Getting the Kinks Out of High-Efficiency Furnaces

by Frank Green

The hvac industry reacted quickly to the "energy crunch" of the mid-1970s by making major changes in natural-gas furnace design. Perhaps they acted too quickly, becuase the dramatic new designs brought with them design errors, recalls, and a host of complaints. Contractors today have reason to be concerned abut product reliability.

Most major manufacturers, however, have gone through several generations of design. With nearly a decade of field experience behind them now, the units' reliability has greatly improved, and we know a lot more about the products, installation methods, and maintenance procedures.

Squeezing Out Btus

The "standard" older gas furnace gave up its high-temperature combustion products (water vapor, carbon dioxide, and acids) to a simple vent. The vent kept the gases hot enough to prevent the water vapor from condensing before leaving the flue. But usable heating Btus escaped also.

To improve efficiency, designers added power burners or power venters to force air through the unit and control the combustion air. They also increased the heat exchanger's surface area to extract more heat from the combustion gases before they left the furnace (see Figure 1).

To extract even more heat, engineers looked next to the water vapor, which is a normal product of combustion. By keeping the combustion products inside the furnace longer, designers were able to condense the water vapor and extract its latent heat.

This boosted AFUE ratings into the 83- to 97-percent range compared to standard furnaces, which range from 58 to 65 percent. (AFUE is a rating of average efficiency over the heating season.) One problem remained, however. The condensed water had to go somewhere. The slight acidity of the condensate meant heat-exchanger materials might rust out prematurely. The standard, cold-rolled, "mild" steel used for years in gas furnaces wouldn't work in condensing furnaces.

A furnace technician tests the controls on a condensing furnace during an annual tuneup. Special training and knowledge of electronics is needed.

The New Generation of Gas Furnaces Won't Fall to Rust, but They Will Need Extra Maintenance

Design and testing among major furnace manufacturers led to the use of a special type of stainless steel. Severla early condensing furnaces used the stainless steel only on the secondary heat exchanger, where the actual condensing occcurred. Mild steel was used for the primary heat exchanger. Designers thought it would always be hot enough to prevent condensation. Unfortunately, during the "off-cycle" the moisture remaining in the secondary heat exchanger migrated into the primary section and corroded theheat exchanger.

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The current generation of condensing furnaces switched to stainless steel for all components—heat exchangers and burners. This combination of materials has improved the products' lifespan to the point where manufacturers are willing to warrant materials for the "lifetime" of the original purchaser.

Products on the market now should be relatively free of catastrophic problems—that is, those that would result in total failure of the unit. As with any complex man-made mechanical device, however, you'll never get an absolute guarantee they will be trouble-free (see "Getting Burned with High-Tech Heaters").

Installation Quirks

Installing a condensing furnace presents its own set of problems. The builder should have a general knowledge of what the hvac contractor is trying to accomplish.

Condensate. First, the condensate must be piped away, but only from the furnace but in some cases from the vent too. Early on, code officials worried about the slightly acidic condensate being discharged into a sewer. Tests of condensate pH, however, showed it to be no more acidic than tomato juice. Combined with other disposal liquids, it was harmless. Most local codes now allow condensate to drain into the sewer. The general contractor can help

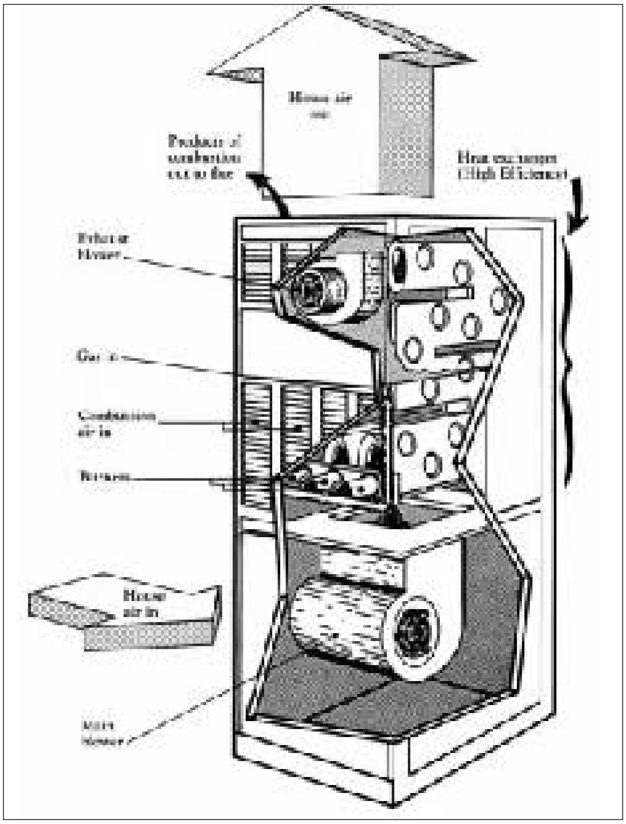

Figure 1. *To make furnaces more efficient, engineers made the path through the heat exchanger longer, as shown in the diagram. In addition, combustion air on many units was drawn through the furnace by a power vent or a power burner. Such "near-condensing" furnaces achieve AFUEs in the 75 to 83 percent range.*

Getting Burned with High-Tech Heaters

by Richard Trethewey

When *The Journal* asked me to offer my observations about high-efficiency condensing furances, I sat back and thought about our experience to date. When I thought about it, I started to get angry. I am part of a fourth-generation 85-year-old heating and plumbing company. We have always, as a company, tried to be a leader in our area. Being a leader means that you try out new products. But some new products hit the marketplace before their time or without proper testing, and this leaves you wide open to a bruising if the product backfires.

I don't want to be a "naysayer" to new technology—to these "dream boxes" that can go anywhere, vent to the outside, and give you terrific efficiency. To be anti-efficiency is to be unAmerican or subversive. But I don't want to use myself or my customers as guinea pigs. So I have a problem.

Having just traveled to Europe on a trip that was dedicated to heating technology, I discovered a continent of manufacturers who test, test again, and then retest their products in the laboratory before they ever put them out in the marketplace. They even have training schools in their factories. Sadly, in my experience, this is not the case in this country.

The condensing furnace has evolved, like all gas-heating technology, from the first "shoe box" gas furnace. Those first very basic gas furnaces offered efficiencies in the 60 percent range. (This was at a time when 60 percent seemed efficient.) They slowly evolved as the furnace manufacturers added spark ignition, vent dampers, and a little higher-efficiency heat exchangers. Furnaces started to move into the 70 percent range.

In our quest for progress, during our energy unrest in the 1970s, we needed to take that 70-percent efficiency and go even higher. Condensing furnaces now are offered with efficiencies over 90 percent. But the closer you get to a 100 percent efficiency, the more troublesome the combustion process is.

When these high efficiency units strive for perfect combustion, water vapor in the exhaust gases becomes a problem. In the 80 percent to 90 percent ranges, these furnaces "condense." The water vapor condensing on the combustion side of the heat exchanger mixes with the products of combustion, forming a corrosive acid liquid. Already some manufacturers are experiencing corrosion problems with these units. Two manufacturers I know of have discovered that all their heat exchangers must be replaced. A recall warning addressed 60,000 units in the field.

About four years ago I sat down with condominium developers, to talk about an upcoming job. They informed me that they needed heating, cooling, and hot water. They had no chimneys for me. And they had a small, awkward space under the stairs in the center of the building in which to place the utilities. The project posed an interesting dilemma.

At about the same time, a newcomer arrived on the scene—a company that advertised heavily, and I mean heavily, in the trade magazines. You couldn't open a trade magazine without spotting this orange furnace and boiler. I discovered they were part of a parent company that was large and very successful. I liked that. I found that this product "scratched my itch." It made hot water. It could vent anywhere. It came in the size and shape I needed for the condos. Well, the euphoria was unbelievable, kind of like a new girlfriend: I thought we could dance all night. I immediately became a "dealer." I got all the technical manuals. The rep came in for technical training. And the world was a nice place.

What I've since discovered is that, yes, these units are beautiful to look at and have beautiful literature. They reminded me of a Maserati, a sleek high-performance car. But like a Maserati, they need special full-time care to keep them out of the shop.

The first things we discovered was that the manufacturer (I'm sure they aren't alone on this), had changed the inside of the product several times without updating the technical manuals. Any time we worked on it, the main office would say "Oh yeah, we've changed that to a . . ." Then one of the heat exchangers melted down. As I expected, the rep told me, "It's an installation error." Maybe it was. But it had been checked by the rep when the job was completed, because I didn't want to hear that remark.

They also forgot to tell us about maintenance until the units had been sitting in the condos for over a year. Then it was up to us to tell the owners that every year, a trained serviceman should come, disassemble the entire furnace, remove the burner assembly (down inside a canister), dip it in coil cleaner, brush it, flush it, hang it up to dry, them reassemble it, readjust the spark ignition, and put it all back together again. And the customer was supposed to pay for two to three hours work. We couldn't find this anywhere in the glossy literature when we first danced with this manufacturer.

And now, the final chapter on this project is that we're getting complaints about rust on the exchanger, which we now have to address. Perhaps this manufacturer's timing was bad. One result is that I'm writing this article with some serious bruises.

In retrospect, I've specified condensing furnaces due more to fit and application than to pure energy savings. I am really not sure if the extra 5 percent annual efficiency is worth it, considering the additional cost of the unit, the additional cost of its installation to deal with the condensate, as well as the additional cost for regular maintenance to keep this Maserati running. At this point in our history, I'm just not sure if we are doing our customers a service.

So what to do? I feel like a fighter in the late rounds of the fight, who's a little dizzy, but still dedicated to keep on keepin' on. I refuse to give up on high technology, but I am cautious about that left hook. To protect yourself and your customers, I suggest you stay away from the new or marginal players in the furnace market. I think, in this case, the R&D departments from the "big boys" in the industry would make me feel more comfortable. Look for established contractors experienced with this level of technology to install the equipment. Finally, don't give up on high-efficiency and condensing technology.

Our energy future is ready and primed for a new crisis. The contractors who are providing high-efficiency energy equipment (and can maintain it), as well as high-efficiency homes, should be in a prime market when the energy tide turns.

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Sizing The Heating System

by Robert Dvorchik

A well-insulated building doesn't guarantee lower heating bills unless the heating system is specifically matched to the building and not oversized. For this to happen, the builder and heating contractor should discuss their options. Before sizing a heating system the heating contractor should consider the insulation quality of the house and the relative cost of locally available fuels. But most important, there needs to be a standardized measure of a heating system's efficiency.

Efficiency. When a manufacturer claims a heating system is "high-efficiency," what does that mean? "High efficiency" is like "all-natural." There's no legal definition of either. If a manufacturer states, "this heating system extracts 86 percent of heat from fuel," is that system 86-percent efficient? Yes and no.

The 86 percent may be an accurate measure of the combustion efficiency (see Figure A), or how much heat is extracted from the fuel while the system is running continuously. But in real buildings, heating systems cycle on and off, so we need an efficiency measurement that accounts for these "off-cycle" losses.

What's your car's mileage when it's warming up in the driveway? You're burning fuel, but not going anywhere. Similarly, combustion efficiency does not account for the time it takes a gas or oil burner to raise the mass of the heating system to operating temperature. Nor does it account for the heat lost up the flue after the burner shuts off.

The AFUE. The "annual fuel utilization efficiency" (AFUE) was developed by the Department of Energy to better predict real-world fuel efficiency. The AFUE, determined by a Department of Energy formula, accoaunts for off-cycle losses, operating losses (heat up the flue) and jacket loss, so it will always be lower than the combustion efficiency. It's based on a lab test, not a field test, but it is a standardized measurement— sometimes compared to the EPA mileage rating for cars. All gas and oil central-heating systems sized for residential and light-commercial must have an AFUE rating (see Figure B). It rates the annual efficiency of a sysstem, not how many Btus a system can deliver (that's the "heating capacity").

Systems with a low 65-percent AFUE are available, and some people install them for their low initial cost. Typical mid-efficiency equipment ranges from 80 to 85 percent. Systems rated at 90 percent and above can get expensive, but the additional costs may be justified in houses with relatively high heating costs. Several high-efficiency units can save you money by not requiring a standard masonry chimney. This can compensate in part for the higher system costs.

Fuel costs. Most people think a high AFUE always means low energy costs. But first consider local fuel prices. Where I live, a 95-percent-AFUE propane system would cost 25 percent more to operate than a 91-percent AFUE oil system because propane is relatively expensive in my area. You must check the per-Btu price of different fuels so you can compare apples to apples (see Figure C).

Spec the AFUE. Check out the AFUE of different systems early in the design process. I sometimes spec a minimum acceptable AFUE, and I ask contractors to submit two bids, one for am id-range system, and another for an AFUE of above 90 percent. Document the AFUE through the manufacturer's specification or in one of several commonly available guides, such as the Institute of Boilers and Radiators' I=B=R Boiler Rating and Efficiencies, available for $9.50 from the Hydronics Institute (P.O. Box 218, Berkeley Heights, NJ 07922; 201/464-8200), or the Gas Appliance Manufacturer's Association's publication, GAmA, which rates warm-air products. It comes out twice yearly, and it is available for $5 an issue from ETL Testing Labs, Inc. (Industrial Park, 3933 U.S. Rt 11, Cortland, NY 13045; 607/753-6711).

Oversizing. A heating system must be sized to deliver the heat required for comfort in the most severe winter weather expected. But a system that puts out significantly more heat than needed will have amuch higher annual fuel cost. Here's why. An oversized system very quickly satisfies the thermostat's call for heat, and then the burner shuts down. Shortly, the building temperature drops below the thermostat's threshold setting, and the burner will fire, and so on, leading to frequent cycling. This can lead to substantial off-cycle losses of betwene 5 and 14 percent, with some burners losing as much as 20 percent. A car in stop-and-go traffic gets fewer miles per gallon than a car cruising at a steady 60. The same goes for yourheating system.

Why oversize? Because the heating contractor is obliged to install a system that delivers enough heat, he may intenationally oversize a system. He wants to guarantee against a mid-winter complaint that the interior temperature won't climb above 50°F even though the heating system is running continually.

When fuel was cheap, oversizing was a recommended procedure. Even now, heating capacity is often determined by a rule of thumb; that is, X Btus per square foot. But this can't be very accurate because not every square foot of a building has been insulated equally, nor is every house the same.

Houses differ. Should a 2,000-square-foot home with R-11 wall insulation, R-19 ceilings, and standard windows receive the same size heating system as a home of identical size but with R-26 walls, R-40 ceilings, and high-performance glass? Did the heating contractors bidding on your last job even ask what the proposed insulation levels were? Or did your bid specs simply require a "high-efficiency" system? Get a heat-loss calculation. Sizing is best done with a heat-loss calculation. It calculates the number of Btus lostper hour through the walls and windows, at the design temperature (the coldest expected winter conditions). A heat-loss calculation applies a formula to every component of the building shell. For instance, you need to calculate heat loss through the total areas of windows, wals, doors, roof, etc. You need to know—or, on older buildings, estimate—the R value of each component of thehouse.

Your heating contrractor should ask for the information necesary for this calculation, and the building plans should clearly specify this information. But I routinely find this is not the case.

Commonly, equipment wholesalers will prepare a heat-loss calculation, along with a distribution system layout, at the request of the contractor. I was once in the office of a wholesale distributor when a plumber made such a request. But he didn't have a clue as to the proposed insulation levels, so they oversized.

Compare heat-loss calculations. Every calculation has its subjective elements, so don't be alarmed if three competing contractors submit different ones. But if each bid is substantially different, start to wonder. On a recent job, one bidder insisted that a 400,000 Btu system was necesary, but I had calculated 250,000 was called for. When I offered to compare heat losses, it turned out he hadn't done one, and used a rule of thumb of 90 Btus per square foot.

Account for losses. The "actual heating capacity" is the system you size with. It is the amount of heat in Btus delivered to the living space of the house while the system is running continuously. It is different from the combustion efficiency and different from the AFUE, becuase it accounts for the distribution losses in the operating of the heating system. It is the figure you size with. Often, manufacturers provide actual heating capacity, but sometimes only the Btu output is given (combustion efficiency times input rating). You must account for losses from even well-insulated distribution systems. If only the Btu output is given, allow anywhere from a low 15 percent to a conservative 40 percent of additional heat loss.

Servicing. Providing service for a high-efficiency system can be a problem if the system is exotic. Many systems will shut down for safety reasons, parts may be scarce, and trained service people lacking. So be aware that service may be more specialized. You may want to include a service contract as part of the bid specs.

By discussing the efficiency, sizing, and future service of your system with your heating contractor, you can keep these problems to a minimum.

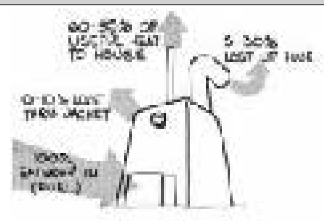

Figure A. *Combination efficiency. The percentage of a fuel's energy converted to usable heat and not lost up the flue during steady-state combustion. This does not account for off-cycle losses, jacket losses, or distribution losses.*

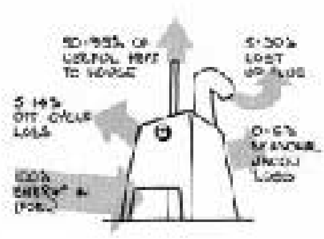

Figure B. *AFUE Annual fuel utilization efficiency. The percentage of a fuel's energy available to heat the building over the heating season. It accounts for off-cycle losses, jacket losses, and draft control and combustion makeup air. It is based on laboratory testing and standardized formulas.*

Heat Value of Fuels

Fuel	*Unit*	*Btus/unit*
Oil	gallon	138,000
Kerosene	gallon	130,000
Propane/lpg	gallon	91,000
Natural gas	therm	100,000
Electricity	kilowatt-hour	3,414
Mixed wood	cord	17,000,000

Note: to compare fuel costs, calculate the cost per million Btus ($/MBTU) for each fuel considered. Use the formula:

$$\$MBtus = \frac{(1{,}000{,}000) \text{ X } (\$/\text{unit of fuel})}{(\text{Btus/unit of fuel}) \text{ X } (\text{AFUE})}$$

For example, if oil costs $1.25 per gallon and the heating system AFUE is 85 percent, the cost per million Btus would be:

$$\frac{(\$1{,}000{,}000) \text{ X } \$1.25)}{(138{,}000) \text{ X } (.85)} = \$10.66$$

Figure C. *A high AFUE doesn't always mean low energy costs because the cost of different fuels varies. Check the per-Btu price of fuels so you can compare apples to apples.*

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out the hvac sub by putting in a drain near the furnace. Condensate drain methods are now well established in the hvac industry.

Noise. Noise and vibration, more than condensate, can create headaches for the installer and general contractor. Most condensing furances have higher airflows to absorb the additional heat coming from the added heat-exchanger surface. This higher airflow produces more sound and vibration. You have to insulate for sound, and isolate the vibration.

Fiberglass duct liner in the first 6 feet of the suply and return ducts, or even in the plenums only, will do much to absorb sound. Flexible connectors in either the plenums or main ducts isolate vibration and keep the floor joists from becoming "sounding boards." Even more vibration can be eliminated byusing vibration pads beneath the furnace base.

Room air temperature. Another problem with the increased airflow is the lower temperature of the supply air delivered to individual rooms. If supply outlets blow this cooler air directly onto occupants, you'll get complaints. Proper system design provides "noncritical" air delivery. In other words, put the outlets where they won't blow on people.

Sizing the system. Generally, most qualified hvac dealers will use the ACCA (Air Conditioning Contractors of America) Manual J as their method for calculating capacity requirements.

Use a perimeter design for distribution. Deliver the supply air to each room on its outside walls, with a blanket of air directed upwards. This blanket of air covers the room heat loss at the plce where it occurs. It also provides imperceptible air motion for the occupants. The same system design works well for summer cooling. When remodeling, you may have to move or adjust the existing ducts and supply registers to keep air away from occupants. The installer should also size the furnace accurately. Make sure he does a heat-loss calculation instead of just replacing the old furnace with a high-efficiency unit having the same Btus. Slightly "oversizing" a furnace can wreak havoc with comfort conditions. An oversized furnace cycles more frequently, giving longer "off" times. Room occupants won't feel as comfortable.

Venting. Venting systems have undergone the same changes as the furnaces themselves. At first, installers put in aluminum vent piping with tightly taped joints. The piping had to be sloped back to the furnace so condensate within the vent would drain back to the condensate drain of the furnace. This system didn't work. A second try at "coated" metals also fell flat.

Better materials such as the high-temperature plastic used in Ultravent (Hart & Cooley, Inc., Holland, Wis.) are now available for furnaces at the low end of the high-efficiency range (up to about 90 percent AFUE). However, as furnace efficiencies rise, the flue-gas temperatures decrease. With true condensing furnaces (roughly 90 to 97 percent AFUE), plastic PVC vents can often be used. Furthermore, furnaces with a power venter or power burner can push the products of combustion out through the vent pipe to the outdoors. With these furnaces, contractors can use an inexpensive side vent rather than a vertical vent or chimney (see Figure 2).

One caution! In general, a high-efficiency furnace cannot have its vent combined with any other gas-fired appliance, such as a water heater. Follow the manufacturer's venting instructions to the letter.

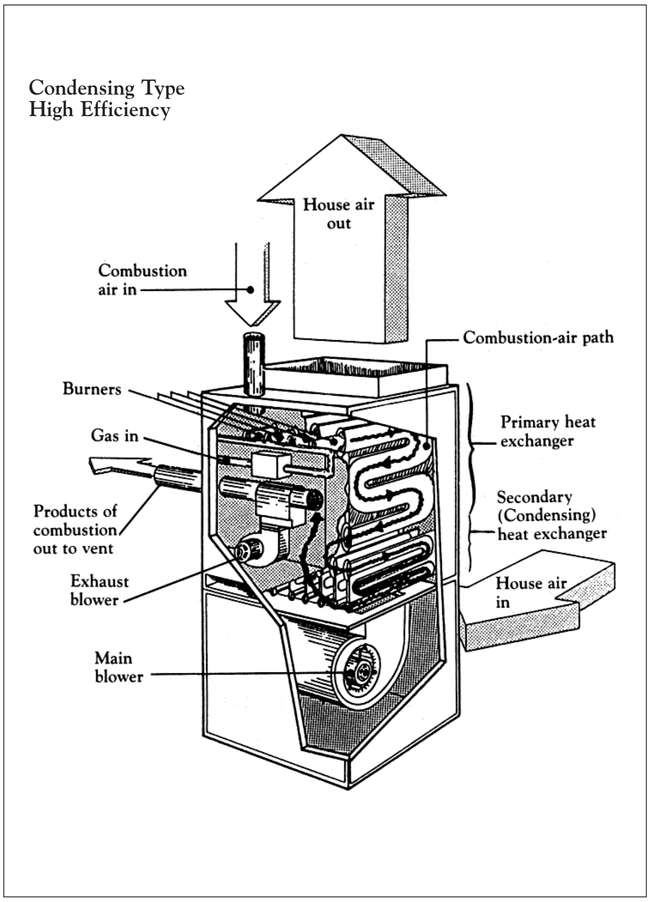

Figure 2. *The condensing furnace tries to capture every possible Btu by using a primary and secondary heat exchanger. Some units use an exhaust blower to vent the products of combustion out a PVC pipe. AFUE ratings range from about 90 to 97 percent.*

Maintenance

Maintaining condensing furnaces is slightly different than maintenance for standard furnaces. Condensing furnaces are equipped with additional operating and safety controls. The serviceworker must have special training. Untrained personnel shouldn't install or service condensing furnaces. Unqualified work can result in dangerous malfunctions.

Some maintenance procedures can be handled by anyone. Cleaning air filters, for example, is a task homeowners should perform. AFUE ratings are based on the furnace maintaining its rated air flow. A dirty filter or any other airflow restrriction will reduce the over-all effidiency of the unit and increase operating costs. Homeowners need to check the condensate drain and the venting system. If either system becomes blocked, the furnace safety controls will shut the furnace off. A yearly service inspection prior to theheating season is recommended. If cooling is also included in the same system, then another inspection before the cooling season begins is prudent.

As a general precaution, stick with a known brand of furnace and rely on a qualified hvac dealer for installation and service. Work with a dealer who adheres to industry standards. Generally, it's the dealer and local distriubtor who follow through on in-warranty and out-of-warranty service. Check the fine print in the manufacturer's written warranty to see what typeof protection it provides.

High-efficiency gas furnaces are here to stay. But they do require additional technical expertise and maintenance. Current products are excellent investments and will perform as expected as long as they are installed and maintained properly. ■

Frank Green recently retired from a career as National Product Manager and Sales Manager for Johnson Corp. (now Magic Chef Air Conditioning), which manufactures high-efficiency furnaces. He is now with Evergreen Marketing Services, in Columbus, Ohio.