RESEARCH AND IDEAS

THE BLOUIN HOUSE—REPORT FROM BROOKHAVEN NATIONAL LABORATORY

Brookhaven National Laboratory (BNL) has just released an in-depth report and analysis, authored by Dan Hagan and Ralph Jones, of a superinsulated house located in South Royalton, Vermont (8851 degree days). Although the house itself is not extraordinary, the report conforms to the high standards set by BNL in reporting earlier houses and contains some new observations and conclusions concerning the design and operation of energy-efficient houses. In this article, we present a description of the house and a summary of the most pertinent observations. The full report is likely to serve as an important benchmark for future analyses of superinsulated houses; we encourage interested readers to obtain a copy (see reference at the end of the article).

The 1,557-square-foot Blouin house is a double-wall design, consisting of two parallel 2 x 4 walls separated by a 5-1/2-inch space, allowing installation of a total of 12-1/2 inches of fiberglass insulation in three layers. The design is a combination of balloon and platform framing. The ceiling contains 16-1/2 inches of fiberglass insulation. The first floor is insulated with 5-1/2-inch fiberglass installed between the joists. The All Weather Wood Foundation (AWWF) is built with 2 x 8's and insulated with 7-1/2-inch fiberglass batts. The basement floor slab rests on gravel fill and a vapor barrier, but is not insulated. Sliding site-built 1-1/4-inch thick urethane window insulation with magnetic seals is installed on all the double-glazed double-hung windows. A continuous 6-mil polyethylene air/vapor barrier was carefully installed in all exterior walls and the second floor ceiling, and is caulked with butyl tape at all joints.

The heating system originally consisted of individual electric resistance baseboard units with integral thermostats in each room. The family was displeased with the large temperature swings allowed by this control system and subsequently turned off all heaters with the exception of two 6-foot units downstairs -- one each in the living and dining areas. These two units are controlled by a common wall thermostat. The basement is unheated.

Ventilation is supplied through a site-built air-to-air heat exchanger. Air is distributed from the heat

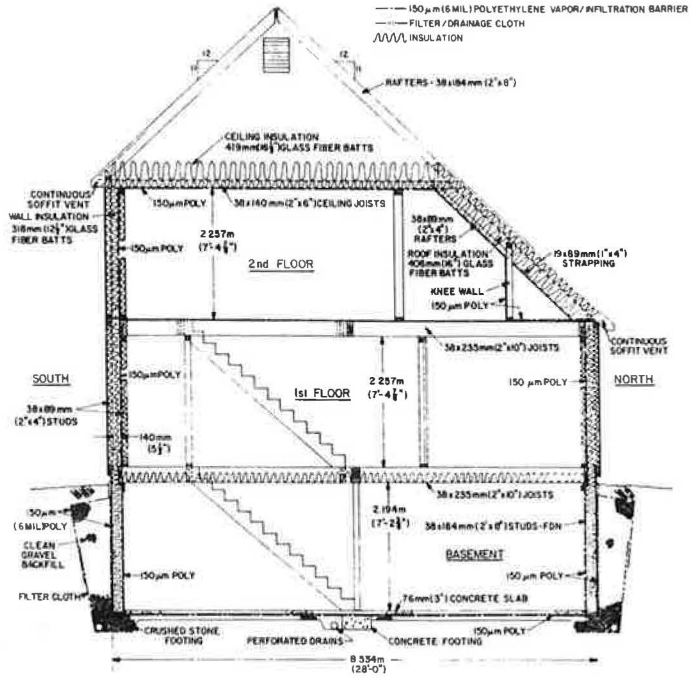


Figure 1
Blouin House—
Typical Framing Section

exchanger to five points and is exhausted from the bathrooms and kitchen. The heat exchanger is controlled by a humidistat.

BNL measured the house air leakage rate using the blower-door pressurization method. Measured leakage under 50 pascals of pressure was 1.6 air changes per hour (acph) -- reasonably tight by present standards. This level of airtightness is impressive in view of the fact that Blouin used double-hung windows rather than casement type which are typically much tighter. The double-hung windows were chosen to conform to conventional New England saltbox design. Tracer gas measurements showed the natural infiltration rate to be about 0.1 acph.

Energy consumption is extremely low. According to Scott Blouin, the average annual electricity consumption for space heating is about 2,000 kWh (4,384 Btu/sq. ft.-yr; 0.5 Btu/sq. ft-degree day).

Figure 1 shows a breakdown of heat gain and heat loss for the Blouin house. Notice that intrinsic heat sources (lights, appliances, people) and solar heat gain supply 69 percent of the total heating load. Notice also that the uninsulated basement floor accounts for as much of the total heat loss as the walls and door.

BNL compared actual measured heating energy consumption with predicted values calculated using the HOTCAN microcomputer program developed by the Canadian National Research Council (see Jan./Feb. 1983 EDU). The HOTCAN program proved accurate to within 10 percent of actual consumption.

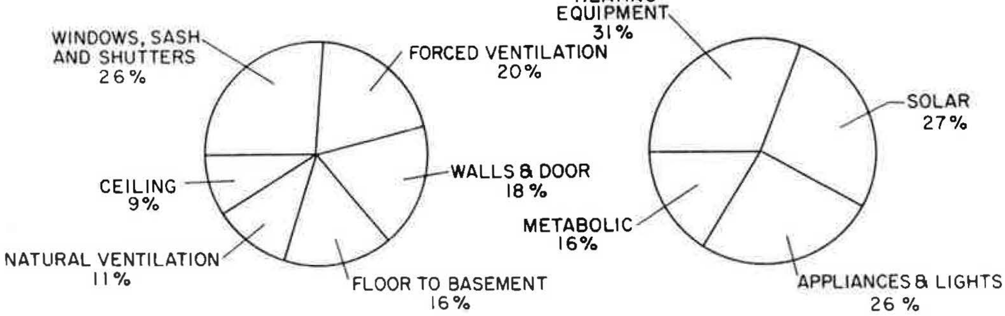


Figure 2
Blouin House—Energy Gains and Losses

NOTEWORTHY OBSERVATIONS

HUMIDISTAT CONTROL RESULTED IN SUBSTANDARD VENTILATION RATE.

This is one of the most important findings in the BNL report. As mentioned above, the ventilation system is controlled by a humidstat which was set between 35 and 40 percent relative humidity. The startling finding was that when controlled in this fashion, the heat exchanger only ran 28 percent of the time. The ventilation system was sized to provide about 0.5 air change per hour of ventilation air -- a popularly accepted standard. But if it runs only 28 percent of the time, it is only providing ventilation at a time-averaged rate of 0.14 air changes per hour!

Many designers rely on humidity as the control factor for residential ventilation systems, assuming that occupants generate sufficient water vapor to activate the system enough of the time. The above findings challenge that assumption. This is not the first time that approach has been questioned. In a recent study of eleven superinsulated airtight houses in Alberta, only two needed ventilation for humidity control. (The study was performed by John Hughes of Passive Solar Design Associates, Edmonton, Alberta.) Pressurization tests showed the houses in the Alberta study to be tight, suggesting that moisture wasn't being ventilated out. Further analysis showed no good correlation between humidity levels and number of occupants. (The two houses with excessive humidity had no or one occupant most of the time). The only conclusion drawn from the study was that house size is the one dominant factor controlling indoor humidity and that large houses may almost never have excess humidity, even if tightly built.

What this means is that to ensure proper indoor air quality, a positive timed control should be used as the main control. Humidistats should be used only as an over-ride for ventilation system control -- boosting the fans to high speed in response to elevated humidity levels in the house.

THE VENTILATION SYSTEM WAS NOT WELL BALANCED

The BNL report punctuates a nagging problem with supply-and-exhaust ventilation systems: the practical difficulty of measuring and balancing airflows. Even with sophisticated equipment, measuring airflow in the duct system during the BNL study was difficult and time-consuming. Furthermore, the BNL researchers found that, whether or not the ventilation system was properly balanced initially, even on a calm day small changes in wind velocity pressure or the closing of a door upstairs would upset the system balance. Because of imbalance in the ventilation system, almost no fresh air was introduced directly to the upstairs.

HEAVY INSULATION DOES NOT NECESSARILY PROVIDE GREATER THERMAL COMFORT

Superinsulation is touted as providing increased thermal comfort due to warmer interior wall and window surface temperatures. Not so, says the BNL report. Using the classic thermal comfort model developed by P.O. Fanger, BNL calculated the indoor air temperature necessary to provide neutral thermal comfort (not too cold, not too hot) for three design cases: 1) the Blouin house built with standard 2 x 4 construction; 2) the Blouin house built to ASHRAE 90A-80 standards (R-19 walls, R-38 ceiling); and 3) the Blouin house as built. The results are shown in figure 2. Notice that with a 30-degree outdoor air temperature, the required indoor temperature for equivalent thermal comfort differs only about 1°F between the superinsulated Blouin design and the conventional 2 x 4 design. The reasons given are that the actual difference in wall surface temperature among the three wall designs is not that great and also that even if window surface temperature does vary significantly, the effect on occupant comfort is relatively small since the windows only comprise about 6 percent of the total room surface.

The BNL analysis did not take into account, however, either the effect of reduced drafts in the superinsulated house or the elimination in the superinsulated house of defects in the thermal envelope which might create cold spots in a conventionally built house.

ENERGY-EFFICIENT APPLIANCES ARE MORE COST-EFFECTIVE IN A SUPERINSULATED HOUSE THAN IN A CONVENTIONAL HOUSE.

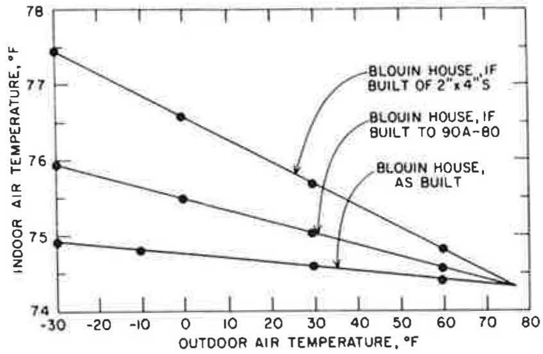
This was a very interesting observation. Energy-efficient appliances use less electricity, but also give off less heat in winter. Thus a portion of the energy saved by the appliances must be replaced by heating equipment energy. But in a comparison of four houses with varying levels of insulation, BNL found that in all cases the increase in heating system energy is a smaller portion of the appliance savings for the better-insulated houses. Although energy-efficient appliances almost always provide short payback periods, the returns are even greater and more energy is saved by the efficient appliances in a superinsulated house than in a less energy-efficient house.

THE THERMAL SHUTTERS FELL SHORT OF EXPECTATIONS.

Many designers now view thermal shutters and shades as a poor investment for energy conservation. Typical reasons given are poor performance and ultimate reliance on occupant interaction. Both misgivings are supported by the BNL study of the Blouin house. First, although the installed shutters had a calculated R-value of R-11.2, BNL found the actual R-value to be only R-8.46 -- 24 percent lower than calculated. Second, in their enthusiasm to save energy, the Blouins kept all the shutters closed on the north, east, and west sides of the house whenever they were not at home. According to the BNL report, that practice actually increased overall energy consumption by excluding incidental solar gains through those windows.

THE AIRLOCK ENTRY WAS NOT WORTHWHILE

Of no surprise was the BNL finding that the airlock entry, which had a net cost of $1,750, was most likely not cost-effective on an energy-saving basis. (They did mention that the room provides great utility in the cold climate as a mud room and winter clothing closet.)



Indoor Temperature Necessary to Maintain Neutral Thermal Comfort in Blouin House. Analysis for 3 Different Levels.

THE HOUSE HAD AN EXTREMELY LOW COOL-DOWN RATE.

One factor that is usually ignored in energy analyses of residential structures is the "time constant," a measure of a building's responsiveness to changes in outdoor temperature. If a building has a long time constant, it responds slowly to changes in outdoor temperature. Passive solar designers are familiar with the concept of time constant since increased thermal mass, such as concrete or water thermal storage, increases the time constant and reduces indoor temperature swings. The time constant depends not only on thermal mass, but also on the thermal resistance of the building envelope. Even though the Blouin house does not include excessive amounts of intentional thermal mass, the high levels of insulation result in a long time constant. With most internal heat sources shut off, window shutters closed, and ventilation system off, the house cooled down only 1.7°F over 6 hours when the average outdoor air temperature was 36.5°F. The authors of the study suggest that, if some temperature fluctuation were permissible, the long time constant might enable the house to take advantage of off-peak electric heating.

For more information, a full copy of the BNL report is available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161. Ask for "Case Study of the Blouin Superinsulated House," #BNL51732. The price is $14.50. For direct inquiry, contact Ralph Jones, Brookhaven National Laboratory, Upton, NY 11973; (516)282-2123.