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Energy Design Update®

The Monthly Newsletter on Energy-Efficient Housing, from CUTTER INFORMATION CORP.

Residential Heating Systems

CUTTER INFORMATION CORP.

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Residential Heating Systems

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INTRODUCTION

The way we heat and cool houses is changing dramatically. The equipment now being installed in new and existing houses bears little resemblance to that which was installed 20 years ago. If current trends continue, the next 20 years may bring similar advances. Some of the changes that have taken place are simply the result of advanced technology, where engineering innovation has created the ability to provide environmental control with greater efficiency, safety, and economy. But many of the changes are the result of shifting demands of occupants and changing characteristics of houses.

Comfort and Health

The primary new occupant demand with regard to residential mechanical systems pertains to indoor air quality. With all the media attention to the issue of radon entry into houses plus latent concern over formaldehyde, nitrogen oxides, and other potentially harmful air contaminants, there is a growing demand among the consuming public for a means to provide clean, healthy air indoors.

In response to this demand, whole-house ventilation systems and high-efficiency air treatment systems, including filtration, electrostatic precipitation, humidification, and dehumidification, are being developed and incorporated into new and existing houses. While these systems are not heating systems, *per se*, they do interface with and affect the design of the house heating system. For example, air treatment of any kind obviously requires air circulation -- thus a tendency toward forced-air heating distribution.

New Improved Mechanical Systems for New Improved Housing

New housing is better insulated and more tightly built than that of twenty years ago. Most new houses don't need 150,000 Btu/hr heating systems. Even in the northern U.S. and Canada, houses with design heating loads of 15,000 to 25,000 Btu/hr are not uncommon. Sometimes the required space heating capacity is not much greater or perhaps even less than the required domestic-water heating capacity. To avoid discomfort and off-cycle efficiency losses of oversized systems, small central heating systems are needed. One important trend has been toward integration of space heater and water heater into a single unit.

Tightly-built houses also need heating systems that are immune to backdrafting and which don't have to fight with other appliances for combustion air. The heating system must be able to work together with a mechanical ventilation system. Although for the most part, major appliance manufacturers have not yet joined in, integrated heating and ventilation appliances have made a successful penetration into the residential marketplace.

HIGH-EFFICIENCY FURNACES AND BOILERS

In the Beginning . . .

The following product announcement appeared in the January 1983, edition of Energy Design Update:

"Recuperative Gas Furnace Which Needs No Chimney

A new gas-furnace heating system manufactured by Arkla Industries recycles hot flue gases until they are cooled to between 150° and 225°F. (Normal flue-gas temperature for a conventional gas furnace is between 300° and 500°F.) The low flue-gas temperature, combined with a power venting system, eliminates the need for a chimney. The relatively cool gases are exhausted through a three-inch pipe which can be installed vertically or horizontally through ceiling or wall. The smallest unit is 40,000 Btu/hr. For more information . . ."

The Arkla furnace, referred to as a "recuperative" furnace, was developed by Smith Jones Corporation. Arkla not only sold the unit under its own name, but also produced it for Trane, GE, and others.

There Were Problems

The Arkla furnace did produce high efficiency, but it suffered from severe heat exchanger corrosion problems. It was one clear indication that producing reliable high-efficiency gas furnaces would not be simple.

Today, nearly every major appliance manufacturer produces a medium- and/or high-efficiency furnace and, although there are still bugs to be worked out, the future of this technology is promising.

What Makes a High-efficiency Furnace?

The basic principle of building a high-efficiency furnace or boiler is quite simple — high efficiency is achieved by extracting as much heat as possible from the combustion exhaust gases and by limiting the amount of excess air passing through the heater. To accomplish that, three primary component modifications are involved: 1) the primary heat exchanger is improved and/or extended; 2) a secondary heat exchanger is added to cool combustion gases even further; and 3) a draft inducer is used to draw combustion gases through the system.

Although the basic principle may be simple, the actual implementation is considerably more complex. The most nagging problem is flue gas condensation. In the ultra-high-efficiency heaters with secondary heat exchangers, the flue gases are cooled to below the dew point temperature, resulting in condensation — thus the term "condensing" furnace or boiler. The problem is that the condensate is acidic and can cause corrosion of the heat exchanger (as happened with the original Arkla units). Special alloys are now used for secondary heat exchangers to prevent corrosion problems.

Sometimes, condensation occurs in furnaces that were not meant to operate as condensing furnaces. These are "borderline" units with AFUE ratings in the mid- to high 80s. To avoid this problem, some manufacturers have moved away from that efficiency range, selling heaters with an AFUE no higher than 80 to 82%.

Problems with High-efficiency Furnaces

"I believe that the complexity of the equipment [high-efficiency gas furnaces] precludes the possibility of long-term, trouble-free operation. If any one of a dozen or more functions fails to take place, a "lockout" will result. In some cases a safety control fails, and what we have come to refer to as a "meltdown" occurs. In this case, the interior of the furnace burns up, requiring wholesale replacement of parts and wiring, or the installation of a completely new furnace."

The above statement, written by a Pennsylvania heating contractor, appeared in New England Builder and, in similar form, in Air Conditioning, Heating and Refrigeration News. Although reports of "meltdowns" are relatively rare, complaints about the complexity and unreliability of medium- and high-efficiency induced-draft furnaces are not. Even though many contractors report absolutely no problems with these new units, some people in the industry feel that more field testing should have been done before they were released into the marketplace.

A Survey of 600 Reported Complaints

Exactly what are the problems being experienced with medium- and high-efficiency gas furnaces and what are the causes of those problems? A partial answer to these questions is provided by an extensive survey performed for Alberta Energy by Howell-Mayhew Engineering, of Edmonton, Canada. A total of 592 complaint reports were solicited from equipment distributors, heating contractors, gas inspectors, municipal inspectors, utility supervisors, builders, educators, government officials, and homeowners. Here's what they found.

Complaints, Causes, and Solutions

System Shutdown — The Number-One Complaint

Almost 60% of the reported complaints concerned furnace shutdown caused by either component failure or false activation of safety switches. Another 16% of the complaints were about system shutdown due to improper installation.

Component Failure

High-efficiency furnaces contain a variety of new components not previously found in residential heating systems — induction fans, secondary heat exchangers, pressure differential switches, temperature sensors, vibration mufflers, pumps and seals, and condensate disposal systems. According to the Howell-Mayhew report, some of the components initially used in the new heating systems were not appropriate for the application. For example, some of the induction fans were not resistant enough to corrosion, resulting in premature failure. In most cases, the defective components were replaced by the manufacturer, even if the original warranty had expired.

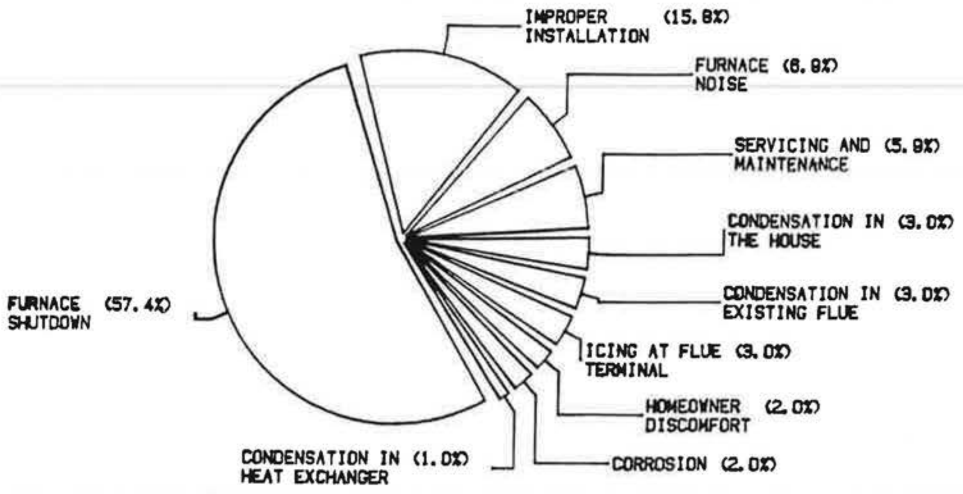


Figure 1 - Complaints reported about medium- and high-efficiency furnaces.
Source: Howell-Mayhew Engineering, Edmonton.

Premature Activation of Temperature/Pressure Safety Switches

To safeguard against venting failures, induced-draft furnaces are normally equipped with temperature and/or pressure safety switches that "prove" adequate flue flow. Excessive temperature or back pressure activate these switches, which causes the furnace to automatically shut down. But in some cases the switches are activated prematurely, causing an annoyance shutdown. Since many homeowners don't know how to operate the manual reset, false shutdowns often end up with a service call.

The cause of premature activation is not always a defective sensor. In some cases, for example, heat from the furnace cabinet and flue activate the temperature safety switch. To solve this type of problem, some manufacturers have relocated the temperature switches.

Improper Installation

High-efficiency furnaces are not as forgiving as conventional furnaces and improper installation can cause noticeable problems. The Howell-Mayhew study cited two examples of how improper installation can result in system shutdown.

One instance is excessive length of flue pipe — beyond the manufacturers' recommended maximum. The static pressure created by an extra-long flue renders the system very sensitive to externally induced back pressure, such as wind-loading. To avoid this problem, installers must adhere to manufacturers' specifications for venting procedures and equivalent duct lengths.

Another mistake that can cause shutdown problems is to slope the vent pipe away from the furnace, causing the condensate that forms in the pipe to flow outdoors where it can freeze and possibly block the flue pipe, resulting in shutdown.

Furnace Noise

Furnace noise accounted for 7% of the total number of complaints.

Three causes of furnace noise complaints were noted in the study. The first was noise from the flue vent echoing off neighbors' houses or other hard surfaces across from the user's house. The solution is to locate the vent terminal so that the noise will be directed toward open space, possibly through the roof.

The second cause of complaints was excessive noise from the induction fan, caused by corrosion of the motor bearings and fan blades. The solution to this problem is already being addressed by incorporating corrosion-resistant fans.

The last cause of noise complaints was the simple fact that homeowners are not accustomed to the normal sound of induction fans or pulse combustion in their homes. Even the sound of a properly functioning system is sometimes objectionable. The only solution to this problem would be effective sound isolation of the heating system.

Servicing and Maintenance Concerns

Six percent of the reported complaints had to do with lack of adequate maintenance and repair services. Not only are high-efficiency furnaces more complex than conventional models, but they vary considerably from one manufacturer to the next, which creates a significant training demand on service personnel. Parts are also more difficult to obtain because of the number of different components.

Condensation in Existing Flue

If a medium-efficiency replacement furnace is vented into an existing chimney, the combustion gases may cool to below the dew point temperature before exiting the flue, resulting in condensation in the chimney. Because the condensate is acidic, damage to the chimney can result.

Another situation where condensation may occur is where a high-efficiency side-venting furnace replaces a conventional furnace and the existing water heater is vented alone into the existing chimney. The water heater is too weak to create adequate draft and the flue gases may cool too quickly, leaving condensation in the chimney. The solution to this problem is to install a properly-sized liner in the existing chimney. The liner increases the velocity of the combustion gases and presents a smaller surface area for heat loss.

Icing at Flue Terminal and on Side of House

Moisture in side-vented flue gases may condense and freeze at the flue terminal or against the exterior siding on the house. A solution to this problem, suggested by the study authors, is to insulate the vent pipe to maintain higher temperature in the exiting flue gases.

Corrosion

The condensate formed in high-efficiency furnaces is mildly acidic and can corrode the heat exchanger and other metal components. The situation is aggravated by airborne contaminants from laundry bleach and other household products. Although this is a primary concern among researchers, it accounted for only 2% of the complaints in the Alberta study. The solution suggested by the study authors is for manufacturers to incorporate more corrosion-resistant materials into their units and/or to use outdoor air for combustion.

Homeowner Discomfort

Only 2% of the total number of complaints had to do with occupant discomfort. The primary cause was the relatively high-volume supply air flow required in some high-efficiency units. The only solution to this problem would be to lower supply air volume (which would result in decreased efficiency) and/or more careful design of the distribution system.

Condensation in the House

Sometimes a high-efficiency furnace is installed in a house and immediately the windows begin to collect condensation. The furnace is usually blamed for adding moisture to the indoor air. But the cause of the problem is not the high-efficiency furnace; it is the removal of the natural-draft furnace, which had been exhausting large quantities of air and moisture from the house. Since the high-efficiency furnace does not exhaust as much indoor air, humidity builds up in the house, resulting in condensation on windows and other cold surfaces.

One solution to this problem is to install a ventilation system to force moisture-laden air from the house.

For More Information:

A complete copy of the Alberta study is available for $20 from Howell-Mayhew Engineering, 15006-103 Ave., Edmonton, AB T5P 0N8, Canada; (403)484-0476.

THE ROAD TO INTEGRATED SYSTEMS

In the October, 1985, issue of EDU, we featured a triple-integrated heating, cooling, and water heating appliance developed by the Gas Research Institute (GRI) in cooperation with Advanced Mechanical Technology, Inc. (AMTI), Newton, Massachusetts. Experimental units were then undergoing field testing by the Gas Research Institute, and were expected to reach the marketplace by the end of 1986. AMTI has completed field tests, but as of the summer of 1987 the appliance had not yet reached the marketplace.

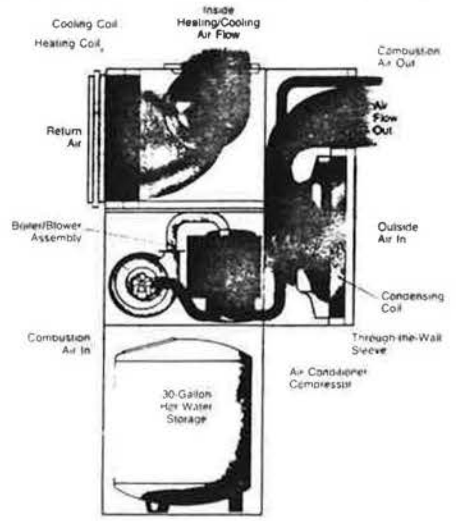


Figure 2 - GRI triple-integrated appliance.

Another attempt at mechanical system integration is a heat pump/heat recovery ventilation system with space heating, domestic water heating, and space cooling capability developed and marketed by Fiberglas Canada Inc. (FCI). Featured in the September 1985 edition of EDU, the FCI system was the first fully integrated residential mechanical system to provide central ventilation as well as heating, cooling, and DHW heating. Initially, the FCI system was imported from Sweden, but it is now being manufactured at FCI's Sarnia Research facility in Sarnia, Ontario. It is not yet available in the U.S.

One Step at a Time -- Integrated Space Heating and Water Heating

Although fully-integrated appliances such as the GRI system may be what we all are waiting for, a gradual evolution toward integration is the more likely course for the mainstream housing industry. A first step is integration of space heating and water heating.

Why do most houses have two fires in the utility room — one for water heating and one for space heating? Because the most popular type of heater is the warm-air furnace and, with only two exceptions (Amana and GlowCore), none have the ability to heat domestic water. But when you think about it, does it make sense to have a sophisticated, 90%-efficiency furnace heating the house when next to it stands a water heater chugging along at 45 to 55% efficiency? A preliminary reaction might be: "No, that doesn't make sense at all; we should get higher-efficiency water heaters." But a better solution would be to somehow combine the furnace and water heater into one high-efficiency unit.

Introducing the Hydronic Furnace

The term "hydronic furnace" will surely cause some of our more technical readers to shudder because it's not a true engineering term. What we are calling a hydronic furnace is simply a self-contained unit that includes a finned-tube water coil, optional cooling coil, water circulating pump, blower, and controls — all pre-piped and wired in a single cabinet.

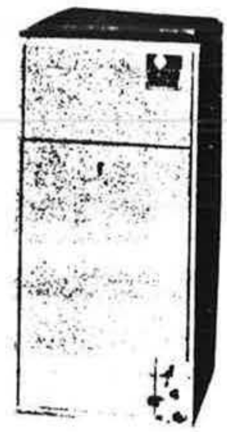


Figure 3 - The Apollo HydroHeat.

Heated water (from any source) is circulated through the coil and, in turn, transfers heat to air that is blown over the coil. Commonly used as terminal heaters in commercial buildings, this type of appliance is usually called a "fan coil." When used as a central heating system in a house, it resembles an electric furnace in which the electric heating coil has been replaced by a hydronic heating coil — thus the term "hydronic furnace."

The most intriguing potential of these appliances is that an ordinary domestic water heater can be used to generate heat for space heating. When first introduced, residential fan coils were intended for use in moderate climates where the heating load is low enough for a conventional water heater to handle both space heating and water heating. But the idea has caught on with designers of energy-efficient houses in cold climates as well. Many moderately sized, well-insulated houses in the northern U.S. and Canada can be heated by a domestic water heater. In fact, we recently received a note from Rob Dumont, energy research engineer at the Prairie Research Station, National Research Council of Canada, who installed a hydronic furnace powered by a 36,000 Btu/hr Rheem side-venting water heater in his own home in northern Saskatchewan (12,000 degree days).

The Apollo HydroHeat

The first hydronic furnace to gain popularity for residential applications was the Apollo HydroHeat (see July 1984 EDU) manufactured by Apollo Industries (now Apollo Comfort Products, Division of State Industries). Originally designed as a coil-in-duct heater and air handler for solar heating systems, the HydroHeat has gained acceptance throughout the U.S., including the northern tier states.

When connected to a water heater, the HydroHeat circulator pump draws water out of the water heater and circulates it through the heating coil (water-to-air heat exchanger). There it loses 15° to 20°F in temperature before returning to the water heater to be reheated. The HydroHeat fan forces air over the heating coil and through the house air distribution system.

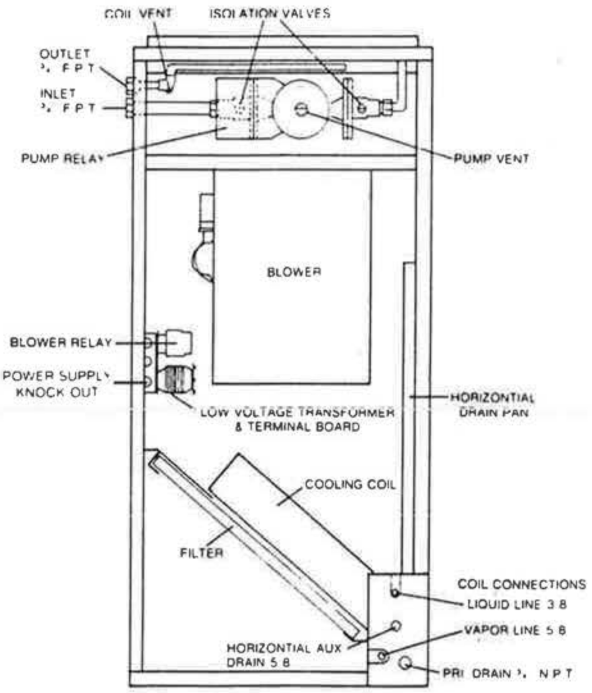


Figure 4 - Schematic of Apollo HydroHeat.

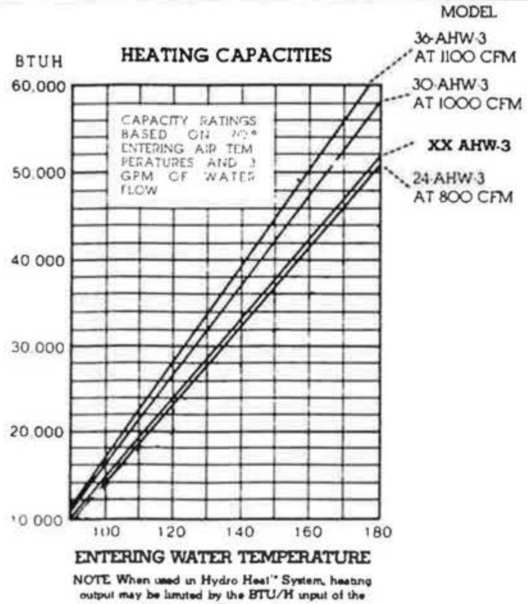


Figure 5 - Heating output vs water temperature, Apollo HydroHeat.

The heating output from the HydroHeat unit depends on the temperature of the incoming water and the fan capacity of the unit (see Figure 5). For example, the 24AHW-3, operating at 800 cfm, has an output of 23,000 Btu/hr with entering water at 120°F, and an output of 36,000 Btu/hr with entering water at 150°F.

The cooling capacity of the evaporator coil ranges from 18,000 to 36,000 Btu/hr.

Apollo sells two other lines in addition to the AHW series — the "Hideaway" HBC series, a smaller unit designed for installation above dropped ceilings and for use with ducted or plenum returns, and the "Retrofit" series, designed to retrofit existing forced warm air furnaces to the HydroHeat system. Another model, the "Cube," is similar to the AHW series, but has separate heating and cooling modules.

For more information, contact State Industries International, Inc., 3216 Wellington Court, Suite B, Raleigh, NC 27609; (919)872-1852.

Two Less Well-known Alternatives to the Apollo HydroHeat

Two alternatives to the HydroHeat are the First Aqua-Therm Aire, manufactured by First Co., Dallas, Texas, and the Fireless Furnace, manufactured by Fireless Furnace Inc., Anaheim, California.

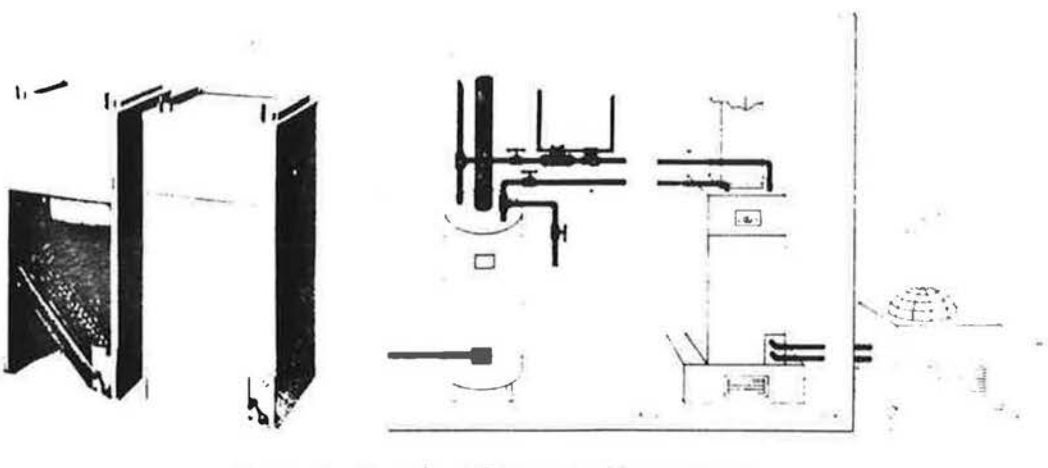


Figure 6 - First Co. VDX vertical fan coil unit.

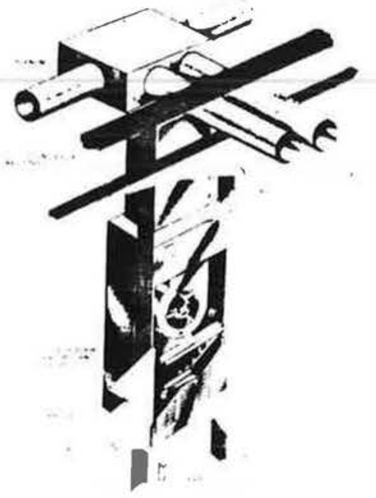


Figure 7 - First Co. RME wall mount unit.

First . . . to last

First Company has been manufacturing residential, commercial, and industrial fan coils for twenty years. If its equipment looks similar to the HydroHeat, that is because initially, it manufactured the basic components for Apollo.

Called Aqua-Therm Aire, the First line of residential fan coil heating and cooling units includes three basic models: the VDX vertical fan coil unit; RME wall-mount vertical fan coil unit; and the HBC horizontal fan coil unit. The VDX and HBC are basically the same as the Apollo AHW and HBC series, but the RME is unique. Measuring 28"w x 21"d x 45"h, this wall-mount unit should prove very practical in situations where space is limited. Within each basic model series, First offers eight different variations with different heating, cooling, and fan airflow capacities.

A distinctive feature of the First line of fan coil heaters is the "Flow Control Module" (see figure 9). Whereas the pump and controls of the Apollo HydroHeat are integrated into the main unit, First packages those components into an external unit that mounts on the water heater (or other hot water source) and plugs into a conventional electrical outlet.

Perhaps the most impressive aspect of the First line of products is the wide range and flexibility of its offerings and the

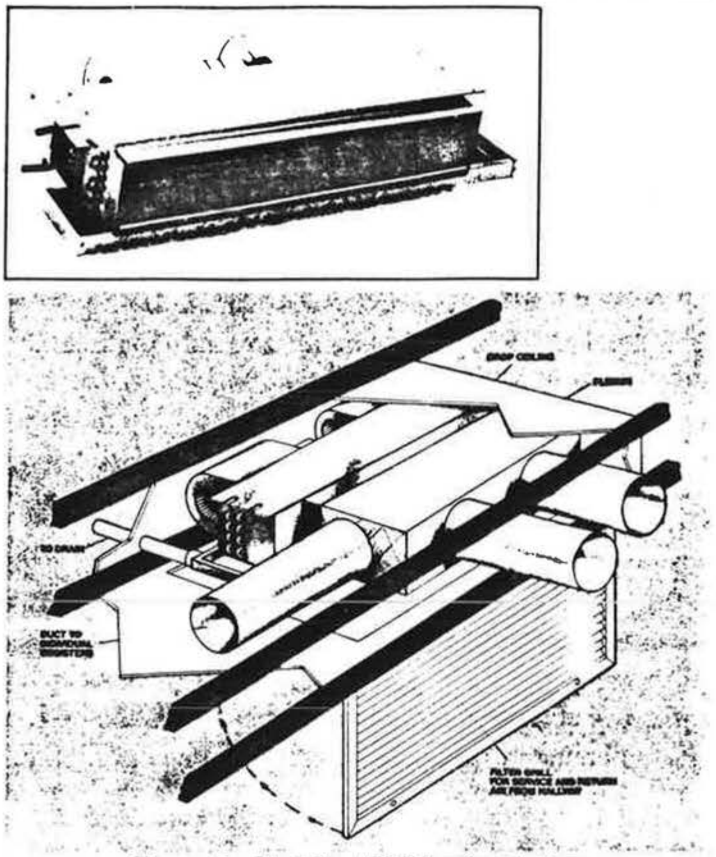


Figure 8 - First Co. HBC horizontal fan coil unit.

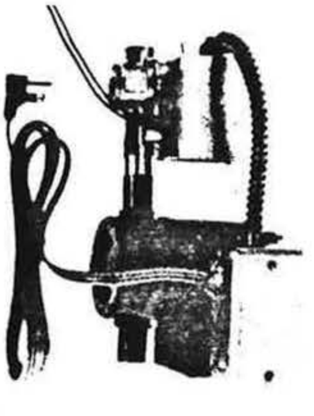
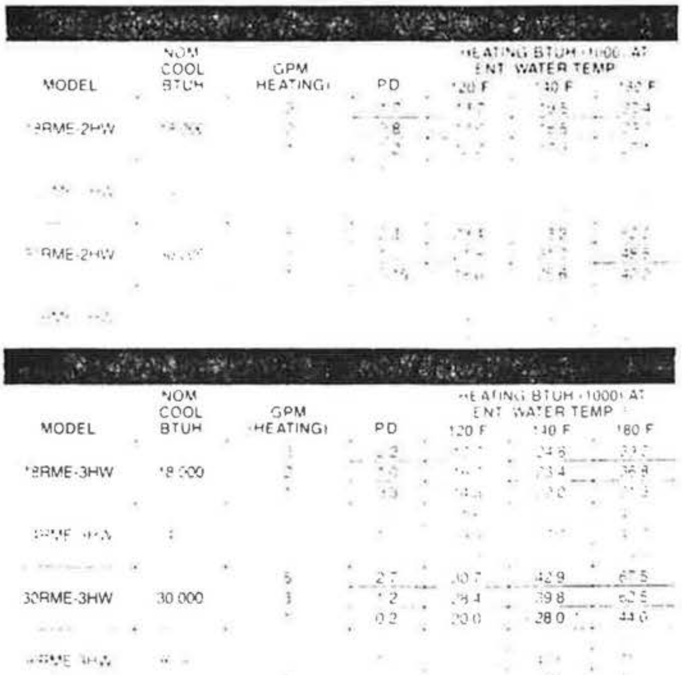


Figure 9 - First flow control module.

competence and clarity of its product literature. To illustrate this point, we have reproduced its performance data table for the RME wall-mount unit below. This unit is available in four cooling capacities ranging from 18,000 to 36,000 Btu/hr (1.5 to 3 tons), and with either a 2-row or 3-row hot water coil. The heating output of the coil varies, of course, with coil inlet water temperature, and the chart gives the output at three different temperatures. Notice the sizable range of output attainable with any single coil. The 18RME-2HW, for example, can supply between 13,700 and 30,400 Btu/hr. Although it is unlikely that anyone would supply 180-degree water to one of these heaters, having the data displayed so clearly gives any designer assurance that his/her system will perform as intended. You would know, for example, that you could increase the output from the 18RME-2HW 50 percent by increasing the inlet water temperature, from 120°F to 140°F. This is particularly important in the residential sector where designers often don't have formal HVAC training.



MODEL	NOM COOL BTUH	GPM (HEATING)	PD	HEATING BTUH (1000) AT ENT WATER TEMP 120 F	140 F	180 F
[illegible]RME-2HW	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	8	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]					
[illegible]RME-2HW	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]						

MODEL	NOM COOL BTUH	GPM (HEATING)	PD	HEATING BTUH (1000) AT ENT WATER TEMP 120 F	140 F	180 F
18RME-3HW	18 000	[illegible]	[illegible]	[illegible]	24.6	[illegible]
		[illegible]	[illegible]	[illegible]	23.4	36.8
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]			[illegible]	[illegible]	[illegible]
30RME-3HW	30 000	5	2.7	30.7	42.9	67.5
		3	[illegible]	28.4	39.8	62.5
		[illegible]	0.2	20.0	28.0	44.0
[illegible]	[illegible]	[illegible]			[illegible]	[illegible]

Table 1
Performance data, first RME fan coil heater.

Availability

First sells its products through plumbing and heating supply distributors. It does not sell directly to the retail market. To obtain a list of First product distributors or for more information, contact First Co., 8273 Moberly Lane, Dallas, TX 75227; (214)388-5751.

The Fireless Furnace

Although it's a bit hard to believe that the idea is patentable, U.S. Patent 4,371,111 for a "Home Heating System Employing a Water Heater as Heating Source" was in fact granted to Richard J. Pernosky on February 1, 1983. Pernosky is president of Fireless Furnace Inc., manufacturer of the Fireless Furnace.

Fireless is a small manufacturer that produces what appears

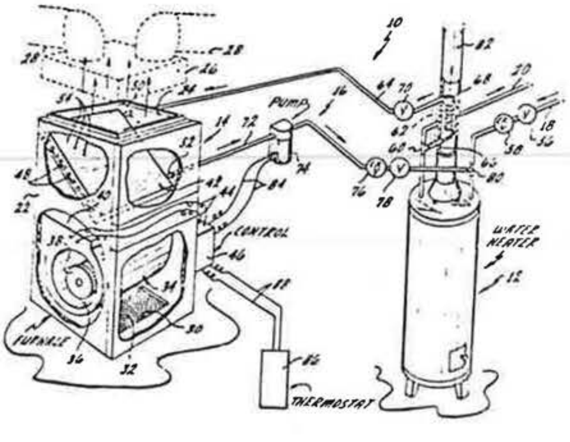


Figure 10 - U.S. Patent #4,371,111, for a "Home Heating System Employing Water Heater as Heating Source," granted to Richard J. Pernosky, February 1, 1983.

Figure 10a - The Fireless Furnace.

to be a quality machine. The configuration is somewhat different from the Apollo HydroHeat or the First VDX, using an A-coil heating coil instead of a flat coil (see figure 10a).

Three models are available with or without expansion cooling coil. All are vertical upflow units. Heating output ranges from 73,080 Btu/hr for the FF80H to 107,840 Btu/hr for the FF120H. Those output figures are for 160°F entering water temperature and 11-gallons-per-minute water flow rate. Unfortunately, unlike the excellent data presentation in the First literature, Fireless provides no heat output data for different water temperatures or flow rates.

For more information, contact: Fireless Furnace, Inc., 623 S. East Street, Anaheim, CA 92805; (714)533-7370.

And Some Plain Vanilla Hydronic Furnaces

Fan coils are neither new nor hard to find. Here are two plain units suitable for residential space heating that have been on the market for at least twenty years:

The HydroTherm Space-Pak

Produced primarily for the Space-Pak air conditioning product line, the HydroTherm Model ESP-B fan coil is available in three sizes with fan capacities of 400, 650, or 900 cfm. The units come with direct-expansion cooling coils ranging in capacity from 1.5 to 5 tons. Heating can be provided either by slide-in electric heaters or hydronic coils.

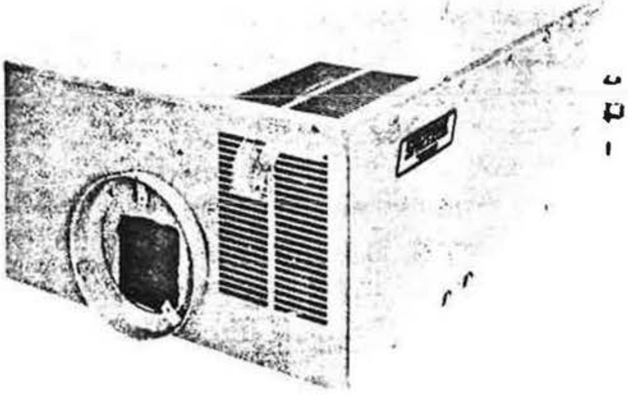


Figure 11 - Hydropulse Space-Pak.

Prices range from $641 to $834. For more information, contact HydroTherm Inc., Rockland Ave., Northvale, NJ 07647; (201)768-5500.

Myson Fan Convectors

Another fan-coil unit with heating capability only is the Myson series, manufactured by Myson Group, Inc., Fredericksburg, Virginia. Myson makes several models of fan-coil units with capacities ranging up to 23,000 btu/hr depending on inlet water temperature.

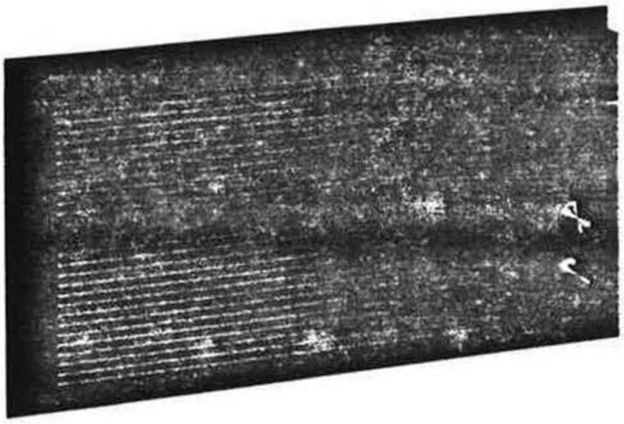


Figure 12 - Myson Fan Convector.

Prices range from around $425 to $660 (list). For more information, contact Myson, Inc., P.O. Box 5446, Embrey Industrial Park, Fredericksburg, VA 22403; (703)371-4331.

Efficiency

A possible shortcoming of the fan coil/water heater concept is limited efficiency. Most conventional water heaters are energy hogs with seasonal efficiencies between 50 and 60%. When used for space heating, however, the seasonal efficiency of any water heater will be higher than if it were used only for domestic water heating because the percent off-time is reduced and thus the relative stand-by loss is lower. In other words, as the total load on the water heater is increased (by making it supply space heat as well as hot water) jacket losses and flue losses become a smaller percentage of the total load.

However, no matter how much load is imposed on the water heater, the seasonal efficiency cannot exceed the "recovery efficiency," which, for the better water heaters on the market today, is in the upper 70 percent range.

Replacing the Water Heater with a High-efficiency Boiler

One way to improve the efficiency of a fan-coil system, and to expand the heating capacity as well, is to power the fan coil with a high-efficiency boiler such as the Weil McLain AHE, the Ener-Quip Netaheat, or the Energy Kinetics System 2000. Any of these units can be set up with two zones — one to power the fan coil unit and a second to generate domestic hot water.

Of course moving from a water heater to a boiler adds significant extra cost to the system. But in return for the extra investment, one gets greater quality and durability in addition to increased efficiency and capacity.

The Next Step — A Boiler Is a Water Heater Is a Boiler

Perhaps the ideal heating source for a fan-coil system was first publicly unveiled at the January 1986 ASHRAE winter meeting in San Francisco. The Mor-Flo Polaris, first mentioned in the July 1985 EDU when it was undergoing field tests, is now being distributed throughout the U.S.

Billed as a water heater, the Polaris uses completely sealed combustion, has an output of 100,000 Btu/hr, and an efficiency in the high 90s. As you may have guessed from its high efficiency, this is a condensing unit — the first condensing water heater to hit the market. To avoid corrosion, the tank is constructed of stainless steel.

Although Mor-Flo is selling this unit as a water heater, it is clearly intended for space heating. In fact, Mor-Flo sells a companion fan-coil unit for space heating.

A Ventilator is a Furnace

What about ventilation? If the current concern over indoor air quality continues, we will probably see increased market demand for mechanical ventilation in homes. When will ventilation systems be well integrated with other mechanical systems? The first promising efforts in that direction were reflected in the heat-pump/heat-recovery ventilator sold by Fiberglas Canada Inc (see page 7). One serious obstacle, however, is the price tag — roughly $3,000 in 1985.

A similar approach is represented by the Therma-Vent "Ventilating Heat Recovery Water Heater," manufactured and sold by DEC International, Madison, Wisconsin. Despite its competent design and effective operational characteristics, the DEC unit, built from a modification of its ThermaStor heat pump water heater (see the December 1983 EDU), has enjoyed only limited market success.

Enter Engineering Development Inc. (EDI) and the Vent-Aire ECS20 Environmental Control System — a heat recovery ventilator with integrated fan coils for space heating and cooling. Simple, practical, effective, and inexpensive, the Vent-Aire system, introduced in the fall of 1985, pointed to the future. Although it was expected that other manufacturers would follow in EDI's footsteps, the most noteworthy new product to follow the ECS20 was a new improved version, the ECS40, introduced by EDI in March 1987.

The Original Vent-Aire ECS20

Basically, the ECS20 is an air-to-air heat exchanger with add-on heating, cooling, and air cleaning components. The individual components clamp together and can be easily taken apart if necessary.

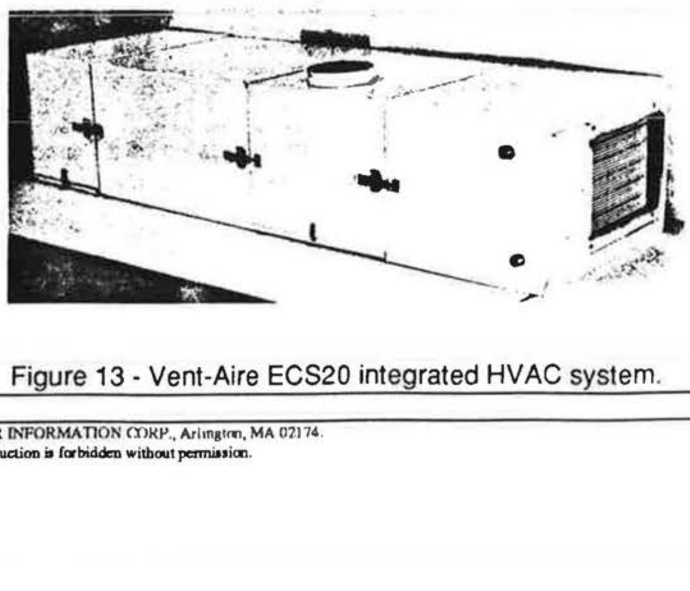


Figure 13 - Vent-Aire ECS20 integrated HVAC system.

Heat Recovery Module

The central component of the ECS20 is the HRM Heat Recovery Module, which contains an aluminum counterflow heat-exchanger core.

Manifold Module

On the cold side of the HRM is the MM20 Manifold Module, which contains the heat exchanger defrost dampers, air diverter, and fresh air filter.

Blower Module

On the warm side of the HRM is the Blower Module, which houses two variable-speed blowers on a common shaft, driven by a single motor. The capacity of each blower ranges from 80 to 220 cfm.

Energy Module

In front of the Blower Module is the Energy Module. Two different Energy Modules are available — EM13 and EM38. The EM13 contains a hydronic heating coil and small circulator pump. It has an output of 13,000 Btu/hr when supplied with 150°F water. The EM38, contains a larger coil and a 400 cfm fan for recirculating house air. Heating output with the EM38 is 38,000 Btu/hr (at 150°F entering water temperature).

Cooling Module

A fifth module, containing a direct-expansion cooling coil, attaches to the warm side of the Energy Module.

System Operation

1. Background ventilation

When the house is <u>not</u> calling for heat, the ventilation fan operates at low speed, which is adjustable from 80 to 220 cfm (enough capacity to ventilate a 3,000-square-foot house). The

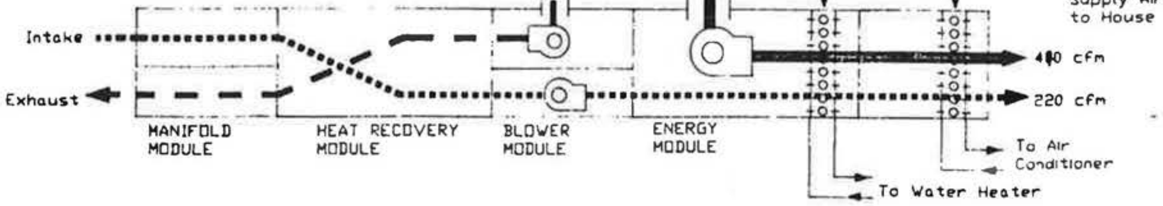


Figure 14 - Vent-Aire ECS20 system -- background ventilating mode.

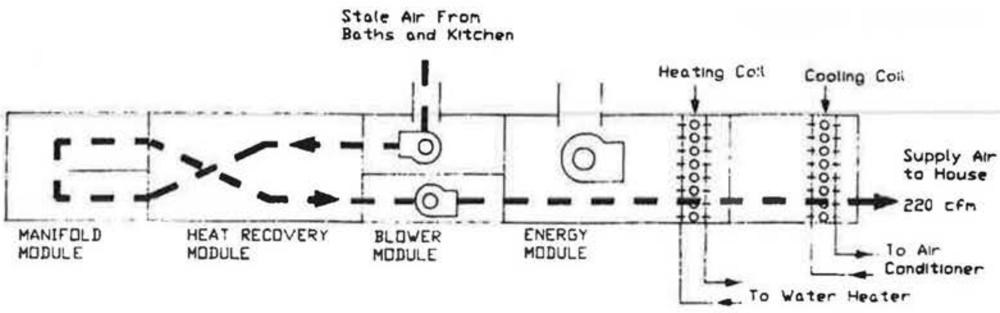


Figure 15 - Vent-Aire ECS20 in defrost mode.

fan automatically boosts to high speed whenever any control, such as humidistat or bathroom manual switch, calls for increased ventilation.

2. Heating mode

When the house thermostat calls for heat, the circulator pump brings heated water to the heating coil in the energy module and the ventilation automatically boosts up to high speed, drawing in a full 220 cfm of outdoor air. With the EM38 Energy Module, the supplementary fan also comes on, circulating 440 cfm of household air in addition to the 220 cfm of fresh air through the heating coil. Thus, a total of 660 cfm of heated air is distributed to the house.

3. Cooling mode

During cooling mode, operation is basically the same except that the cooling coil is activated and the heating coil is not. Incidentally, the EDI literature states that the cooling coils are "sized for the requirements of energy-efficient homes, providing dehumidification without overcooling." It sounds like EDI is aware of the problem of mismatching sensible heating factor of equipment and house that is common in energy-efficient buildings (see the November 1984 EDU for more on that problem).

4. Defrost mode

Freezing of the heat exchanger core is sensed by a thermistor located in the exhaust air stream. Defrost is accomplished by a simple damper arrangement which closes off the cold air intake and recirculates the warm exhaust air back through the heat exchanger core (Figure 15).

The New Vent-Aire ECS40

The Vent Aire 20 Series caused a noticeable stir in the residential mechanical systems marketplace. We have interviewed builders from Alaska to Virginia who have used it. Without exception, all have been more than satisfied with system price, performance and, most importantly, company support. But the new "40" series is likely to expand EDI's impact even further.

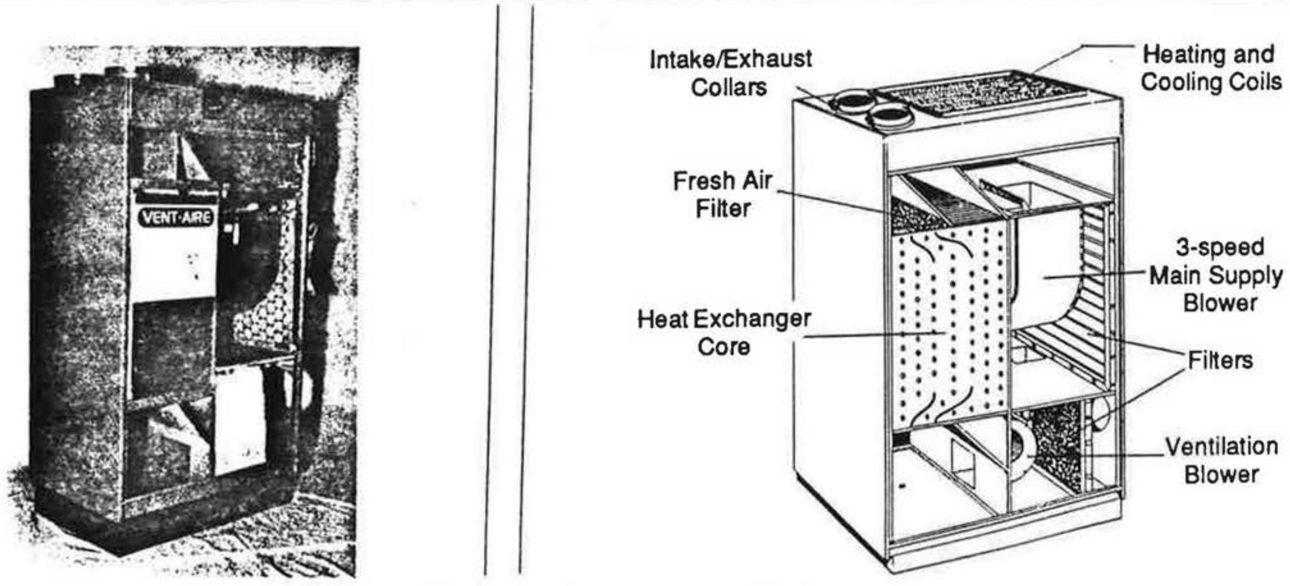


Figure 16 - The Vent-Aire ECS40.

Standard Looks

Perhaps the only problem with the original Vent-Aire was its looks. Not ugly, just unusual — a horizontal box with snap-together modules hanging from the basement ceiling. For the average homebuyer it may have been a little too foreign. The 40 Series eliminates that problem. It looks like a furnace (see figure 16).

Heating

Two options are available for heating with the ECS40 — either a hydronic coil with 60,000 Btu/hr maximum capacity or an electric resistance coil with 30,000 Btu/hr capacity.

Cooling

A direct-expansion cooling coil fits on top of the Vent-Aire unit. Currently two sizes are available — 18,000 Btu/hr and 30,000 Btu/hr (1.5 and 2.5 tons respectively). The cooling coils are manufactured by McQuay.

Whole-house Ventilation

Fresh air is brought into the house and stale air is exhausted via two variable-speed blowers with airflow capacity ranging from 80 to 220 cfm each. Another improvement in the 40 Series over the old 20 Series is the use of separate fan motors for each fan, allowing individual control of intake and exhaust air flows (see "Equalizer," below).

Ducts leading to the outdoors attach to two collars on the top of the unit, making for a neat appearance. The stale-air exhaust return from bathrooms and kitchen attaches to a third collar located near the base of the unit.

And Introducing . . . The "Equalizer"

Although it sounds like something from a Charles Bronson movie, the Equalizer is actually a potentially very useful ventilation system option. Basically, it is an electronic device that controls air pressure in the house by independently varying the speed of the two ventilation fans. Thus, with the Equalizer, it is possible to maintain the house at a slight positive pressure relative to outdoors (perhaps to inhibit radon entry through the basement), or negative pressure (to prevent moisture condensation problems in cold climates).

For more information:

Engineering Development, Inc., 4850 Northpark Drive, Colorado Springs, CO 80907; (303)599-9080.

SELECTING THE "BEST" HEATING SYSTEM

Amidst all the changes in residential heating equipment, designers and builders continue to search for the "best heating system." But is there such a thing? Probably not; at least not yet. First of all, people's values vary. To some, installation cost is the most important factor; to others, annual operating costs may be more important. Some like the feel of radiant heat, while others complain that it is uncomfortable. Some are concerned about indoor air quality and prefer to have mechanical ventilation; others don't care. Houses are also different. Some are conventionally insulated; some are "superinsulated"; some have significant solar gain; others don't. Some are large and sprawling; others are compact with open floor plans. These and other variables all affect the design of a residential heating system.

How do you select the best (or maybe we should say "most appropriate") heating system for a particular house? Let's look at a sequence of questions and a logic process that should lead you toward that goal. We should keep in mind, however, that this technology is moving fast: the best system today will probably be improved upon tomorrow.

1. Calculate the Design Heating Load

The design heat load is the theoretical maximum amount of heat that will be needed during the coldest weather in a particular climate. As a very rough guideline, in a climate with a winter design temperature of 20°F, a typical new 2,000-square-foot house will have a design heat load between 10,000 and 50,000 Btu/hr. In a climate with a design temperature of -10°F, typical design heat load will range from 16,000 to 80,000 Btu/hr.

The design load is important not only for sizing the heating unit, but also for selecting the type of system. For example, with a design load of 20,000 Btu/hr you could easily use a fan coil with domestic water heater or in-space electric convection heaters. But with a design load of 50,000 Btu/hr. you would need to look at more heavy-duty systems.

2. Calculate a Rough Annual Energy Consumption

The purpose of looking at predicted annual energy consumption is mainly to weigh annual heating energy costs against system installation costs.

Note on Calculation Accuracy and the Use of Computer Programs

A plethora of programs for personal computers are available to perform heat load and annual energy consumption calculations. These programs have the enormous advantage of allowing the designer to perform "what if" analyses, in which he or she can modify one or more components in a house and then recalculate the heat load almost instantly. Other advantages of these programs include sophisticated solar calculations, below-grade heat loss calculations, and elaborate report presentation formats. But, as far as accuracy goes, keep in mind that the basic heat loss calculations are only accurate to within 10 or 20 percent at best and for the purposes of selecting and sizing a heating system, hand calculations can be just as accurate as computer programs.

3. Select Fuel Type

Thanks to recent efforts from Madison Avenue, choice of heating fuel has become as much an emotional issue as a practical one. In the Northeast, we hear radio ads warning us of the insidious dangers of gas heat. Counteradvertising by the gas industry tells us about the foolishness of storing expensive and dirty oil underground, wasting our money. In the Southeast, a masked rider on a white horse chases the evil electric heat-pump guys from the neighborhood, replacing their systems with clean burning gas furnaces. In any area of the country, some people will object to any form of electric heating because of the inherent inefficiency of the system of electric power generation and its overall negative impact on our national energy picture.

There is little question that gas is the least expensive fuel per Btu of delivered heat. But electric heating is usually the least expensive to install. If the choice between those two fuels is based on economics alone, then you need to weigh installation cost against annual fuel cost.

For example, if the predicted annual energy consumption for a house is 50 million Btu, then electricity will cost $600 to $700 more per year than gas and a high-efficiency gas system may be justified. If, on the other hand, the predicted annual energy consumption is only 10 million Btu, then the annual cost for electricity will be somewhere around $150 more than the annual cost for gas. It may not be worth it to install a high-efficiency gas system. Of course, the actual numbers depend on the relative price of fuel and equipment in your area.

Oil heat is a special case. At present, oil is more expensive than gas (per delivered Btu of heat). But we are beginning to see high-efficiency oil equipment (Yukon and Dornback furnaces -- see the January 1986 and November 1986 EDUs) and oil prices are dropping on the world market. If those trends continue, oil may become an economical alternative to gas as a primary fuel.

4. Decide on Ventilation

We believe that every house should have some type of mechanical ventilation system that will distribute fresh outdoor air to each room of the house. However, this opinion is not held by all in the industry and the decision whether to include a ventilation system must be made by each individual designer.

If the house is to have a ventilation system, then a warm-air heating distribution system will make sense because the ductwork will be in place. Keep in mind, however, that ventilation ductwork is not necessarily the same size as traditional heating ductwork.

5. Decide on Central Air Conditioning

As with ventilation, the presence of air conditioning ductwork will lead toward warm-air heat distribution. Nothing new here.

6. Select System Configuration

This is the end of the road. Having determined heating load, annual energy consumption, fuel type, ventilation, and air conditioning requirements, one should be able to select the most appropriate system.

In selecting systems for consideration, we have not looked at every possible configuration, but rather stuck to those that in our opinion, are most practical for today and the very near future. One important assumption was that natural-draft atmospheric combustion equipment is unacceptable for new housing. All heating equipment should be either direct vent, induced draft, or power vented. (Power-vented devices are those that use fans to expel flue gases outdoors, but do not necessarily draw combustion air through the appliance.)

A. Central Heating with Warm-air Distribution

If any system can be classified as an all around "best" for modern housing, this is it. The main reason is that warm-air distribution allows for the most latitude in environmental control. As the public consciousness of the indoor environment increases, demand will probably rise for air cleaners, humidifiers, and other air treatment systems in addition to outdoor ventilation. These components will probably be treated as marketing features for new housing.

As pointed out above, if a house has mechanical ventilation or central air conditioning, then warm-air heating makes sense because the ductwork is already in place. Let's look at three alternatives for forced warm-air-heat.

1. Conventional Furnace

When you think of warm-air heating, a gas or oil furnace is usually the first system to come to mind. The past few years have seen a variety of new high-efficiency direct-vent and induced-draft gas furnaces (see cross-reference chart, Appendix A).

One disadvantage of conventional furnaces is that, except for two brands of gas furnaces, none are capable of water heating. The two exceptions are the Amana Energy Command and Glowcore. With any other furnace, a separate water heater will be necessary. With oil furnaces, the situation is pretty much the same. If atmospheric combustion heaters are elimanated, the only acceptable oil furnaces are the Yukon EX-95 (see the January 1986 EDU) and the Dornback (November 1986 EDU), both of which are power vented. Neither oil furnace has water heating capability.

2. Hydronic Furnace Powered by Domestic Water Heater

This system is very attractive if the heating load of the house is low enough to be satisfied by a domestic water heater. Most domestic water heaters have energy input in the range of 35,000 to 40,000 Btu/hr, although a few have input ratings as high as 60,000 or 70,000 Btu/hr. Since most water heater manufacturers don't list output, it is very difficult to evaluate the actual capacity of those units. Also, the output of a water heater varies with the temperature of the water in the tank. A reasonable guideline is to assume that the output is roughly 60 to 70 percent of the input. Thus, as a rule of thumb, this type of system will work well if the design heating load is 25,000 Btu/hr or lower. Of course, higher loads can be accomodated with one of the higher-capacity water heaters, or possibly with a commercial heater.

3. Hydronic Fan Coil Powered by a Boiler

Using a boiler instead of a water heater to power a fan coil provides higher efficiency, greater capacity, and more durability at a higher cost. The distinction between water heater and boiler begins to get hazy in light of new appliances such as the Mor-Flo Polaris heater.

B. Central Heating with Hydronic Baseboard Distribution

The main advantage of a hydronic baseboard heating system is ease of zoning. The disadvantage is that it lacks the potential for air treatment that forced warm-air distribution has. Also, if the house has a ventilation system, then it will have two separate and parallel distribution systems — one for heat and one for air. That redundancy is not likely to be cost-effective.

C. In-space Heating (Area Heating)

As the term implies, "in-space" heating systems are those in which the heat source is located within the space to be heated. It is also referred to as "area heating."

In-space heating has two primary advantages: 1) it can be inexpensive to install; and 2) it allows easy and effective zoning. A recent study at Oak Ridge National Laboratory showed that zoning can cut energy costs by as much as 30 percent.

When considering in-space heating, a primary decision will be fuel choice — electric versus gas. Electric area heating is less expensive to install, allows more flexibility, and is aesthetically more acceptable than gas area heating. Gas heating, on the other hand, typically has faster pickup and is less expensive to operate.

1. Electric Radiant Ceiling Heat

In the past, the most common types of electric radiant ceiling heat were electric cables or hot water pipes embedded in plaster or between two layers of gypsum board. Those systems enjoyed only limited popularity because they were expensive to install and because people sometimes complained of the "cold feet syndrome." Both those problems have been all but eliminated.

First, with the new plastic laminates, the cost for electric radiant ceiling heat has been reduced to a fraction of the cost of the old type systems. Second, cold feet should not be a problem in new, well-insulated houses. The reason for the cold feet syndrome was that radiant heat warms people and objects before it warms the room air. If your feet are under a table, then the radiant heat can't reach them and they get cold against the cold floor. But in an energy-efficient house, the floor is well insulated and not cold. Feet should stay warm, even if not directly exposed to the radiant heat.

Radiant heat has several distinct advantages. Many people find it very comfortable. Since it warms people and objects, not air, it can create a feeling of warmth even when the room air temperature is low. Also, hidden behind the ceiling gypsum board, it is invisable and silent.

A complete discussion of electric radiant ceiling heat is presented in the following section.

2. Electric Convective Heat

Electric convective heaters have never been popular in residential applications except in bathrooms. But a new product, the Cadet (see the March 1985 EDU), deserves consideration. The Cadet is a recessed heater that installs in a 2x4 stud bay. The reason we mention it here is because it is extremely quiet and not particularly expensive (around $100).

If your annual energy requirements are low enough to allow electric heat, the Cadet is a viable alternatifve to electric baseboards and electric radiant-ceiling heat.

3. Electric Baseboard Heat

Of all the options discussed, electric baseboard heating is the least expensive to install. This is clearly the "low-cost alternative" when electric heat is economically acceptable and the prime decision factor is installation cost.

4. Gas Heaters

Approximately twelve manufacturers produce small wall-mounted, direct-vent gas space heaters, ranging in output from 8,000 to 50,000 Btu/hr (see the December 1985 EDU for listing). The main drawbacks of these heaters are appearance (not out of sight like radiant ceiling heat) and sometimes noise (some are fan-forced, others not). The advantages are fast pickup and low cost of operation compared to electric heating.

ELECTRIC RADIANT CEILING HEAT

FACTS AND FICTION ABOUT ENERGY SAVINGS WITH RADIANT CEILING HEAT

Radiant Ceiling Heat Is Great

Inexpensive, invisible, clean, silent, and maintenance free — all reasonably accurate descriptions of electric radiant ceiling heat. In the days of drafty, poorly-insulated houses, some people didn't like radiant ceiling heat, complaining that it caused hot heads and cold feet. But in today's well-insulated houses, radiant heat is very comfortable. In fact, with proper ventilation and air circulation, electric radiant ceiling heat may be the heating system of choice in modern energy-efficient houses (assuming electricity is not prohibitively expensive).

But . . .

Because radiant heat transmission is an engineering subject with which the average person is not very familiar, it is easy to exaggerate and misconstrue its effect on building energy dynamics. In fact, advertising copy writers for radiant heating products have had a heyday describing how radiant heat warms our houses like the sun and saves 20 to 50 percent on our energy bills compared to other heating systems. In general, savings even close to that are extremely unlikely. Let's look at some facts and fiction.

FACT: Radiant Ceiling Heat Saves Heating Energy Because It Allows for Effective Zoning of the Heating System

A few years ago, a monitoring study of 120 homes was performed by Al Bierbaum, chief engineer for the Iowa Association of Electric Cooperatives, to compare the performance of air-to-air heat pumps, electric furnaces, and radiant ceiling heat. Bierbaum concluded that when compared to heat pumps and electric furnaces, "a radiant-heated home has the lowest kW demand and also requires the least amount of energy, thus making it the most beneficial system for both the consumer and [electric] cooperative." But Bierbaum states in his final report that "the main reason radiant is superior to the other systems in terms of kWh usage is the fact that the home owners only heated the rooms being used." In other words, zoning saves energy, whether it be baseboard, radiant, or other type of distribution.

FICTION: Radiant Ceiling Heat Reduces Energy Consumption by 20 to 50 Percent Because It Allows People to Operate Their Houses at a Cooler Temperature

This statement sounds good and it refers to proven physical phenomena. In fact, it may even be true for some applications of radiant heat, such as high-intensity gas heaters in industrial applications, but it can hardly be true for homes with radiant ceiling heat. Let's look at the explanation usually given for why this works and then examine the fallacy in that explanation.

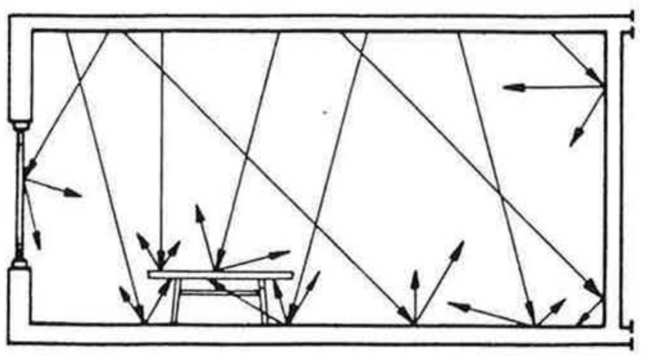


Figure 17 -- A warm ceiling radiates infrared radiation to other surfaces and objects in the room without warming the air in between.

The Principles

A heated ceiling radiates infrared radiation, which warms the surfaces of walls, floors, and objects in a room without warming the air in the room (Figure 17). Let's say that in some hypothetical room the air temperature is 62°F, the ceiling is 90°F to 100°F (typical for radiant ceilings), and the other surfaces are 68°F.

Normally, people feel cool at 62°F, but since the surfaces in this room are warmer than the air, people feel warmer. In fact, depending on the specific conditions, a person in this room with the 62°F air temperature may feel just as warm as another person in a room at 68°F but with cooler room surfaces (Figure 18). This is the magic of radiant heat — the temperature sensed by room occupants, called the operative temperature or the mean radiant temperature, is higher than the dry-bulb air temperature.

The Claim

The energy-saving claims for radiant heat are based on the fact that since the room with radiant heat is at a lower temperature, heat loss and energy consumption will also be proportionally less.

The Problems with the Claim

1. The warm ceiling and other warm room surfaces will heat the cooler air. As long as the output from the radiant ceiling is greater than the heat loss from the house, the air temperature will rise. Eventually, as the ceiling cycles on and off under thermostat control, the air temperature will approach normal room temperature. With the indoor air temperature at normal levels, heating energy consumption will be the same as with any conventional heating system.

Figure 18 -- Warm surface temperatures allow room occupants to feel warmer at cooler air temperatures. The cooler air temperature results in lowered heat loss from the room.

2. Since the radiant ceiling warms the exterior walls and floors, heat loss through those surfaces is increased. Calculations performed for the California Energy Commission by Gregg Booth of Pacific Gas and Electric (PG&E) show that a radiant ceiling at 110°F increases the heat loss through walls, windows, and floors by 4.7%.

Lack of Proof of the Claim

We tried to find field or lab studies showing that radiant ceiling heat does in fact save energy. We did find a body of research data showing that people can feel warm at cooler temperatures if the surrounding surfaces are warm, but that doesn't prove that radiant ceilings save energy.

The Rose-Hulman Study

The most commonly cited research is a 1979 report published by the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) and written by Herbert R. Bailey, professor at the Rose-Hulman Institute of Technology. This study is the closest thing we could find to field-measured savings from radiant heat. Bailey did find 15% savings with radiant heat compared to forced-air heat, but unfortunately his experiment had little resemblance to a residential heating system. The test building was a large metal building with 3 inches of wall insulation, an uninsulated concrete slab, and a 600 cfm exhaust fan. The radiant heating system consisted of six 25,000 Btu/hr high-intensity surface combustion gas radiant heaters — completely different from the low temperature residential radiant ceiling systems.

In other words, the results of the Bailey study cannot be transferred to a residential situation.

The California Energy Code

The California Energy Code treats electric radiant ceiling heat as if it has an efficiency of 104%. The justification for that increased efficiency is based on a calculation method developed by Booth at PG&E. He concluded that with a radiant ceiling system, the indoor temperature could be lowered 2.24°F without loss of thermal comfort and that the net energy savings, taking into account increased heat loss through walls, should be 3%.

Booth's analysis was performed for a 73°F indoor temperature and didn't take into account the fact that the warm ceiling would warm the interior air. We therefore feel that his estimate of 3% savings is probably optimistic. Even if he is correct, 3% is a far cry from the 20 to 50% claimed by manufacturers of radiant heating systems.

Exceptions:

There are situations where the setback theory works and where radiant heat really shines (pun intended) for saving energy.

1. Treating Your Heat Like Your Lights

If a room is used intermittently, a high-output radiant heating system used to provide thermal comfort quickly only during occupied times would surely consume less energy than heating the room with a baseboard or warm-air distribution system. This type of application requires a fast-response system such as the Enerjoy or Aztec panels. It also requires that panels be located above the area where people will be sitting or standing.

2. Sunspaces and Other High-Heat Loss Areas

Any room with a very high heat loss, such as a glass enclosure or a space with a necessarily high ventilation rate, will benefit from energy savings with radiant heat. If the heat loss from the space is greater than the output from the radiant ceiling, then the radiant heat will provide thermal comfort without heating the air up to normal room temperature.

3. Spot Heating

Any large space in which only a small area needs to be heated, such as a basement workshop, is another good candidate. In those situations, heating the air throughout the space for thermal comfort would be much more expensive than using radiant heaters.

ELECTRIC RADIANT CEILING BUYER'S GUIDE

General Types

Electric radiant ceiling heating systems can be loosely fit into four categories:

1. Flexible element heaters
2. Gypsum board with embedded heater wires
3. Modular heating panels
4. Radiant heating cable

What to Look for

1. Watt Density

The power output or watt density of radiant heating systems is important because it affects operating temperature, response time, and total area required for the system. Expressed in units of watts per square foot (W/ft^2), typical watt densities for available radiant heating products fall into two ranges: 1) 15 to 25 W/ft^2 for the low-temperature radiant heating systems, and 2) 40 to 100 W/ft^2 for the high-temperature modular radiant heating panels. The high-watt-density units can only be used in exposed applications. For concealed application behind the ceiling sheetrock, to prevent overheating and/or damage to the sheetrock, the maximum watt density is about 25 W/ft^2.

[NOTE: To convert from W/ft^2 to Btu/hr-ft^2, multiply by 3.413.]

2. Concealed Versus Exposed Installation

All the flexible heaters and the Thermaray gypsum heater are made for concealed installation. Panelectric and the modular panels are intended for exposed applications.

The main advantage of concealed installation is appearance; the system is invisible. The advantage of an exposed system is faster response and higher element temperature. For retrofit application, exposed installation is the only alternative unless the ceiling sheetrock is to be removed.

3. Cost

Comparing the cost of radiant heating systems is tricky because the amount of labor required for installation varies considerably from one system to the next. For example, among the flexible radiant heaters, some come precut with prefastened terminals, while others come in rolls that are cut and wired in the field. Field attachment is an added labor cost. On the other hand, the prewired type must be carefully planned and ordered in the proper sizes. Any changes or mistakes could translate into lost time or money.

If prewired panels are selected, another feature to check is length of the leads and method of connection to the house wiring. Extra boxes will increase the cost of installation.

To give some indication of cost, we have listed in Table 2 some typical 1987 costs for material only in terms of dollars per kilowatt capacity. Keep in mind that these numbers are extremely rough, particularly for the precut systems where the cost per kW drops considerably with the larger sizes.

Flexible Element Heaters

Flexible element radiant heaters consist of a conductive element sandwiched between two sheets of insulating plastic. The flexible assembly is stapled to the underside of the ceiling joists before the ceiling sheetrock goes up.

BRAND NAME	TYPE	WATT-DENSITY		COST PER KW **
		(W/ft2)	(Btu/hr-ft2)	
Aztec Panels	Modular Steel	62.5, 95	213.3, 324.2	$181 - $272
Berko	Modular Steel	62.5	213.3	$200
Enerjoy	Modular	50	170.7	$337
ESWA	Flexible	12.5--16.7	42.7--57.0	$85 - $130
Flexel	Flexible	22	75.1	$118
Flex-Heat	Flexible	25	85.3	$ 90
Flexwatt	Flexible	25	85.3	$100
Panelectric	Exposed gypsum panel	15	51.2	$ 83
Suncomfort	Exposed gypsum panel	15	51.2	n/a
Therma-Ray	Concealed gypsum panel	21.5	73.4	$165

** Manufacturers are reluctant to quote materials prices for radiant heating products. They usually prefer to quote on a basis of installed cost in dollars per square foot of house. The prices listed in this table are representative but approximate and should be used only as a guide for preliminary comparison, not for job estimating. Installation cost varies considerably from one product to the next.

Table 2
Listing of available radiant electric ceiling heaters.

Figure 19 - Flex-Heat installed in ceiling.

The main advantage of this type of system compared to other types is portability. You can literally transport an entire house-heating system in the trunk of a car. With some products, such as FlexWatt, you can almost carry a whole system under your arm!

One disadvantage of flexible heaters is slow pickup, especially those with lower watt density. Installed behind the ceiling sheetrock, they can take up to 30 minutes to reach operating temperature.

A key decision when selecting a flexible radiant heaters is whether you prefer precut elements with factory installed terminals, or continuous rolls which are cut and wired in the field.

Four brands of flexible radiant heating systems are available in North America:

Flex Heat

Manufactured by Thermofilm Corporation, Concord, Ontario, Flex-Heat is one of the oldest of the flexible radiant ceiling heaters. The conductive element in Flex-Heat is a fiberglass cloth that is coated with a carbon-graphite solution. A copper bus-bar runs down either edge of the element leading to the wiring terminals.

Flex-Heat comes in precut lengths ranging from 2 to 13 feet in 1-foot increments. Terminals are installed at the factory. The watt-density is 25 W/ft^2. The price is roughly \$80 to \$90 per kilowatt of capacity.

For more information on Flex-Heat, contact: Thermofilm Corporation, 8241 Keele St., Concord, Ontario L4K 1Z5; (416)669-4166 or Energy Engineering Inc., 6625 Mt. Wellington Drive, San Jose, CA 95120; (408)268-4075.

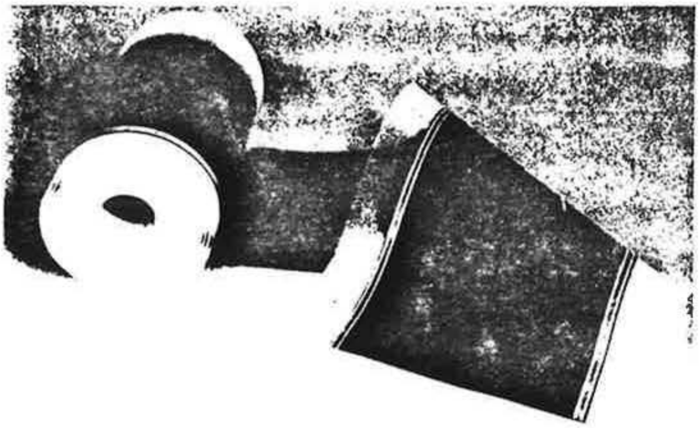


Figure 20 - Aztec Flexel.

Aztec Flexel

Manufactured in Scotland and distributed in North America by Aztec Marketing, a division of Aztec International, Ltd., Flexel is another old-timer in the radiant heater industry.

Flexel is similar to Flex-Heat; a carbon-graphite conductor on a fiberglass substrate is sandwiched between two layers of nonconductive plastic. Copper busbars run down either side of the element.

The watt density of Flexel is 22 W/ft^2. It is available in rolls which can be cut to length and wired in the field, or with factory-installed terminals — a nice flexibility. The list price for the product is $260 for a 100-foot roll of 16" wide material. That boils down to about $118 per kW. Contractors' price is less.

For more information, contact Aztech International, Ltd., 2417 Aztec Road, N.E., Albuquerque, NM 87101; (505)884-1818.

Figure 21 - The Flexwatt system.

Flex-Watt

Flexwatt is the new kid on the block, manufactured by a completely different process than any of the other flexible heaters. As with Flex-Heat and Flexel, the conductive element in Flexwatt is a carbon-graphite mixture, but rather than apply the conductive substance to a fiberglass substrate, Flexwatt applies it directly to the plastic. It is essentially a printing process using conductive carbon-graphite ink. The ink is printed in a zig-zag pattern forming "panels" about one foot long. The result is a very neat and compact product, sold in rolls of 12-, 16-, and 24-inch widths. The watt density is 25 Watts/ft^2. For installation, the rolls are cut on site and wired using clamps and a special crimping tool supplied by the company.

Flexwatt just may be the rising star in the flexible radiant heating market. A key advantage is portability. No other heating system is as small and light. The big question has to do with terminal attachment. How much labor is involved and how safe and reliable are the crimped connections? Will electricians attempt to do the job with ordinary pliers if they lose or forget their special crimping tool? Other than those questions, we could find no reason not to rate this product a winner.

The price for the Flexwatt element is about $100 per kilowatt — slightly more expensive than other flexible heating elements.

For more information, contact Flexwatt Corporation, 611 Neponset Street, Canton, MA 02021; (617)821-1111.

Eswa

ESWA is the only one of the flexible radiant heating products to use a metallic conductor — a thin foil stripe — between two sheets of plastic.

Operationally, the most distinctive feature about ESWA is its lower watt density — 14, 16, and 18 W/ft^2 (based on total element area including deadband area). The lower watt density means cooler ceiling temperatures. Typical operating temperatures are in the range of 77°F to 95° F at the ceiling surface. ESWA also sells a line of product, intended for floor heating, which has even lower watt densities — 6.0, 8.5, and 11.0 W/ft^2. The reason for lower watt density in the floor is that wooden floors have a higher thermal resistance (R-value) than ceiling sheetrock and if the higher powered heaters were used in a floor, they would overheat.

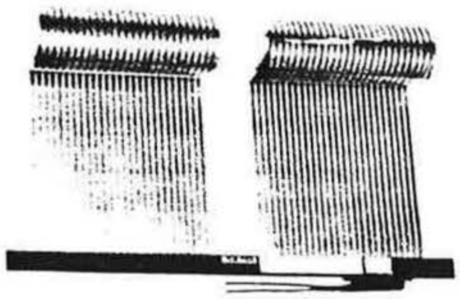


Figure 22 - ESWA heating elements.

ESWA is available only in precut lengths with prewired terminals. It can be purchased either with pigtail wiring attached or with push-wire connectors on the elements which can accept 14-gauge wiring. One potential advantage of the ESWA product is that it is available in widths up to 48 inches and lengths up to 14 feet, reducing the amount of wiring necessary in some applications. A disadvantage is that the pattern of the foil conductor is a single continuous strip. If the foil strip gets punctured or broken anywhere, the entire panel goes dead. That won't happen with any of the other flexible heaters.

ESWA is manufactured in Norway by STK and distributed in North America by ESWA Heating Systems Inc., 4380 D Viewridge Avenue, San Diego, CA 92123; (619) 268-3431.

Gypsum Board with Embedded Heater Wires

Gypsum board radiant heaters consist of regular gypsum wallboard with nichrome heater wires embedded in the center. Only two companies -- Therma-Ray and Panacron -- make it and their products are quite different in form and application.

Therma-Ray

Therma-Ray panels are designed for installation between the joists, above the ceiling sheetrock. The 1/2-inch-thick panels come in 9-, 12-, 18-, and 21-inch widths and lengths ranging from 2 to 13 feet. The watt density is 21.5 W/ft2.

To install Therma-Ray, plastic strips are stapled across the bottom of the ceiling joists to temporarily hold the heater panels in place until the ceiling sheetrock goes up. The panels are then slipped into place over the plastic strips. They are not fastened, but simply rest on top of the ceiling sheetrock after it is installed.

The Therma-Ray panels are prewired with short leads that are connected to the house wiring with tap-on connectors. Although each individual panel must be wired separately, the tap-on connectors make the job fairly painless, allowing the connection to be made without removing the primary insulation from the wiring cable.

One advantage of Therma-Ray is that it is the only concealed radiant heating system that is accessible for repair and/or replacement (in a top-floor installation with attic only). Since the panels are lying on top of the ceiling sheetrock, they can be accessed and removed from the attic if necessary. A disadvantage is cost. The price for a 10'x12" Therma-Ray panel

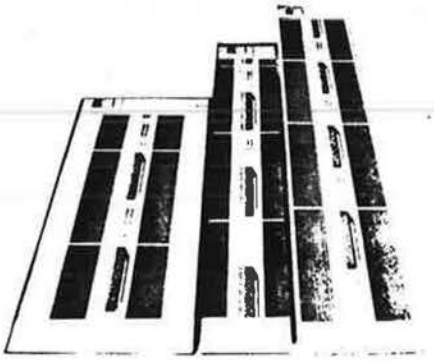


Figure 23 - Therma-Ray panels.

(215 watts) is $35.48 ($165/kW). The cost per kilowatt is even higher for the smaller-size panels. At those prices, it's hard to see how Thermaray can compete against the flexible element products.

For more information, contact Therma-Ray, P.O. Box 516, Old Saybrook, CT 06475; (203)399-7933.

Panelectric

Panelectric is unique among the radiant heating products. The basic material is the same as Therma-Ray — gypsum wallboard with nichrome heater wires in the center -- but Panelectric panels are full-sized sheets which serve as the ceiling sheathing as well as the heating element. (Also, Panelectric is made with 5/8-inch gypsum board, compared to Thermaray's 1/2-inch.)

Panelectric has been around for a long time. It was originally produced and sold by National Gypsum Gold Bond. A few years ago, Gold Bond's manufacturing facilities were sold to Panacron, Inc., Irvine, Kentucky. Panelectric panels are hard to find in some areas of the country but, according to Panacron Vice President Jim Oaks, the reason for the spotty distribution has to do with the product's selling history under Gold Bond. Oaks says that Panacron is currently widening its distribution area.

Panelectric panels are 4 feet wide and come in lengths of 6, 8, 10, and 12 feet. Some of the panels have heating element over the entire area, while others have a "trim end" (see figure 24) area with no heating element. A nailing area around the perimeter is clearly marked.

The Panelectric panels have a lower watt density (15 W/ft^2) than Therma-Ray and most of the flexible element heaters, but since it is exposed to the room, the Panelectric operating surface temperature should be about the same as those other products.

The most attractive feature about Panelectric is cost. A 4'x12' 720-watt panel is about $60.00 ($83/kW). Wiring costs should also be low. Each panel comes with a pre-attached 18-foot lead that is wired directly to the thermostat. Because of the large area of the panels, relatively few connections are required. Finally, since the Panelectric panels are also part of the ceiling sheetrock, a portion of the cost of the sheetrock could justifiably be subtracted from the cost of the Panelectric system.

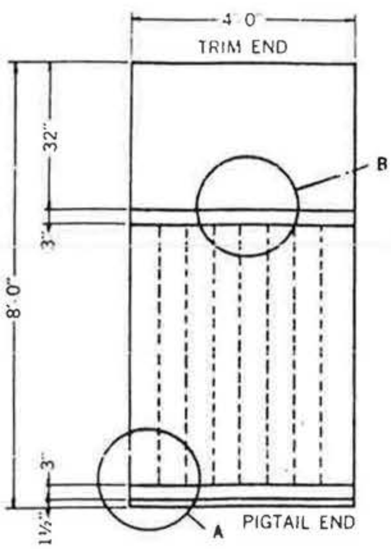


Figure 24 - Panelectric panels.

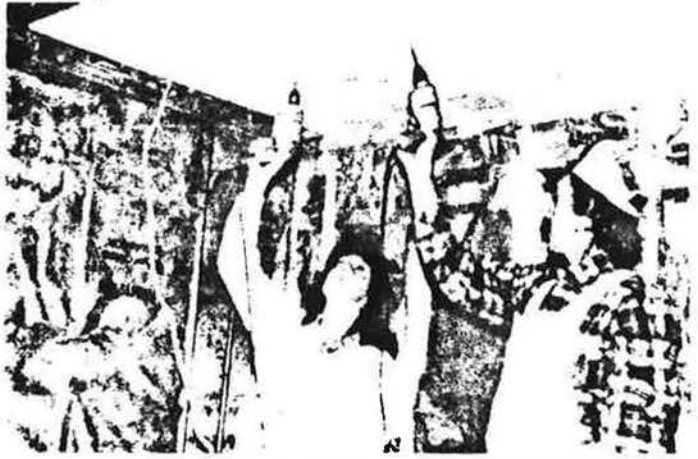


Figure 25 - Is this guy concentrating on his work???

But Panelectric also has a few potentially serious drawbacks. First is shipping size and weight. Whereas a full Flexwatt system for a house can almost fit under your arm, a Panelectric system will fill a small truck. Second is low flexibility compared to other systems. The Panelectric system must be preplanned and specific size panels must be ordered in advance. If the homeowner decides to put a ceiling light fixture where a 4'x12' Panelectric panel was to have gone, something has to change. Third is availability. Even if Panelectric becomes more widely distributed, will all the various sizes be available? And finally there is the need for quality control during installation. Panelectric is installed by sheetrock crews. They must be very careful not to nail or screw in the wrong place. Since the heating element is one continuous wire, breaking the wire in one place puts the whole panel out of commission. A misplaced nail hole would be easy to cover up with some tape and mud but very hard to find later when the panel doesn't work.

For more information, contact: Panacron, Inc., Route 4, Highway 89, Irvine, KY 40336; (606)723-7731.

Aztec Suncomfort

Manufactured for Aztec Marketing, Inc. by Panacron, Suncomfort is the same product as Panelectric. For Aztec's address and phone, see its listing under Flexel.

Modular Heating Panels

Modular heating panels are high-temperature panels that are surface or recessed mounted on ceilings or walls. Modular panels have two distinct advantages: 1) they are easy to install and well suited for retrofit; and 2) they typically have a much higher watt density than other types of radiant heaters, making them more effective as spot heaters in cool areas.

Enerjoy

Enerjoy panels, produced by Solid State Heating Corporation, New Canaan, Connecticut, have a laminated carbon-graphite heating element known as "Energy-Kote," formerly marketed as TVI Energy-Kote by TVI Corporation, Beltsville, Maryland. The heating element is backed up by a 1-inch-thick layer of high-density (6 lb/ft^3) fiberglass insulation. The front facing is a textured, paintable surface coating. The watt density of the Enerjoy panel is 50 W/ft^2. Panel sizes range from 2'x2' (200 watts) through 4'x 8' (1640 watts).

Due to their higher watt density and exposed installation, Enerjoy panels operate at a much higher temperature than flexible heating elements. Typical panel surface temperature is about 180°F. At that temperature, the radiant heating effect is quite noticeable, particularly at close range, making these panels very effective for offsetting radiant cooling caused by large windows or skylights.

Another advantage of Enerjoy's exposed surface and high watt density is fast response time. Solid State's advertising campaign uses the hook line "Treat Your Heat Like Your Lights," meaning that if you feel cold, just flip a switch to feel warm. With Enerjoy panels, you can do just that. The panels warm up in about five minutes, providing thermal comfort quickly, (as long as you are standing under the panel), even though the room may still be cool.

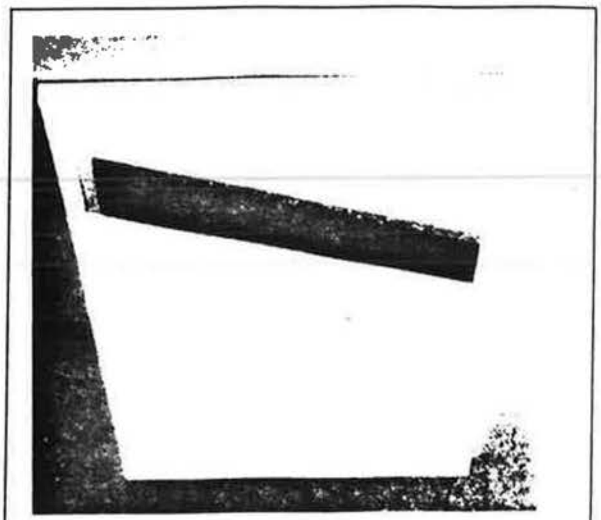


Figure 26 - Cutaway of Enerjoy radiant heating panel.

A good example of an application that exploits the advantageous features of high-temperature panels was sent to us by designer Chuck Silver, president of Solaplexus, New Paltz, New York. Silver installs pairs of Enerjoy panels on either side of large skylights over sleeping areas. Here's a place where, because people are generally inactive, radiant cooling of an overhead skylight might be uncomfortable. The radiant heating panels, with their fast response time, eliminate the problem at the flick of a switch.

A drawback of Enerjoy panels is that they are visible. Although they are paintable, can be recessed, and with enough finesse, be made to either complement or blend in with some ceilings, they don't share the "invisible" advantage of other types of radiant heaters.

Per kilowatt of capacity, Enerjoy panels are expensive. Contractor's price for a 2'x4' (400 watts) panel (panel only) is $135.00 ($337.50/kW). Even though installation labor costs are relatively low, to install an entire heating system composed of Enerjoy panels would be very expensive compared to other radiant systems. Unless the fast response time is a prime requirement, they are probably not the best choice for the main heating system in new construction. The most appropriate use for these panels is as supplemental perimeter heaters, spot heaters in cool areas, and retrofit applications.

For more information, contact Solid State Heating, P.O. Box 5401, Norwalk, CT 06856; (203)866-9963.

Aztec Radiant Heating Panels

Aztec heating panels are similar to Enerjoy, using a graphite heating element backed up by an inch of fiberglass insulation. But unlike Enerjoy, the Aztec panels are cased in galvanized steel (22 gauge on the front and 24 gauge on the back), making them heavier but sturdier than Enerjoy. The Aztec panels have all the same advantages of high temperature and fast response that Enerjoy has. One minor drawback of the Aztec panels is that the fiberglass insulation behind Aztec's heating element is only 1-pound (R-3.3) density versus

Enerjoy's 6-pound (R-4.0) material. The lower R-value of the Aztec insulation means higher surface temperature on the backside surface of the panels.

Figure 27 - Aztec radiant heating panel installed on ceiling.

Aztec panels are available in two watt densities — 62.5 and 95 W/ft^2. The 95 W/ft^2 panels operate at a surface temperature of about 200°F. A variety of sizes are available ranging from 2'x2' to 2'x8'. Also, 14"- and 22"-wide panels are available for recessed mounting between joists (exposed, not concealed behind the sheetrock). The price for a 2'x4' 750-watt T-bar panel is $136. The same size panel at the lower watt density (2'x4', 500 watts) is the same price. Both are available with a frame for surface mounting for an additional $35.00.

For contact information, see the Aztec listing under Flexel, above.

Berko CP Metal Ceiling Panels

Berko ceiling panels, produced by Berko Electric, Peru, Indiana, have a wire heating element bonded to a steel-face panel. Used mostly in commercial applications, the exposed face of the Berko panel is an off-white textured baked enamel.

Available in 2'x4' and 2'x6' sizes, the watt density of the Berko panel is 62.5 W/ft^2. The price for the CP500-208, a 2'x4' 500-watt panel, is about $100.

For more information, contact: Berko Electric, P.O. Box 188, Highway 19 North, Peru, Indiana 46970; (317) 472-3921.

Cable Systems

With the advent of flexible element heaters, cable ceiling heating systems are pretty much history for residential applications. Installation is difficult and time consuming. First, a layer of sheetrock is applied to the ceiling and the cable is stapled onto the sheetrock. Then plaster is applied over the cable to form a plastered ceiling with embedded cable. An alternative method is to install the cable in a bed of plaster sandwiched between two layers of sheetrock. The total process takes several days. The cost of the cable is about $.10/ft.

One brand of radiant ceiling cable is RCC cable, available from Berko Electric, P.O. Box 188, Highway 19 North, Peru, Indiana 46970; (317)472-3921.

DUTY CYCLERS FOR HOUSES

"No longer do you have to face the never-ending horror of constantly rising gas and oil bills. The Temper-Sensor from The Master's Company can save you thousands of dollars on unwanted and unnecessary energy usage. Attached directly to your forced-air furnace or heat pump, the Temper-Sensor downsizes your heating and air conditioning systems, allows for desired comfort levels, and enables the system to seek its own efficient operation level." — From Temper-Sensor brochure.

Even if you haven't read Temper-Sensor advertising before, you probably have seen some promotional literature for one of the many control devices, commonly referred to as "duty cyclers," that claim to increase the efficiency of residential heating and cooling systems by modifying the control logic of heating and cooling systems.

Some duty cycler manufacturers claim energy savings "up to 40%" for their product (although those claims were challenged in a Federal Trade Commission action (see the February 1986 EDU), and we constantly receive inquiries at EDU asking whether duty cyclers work to save energy and increase comfort. Despite several months of research, the answer to that question is still a bit hazy, but we were able to gather some good research analyses and field test results. All in all, residential duty cyclers appear to be of little or no value for new housing with high-efficiency heating and cooling systems. For retrofit applications, they are of no value for controlling air conditioners, but may be of some value for reducing fuel consumption by older, less-efficient heating systems.

What Is A Duty Cycler?

If you ask a mechanical engineer to define the term "duty cycler," he or she will probably describe a control device used in commercial buildings to shed electrical load by cycling certain devices on and off during peak load times. The purpose is to avoid high electricity rates which are set according to peak demands.

Figure 28 - The Temper-Sensor, distributed by the Bisbee Company, Grinnell, Iowa, selling for $300, appears to be little more than a supplemental high-limit switch.

Figure 29 - The Enerex EN-3 Microcomputer, from Save Energy America, Inc., Spokane, Washington, guarantees 20% savings on forced-air electric or heat pump applications.

The devices sold as duty cyclers for residential heating and cooling systems are completely different from commercial duty cyclers. Despite variations in control logic and extra features, all residential duty cyclers do basically the same thing: they cycle the burner or compressor off for a portion of the time that the thermostat is calling for heating or cooling.

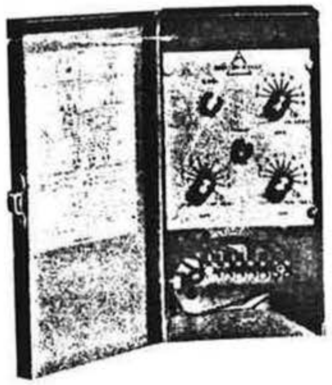


Figure 30 - The Master Cycle claims it can decrease energy consumption between 15 and 30%.

The first devices to hit the market several years ago were quite simple: they were either timers which could be set to cycle the burner or compressor off for a certain percentage of the time, or they were temperature-sensing devices which controlled burner or compressor operation to maintain lower (for heating) or higher (for cooling) air temperatures in the supply or return plenums. With the advent of low-cost, solid-state electronic hardware, more sophisticated duty cyclers have hit the market. Some of them monitor total system performance and adjust the percentage of off time proportionately to the need for heating or cooling. The more sophisticated devices include logic that removes the duty cycler from the control circuit if and when the device is preventing the heating or cooling system from meeting load demands. (See section on the Georgia Tech study below for a description of various types of control logic.)

Why Do Duty Cyclers Save Energy?

That's the question of the day. Despite extensive digging, we were not able to find any good watertight explanation for how these devices might provide the 15 to 40% energy savings claimed by many manufacturers. Some of the explanations make sense for older low-efficiency heating systems, but not for new high-efficiency furnaces and boilers. None of the explanations make sense for air conditioners.

In general, explanations for how duty cyclers save energy fall into two main categories: 1) they cause effective "downsizing" of the heating or cooling system, matching the system to varying loads; and 2) they allow for "harvesting" of warmth or "coolth" that is stored in the mass of the air handler and ductwork.

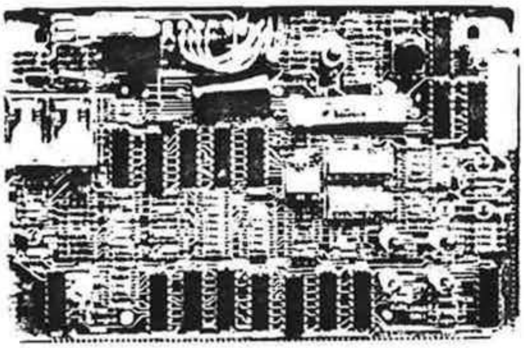
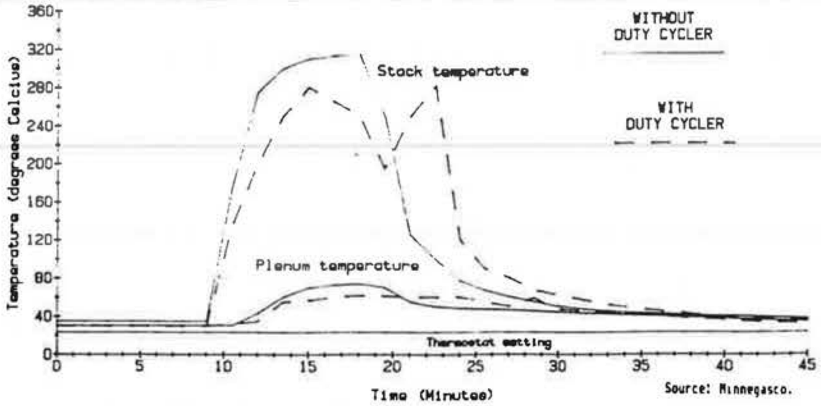


Figure 31 - The innards of the Savit 130, from Electronic Systems International, Norcross, Georgia, illustrates the use of complex solid-state electronics in the current generation of duty cyclers.



Source: Minnegasco.

Figure 32 - Temperature profile in older furnace over one burner cycle with and without duty cycler operating.

1. "Downsizing" the System

In a sense, cycling the burner of a furnace or boiler on or off produces a similar effect to lowering the firing rate or downsizing the burner. Let's look at an actual example:

Figure 32 shows the temperature profiles at the stack and at the supply plenum of an older furnace. The data in the graph are actual results of a lab test performed by Minnegasco Gas Company to measure the efficacy of the Gem Energy Sentry duty cycler. The Gem unit works by sensing the temperature of the air in the supply plenum and reducing burner "on" time whenever the supply air exceeds 120°F. The solid lines represent the temperatures without the duty cycler and the dashed lines represent the temperatures with the duty cycler.

The duty cycler has three effects: 1) burner "on" time is longer; 2) stack temperature is generally lower, with a significant drop during "off" cycles; and 3) supply plenum temperature is lower. The lowered stack temperature should theoretically result in increased efficiency.

But . . .

Although the "downsizing" theory makes some sense, certain factors work against the increase in efficiency:

A. Since each burner cycle lasts longer, the amount of air lost up the stack could be greater, resulting in more air infiltration into the house. That effect wouldn't show up in tests such as those performed by Minnegasco.

B. Each time the burner shuts off and on again, it takes time for the combustion process to get up to maximum efficiency. The net effect is that the burner spends relatively more time operating at a lower combustion efficiency.

C. With new high-efficiency systems, the heat exchangers are lighter and have more surface area. Flue gas temperatures are already very low and it is unlikely that controlled cycling would do anything to increase overall efficiency. The energy savings due to "effective downsizing" probably only apply to older, inefficient heating systems.

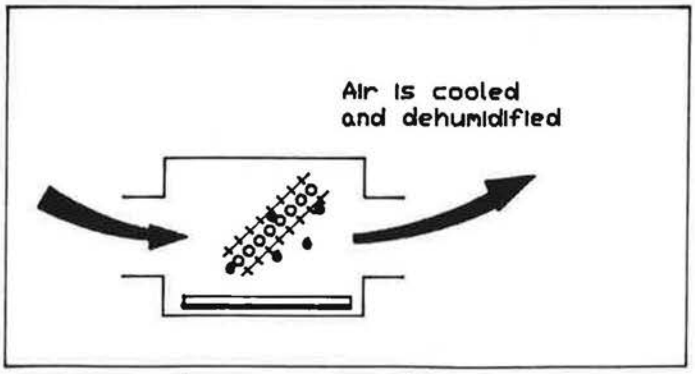
D. For air conditioners, the theory is simply wrong. A recent study performed at the National Bureau of Standards by William Mulroy showed that duty cyclers do not increase the efficiency of compressor-type air conditioners. The following is quoted from Mulroy's final report:

"There is no short-cycling device control strategy that would increase the efficiency of a residential air conditioner or heat pump . . . beyond that provided by a conventional thermostat. In fact, such short-cycling devices would cause a loss of efficiency in meeting the imposed building load. This loss, which would occur in applying such a device, was observed to be greater for units of low cyclic efficiency that those of the highest efficiency." [Underlining our emphasis.]

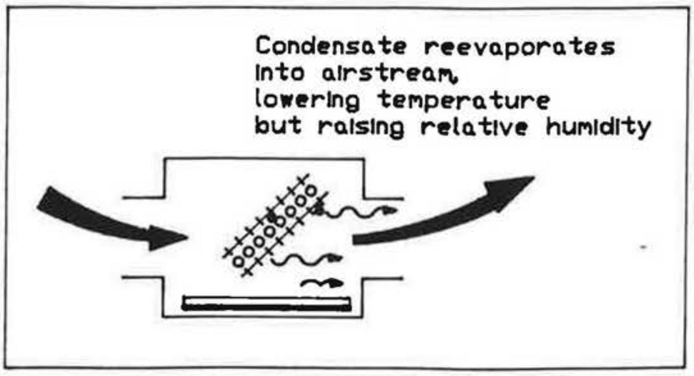
2. Harvesting Of Warmth or "Coolth" from Heat Exchanger And Ductwork

The theory is simple. When a furnace or boiler shuts off, some amount of heat is left in the mass of the heater and in the distribution ductwork. If the fan is allowed to run longer after the burner shuts off, some of that heat can be recovered and distributed to the house. The same theory applies to harvesting "coolth" from air conditioning systems.

That this theory works was illustrated in test results performed by Brookhaven National Labs on the Energy Kinetics System 2000 boiler (see the January 1986 EDU). The System 2000 has a built-in control logic that purges the system after each firing cycle to extract heat from the mass of the boiler.



A. compressor on; fan on.



B. compressor on; fan off.

Figure 33 - Air Conditioner under duty cycler control.

But . . .

A. If the heating system and ductwork are located within the living space, then the heat or coolth stored in those elements is not wasted, but rather will be dissipated to the living space.

B. New high-efficiency equipment is usually relatively light and thus stores much less heat than older, heavier equipment.

C. If the fan is run too long, supply air may become uncomfortably cool.

D. For air conditioners, again, the theory and strategy are simply wrong. The problem with air conditioning is that, when the fan is run after the compressor shuts off, condensed water on the cooling coil is re-evaporated, thus increasing the relative humidity in the house. When the condensate re-evaporates, the supply air is cooled (just as with an evaporative cooler), but the overall cooling load is increased due to the elevated humidity (see Figure 33).

This process was studied by Mukesh Khattar at the Florida Solar Energy Center. Khattar found that "compressor cycling devices (which systematically cycle off the compressor and let the fan operate with the aim of using stored cooling in the coil) actually reduce effective moisture removal from the air conditioner and lead to undesirably higher indoor humidities."

Laboratory Testing Data Is Essentially Nonexistent

Minnegasco and the Gem Sentry

The only lab testing data we could find of any duty cyclers was from a test of the Gem Energy Sentry performed last year by Minnegasco Gas Company, Minneapolis, Minnesota. When we first saw that test report we thought it might be the saving grace for the residential duty cycler industry because it showed savings of 10.5 and 19.3%. Needless to say, Gem had no complaints about those results. Its advertising literature claims that savings from 15 to 40% are possible. A footnote on its brochure explains that "this claim is supported by controlled laboratory tests conducted by a major public utility in the State of Minnesota."

But there is one problem. The entire Minnegasco test consisted of operating a furnace over three burner cycles with and without the Gem unit operational. (Data for one cycle are shown graphically in Figure 32.) That's it! The test was truly "quick and dirty" and the results are tenuous at best. We spoke to two Minnegasco staff members who were responsible for conducting the test and interpreting the data. When asked for an explanation of how the duty cycler saved so much energy, one replied: "I personally don't believe they do save energy. I wrote the report gritting my teeth." The other told us that "the savings projections might be a little far-fetched." In other words, so much for "controlled laboratory tests by a major public utility."

The bottom line is that no laboratory tests have yet confirmed or quantified the energy saving capability of residential duty cyclers.

What About Field Tests?

Heating Mode: The Spoon River Study.

Despite the proliferation of residential duty cyclers, little field testing has been done to measure the efficacy of these devices. The most comprehensive study was performed from 1981 to 1985 by Spoon River College, Canton, Illinois, in cooperation with the Energy Resources Center at the University of Illinois at Chicago.

Researchers at Spoon River lab tested every duty cycler available at the time of the study. Based on a set of predetermined performance criteria, they selected the "Furnace Governor," manufactured by Electronics Systems International (ESI), for field testing. A total of 234 units were installed in residences in four Illinois counties in September of 1983. Another 88 residences were selected to participate in the study as part of a control group. Both samples had previously received weatherization assistance through a federally funded program.

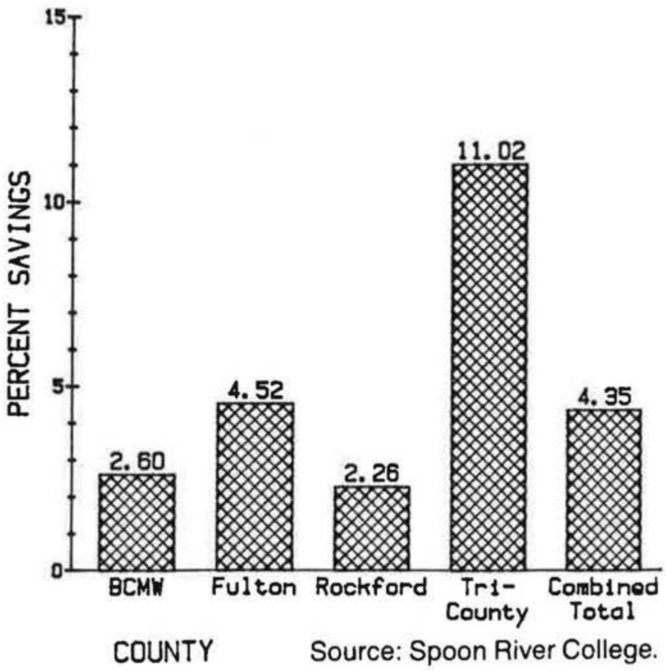
Results

1. Average savings were 4.35%

Energy savings, calculated by comparing fuel consumption before and after installation of the duty cyclers, varied considerably between counties, ranging from 2.60 to 11.02% (Figure 34).

2. Over 35% of the test houses showed no savings at all.

Of the 93 test houses in the study, 33 showed either no reduction in fuel consumption or an increase in fuel consumption after installation of the duty cycler. Figure 35 shows those results.



Source: Spoon River College.

Figure 34 - Percent savings from installation of duty cyclers in 93 test houses in 4 Illinois counties.

Conclusion

The final report of the Spoon River study admits that the number of houses studied was relatively small. The measured savings may not be statistically significant. The best conclusion we can draw from this study is that duty cyclers may save some heating energy sometimes. With an average savings of 62 ccf of gas, the total dollar savings at current prices would be roughly $40 per year

Cooling Mode: The Georgia Tech Study

The only field monitoring we could find of duty cyclers used to control air conditioning in a warm climate was a study published in 1984 by the College of Architecture, Georgia Institute of Technology. Four duty cyclers with differing control strategies were tested. Not all of these models are still available, but the various control strategies are representative of the types of logic used by most systems on the market today.

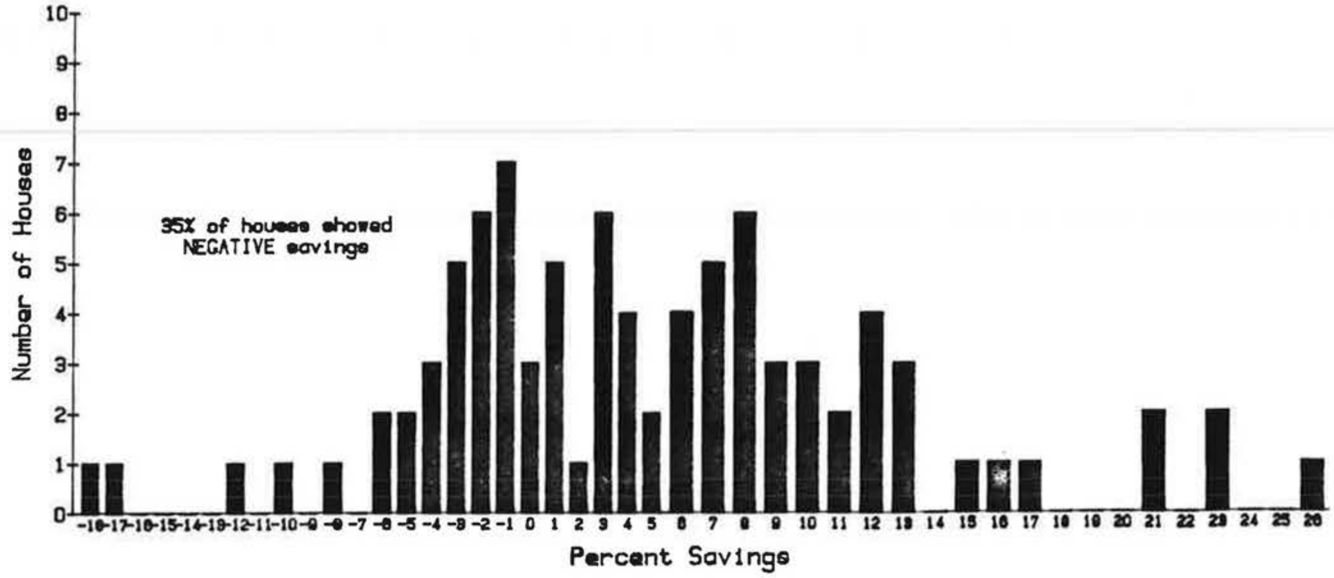


Figure 35 - Number of houses showing various percentage savings after installation of duty cyclers.
Source: Spoon River College

1. SavIt Model S-110, manufactured by Electronic Systems International.

This was the simplest of the four devices tested. It is basically a timer that can be adjusted for 3, 5, or 6 minutes compressor off time for every 15 minutes of operating time when the thermostat is calling for cooling. It is important to note that this unit leaves the fan running when the compressor is turned off.

2. SavIt Model S-120

This unit is more sophisticated than the SavIt model S-110. Initially it turns the compressor off for 3 minutes out of every 15. Then it checks to see whether the thermostat is satisfied. If it is, the Model 120 then increases the off time for the next cycle and continues to increase the off time until it equals some fixed period (believed to be about 6 minutes). If at any point the house thermostat is not satisfied, then the Model 120 decreases the off time until it gets back down to 3 minutes. The fan is left running whenever the compressor is off.

3. The Energy Computer, manufactured by Electro Tech Manufacturing.

The Energy Computer is a microprocessor controller that monitors the thermostat and calculates the running time of the air conditioning system every fifteen minutes, all day long. The unit stores the information in memory and calculates the running time for the next fifteen-minute cycle, always trying to reduce running time of the compressor. The minimum off time is 4 minutes. If the thermostat is satisfied while the compressor is turned off by the Energy Computer, the off time increases on the next fifteen- minute cycle. If the thermostat is not met during a fifteen-minute cycle, the Energy Computer will decrease the off time until the minimum 4-minute off limit is reached. If the thermostat is still not met in the next fifteen-minute cycle, the duty-cycler will turn itself off until the thermostat is satisfied. It then begins the whole process over again. The fan is allowed to run for a short period of time after the compressor is turned off (roughly 2 minutes).

4. The Energy Saver, Model AE-1A, manufactured by AE Management Systems.

This unit starts with a fixed minimum off period of 6 minutes out of every 30 minutes. It measures the temperature of the return air with a thermistor located in the return air plenum. In the cooling mode, when the return air temperature drops below 76°F, the off time is increased, reaching 100% off if the return air temperature reaches 72°F.

Results of the Georgia Tech Study

Energy Savings

To test for and measure energy savings, the four duty cyclers were operated every other day during the test period. Electricity consumption was measured and savings were calculated as the difference in electric usage between days with and days without the duty cycler operational. Figure 36 shows the measured savings.

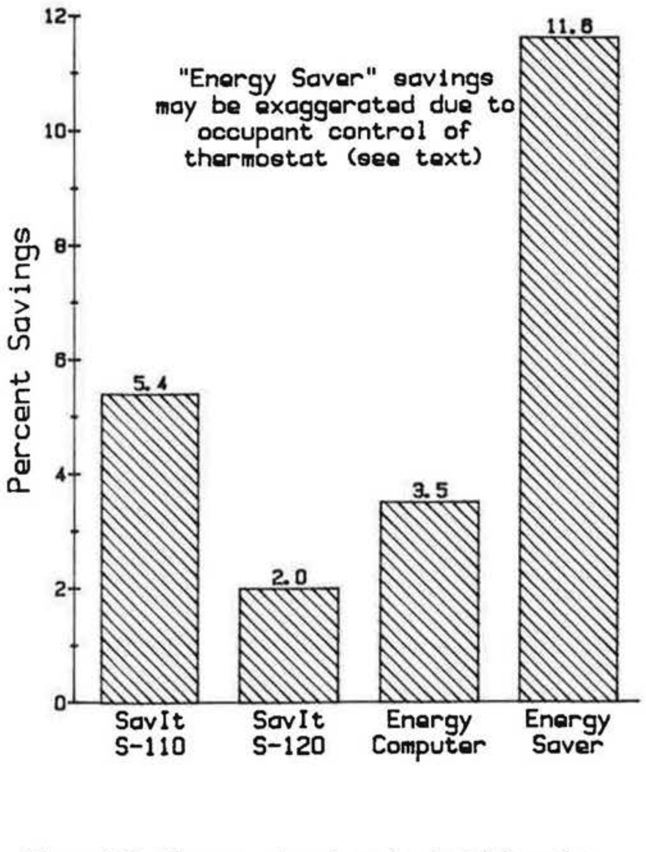


Figure 36 - Measured savings in electricity using four brands of duty cyclers for air conditioner control.
Source: Georgia Institute of Technology

It should be noted that some of the measured energy savings shown in Figure 36 may be too high. The reason is that the duty cyclers allowed the indoor dry-bulb temperature and indoor relative humidity to rise during days when the cycler was operational. Consequently, on the following day, when the thermostat took over without the duty cycler, it had an extra load to handle. The extra load on the "non-duty-cycled" days tended to exaggerate the savings attributed to the duty cycler.

The reported savings for the Energy Saver are particularly suspect. That unit literally takes control of the indoor environment, preventing the temperature from ever going below 72°F. In the Georgia study, the occupants often set the thermostat below 70°F. On days when the duty cycler was not operational, the air conditioner worked until the 70°F or lower temperature was attained. But on days when the duty cycler was working, the house was never cooled below 72°F. Had the house occupants left the thermostat set to 72°F, the savings attributed to the duty cycler would have been less.

Comfort

The main impact of the duty cyclers on comfort was to increase indoor relative humidity in houses controlled by those duty cyclers that kept the fan running when the compressor was off (the two SavIts).

Compressor Cycling Frequency and Warranty Considerations

There are concerns regarding the increased number of times that the compressor cycles and the short length of time the compressor remains off when controlled by a duty cycler. Figure 37 shows the number of daily compressor cycles counted in the Georgia Tech study with and without the duty cyclers operative. Two of the duty cyclers — the SavIt S-110 and the Energy Computer — caused the number of compressor cycles to roughly double while the remaining two cyclers had much less effect. No explanation for that phenomenon is given in the study report.

The major equipment manufacturers publish guidelines on the use of duty cyclers with their equipment. Table 3 is a summary of those guidelines, as listed in the Georgia Tech report, for equipment manufactured by Carrier, Lennox, G.E., and Trane. Notice that the two SavIt models and the Energy Computer fail to pass the permissible criteria for all four manufacturers. All three units use a shorter "off" cycle than the minimum five minutes required by the manufacturers. While the Energy Saver meets the requirements of Carrier and Lennox, its "off" cycle of six minutes is less than the seven minute minimum "off" cycle permitted by the General Electric and Trane criteria.

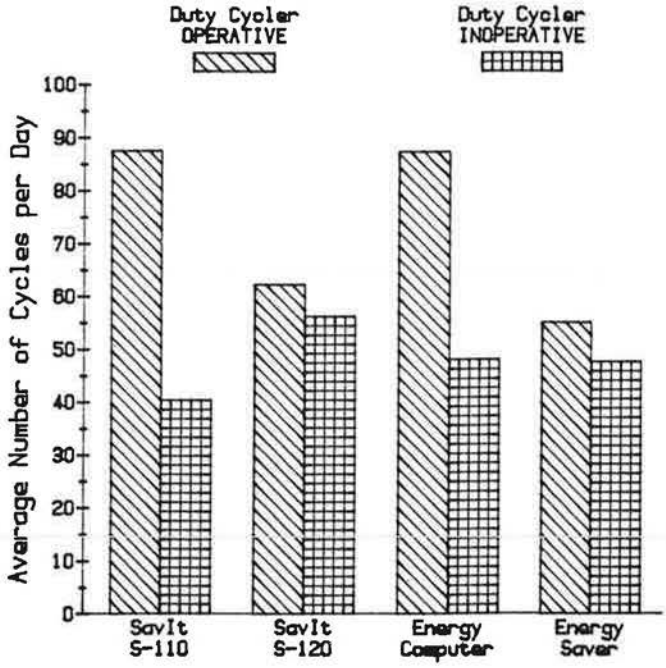


Figure 37 - Comparison of compressor cycles with and without duty cyclers.

Source: Georgia Institute of Technology

Each of the manufacturers mentioned supplies a fact sheet concerning the use of duty cyclers with their equipment. The following are a few quotes from those fact sheets, as reproduced in the

EQUIPMENT TYPE	MANUFACTURER	MINIMUM OFF TIME	MAXIMUM OFF TIME	MINIMUM RUN TIME	MAXIMUM CYCLE/HR.
Room Air-Conditioners	Carrier	5 mins.	*	10 mins.	3
	Lennox	*	*	*	*
	G.E.	*	*	*	*
	Trane	*	*	*	*
Single Piece Packaged Units	Carrier	5 mins.	*	10 mins.	3
	Lennox	5 mins.	*	10 mins.	*
	G.E.	7 mins.	45 mins.	20 mins.	*
	Trane	7 mins.	45 mins.	20 mins.	*
Two Piece less than 25' Length Interconnecting Tubing	Carrier	5 mins.	*	10 mins.	3
	Lennox	5 mins.	*	10 mins.	*
	G.E.	7 mins.	45 mins.	20 mins.	*
	Trane	7 mins.	45 mins.	20 mins.	*
Two Piece more than 25' Length Interconnecting Tubing	Carrier	5 mins.	*	15 mins.	2
	Lennox	5 mins.	*	10 mins.	*
	G.E.	7 mins.	45 mins.	20 mins.	*
	Trane	7 mins.	45 mins.	20 mins.	*
Heat Pump	Carrier (1)	5 mins.	*	15 mins.	2
	Lennox (2) (3)	5 mins.	*	10 mins.	*
	G.E. (4) (5)	7 mins.	45 mins.	20 mins.	*
	Trane (4) (5)	7 mins.	45 mins.	20 mins.	*

* Not specifically addressed
(1) No compressor cycling below 20°F outside ambient
(2) Normal defrost cycle should not be altered
(3) Compressor must not be cycled off for long periods of time at ambient temperatures below 20°F
(4) Do not interrupt power to sump heat
(5) Do not use with two speed Heat Pump Systems

Table 3
HVAC manufacturers load control performance criteria.

Georgia Tech report. Notice that the Trane/G.E. excerpt includes a discouraging statement about the efficacy of duty cyclers.

1. Carrier Corporation

"Any liabilities incurred as the result of the installation of these controls rest with the manufacturer of the control devices and the installer. Should the installation of these controls result in the premature failure of a component of Carrier equipment, warranty credit would be in question."

2. Lennox Company

"Lennox equipment is listed by Underwriters Laboratory or American Gas Association and is in compliance with the appropriate ANSI standards as they are manufactured. Control system modifications will void the listing and may not comply with the ANSI standards. Any accident caused by such modification would be the liability of the designer and/or the installer of the field-furnished devices."

3. Trane / General Electric

"The warranty on General Electric brand equipment covers manufacturing defects. Obviously, if a component fails due to misapplication or malfunction of a load-shedding device, the warranty will not apply."

"Load-shedding devices may 'prevent' in heating, cooling, or both. The energy savings come about since the equipment is not permitted to run when it normally would respond to a thermostat call. Less run time means fewer kilowatt hours but also poorer temperature and humidity control. It may be possible to save as much energy by merely changing the thermostat setting."

Conclusion

Unless we have missed some important evidence to the contrary, our conclusion is that duty cyclers don't make sense for new homes. For retrofit applications, they may save some energy, but the amount of those savings is in question. We found absolutely no evidence indicating that duty cyclers could ever achieve the 15 to 40% savings claimed by some manufacturers. Given typical price tags ranging from $300 to $600, it is unlikely that these devices will ever pay for themselves in energy savings.

This conclusion is echoed in a recent ASHRAE technical paper written by Professor V.W. Goldschmidt at Purdue University: "Duty cyclers will have no effect on resistance heating systems, a detrimental effect on compressor-driven systems (air conditioners and heat pumps), and a small, if any, benefit on combustion fired furnaces."

Reports cited in this article:

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The Effect of Short Cycling and Fan Delay on the Efficiency of a Modified Residential Heat Pump, by William J. Mulroy, National Bureau of Standards. Available from American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE), 1791 Tullie Circle, N.E., Atlanta, GA 30329. Paper # SF-86-17 No. 1.

Fan Cycling Effects on Air Conditioner Moisture Removal Performance in Warm, Humid Climates, by Mukesh Khattar. Available from Florida Solar Energy Center, 300 State Road 401, Cape Canaveral, FL 32920. Paper # FSEC-PF-75-85.

Duty Cycler Evaluation, Final Report by James M. Akridge, College of Architecture, Georgia Institute of Technology, Atlanta, GA 30332. Available from Georgia Office of Energy Resources, 270 Washington St., S.W., Atlanta, GA 30334; (404) 656-5176. (contact Robin Meyer.)

Minnegasco test of Gem Energy Sentry Duty Cycler. Contact: Minnegasco, 201 South Seventh St., Minneapolis, MN 55402; (612)372-4664.

On the Use of Duty Cyclers in Residential HVAC Systems, by V.W. Goldschmidt. Available from American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE), 1791 Tullie Circle, N.E., Atlanta, GA 30329. Paper #NY 87-19-2.

APPENDIX

HIGH-EFFICIENCY HEATING SYSTEM CROSS-REFERENCE CHART

This appendix contains a complete cross-reference chart of heating systems available in residential sizes with an annual fuel utilization efficiency (AFUE) of 81% or higher. It should be useful for selecting and/or comparing available units.

For each model or series, we have listed heat output, maximum AFUE, length of warranty period, and a checklist of important features such as outdoor air for combustion, direct outside venting, etc.

The reason the AFUE is listed as "maximum" is because within each series there are often minor variations in efficiency among models. Typically, but not always, the smaller units in a series will have a higher efficiency than the more powerful models. We've selected 81% as the cutoff point for inclusion in this chart because many manufacturers sell a block of models in the 75.0 to 80.5% efficiency range, plus one or two models with efficiency higher than that. The 81% cutoff is low enough to include representative high-efficiency models from most manufacturers, yet high enough to eliminate the larger block of medium-efficiency units.

The listing was compiled by Roger Harris, technical consultant at the Hampden County Massachusetts Energy Office. A previous version of the following cross-reference chart appeared in the September 1986 edition of EDU. The following version has been updated for this special report.

Heading Systems Available in Residential Sizes with an A.F.U.E. of 81% or better

CAST IRON OIL-FIRED BOILERS

CAST IRON OIL-FIRED BOILERS	DOE-rated Output (x 1000)	A.F.U.E. Range (%)	Water Container Range (gal.)	P = Power Burner F = Forced Draft I = Induced Draft	S = Stack Damper B = Burner Inlet Damper	Direct Outside Venting	Wet Base Boiler	Steam Model Available	Warranty
Buderus Logana 3.10	55.68 - 281.88	86.6 - 87.3	7 - 18	P			X		10L
Burnham VI series	89.0 - 245.0	83.2 - 85.4		P			X		20L
Burnham V3 series	122.0 - 241.0	80.0 - 82.4		P	S opt.			X	20L
Chappee Malaga series	53.7 - 236.0	84.0 - 85.9	3.8 - 11.25	P			X		
Circle Combustion	83 - 253	84.8 - 87.1		P			X		
Crown Bahama	60.0 - 265.0	- 85.0		P			X		20L
Crown Freeport series	92.0 - 167.0	85.4 - 87.6	4.2 - 6.8	P			X		20L
Dan Heat		- 85.0		P	B		X		20L
Dunkirk Empire series	92.0 - 239	83.7 - 86.0		P					
Dynatherm CI series	53.7 - 236.0	84.0 - 85.9	3.8 - 11.25	P			X		
Governale GR series	119 - 189	84.1 - 84.4		P			X		
Hydrotherm WO-AW series	102.0 - 219.0	80.0 - 82.0		P			X	80.3 (101)	20L
NECA Midy, Midytherm, Mjr	60.0 - 307.0	84.5 - 86.7	3.5 - 17.7	P	B		X		20
Peerless HEO	91.0 - 236.0	80.4 - 83.2		P				X	20L/1L
Peerless JO-TW series WB series	92.0 - 241.0 92.0 - 241.0	83.8 - 86.5 81.7 - 83.9		P P				X X	20L/1L
Pensotti R series	75 - 158	83.1 - 83.6		P			X	X	20L/3L
Sears #229.944 (13 - 25)	92 - 239	83.7 - 86.0		P					
Slant-Fin Liberty series	134 - 375	83.45 - 84.15	83.33 - 84.45	P			X		
Slant-Fin Malibu series	101, 120, 179, 237	81.0 - 83.6		P			X	81.2 (99K)	
Smith, H.B. series 8	91.0 - 250.0	84.3 - 86.2	11.7 - 21.9	P	B		X	X	10L/3L
Tekton/Sime AR series	102 - 163	84.1 - 84.4		P			X		20L
Steldrad CR-1	54.0 - 266.4	- 88.5 prelim.	6.1 - 21	P			X		20
Ultimate PFO series	64.0 - 301.0	82.9 - 87.6		P	B		X		10L
Ultimate selected K series	78.0 - 284.0	80.2 - 87.9		P	B				10L
Utica Star Fire II series	79.0 -231.0	82.5 - 86.5 81.0 - 84.0	10.5 - 16.5	P	B (S opt.)				
Vaillant F75/F70 series F80 series	69.0 - 224.0 69.0 - 224.0	85.5 - 87.0 81.0 - 84.0	X (F70) 10.5 - 16.5	P P			X X	X	10L
Weil-McLain 68 series	86.0 - 248.0	82.1 - 82.7 (S) 84.1 - 86.1		P	B		X	X	20L

Heating Systems Available in Residential Sizes with an A.F.U.E. of 81% or better	DOE-rated Output (x 1000)	A.F.U.E. Range (%)	Water Container Range (gal.)	P = Power Burner I = Induced Draft	S = Stack Damper B = Burner Inlet Damper	Direct Outside Venting	Flow Pattern	Outside Air for Combustion	Condensate Drain	Wet Base Boiler	Steam Model Available	Scotch-Marine Boiler	Wall-hung Boiler	Warranty
STAINLESS STEEL OIL-FIRED BOILERS														
Elf Technologies "Turbo Plus"	70.0 - 120.0	- 92.0 prelim.			B	X								
STEEL OIL-FIRED BOILERS														
Axeman-Anderson Olympia I	80.0 - 103.0	83.9 - 88.1	9	P	S					X				20L
Axeman-Anderson PO-2 & NPO series	92.0 - 227.0	81.1 - 88.7	15 - 28.5	P	S					X				20L
Axeman-Anderson Vesta (PVT series)	100 - 173	80.1 - 82.6 82.8 - 84.7 (S)	12 - 13	P	S opt.									20L
Burnham RSM Series RS-D	96.0 - 163	80.0 - 86.0		P	S									20L
Burnham MP Series	108.0 - 138.0	83.6 - 85.5		P	S opt.						X			
Columbia TE Series	91 - 153	82.8 - 86.8		P	S opt.									20L
Columbia CF series	79 - 231	81.0 - 84.0 82.5 - 86.5		P	S									20L
Crown Energy-pak	93.0 - 153.0	80.2 - 82.7		P	S									
Dynatherm RS Series	88.0 - 197.0	82.5 - 85.7	16 - 32	P						X				
Dynatherm Migon series (MX, MXC, MXS)	104 - 146	83.0 - 89.1		P						downfired wet leg				
O'Brien Products Nova 240/360 Dynatherm FPB Series	104.0 - 212.0	83.9 - 88.5	25 - 52	P						X			X	Lifetime
Electric Furnace-Man PK450T and "Little David" PK400T	53.0 - 117.0	83.2 - 84.9	13 - 20	P										10
Energy-Kinetics "System 2000"	102.0 - 120.0	84.0 - 87.0	2.5	P		X opt.				X			X	10L
Ford FD Series	112.0 - 168.0	80.0 - 80.7	8.10 - 12.0	P										10L
Ford Titan LM-70	70.0	- 85.0	2.4	P						X				10L
New Yorker FR Series	98 - 232	80.9 - 82.8	20	P	B					X	X			20L
Tarm, H.S. Alphs	100 - 75	85.2 - 87.1	21 - 34	P						wet leg				20L
Tarm, H.S. 900 Series	80.0 - 176.0	85.9 - 86.8		P						X				20L
Thermo Dynamics Blueray II BY Series	70.0 - 120.0	82.1 - 87.0	26 -32	P	S					X			X	25L
Thermo-Dynamics Blueray III VTF Series	115.0 - 269.0	81.8 - 83.7	14 - 25	P	S									25L
Trianco TOC Series	96.0 - 203.0	85.2 - 86.3	13.5 - 22.7	P	B									20L
Trianco TRO Series	68.0 - 194.0	83.5 - 85.8	6.7 - 15.8	P	B									20L
STEEL/CAST IRON OIL-FIRED BOILERS														
Teledyne Laars ECCO Series/JF	91.0 - 108.0	83.1 - 84.0		P						wet leg				10L
CAST-IRON OIL FURNACES														
XXth Century "XXtra Heat"	72 - 77	- 86.0		P	B		U							Lifetime

*Many of these boilers are availabe with Carlin or Beckett burners which offer an optional adapter for outside combustion air.

Higher Efficiency Oil-fired Furnaces

STEEL OIL-FIRED FURNACES

81.0% or Better A.F.U.E.

	DOE-rated Output (x 1000)	A.F.U.E. Range (%)	P = Power Burner I = Induced Draft	Direct Outside Venting	Outside Air for Combustion	S = Stack Damper B = Burner Inlet Damper	Condensate Drain	Condensate Neutralization	Stainless Steel Final Heat Exchange	Gauge Steel Construction	Flow Pattern	Warranty
Adison Weatherking OLB-F	100	83.0	P								L	
Airco Products "Airco"	78-115	81.7 - 85.0 85.0-87.7	P P			S					U U	
Arco Arcoaire, Climate Control Comfortmaker:COUB, COLB, most DOHA series*, all by Snyder General	74 - 122	80.5 - 84.3	P			S					U, L, H*	20L
Bard F100CF, F97, F120L, C-1, C-2	99, 142, 192	80.0 - 83.5	P								D, L	20L
Bard Selected OH, OC, OL models	83-123	82.3-84.5	P			S					U, D, L, H	20L
Century Patriot 80+ Series (Comfort-Aire) by Heat Controller	77 - 158	80.0 - 84.04	P								L	
Circle Combustion	77 - 122	84.9 - 88.0	P	X opt		B					L, U	20L
Clare Brothers	76 - 118	82.0 - 84	P								U, L	
Cox Wondaire		- 83.0	P									
Dornback Furnace & Foundry Co. HEO Series	66.5 - 99.75	- 95.0 (preliminary)	P/I	X	X opt.		X	X	X		U	20L
Dornback UFO, ACO, ACF, SO Series	57.8 - 117.2	82.6 - 84.5	P			B					U, D, L, H	20L
DuoMatic/Olsen	78 - 171	83.7 - 87.8 80.0 - 87.1	P			S					U, D, L	10
Econo Tech II Model 60Y	59 - 79	84.5 - 86 prelim	P			B				16g	U	
EnerRoyal Eneroil Comfort - Plus	75.5 - 116.3	94 - 96	P/I	X			X		X		L	20L
EnerRoyal Eneroil Comforter ER Series	56 - 181.6	80.0 - 85.3 85.1 - 87.1	P			S (opt.) S					U, D, L, H	20L
Ford WO Series (most models)	84 - 112	81.6 - 86.4	P			S				16g	U, L	10L
Glowcore (selected models)	83 - 123	82.5 - 84.5	P			S					U, D, L, H	
Heil-Quaker Heil (selected models)	87 - 152	80.1 - 83.9	P								U, D, L	15
Magic Chef (Armstrong, Air-Ease, etc.) (L series with stack damper)	83 - 123	82.5 - 84.5	P			S					U, D, L, H	15L
Metromatic Mfg. LB, HB, SU (84, 100, 120)	84 - 120	80.0 - 82.4	P							12g	U, L, H	Ltd. Lifetime
Newmac Mfg. Inc., WL & NH models	77 - 177	- 86.8	P							14g	L	20L
Oneida Royal w/ Blue Angel Burner	58 - 183	80.0 - 84.3	P			B					U, D, L, H	Lifetime/20L
Sears #867.7414 (21, 31, 50, 70, 80 suffix)	87 - 116	80.1 - 83.9	P			S					U, D	
Thermopride (except OH16-225)	56 - 148	80.5 - 87.1	P			S				13g	U, D, L	Ltd lifetime
Whirlpool (selected models)	87 - 152	80.1 - 83.9	P			S					U, D, L	
Williamson Oilsaver	93 - 224	82.6 - 84.4 86.1 - 87.4	P			S					L	20L
Williamson Temp-O-Matic & Rear Flue Models	84 - 156	80.0 - 81.7 - 88.5	P			S (opt.)					U, D, L	20L
Yukon Ultima EX 95	66 - 85	90.6 - 93.8	P/I	X		B	X	X	X		U, H	20L

* Flow Pattern Codes: U = Up-flow or "Hi-boy", D = Downflow or counterflow, L = Lowboy, H = Horizontal flow models.

* Carlin & Beckett offer a burner adaptor for outside combustion air.

Higher Efficiency Gas-fired Furnaces
STEEL GAS-FIRED FURNACES

	DOE rated Output (x 1000)	A.F.U.E. Range (%)	P = Power Burner I = Induced Draft	S = Stack Damper B = Burner Inlet Damper		Direct Outside Venting	Outside Air for Combustion	Condensate Drain	Condensate Neutralization	Stainless Steel Final Heat Exchange	Flow Pattern	Warranty
Addison Weatherking GUWHC series	32.0 - 115.0	90.3 - 93.3	I								U, D	
GUWHE series	37 - 113	80.0 - 81.1	I			X		X		X	U	
Airco Products, Airco AHMS	43 - 117	81.0 - 83.0	I								U	
Amana Air Command	67 - 126	81.2 - 84.2		S								
Amana Energy Command	39.0 - 95.0	94.5 - 97.0	P			X	X	X	X	X	U	
Arco Aircoaire APGDA series	40 - 79	80.2 - 82.0									D	
AGUC series	43 - 115	90.3 - 93.3	I			X				X	U	
Arkla/Preway Recuperative	35.0 - 103.0	- 87.1	I			X		X		X		
Bard IH, IC, IL series	48.0 - 119.0	81.0 - 83.0	I								U, D, L	20L
XC, XH series	48 - 114	91.1 - 95.8	I			X		X		X	U, D	
Borg-Warner (P1 or PA) (Fraser-Johnston)UMDO8N03701A		-81.1	I								U, D	
Borg-Warner (Fraser-Johnston)Heat Pipe	37 - 88	84.6	I								U	20L
Borg-Warner (Fraser-Johnston)PAUED series	57 - 115	90.3 - 92.4	I			X		X		X	U	
Bryant The Formula 1000 & 2000 Series	39 - 139	81.9 - 83.4	I								U, D, H	20L
Bryant Plus 90	41-122	92.2 - 97.3	I			X	X	X		X	U	20L
Carrier Super Furnace	39 - 139	81.9 - 83.4	I								U	20L
Carrier Weathermaker SX	40 - 121	92.2 - 97.3	I			X	X	X		X	U	20L
Circle Combustion CCLB/CCHB series	76 - 123	80.6 - 83.4	I					X opt			U, L	
Clare Brothers Megasave I HEHB series	29 - 114	94.0 - 97.0	I			X				N/A	U, D, L, H	
Comfortmaker CGUA series/DGHD		80.0 - 83.0										20L
Climate Control (selected models)	32 - 96	- 83.2	F								U, H	10L
Comfortmaker, Climate Control, CGUC series	38 - 110	90.3 - 93.3	I			X		X	opt.	X	U	20/10
Coleman Co "T.H.E."	41-84	89.3 - 92.1	I			X				N/A	U	
(selected models)	41-96	80.5 - 82.5	I								U	
Consolidated Ind., "Premier" HBA (selected models)	33 - 50	80.0 - 82.0	I								H	
Cox Wondaire		- 82.5										
Dayton Electric Mfg., 3E4 series	47 - 113	91.4 - 96.0	I			X		X			U	20L
Duomatic Olsen Ultramax HCS	38 - 83.6	92.0 - 95.7	I			X	X	X	X		U	20L
Glowcore UGR, DGX, UGX series	38 - 94	90.0 - 97.1	P			X	X	X		X	U, D	20L
Glowcore UGE w/ damper	33 - 97	80.2 - 82.5		S							U	
Reclaimer 80 (also sold as "Comfort-Aire")	37 - 113	80.1 - 81.1	I								U, D	
Heat Controller Reclaimer I	35 - 103	85.0 - 87.1	I			X		X		X	U, D	20L
Reclaimer II	38 - 110	91.0 - 95.0	I			X	X	X		X	U, D	20L
Heil-Quaker Corporation Energy Marshall II	47 - 114	91.1 - 96.0	I			X	X opt.	X		X	U, D	

Key for Flow pattern column: U = Upflow or Hi-boy, D = Downflow or Counterflow, L = Low-boy, H = Horizontal flow models

Higher Efficiency Gas-fired Furnaces
STEEL GAS-FIRED FURNACES

	DOE-rated Output (x 1000)	A.F.U.E. Range (%)	P = Power Burner I = Induced Draft	S = Stack Damper B = Burner Inlet Damper	Direct Outside Venting	Outside Air for Combustion	Condensate Drain	Condensate Neutralization	Stainless Steel Final Heat Exchange	Flow Pattern	Warranty
Lenox Conservator III (most models)	41-81	80.0 - 81.0	I							U,D	15L
Lenox Pulse Furnace	38 - 95	90.2 - 97.0		B	X	X	X		X	U,D,H	20L
Magic Chef Ultra Series	53 - 95	85.2 - 87.3	P				X		X	U,D	20L
Magic Chef Ultra 97 Series	39 - 94	93.0 - 97.1	I		X	X	X			U	
Rheem / Rudd 90 Plus	43 - 115	90.3 - 93.3	I							U	
Sears "Kenmore 90" (manufactured by Heil)	38 - 114	91.1 - 96.0	I		X		X		X	U,D	
Suburban Dynatwin	35 in.	85.9	I		X	X				H	Heat & A/C
ThermoProducts IGH series Thermopride	62 - 128	81.8 - 82.2 84.1 - 84.3	I	S opt.						U	Ltd. Lifetime
ThermoProducts AG series Radiant	64 - 144	80.0 - 82	P	B						U, D, L	Ltd Lifetime
ThermoProducts PG series Octatherm	128 - 132	80.0 - 81.5 83.5 - 84.9 (S)	P	S						U, L	Ltd. Lifetime
ThermoProducts GL series Octatherm	80 - 152	81.0 - 82.6		S						L	Ltd. Lifetime
Thermopride IGH series	62 - 128	81.8 - 82.2	I	S opt.						U	Ltd. Lifetime
Trane Elite	35 - 104	85.5 - 87.1	I							U	10L
Trane Elite Plus	38 - 110	90.2 - 95.0	I		X	X	X		X	U, D	10L
Trane Executive BLU, BLD045-112L	36 - 123	81.9 - 83.4		S						U, D	20L
Whirlpool (selected models)(Heil identicals)	39 - 117	80.0 - 82.6		S						U, D	
Whirlpool Tightfist II	38 - 114	91.1 - 96.0	I		X		X		X	U, D	
Williamson Gasaver II	60 - 110	81.0 - 84.2	I		X					U, L	25L
Williamson High Efficiency Condensing Furnace	38 - 110	90.2 - 95.0	I		X	X	X		X	U, D, L	20L

Key for flow pattern column: U = Upflow or High-boy, D = Downflow or Counterflow, L = Low-boy, H = Horizontal flow models

Heating Systems Available in Residential Sizes with an A.F.U.E of 81% or Better

CAST IRON GAS-FIRED BOILERS

CAST IRON GAS-FIRED BOILERS	DOE-rated Output (x 1000)	A.F.U.E. Range (%)	Water Container Range (gal.)	P = Power Burner F = Forced Draft I = Induced Draft	S = Stack Damper B = Burner Inlet Damper	Direct Outside Venting	Outside Air for Combustion	Condensate Drain	Wet Base Boiler	Condensate Neutralization	Wall-hung Boiler	Steam Model Available	Warranty
Burnham 2 Series & 4 Series (with IID & Damper)	31 - 244	80.8 - 82.2			S							X (series 4)	
Axeman-Anderson HEV Series** Bryant Model 237A Series A	35.7 - 124.0	82.9 - 84.5	1.75 - 5.5	I								X (selected 235A)	
Buderus Logangas 4.32	53.9 - 558.0	82.3 - 83.3	3 - 15	I	S				X				
Burnham XG-1000	30.0 - 85.0	80.3 - 84.3		I		X	X				X		
Burnham XG-2000	54.0 - 137.0	82.7 - 84.3 85.1 - 87.2 PV		I		PV models		(PV)		X			
Burnham XG-4000	88.0 - 147.0	83.3 - 83.5		I								X	
Circle Combustion CB2A series	80.0 - 242.0	81.5 - 82.8		P									
Columbia CEG ID Series M-ACB ID Series	32.0 - 205.0	80.3 - 82.5 81.0 - 84.1											
Crown XE Series	35.7 - 124.0	82.9 - 84.5		I	S	X							
Dunkirk XE Series. "Blue Circle" Metsger XE Series**	35.7 - 124.0	82.9 - 84.5		I	S							X (selected V series)	
Ener-Quip Netaheat	44.4 - 64.5	84.9	10 pints	I		X	X				X		20L
Hydrotherm WO-AW Series HI-B Series	102 - 219 67 - 132	80.0 - 82.0 82.3 - 83.5		I									
Intermark Zenith 90Plus Series	59.0 - 342.0	-92.2 prelim.	2.9 - 3.7	I		X		X					20L
Pennco FS Series Smith H.B. PVG series Sears 229.9644(21-51)	35 - 120	82.9 - 84.5		I									
Peerless ID HD Series 85	37.0 - 280.0	80.9 - 83.54			S								
Peerless ID HD Series 61	97.0 - 230.0	81.1 - 81.3										X	
Slant-Fin Galaxy (select models) and GG Series	53.9 - 223.0	80.0 - 82.9			S								
Teledyne Laars JVS-V	42.0 - 183.0	81.9 - 83.7			S				wet leg				20L
Ultimate PFG Series G Series (most models)	43.0 - 198.0	81.5 - 86.2		P									10L
Ultimate IPW Series	35.7 - 124.0	81.8 - 83.7		I	S								
Utica M-AGB-ID Series	32.0 - 165.0	81.0 - 84.1			S								
Utica PEG-AID Series	61.0 - 243.0	80.2 - 82.5			S				X				
Vaillant GA 92 EI Series	35.0 - 180.0	81.2 - 86.2			S				X				
Weil-McLain HE Series	55 - 137	82.2 - 82.4		I		X							20L
Weil-McLain AHE Series	33.0 - 51.0	85.3 - 85.5		I		X	X		X*	X	X		20L
Weil-McLain VHE Series	59.0 - 147.0	87.0 - 87.4		I		X		X					20L
Weil-McLain EG Model EG-PID	63 - 203	80.6 - 82.7			S							X	

Heating Systems Available in Residentail Sizes with an A.F.U.E. of 81% or Better **COPPER COIL GAS-FIRED BOILERS**	DOE rated Output (x '000)	A.F.U.E. Range (%)	Water Container Range (gal.)	P = Power Burner F = Forced Draft I = Induced Draft	S = Stack Damper B = Burner Inlet Damper	Direct Outside Venting	Outside Air for Combustion	Condensate Drain	Wet Base Boiler	Condensate Neutralization	Wall-hung Boiler	Scotch-Marine Boiler	Steam Model Available	Warranty
BGP HeatMaker Series	52.0 - 107	82.0 - 87.0	.25	P		X	X		wet leg					10L
BGP Triple integrated appl	45.5	- 90.6 est.	.25	P		X	X		wet leg					
Hydrotherm Celtic Deluxe (FF)	42.0 - 75.0	80.1 - 80.2	low			X	X				X			
Hytech Paloma-Pak	33.3 - 102.3	83.0 - 84.3	.25			X					X			10L
Thermar Power Master		81.0 est.	<1			X	X				X			
STEEL GAS-FIRED BOILERS														
Axeman-Anderson PG Series Olympia 1 GL Series	92.0 - 269.0	81.8 - 83.7	14.5 - 38.1	P	S				X					20L
Energy-Kinetics "System 2000" with Oertliburner	102.0 - 120.0	83.0 - 87.0 estimated	2.5	P		X opt.	X opt.		X			X		
Hydrotherm Hydropulse	44.0 - 132.0	90.1 - 91.2				X	X	X	X					
STAINLESS STEEL GAS-FIRED BOILERS														
Glowcore	79.9	- 88.8	.25	I		X	X	X	X					20L
Mor-Flo Industries Polaris	94.0	- 94.0 prelim.		P		X	X	X	X					

*Neutralization by return water temperature control

** These boilers are nearly identical

Please note that gas-fired systems over 86% will produce some condensate. Venting these systems into a conventional chimney is not recommended. Also, carefully consider the materials used by the manufacturer to guard against corrosion.