Residential Energy Conservation Strategy

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AN energy conservation strategy for a private home in Columbus, Ohio, was based upon savings predicted by calculations. The benefits that resulted, and are described here, are based on the metered energy consumption of the residence over nine years.

The test house is a three bedroom ranch with about 60% basement and the balance, crawlspace. The house is oriented east-west with garage on the west end and the front of the house on the north side. The basement area is mostly finished, and the combined living space constitutes about 2000 sq ft. Both levels are heated to 70–71F and cooled to 73–74F, these temperatures representing the personal choice of the occupants. Nighttime temperature is set back about 10F for 7–8 hours on heating only. The attic is well ventilated, with nearly continuous soffit ventilation and end vents in the attic space. The house has plywood sheathing and a ¼ in. air space behind wood siding. Before the conservation measures were implemented, two-thirds of the windows were equipped with storm windows, and the house was insulated with 1½ in. batt in the outside wall and 4 in. of mineral wool in the attic.

Heating requirements were tracked on a degree day basis and the ratio of fuel (natural gas) to degree days expressed in terms of CCF/DD (CCF=hundred cubic ft). As anticipated, the conservation changes resulted in a reduced CCF/DD ratio. The real benefit to the homeowner, however, exceeds that suggested by the reduction in the ratio.

Degree days are commonly based at 65F, on the premise that at 65F outdoors, the indoors can be maintained at 70F without need for either heating or cooling. Incidental heat gain from people, equipment, insolation, etc., provides the balance to the heat loss. Prior to the implementation of conservation measures, the test house conformed well with the 65F base. With some of the measures in place, however, it became apparent that the base temperature had shifted downward significantly.

In Columbus, Ohio, using a base of 65F, there are about 5700 heating degree days annually (see Table 1). Reducing the base by 5F (*i.e.* to 60F) will account for a reduction in the number of heating degree days to 4513, a reduction of 21%. A 10F reduction in the base—to 55F—results in a reduction by 39%, to 3480 degree days; and bringing the base down to 50F leads to an annual heating degree day total of 2592, which is 54% below that from the number based on 65F.

We believe that half the energy savings that result from weatherization are due to base temperature reduction. Hence, to accurately forecast the energy consumption of a building, the base temperature must be identified. The number of expected degree days, using this base, will provide a good basis for calculating the expected energy requirement. If historical consumption has been identified on the basis of energy per degree day of known base, the forecast can be very accurate.

The first important conservation measure applied to the test house (Table 2) was insulating the outside walls, attic, crawl space, and basement walls. At the same times, cracks in the construction were located and sealed. This was accomplished by using a blower to exhaust air from the house, and then locating the cracks by feeling for leakage into the house. At the outset, the volumetric flow rate of air was measured, with an anemometer, through each room and through the fan. The sum of flows through the rooms equalled the flow through the fan. As cracks were sealed and the static pressure differences between the inside and outside of the house increased from the initial 0.02 in. of water to 0.35 in., the leakage became difficult to locate, yet the volume discharge was still approximately 2000 cfm. Because of measurement errors at low flow rates the volume contributions of each room could no longer be correlated with the volume through the fan.

With heating system operation and cessation of natural ventilation, there was a significant increase in relative humidity. Acceptable humidity levels were attained by leaving the fireplace damper open with the glass fireplace doors closed.

Early observations indicated that house base temperature had dropped to 50–55F; the lower, the more solar gain.

The effect of weatherization on summer air conditioning costs was, surprisingly, nil. Given relatively small temperature differentials between inside and outside night temperatures, and good insulation,

Table 1. Columbus, Ohio Degree Days (1941–70)

Base Below	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Annual*
70	1290	1112	955	564	294	64	20	45	167	167	849	1213	7068
65	1135	972	800	418	176	13	0	8	76	342	699	1063	5702
60	980	832	645	279	92	0	0	0	20	208	549	908	4513
55	825	692	503	163	34	0	0	0	0	111	399	753	3480
50	677	552	367	83	10	0	0	0	0	42	258	608	2597
45	531	421	251	28	0	0	0	0	0	12	137	466	1846

Table 2. Conservation Steps and Results

*CCF/DD**	*Base Temp*	*Conservation Steps*
.19	65F	Prior to conservation work
.134	65F	Insulated crawlspace walls, night setback, fresh air to furnace
.114	63F	Installed new gas furnace with electric ignition, timed blower initiation
.0797	56F	Sealed cracks to reduce infiltration, added 8" fiberglass to attic, insulated outside walls, insulated basement walls with 2" foam
.0718	51F	Installed pulse boiler and heat exchanger to heat domestic water

*CCF/DD = (Hundreds of cubic feet of natural gas)/(degree days base 65F)

very little heat is lost at night. Even with high sun angle and relatively little solar gain, maintaining 73–74F indoors resulted in a cooling season base temperature of 50F. Given Central Ohio's average summer season with more warm than cool nights, the air conditioner operated longer hours to compensate for the houses's inability to rid itself of heat gain from people, appliances, and lighting. This increased energy consumption was offset by the enhanced capability of the better insulated house to fend off outdoor heat; hence, cooling was required on hotter (hence, fewer) days. The solution is an exhaust ventilation fan that quickly drops inside temperature at night to within a couple of degrees of outside temperature, negating the need for refrigeration for part or all of the next day. (*Editor's note:* According to the "weather bureau," minimum temperature at Port Columbus International Airport for July 1984 never exceeded 68F.)

The next priority of conservation was indoor air quality. First the sources of moisture load were identified as people and activities such as washing, bathing, cooking, and laundry. We estimated the daily moisture load for this family of 3–4 to be about 30 pounds of water. Using this as a basis, the ventilation requirement was calculated for various outside temperatures to keep the windows free from condensation, with the assumption that the outside air was 70% relative humidity. A constant ventilation on the order of 50 cfm, regardless of the outside temperature, would meet the condition of keeping the windows clear of condensation. A 65% efficient air-to-air heat exchanger was designed and built, using common readily available materials and basement workshop methods. Two blowers were used, one to draw air into the house and through the heat exchanger and deliver it to the cold air return of the furnace, and the other to remove air from the crawlspace, pass it through the heat exchanger and discharge it into the attic space. The damper to the fireplace could be kept closed; the windows remained clear and the house had a notably fresh atmosphere.

Since the walls had been insulated with urea-formaldehyde insulation, we invited the local health department to test the air quality for radon and formaldehyde. Tests were done in cooperation with the Ohio Department of Energy. A very acceptable formaldehyde gas concentration of 0.114 ppm was detected. The radon release rate was measured at 1.2 piccocuries per liter per hour, which compares favorably with values in seven houses tested that ranged from 1.05 to 55 picocuries per liter per hour. The test results indicated low levels of the pollutants in comparison to several other houses tested at about the same time, though the house was one of the tightest in the group.

The conservation of house heating energy reduced the annual energy required for space heating to slightly less than the annual domestic water heating energy requirement (about 400 CCF). The next step was to implement a water conservation program. Shower heads with flow rates of 2 gpm were installed, resulting in a 25% reduction in total hot water usage. A solar water heating system was then developed which used no electric power or controls, which was entirely mechanical and used a working fluid that was nontoxic, nonflammable, noncorrosive, and which had moderate working pressures. The controls included automatic defrost of the solar panel, and an adjustable preset maximum temperature that would limit operation of the system. The construction used methods and skills common to the HVAC industry, and a patent was obtained.

The last significant change was to replace the "modern" furnace—equipped with electric ignition, stack damper, and timed initiation of blower operation—with a pulse combustion boiler. A heat exchanger was also installed to heat the domestic water. The resulting temperature of the house became much more uniform. With a conventional furnace, when the thermostat is satisfied the fuel is cut off and the blower continues to operate until the heat exchanger is cooled. This results in continued heating, raising the space temperature. With the pulse boiler there is no vent stack waiting to leak the heat outdoors. When the thermostat is satisfied, the blower is stopped. With the anticipator properly set the temperature is generally within a 1F band.

Use of a pulse boiler instead of a pulse furnace seemed to have two advantages. First, the boiler heats water which in turn can be used to heat domestic water by means of a heat exchanger. The boiler water is also used to heat air passing through the furnace by means of an "A" coil. A divert valve is used to direct the flow of water to the desired device. Heating water has priority over heating the house, since a water storage tank was not used and water is heated as needed. By applying the pulse boiler to both space heating and domestic water heating there is a greater opportunity for saving energy. The second advantage is quieter operation. The gentle buzzing noise characteristic of pulse combustion equipment is associated only with the boiler, and is effectively isolated from the duct system and air stream.

The net result of the conservation steps was to reduce the annual house heating energy requirement from approximately 1060 CCF of natural gas to 410 CCF and annual water heating energy requirement from approximately 400 CCF to 234 CCF. There were 5718 base 65F degree days in the period. The combined savings at the present rate of $.65/CCF was $530 per year. From another viewpoint, the total cost of heating the house and domestic water at the present rate is $419 per year.

Other important benefits are a far more comfortable house because of uniform temperatures, good ventilation, etc.

Cost effective conservation steps can take many forms depending on the available resources. The following conclusions, drawn from observations of the test house and other houses, can help identify strategy. Observations of similar situations by others, as well as criticism of his conclusions, would be of interest to the author.

1. Locating and sealing construction cracks is generally more cost effective than insulating.

2. Insulating crawlspace walls, basement walls, and attic is more cost effective than doing outside frame walls.
3. Insulating outside walls (plaster or drywall) is best done from the inside if the insulating can be coordinated with redecorating. The inside holes are easily repaired and stay fixed. Holes in the outside brick (mortar joint), wood siding, etc. are not repaired as easily and may not stay fixed. Changes in temperature and moisture can cause plugs to loosen.
4. Turning the thermostat lower, or using setback for night or other unoccupied periods, can be very effective, but is limited in scope. For heating seasons in the 5000-6000 degree day range, each degree lower in temperature for the entire season saves about 3% in annual fuel cost. Resetting 9F at night for 8 hours (one third of a day) for example is an average of 3F for a day and would save 3%×3F or 9%, except that the savings only occur as the house cools down naturally. In mild weather the temperature may not drop 9F overnight. If it dropped 6F in 8 hours the average would be (0+6)/2 or 3F reset for 1/3 of a day or the equivalent of 1F reset for that day.
5. Vent dampers can be effective in reducing infiltration/exfiltration and if used should be installed on all vented appliances. Thermally actuated types are less expensive, and if they are constructed with bimetal vanes that merely straighten out to open up when the appliance turns on, there is little that can go wrong with them. There is, however, some spillage of combustion gases for a few seconds before they open up.
6. The efficiency of the heating equipment is not nearly as important as conservation to reduce the heating requirement. If the annual energy requirement is on the order of 600 CCF of natural gas @ $.65/CCF, the difference in energy cost between a furnace with 80% efficiency and a system with 97% efficiency is about $85/year. If the more efficient equipment could be purchased for $700 and the cost of money was 12% per annum, the cost of money would balance the savings, but never amortize the cost. Since the extra efficiency probably would cost more than that anyway, it is probably better to spend the money on conservation to reduce the heat loss instead of buying more efficiency.

7. Conservation is limited by diminishing returns. If an attic is improved from R-6 to R-30 the heat loss will be reduced in proportion to the reciprocal of the R number, 1/6 to 1/30 or 20% of the original loss. Adding another R-30 to make it R-60 would cost perhaps twice as much and reduce the loss to 10% of the original amount. This probably would not save enough more to justify the extra insulation in a moderate climate. It depends on the climate, cost of energy, and the cost of money. It is a good idea to do some arithmetic and compare the economic alternatives.

With a BSME from Walla Walla College in 1960, B. L. Knecht joined Worthington Foods, Inc. In 1971 the plant underwent expansion and many opportunities for energy conservation became available. During ten years the consumption of fuel, electricity, and water were reduced to about half, while production increased about fourfold.

Mr. Knecht extended his conservation efforts to his home, to a local church, a school building, and ultimately began a sideline in locating and sealing air leaks in houses. He is a professional engineer and a member of ASHRAE and AEE. The house referred to in this article is his own.