SPECIAL REPORT

WATER HEATERS FOR SUPERINSULATED HOUSES

Are there special considerations to be taken when selecting a water heater for a superinsulated house? Yes, a few. First, the "superinsulated" characteristics of the house warrant some consideration, and second, if the object is to build an energy-efficient house, then some attention should generally be given to the selection of an efficient water heating system.

To avoid any confusion, let's assume that by "superinsulated house" we are talking about a house that:

1) is relatively airtight (3 to 5 acph at 50 pascals);
2) has very low heating and cooling demands due to its airtightness and high levels of insulation; and
3) includes some form of controlled mechanical ventilation.

How do these factors affect the water heater selection process?

1) Tight construction

As mentioned several times in past editions of EDU, atmospheric combustion (natural draft) water heaters -- those that rely on natural buoyancy to draw hot flue gases through the heater -- are potential hazards in tightly built houses. Exhaust fans, central vacuum cleaners, clothes dryers, or imbalanced ventilation systems can cause hazardous flue backdrafting. Particularly worrisome is the possibility of slight backdrafting, which would probably go unnoticed, yet could seriously affect indoor air quality. The recommendation, therefore, is to select a water heater that is resistant to backdrafting or, if that's not possible, to install an outdoor air intake, close to the water heater, to supply combustion makeup air. The second solution is less desirable because it depends on the dubious assumption that nobody will ever close off the outdoor air intake.

There are several selection options for non-backdrafting water heaters:

A. Electric resistance heaters;
B. Electric heat-pump water heaters;
C. Solar water heaters;
D. Induced draft or sealed combustion gas water heaters;
E. Integrated water heating / space heating systems.

A year ago, no sealed combustion storage tank water heaters were available. Now there are at least two -- the State (see December 1984 EDU) and the Rheem (see April 1985 EDU). There are also two sealed combustion instantaneous water heaters -- the Hydrotherm Celtic and the Thermar. Chances are that we will be seeing more sealed units on the marketplace as demand for them increases.

In an integrated system, water heating may be accomplished by drawing heat from a sealed combustion or induced draft boiler or furnace. (The Amana Energy Command is the only furnace that has water heating capability.)

2) Low space heating and cooling load

If the heating load of a superinsulated house is low enough, the domestic water heater could be used to supply hot water for space heating. The Apollo Hydroheat is an example of a system designed for that purpose. Cooling and dehumidification can be provided by a heat pump water heater (HPWH). Some HPWH's have nearly one ton of cooling capacity. Although some creative control strategy would be called for, one of those units could serve as the primary air conditioner in an energy-efficient house in a moderate climate. (We'd welcome hearing from anyone who has tried it.)

While we're discussing heat pump water heaters, we should mention that they will generally work at a higher net efficiency in a superinsulated house (in cold climates) than in a conventional house. Here's why:

Heat pump water heaters boast coefficient of performance (COP) up to 3.4. Generally speaking, that's equivalent to an efficiency of 340 percent! One would therefore assume that a heat pump water heater would be nearly three times as efficient as an electric resistance water heater, using only one-third as much energy. However, that's a bit of an oversimplification because from one-half to two-thirds of the heat delivered by a heat pump water heater comes from the air surrounding the unit. If the heat pump is located in a heated space, then you are simply robbing Peter to pay Paul; i.e, taking space heat and putting it into the hot water. One study conducted by Maier Perlman at the Ontario Hydro Research Division showed that with a 60-gallon-per-day hot water draw, a heat pump water heater will increase the space heating load by 7%. Larger water draws will cause proportionately larger space heating penalties.

But the more energy-efficient a house is, the better a heat pump should look. Why? Because the heating season is shorter. For example, the Ontario Hydro study assumed that the heating season is 250 days long. For some superinsulated houses, the time when heat is needed is much shorter than that and there is often excess heat in the house during winter months. At those times, the energy taken by the heat pump is waste heat. It would be thrown out by Peter if the heat pump didn't take it to give to Paul.

Finally, the energy efficiency of the house affects the cost effectiveness of desuperheaters. Sometimes called "heat reclaimers," desuperheaters are heat recovery devices that reclaim waste heat from the hot gas discharged by the compressor of an air conditioner (or heat pump heater). The recovered energy is then used to heat domestic water. Several manufacturers sell desuperheaters for retrofit application and a few equipment manufacturers are offering desuperheater water heaters as options for their central air conditioners and heat pumps.

Since the desuperheater only collects heat when the air conditioner or heat pump is running, the cost effectiveness of the system depends somewhat on how much the space cooling or heating system runs. The more energy-efficient a house is, the less those systems run. In very hot climates, the effect of the house energy efficiency is probably negligible because the air conditioner will still run more than enough to generate all the hot water needed. But in moderate climates, the effect might be substantial and the desuperheater may not supply enough hot water to justify its installation.

For those interested in further information about desuperheaters, an excellent analysis of their cost effectiveness can be found in a recent ASHRAE paper. See "Economic Viability of Heat Pump Desuperheaters for Supplying Domestic Hot Water," by M. Olszewski, ASHRAE Transactions 1984, Volume 90, Part 1B, p. 169.

3) Ventilation system

The main consideration surrounding the presence of a ventilation system, other than combustion air supply and backdrafting, is the potential for using a heat pump heat recovery ventilator for heating domestic water. Fiberglas Canada is now selling one such unit in Canada; DEC International should have a unit for the American market soon (see March, 1985 EDU for details).

SELECTING WATER HEATER CAPACITY

What size water heater will a proposed house need? When considering capacity, one should look at what is called the "first hour rating" of the water heater. The first hour rating is the amount of hot water that the heater can supply during the first hour of operation. It depends on more than just storage tank size as we shall see later.

The Gas Appliance Manufacturers Association has devised a method for calculating required first hour capacity. The following is a summary of that method:

1. Determine during what general time of day (morning, noon, evening) there is usually the most use of hot water in the home.
2. Use the following table to determine the required first hour capacity or peak demand:

Use	Average Gallons of Hot Water per Usage	x	Times used during 1 hour	=	Gallons used in 1 hour
Shower	20		______		______
Bath	20		______		______
Shaving	2		______		______
Hands and face washing	4		______		______
Hair shampoo	4		______		______
Hand dishwashing	4		______		______
Automatic dishwasher	14		______		______
Food preparation	5		______		______
Automatic clothes washer	32		______		______
TOTAL REQUIRED FIRST HOUR CAPACITY					______

<u>Example</u>
A typical household morning routine might include 2 showers, 2 shampoos, 4 hands and face washing, and 1 food preparation between 7:00 and 8:00 A.M. The peak water demand will therefore be:

2 showers	20 x 2 = 40
2 shampoos	2 x 4 = 8
4 hand/face wash	4 x 4 = 16
1 food prep	1 x 5 = 5
TOTAL	69

REQUIRED FIRST HOUR CAPACITY = 69 gallons

The first hour rating of a water heater (listed on the "Energyguide" label on all water heaters except heat pump water heaters), depends upon the size of the storage tank <u>and</u> the heat output of the burner or heating element. This is important. Many people simply choose a water heater by tank size. But the more powerful the water heater, the less storage is required to achieve an equivalent first hour rating. Gas heaters typically have higher energy output than electric heaters and the first hour rating of gas heaters will therefore usually be considerably higher than the first hour rating of electric water heaters with equal storage capacity. For example, the State Industries 50-gallon electric water heaters have first hour ratings of about 55 gallons while the State 50-gallon gas water heaters have first hour ratings ranging from 69 to 77 gallons. Ruud has a 50-gallon gas heater with a first hour capacity of 95 gallons. (By the way, even though they are not very common, oil water heaters typically have the highest first hour rating for a given storage capacity. For example, the Ford Products Corp. Model CF50E 50-gallon oil fired water heater has a first hour rating of 121 gallons. This is not unusual for oil-fired heaters.)

<u>What about instantaneous water heaters?</u>

Instantaneous water heaters are a different story. With these heaters, since there is no storage, the first hour capacity is the same as the overall recovery rate (amount of hot water a heater can supply continuously) and depends completely on the output of the burner or heating element.

Here's a guideline: To supply a single bathroom (one shower at a time), an instantaneous water heater should be capable of supplying 2.75 to 3.0 gallons of water per minute at a temperature rise of 80 to 100 degrees. If the temperature of the water coming into the house is warm (above 60°F), an 80-degree rise is sufficient; if the incoming water is less than 50°F, a 100 degree rise is needed.

Some manufacturers of instantaneous heaters list the recovery rate in their literature, some don't. However, if you know the heat output in Btu/hr, the recovery rate is very easy to calculate using the following equation:

Recovery rate (gallons per minute)	=	heater output (Btu/hr)	/ (60 x 8.34 x temperature rise (degrees F))

Example: What is the recovery rate of an instantaneous water heater that has an output of 80,000 Btu/hr if the desired temperature rise is 90°F?

Solution: Recovery Rate = 80,000 / (60 x 8.34 x 90)
= 1.8 gallons per minute

Thus this water heater would probably not assure adequate hot water for bathing, especially if other water consuming activities are going on in the house.

NOTES: The 60 constant in the equation converts gallons per hour to gallons per minute. The 8.34 constant is the number of Btu required to raise the temperature of 1 gallon of water 1 degree F.

SELECTING FOR ENERGY EFFICIENCY AND COST EFFECTIVENESS

Three terms are commonly used when referring to efficiency of water heaters -- "recovery efficiency," "standby loss," and "energy factor." Recovery efficiency refers to the efficiency with which heat is transferred from the flame or heating element to the water during "cold start" operation. The recovery efficiency is essentially 100% minus whatever is lost up the flue. (In electric heaters, the recovery efficiency is 100%.) Standby loss is the percentage of heat lost from the stored water per hour compared to the heat content of the stored water. Typical standby losses range from 1% to 3%. The most important yardstick of water heater efficiency is the Energy Factor (EF). Similar to the AFUE for furnaces and boilers, the EF is a measure of the overall efficiency of a water heater based on recovery efficiency and cycling losses. It is expressed as a decimal where 1.00 would be equivalent to 100% efficiency. The EF is used for comparing the cost effectiveness of various types of heaters.

Figure 1 shows the range of energy factors for the various types of water heaters.

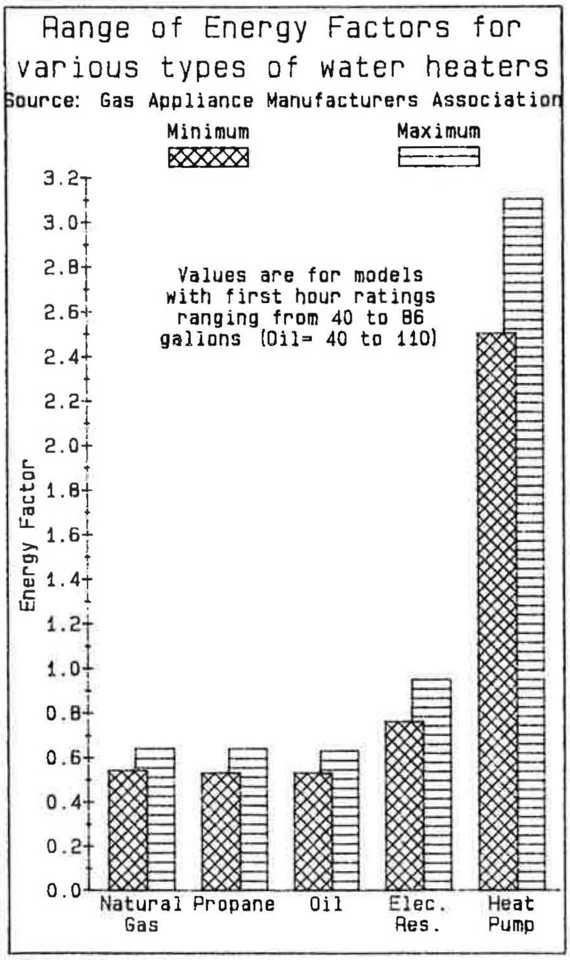

Figure 1

Calculating Annual Energy Cost

The U.S. Department of Energy, in its procedures for evaluating water heater performance, assumes that the average household uses 64.3 gallons of hot water per day. That figure is supported somewhat by the BECA-D study by Lawrence Berkeley Laboratory -- a compilation of data of approximately 11,000 water heater installations -- which shows an average household usage of about 60 gallons per day. If we assume that the DOE figure is correct and we further assume that on the average, the temperature of incoming water is raised 90 degrees, then it is easy to calculate the annual cost for water heating using the following equation:

For natural gas heaters:
Annual energy cost =
(176 / EF) x [price for gas ($/ccf)]

For electric heaters
(resistance or heat pump):
Annual energy cost = (5162 / EF) x
[price for electricity ($/kWh)]

Example: Let's compare the annual energy cost of the following three water heaters:

A. A.O. Smith 50-gallon gas water heater	EF = .51
B. A.O. Smith 52-gallon electric water heater	EF = .88
C. DEC International Thermastor 80-gallon heat pump water heater	EF = 3.40

Gas price	$.65/ccf
Electricity price	$.08/kWh

Solution:

A. A.O. Smith gas
Annual cost = (176/.51) x $.65
= $224/year

B. A.O. Smith electric
Annual cost = (5162/.88) x $.08
= $469/year

C. DEC
Annual cost = (5162/3.4) x $.08
= $121/year

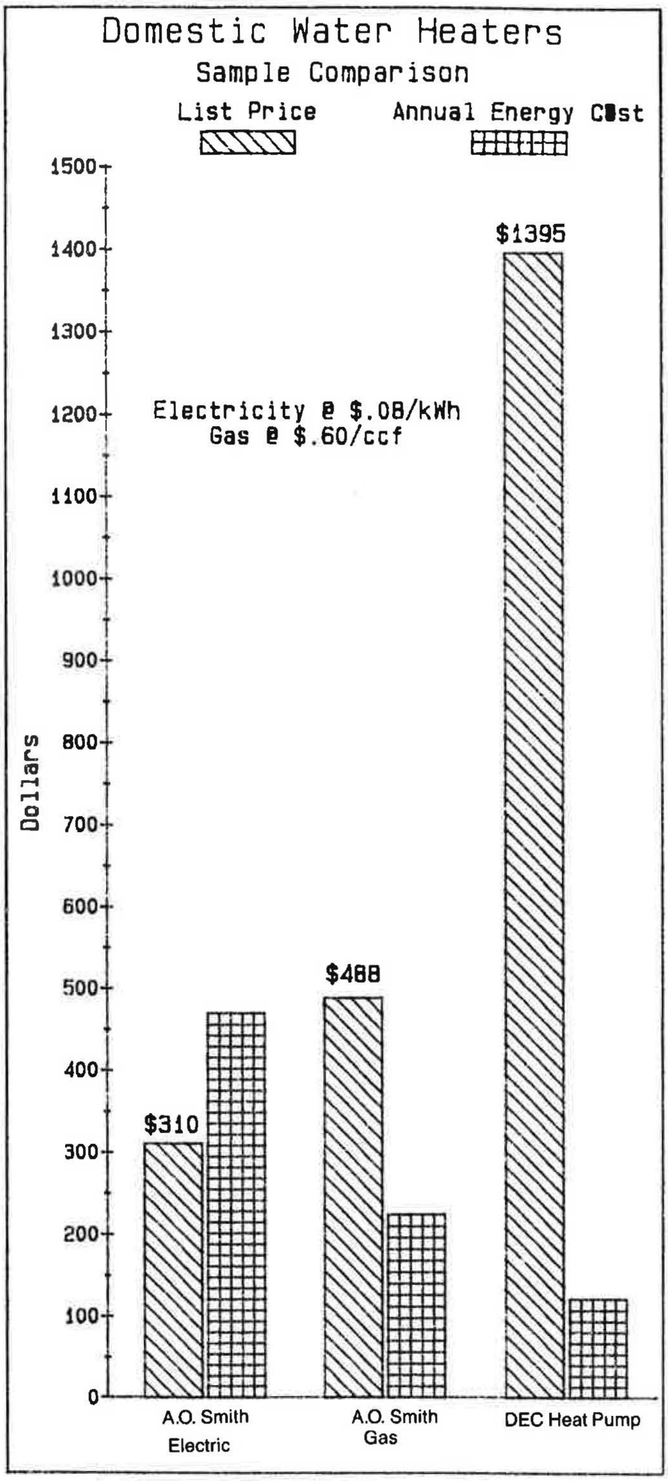

Figure 2
Comparison of first cost and annual energy consumption for three water heaters.

Which unit is most cost effective? As shown in Figure 2, the heaters with the higher prices have the best efficiency. No surprise there. But is the heat pump efficient enough to warrant the large initial investment? Table 1 shows an economic comparison among the various options.

Table 1

Comparison	Extra Cost (Difference in list cost)	Savings (Difference in annual energy cost)	Simple payback
A. Gas vs electric	$178	$245	0.7 years
B. Heat pump vs gas	$907	$103	8.8 years
C. Heat pump vs electric	$1,085	$348	3.1 years

A FEW QUALIFICATIONS

1. The three heaters illustrated in the above example are all expensive high-quality units. Naturally, other heaters with different prices will give different results. For example, Sears makes a 50-gallon gas water heater, with a slightly higher EF than the A.O. Smith, that sells for only $229.

2. The COP of any heat pump water heater is not constant; it varies as the temperature of the water in the tank varies. The COP is highest when the water in the storage tank is cold. As the water in the tank is heated, the COP drops. This is important because with some types of usage patterns, the actual COP will be significantly lower than the rated COP of the unit. Consider this example: Suppose a heat pump water heater is installed in a small office building where the only hot water usage is for hand washing. The average draw is a gallon or two which lowers the storage tank temperature only a few degrees. The heat pump would always be operating at a low COP because the tank temperature would always be high.

Now consider an opposite situation: Suppose a heat pump water heater is located in a small dormitory where it is used only three times per day for dishwashing. During each usage, the tank is drained almost completely. When the heat pump comes on, it will be operating at its highest COP because the tank will be filled with cold water.

This phenomenon is illustrated in another study performed by Perlman at Ontario Hydro. In that study, he monitored the actual performance of five heat pump water heaters -- four in residences and one in a restaurant. Figure 3 shows the results of that study. Notice that in three of the residences, the actual measured COP ranged from 1.4 to 1.7, even though the rated COPs were all 2.54. In the restaurant installation, the measured COP was closer to the rated COP of the unit.

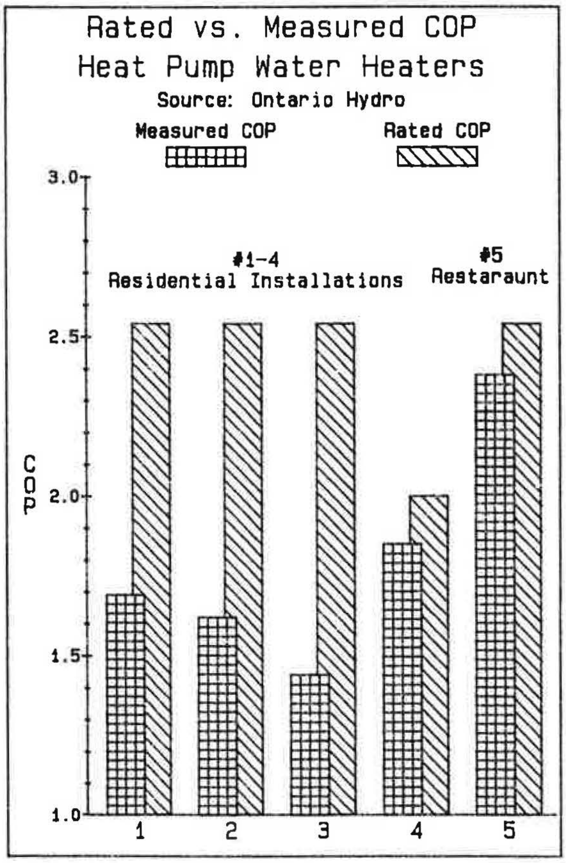

Figure 3