



Additional disadvantages of the ECM system result from the complex nature and high cost of the system. In a 1998 article in **Appliance**, author P. Davis explains that ECM systems contain a microchip that must be programmed with the motor's specifications. This step could require a trained technician to go to the manufacturer or to the installation site to program the system with the proper parameters. This process adds even further to the cost of the ECM system, which is already more expensive than the OPE system. The ECM systems claim its energy savings recover the cost of the system within 6 to 18 months. An OPE system, however, can be fit to an existing HVAC unit, so the consumer will be able to start saving money almost immediately.

Still another drawback of the ECM system is its complexity. Like the PWM control system, this complexity can lead to a greater potential for malfunction. In comparison, the simple design of the OPE system has been initially tested to be very reliable.

The PWM and ECM systems appear to be the major technologies used in variable-speed control. Both of these systems are established in the HVAC industry and have proven to be effective motor controls for increasing the efficiency of HVAC units. However, the OPE system does have distinct advantages over both of these systems. These advantages include the ability to offer continuous variable-speed control, the capability to match current conditions with maximum motor efficiency, system simplicity, and the ability to be retrofit to any motor being used in the industry.

The only disadvantage the OPE system has is its lack of testing and presence in the industry. Once the technology has been sufficiently tested and results documented, the OPE system should compare favorably with competing technologies in the industry.

## **Market-Entry Barriers And Opportunities**

### **Barriers to Market Entry**

The research conducted for this market assessment identified several market-entry barriers the subject technology should expect to encounter along its commercialization path. These barriers are described below:

- **Existing Technology** — Although no technology currently exists that offers substantially similar retrofit and motor-control capabilities, variable-speed technology is currently available on the HVAC market. These technologies have proven to be somewhat reliable and have increased the energy efficiency over fixed-

speed motor systems. However, cost, complexity, installation issues, and field repairs impede more widespread use.

- **Reluctance to Try an Unproven Technology** — The HVAC industry, manufacturers, and contractors are understandably unwilling to implement an unproven technology. Because most HVAC manufacturers currently have some type of variable-speed technology available, the industry is in no hurry to switch to the **Closed-Loop Intelligent Programmable Control** technology without proven results. Contractors also expressed reluctance to try a new product that is not currently being used by manufacturers. In addition, most repairs by the contractors must be made with original manufactured parts when still under warranty, making it virtually impossible to move into the market through the normal contractor distribution channels.
- **Retrofit Capability** — Some concerns were expressed regarding the retrofit unit's compatibility with all of the components of an HVAC system. Again, acceptance of this aspect of the subject technology is possible with test results and documentation.

## Market Opportunities

Research also identified some very promising opportunities for the subject technology:

- **Testing Opportunity** — Travis Manning, Control Specialist for Hannasch Electric/Magnum Engineering, expressed great interest in the subject technology. Manning offered to test the technology at the company's facility.
- **Significant Industry Interest** — There is substantial interest in the subject technology's benefits in the industry. Lennox's Sales Director Bob Kowynia and York International's Product Manager Bill Farris both stated that once the efficiency claims and reliability issues are proven, their respective companies may be interested in implementing the technology.
- **Growth in the HVAC Industry** — The industry has experienced record sales in each of the past three years, and forecasts project these growth numbers will continue over the next three years. The real benefits of variable speed are well established, and as awareness grows and cost drops, variable speed could become the

norm. In addition, along with the new units to be manufactured, tens of millions of older units have been installed in homes around the county, providing a huge retrofit market.

- **Shift To More Energy-Efficient HVAC Units** — The industry continues to shift to more efficient HVAC units to reduce energy consumption. This shift will be even more pronounced in the near future with the implementation of the DOE mandated 12 SEER efficiency rating scheduled to take effect in 2006.

## Conclusion

In recent years, many mechanical systems such as air conditioners have moved from fixed-speed to variable-speed in order to achieve higher comfort levels, lower energy consumption, higher system reliability, and lower noise levels. To achieve these goals, manufacturers have turned to a variety of different motors and controls. These systems, however, are very complex and often designed around a specific motor or system. As such, they are also much more costly.

The subject technology, a **Closed-Loop Intelligent Programmable Control** system, offers an impressive list of benefits through a simple, universal method of control at a significantly lower price. This technology is designed to be applied in both original equipment and in a retrofit capacity for existing units. If the technology is retrofit, the savings can be two to three times that of a new single-speed unit and up to ten times that of a new variable-speed unit.

The market in the HVAC industry is currently expanding. Each of the last three years has documented record sales, and projections for the next few years are to sustain such sales records or increase them. Perhaps even more important are the more than 85 million HVAC systems that have been produced and installed over the last 20 years. These in-place units represent a huge market for the subject technology's retrofit capabilities, especially given the preference of the retrofit option relative to replacing an entire HVAC system or having to upgrade to a new costly variable-speed motor.

Although variable-speed technology is available in residential HVAC units, current technologies appear to be costly and highly complex with more potential for operational problems. Based on feedback for this report, the HVAC industry is ready for a variable-speed technology that can increase energy efficiency in a less complex, more reliable manner.

Even so, the industry is reluctant to implement a new product without extensive real-world information and testing. Once the subject technology has successfully completed this phase of development, however, at least two major HVAC manufacturers – Lennox and York – have expressed significant interest in evaluating the technology. In addition, an independent engineering company that designs commercial and residential HVAC systems expressed a great deal of interest in the technology and offered to help test the product in a proper environment.

The developer of the subject technology has already produced several working prototypes, and initial test results have shown 20 to 60 percent efficiency gains versus single-speed operation. There seems to be considerable market interest if testing can be performed on a larger scale to show a history of reliable use and maintained efficiency levels. Once testing results satisfy the industry, it appears significant commercial potential exists for the subject technology.



## PROJECT REVIEW

This market assessment began with a review of the materials submitted to the U.S. Department of Energy by the awardee, Opto Generic Devices, Inc., and further information was obtained in an interview with the president of the company, Mr. Ormonde G. Durham III. The submitted information and the interview assisted the investigator in narrowing the areas of primary and secondary research and focus on the objective of the market assessment. The interview was particularly helpful in pinpointing the main benefits of the subject technology, its stage of development, potential markets, and the perceived competitive environment.

Literature searches were then conducted using the Internet and business and news databases, such as *LEXIS-NEXIS*, *Business Browser*, *CompTech*, and *D&B Marketplace*. The purpose of this initial secondary research was to explore the current market and identify possible competition. This process also helped identify key associations and industry contacts. Homepages of associations such as the Air Conditioning and Refrigeration Institute (ARI), the American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc. (ASHRAE), and the Air Conditioning Contractors of America (ACCA) provided useful industry data and contacts. A search of associated articles and reports also provided key information regarding the current market environment and future projections.

Research was then focused on interviews to obtain a more detailed description of the industry. These contacts were most valuable in identifying and providing information regarding competing technologies and the market potential of the subject technology.

The interviews included contacts with several specific groups including: ARI, ASHRAE, and ACCA. Several leading researchers, referred to the analyst through contacts at associated organizations, were then contacted to discuss their opinions of the subject technology and its market potential. In addition, representatives from several large manufacturing companies were interviewed to discuss current market trends and technologies.

The discussions with the manufacturing representatives provided necessary information on entering the market and what barriers might be faced. Finally, several regional and local distributors and contractors were interviewed to discuss their current sales trends and whether or not it would be feasible for a new technology to enter the market at this

level. Again, the information gained during these discussions was essential to the evaluation of the market potential for the subject technology.

Suggestions from the awardee involving technical aspects of the technology were also appreciated. These suggestions would have been more helpful, however, if they had been received in a more timely manner to give more time for follow-up questions with individuals in the industry. Several attempts to contact representatives that had been previously interviewed were made, but these attempts were not successful. However, it is the opinion of the investigator that the secondary research and the previous interviews held with industry experts offer sufficient information to complete an accurate and objective assessment of the subject technology's market potential.

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