# ENERGY BALANCES IN A LOW-ENERGY HOUSE

**M.E. Lux**


## ABSTRACT

A low-energy house was built in Saskatoon in 1980 as part of a demonstration project. This paper describes the energy balances that were measured on the house. A heat loss characteristic was obtained by using electric heat and measuring all the energy inputs under steady state conditions. Electricity consumption was compared with a HOTCAN 2.0 computer prediction for energy consumption. A separate heating system consisting of a natural gas forced air furnace with spark ignition and chimney stack damper was used alternately in place of the electric heating system. The performance and efficiency of the gas heating system were a function of the indoor-outdoor temperature difference. Airtightness and air infiltration were substantially lower than levels found in typical Canadian dwellings. The author discusses the implications of adding ventilation at different levels to provide for various air change rates.


## INTRODUCTION

With an increased number of low energy houses being built and public awareness of such dwellings improving, the Prairie Regional Station of the Division of Building Research (DBR) undertook to test a low-energy house located in Saskatoon. The house chosen was one of 14 demonstration homes known as the Energy Showcase, built in 1980 in the Saskatoon subdivision of Lakeview.

The house is a bungalow, of double-stud wood frame construction with a polyethylene vapor barrier on the outside of the inner wall (OEC 1980). Approximate insulation values as installed are given on the first sheet of the HOTCAN 2.0 computer calculations (Table 1, Dumont et al. 1982). The heated floor area of the house is 208 $m^2$ (2240 $ft^2$) including both the main floor and the basement. The design heat loss is 5.3 kW (18000 Btu/h) at a temperature difference of 55 K (99 F). The calculated annual space heating load for the unoccupied house is 41 GJ (39 million Btu), with a base electrical load for lights, etc., of 14 kWh per day. An occupied dwelling of similar size and of 1970 standards of construction would have an annual space heating load of 110 GJ (104 million Btu) (Hedlin and Orr 1978).

## EXPERIMENTAL PROCEDURE

### Heat Loss Measurements

One of the main concerns from the start of the project was the determination of an accurate heat loss characteristic. Computer calculations using the HOTCAN 2.0 program were run using average monthly data, with single values to represent indoor and monthly outdoor temperatures. Over the period January 5 to April 30, 1981, the average daily indoor and

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outdoor temperatures were recorded, using as many as 40 temperature points distributed throughout the house and averaged every 30 seconds to give the daily averages. Daily electrical and natural gas meter readings, when applicable, were recorded as well. The daily energy consumption data based on the average daily temperature difference enabled a check to be made of the HOTCAN 2.0 results. A separate heating system, consisting of two 1500 W fan-forced electric resistance space heaters on the main floor and one 2000 W fan-forced electric resistance heater in the basement, was installed. The sizing and placement of these heaters was based on the computer calculations to maintain adequate temperatures on the main floor and in the basement. The thermostatic control for the heaters was located in a central position in the living room. This electric heating system was used alternately in place of the existing natural gas furnace, although the furnace fan was running almost continuously for all tests. During electric heating periods, the furnace combustion air intake was blocked and the chimney damper was left closed. A heat exchanger was supplied with the house and the air ducts to the outside were also sealed during all tests. Solar gains, through the south-facing window, were estimated using total daily solar radiation data for a horizontal plane. These data were transposed to the vertical plane using the method of Balcomb et al. (1980). Shading coefficients for the south-facing windows were also incorporated. The domestic hot water system was shut off during the testing period to eliminate this heat source.

### Furnace System Efficiency

From the operating periods with gas and with electricity, the efficiency of the natural gas furnace system could be determined. Several losses occur in the burning of natural gas, so that the furnace will have a combustion efficiency and unit efficiency of less than 100%. In addition to this, the burning of natural gas and the presence of a chimney can cause an increase in air infiltration. This increase can be minimized by blocking all penetrations of the building envelope when the furnace is not in operation. This was attempted by adding an airtight furnace room with a duct for outside combustion air. However, even with such an installation, some house air may leak past the furnace room wall, and house air and combustion air can mix due to leaks in the furnace ducting within the furnace room.

### Airtightness and Air Infiltration

Air infiltration is one of the major causes of heat loss in existing houses of standard construction. The air infiltration is related to the airtightness of the building. The airtightness of the test house was measured under a forced negative pressure using a fan pressurization unit (Orr and Figley 1980). Values were obtained before the house was completely finished in August 1980 and again in February 1981. After this, the furnace room was resealed and another pressure test made in March 1981.

Infiltration measurements were also made using DBR's original Mark II $SF_6$ tracer gas unit. This is a single-zone unit, programmed to automatically maintain a constant concentration of $SF_6$ and calculate actual airflows and air change rates under normal conditions. Tests were conducted both before and after the furnace room was sealed in February and in April and May. During the tests the house heat exchanger was sealed off from the outside and not run.

## RESULTS

### Heat Loss Calculations

A HOTCAN 2.0 computer prediction is shown in Table 1. The first page gives the areas and effective thermal resistance (RSI) values for the component parts of the house. The air change rate reflects the average natural rate measured in the house with no forced ventilation. This rate would probably not satisfy the need for fresh air in a normal household and would have to be supplemented by some forced ventilation. The second page of Table 1 includes a monthly breakdown of the thermal load of the house, the solar fraction, auxiliary energy requirements, and total energy consumption. The thermal load is the total heat loss of the house minus the base load electrical gains and the heat input from hot water heating and from occupants. The predicted annual space heat requirement is 41 GJ (or 39 million Btu).

Two additional HOTCAN 2.0 computer predictions are shown in Tables 2 and 3 to reflect more typical occupancies. The daily energy consumption for domestic hot water is assumed to be 15 kWh/day and there is some sensible heat gain from people. In Table 2 the 0.15 ac/h of natural infiltration is supplemented by an additional 0.2 ac/h of ventilation. This does not pass through a heat recovery device; it may be provided by a balanced fan set at 0.2 ac/h or by an exhaust fan at 0.35 ac/h. The predicted annual space heat requirement is 52 GJ (49 million Btu). In Table 3 the natural infiltration rate is supplemented by an additional 0.35 ac/h. This is assumed to be obtained via an air-to-air heat exchanger with an average heat recovery effectiveness of 70%. The air change rate shown on the first page of Table 3 is 30% of the ventilation plus the natural infiltration. The predicted annual space heat requirement is 43 GJ (41 million Btu).

From the computer prediction in Table 1, a plot of predicted furnace heating rate at 100% efficiency versus the average daily indoor-outdoor temperature difference was obtained for the unoccupied house (Figure 1). One point was calculated for each of the average monthly temperatures in Saskatoon. The number beside the point indicates the month for which the data are given. If a least squares linear regression is applied to the complete data set, the resulting equation is:

$$Q = 0.392 + 0.0777 \cdot \Delta T \tag{1}$$

where Q is given in kW, $\Delta T$ in Kelvin, and the index of determination is equal to 0.996. Points may not fall directly on the line due to variations in the solar gain that are not reflected in the temperature difference.

## Heat Loss Measurements

Figure 2 is a plot of the actual total fuel consumption of the unoccupied house versus the average temperature difference. Conditions in the house and its operation were similar to those in Figure 1. Two data sets are shown: one is for those periods when the gas furnace was used to provide space heat and one indicates the use of electric resistance heaters. All points are three- or four-day average values. Temperatures throughout the house were maintained at constant levels during electric heating periods by placement of the heaters according to the predicted heat loss, by keeping all interior doors open and by nearly continuous operation of the gas furnace recirculating fan. Even in the brief periods when the fan was not run, the temperatures remained the same because of the low thermal losses of the house and the distribution of the heat sources. For each of the data sets (gas and electric), a least squares linear regression was applied, resulting in the equations for energy consumption per day. For electric heating periods the equation is:

$$Q_E = 0.416 + 0.0894 \cdot \Delta T \tag{2}$$

The index of determination for the data is 0.633 and the standard error of estimation is 0.430 kW.

For gas heating periods the energy consumption included all purchased electricity and all purchased natural gas for the furnace. The resulting equation is:

$$Q_G = 0.256 + 0.120 \cdot \Delta T \tag{3}$$

The index of determination is 0.815 and the standard error of estimation is 0.518 kW.

The total heat loss of the house can be found by adding all heat gains into the space, including solar at steady-state conditions within the dwelling. This was done by using the energy consumption data for the electric heating periods and adding the solar gain for each point. The solar input was assumed to be utilized completely, based on the Gain Loss Ratio (GLR) method of Barakat and Sander, where GLR is small (Barakat and Sander 1982). Electric consumption was assumed to be utilized at 100% efficiency. Figure 3 is a plot of the heat loss characteristic of the house. The equation for the least squares linear regression is:

$$Q_L = 1.32 + 0.0825 \cdot \Delta T \tag{4}$$

where $Q_L$ is the total heat loss of the house. The index of determination is 0.616 and the standard error of estimation is 0.411 kW. The slope of the line is the heat loss characteristic. The intercept indicates a heat loss through the basement floor and the basement walls below grade. This heat loss is present even with an indoor-outdoor temperature difference of zero. The equation for measured total heat loss gives a design heat loss of 5.86 kW at a design temperature difference of 55 K (99 F) although no measurements could be made at that temperature. This compares with the predicted rate of 5.3 kW at a similar temperature difference.

## Furnace System Efficiency

The furnace system efficiency can be measured using the heat loss characteristic of the house. The natural gas furnace installed was a unit of 17.6 kW (60000 Btu/h) burner capacity and 14.1 kW (48000 Btu/h) bonnet capacity and was supplied with spark ignition for the pilot flame and an automatic damper for the chimney. Furnace system efficiencies were calculated by first estimating the house heat loss from Figure 3 based on measured heat loss with electric resistance heating, and subtracting all electrical and solar gains. This left the load to be made up by the natural gas furnace. The load divided by the consumption provided the resultant system efficiency. Figure 4 shows the furnace efficiency versus the above-grade temperature difference. The data points are taken from the same three- and four-day periods as the natural gas consumption data in Figure 2. The average furnace system efficiency is 64%. There is a correlation coefficient of 0.909 for a second order curve fit as shown by the dotted line. The resulting equation is:

$$\text{Efficiency (\%)} = 0.60 + 3.68 \cdot \Delta T - 0.05 \cdot (\Delta T)^2 \tag{5}$$

with a standard error estimate of 2.75%. Note that this approach for determining system efficiency is based on daily average data and by definition, this furnace system efficiency includes losses associated with the distribution system and increased infiltration.

## Airtightness Tests

Figure 5 shows the results of airtightness tests done on the house during August 1980. At that time, the airtightness was found to be 0.53 ac/h at a negative internal pressure of 50 Pa (0.2 in $H_2O$). For this result, the chimney, combustion air inlet, and all vents were blocked. With the house in the as-received condition, the airtightness level was 0.95 ac/h at the same pressure condition.

Figure 6 shows the results of three airtightness tests done during February 1981. The topmost line shows the result of the as-received test with the furnace room door open. The airtightness level was found to be 1.24 ac/h at 50 Pa. The next line shows the minimal effect of closing the furnace room door. The airtightness level was 1.22 ac/h at 50 Pa, indicating that the furnace room seal was so poor that it did not affect the airtightness. The bottom line shows the airtightness to be 0.65 ac/h at 50 Pa with all vents sealed as for August 1980.

After this test, the furnace room enclosure was sealed as well as possible. Taking three tests to match the February tests produced results at 50 Pa of 1.08, 1.04, and 0.61 ac/h (Figure 7). This indicated a somewhat tighter furnace system and a general drop in the airflow for all tests.

## Air Infiltration Tests

Air infiltration was measured by tracer gas during both gas and electric heating periods before and after the furnace room was sealed. During gas heating periods in February, the average infiltration was 0.143 ac/h. The average wind speed for the period was 3.2 m/s (7.2 mph) and the average temperature difference was 29.3 K (52.7 F). The corresponding airtightness level for this period was 1.22 ac/h at 50 Pa.

During electric heating periods in February, the average infiltration rate was 0.084 ac/h. All electric measurements were taken with the furnace chimney and combustion air inlet blocked off. The average wind speed was 3.1 m/s (6.9 mph) and the average temperature difference was 27.3 K (49.1 F), conditions close to the February gas heating period. Thus it is interesting to note a reduction of approximately 41% of the air change rate by shutting down the gas furnace. The corresponding airtightness for this period was 0.65 ac/h at 50 Pa.

The average infiltration in April, during gas heating, was 0.096 ac/h. The average wind speed was 4.3 m/s (9.6 mph) and the average temperature difference was 17.1 K (30.8 F). The corresponding airtightness level for this period was 1.04 ac/h at 50 Pa. The April tests show a reduction of 33% of the air infiltration, although a large portion of this could be due to changes in the weather (Shaw 1981).

In April and May after the furnace room envelope was sealed, the average infiltration while using electric heat was 0.051 ac/h. For this period the airtightness level was 0.61 ac/h at 50 Pa. Again, comparisons with the February period are difficult to make because of the change in the weather. However, it is interesting to note approximately 47% less air infiltration when using electric heat, compared to the corresponding gas heating period.

## DISCUSSION

The HOTCAN 2.0 predictions for energy consumption versus the temperature difference are generally lower than the actual consumption (Colborne et al. 1983; Dumont et al. 1983). This is the case for the unoccupied test house but the prediction still falls within approximately 12% of the actual consumption when using electric heat (compare Fig. 1 with electric heating in Fig. 2). This is within the standard error of estimation using the equation for electric heating periods. A low infiltration rate, averaging between 0.051 and 0.084 ac/h for electric heating periods and 0.096 and 0.14 ac/h for gas heating periods, contributed to the low space heat energy requirements. This is generally considered to provide too little fresh air for acceptable indoor air quality. In most occupied low-energy houses the infiltration is supplemented with additional ventilation air. This ventilation may be passive, as in the case of an open chimney or operating openings in or near windows, or a combination of openings in the building envelope. The ventilation may be forced and may be balanced or unbalanced. A balanced system has equal forced air rates blowing into and out of the house. An example of an unbalanced system is an exhaust fan system capable of venting the whole house. The makeup air is then brought in through openings in the building envelope provided for this purpose and through cracks and unplanned openings. Heat recovery can be applied to either a forced ventilation system, via a heat exchanger for a balanced system, or an exhaust-air-source heat pump for an exhaust fan. Shaw (1983) discusses the implications of using balanced and unbalanced forced ventilation systems.

Two additional HOTCAN 2.0 runs show the predicted relative effects of occupancy on the Milbrandt house. Both runs include average occupancy heat gains, with the addition of 15 kWh/d energy use for domestic hot water and 3.2 kWh/d sensible heat gain from people. One run shows the effect of an air change rate of 0.35 ac/h. This is an average of a number of typical air change rates measured in Saskatoon residences of standard construction (R.S. Dumont, personal communication). No heat recovery is employed on the extra ventilation. Based on the predicted values, the space heat requirement increased by 27% for this case, compared to the unoccupied house under test conditions, or from 41 GJ (39 million Btu) to 52 GJ (49 million Btu). The predicted figure of 52 GJ for increased insulation levels and a typical amount of infiltration compares favorably with the value of 110 GJ (104 million Btu) measured by Hedlin and Orr (1978).

The second run shows the effect of an air change rate of 0.5 ac/h as recommended in such programs as the R2000 energy program. This is accomplished by the installation of an air-to-air heat exchanger running at 0.35 ac/h. Heat recovery effectiveness of the heat exchanger is 70%. This extra ventilation increased the space heat requirement by 5%, compared to the unoccupied house under test conditions.

Furnace system efficiency in the test house was found to be a function of temperature difference. At lower indoor-outdoor temperature differences, the efficiency dropped, so that at a temperature difference of 15 K (27 F) the efficiency was 45%. This is in agreement with the findings of Janssen and Bonne and others, who found that fuel consumption increased with increasing furnace overcapacity at a given load (Janssen and Bonne 1977). At lower temperature differences, the overcapacity of the furnace increases. The equation for the curve also suggests a drop in the furnace efficiency with increasing temperature differences above 40 K (72 F). This may not be an accurate representation of the furnace operation. The data points at the higher temperature differences indicate the curve may be flattening so that the furnace system operates at a steady efficiency of between 65% and 70% above a 40 K (72 F) temperature difference. The curve shown on Figure 4 indicates the furnace efficiency is dropping above a 40 K temperature difference. This may be only an apparent drop, due to limitations in the curve fitting process; the curve is also strongly influenced by an apparent high efficiency at a temperature difference of 30 K (54 F). The limits of accuracy for the efficiency may account for a measurement higher than it is meant to be at that point. More data points are needed with 50 to 60 K (90 to 108 F) temperature differences to prove any trends in furnace efficiency at high temperature differences. Such average temperature differences did not occur during the period when the house was available for testing.

The airtightness of the house shows relatively little change over the period of the three pressure tests. The first test was done in summer and the second and third tests were done in winter. The winter tests show a very slight increase in the airtightness test results. This is due, in part, to the colder, denser air entering through the building envelope during the winter months, allowing more warm inside air to be exhausted at the same building pressure. All the test results compare favorably with airtightness tests reported by Dumont et al. (1981) for current standard construction and low-energy houses.

## CONCLUSION

The low-energy house has been studied with particular emphasis on its heat loss characteristics and airtightness and air infiltration in an unoccupied state. The heat loss characteristic of the house was measured as 0.0825 kW/K (282 Btu/h•F), substantially lower than that for conventional housing (even considering that the house was unoccupied). Computer predictions were used to estimate the effects of occupancy and a forced ventilation rate. With an additional 0.2 ac/h of ventilation, the space heat requirement would increase by 27% if average occupancy gains were also included. Using a heat recovery ventilator with an effectiveness of 70% to provide an additional 0.35 ac/h would increase the space heat requirement by only 5% with average occupancy.

Efficiency of the natural gas furnace and distribution system was found to drop with increased overcapacity; that is, when the indoor-outdoor temperature difference was less, the furnace efficiency was lower. Evidently furnaces should be carefully sized to match the heating requirements and design heat loss of a low-energy house.

Airtightness was measured between 0.53 and 0.65 ac/h at 50 Pa (0.2 in $H_2O$). Colder outdoor temperatures at the higher value could account for some of the increase. Still, the figures remained relatively constant, indicating no failure of the building envelope in handling any of the air pressure differences across it.

## ACKNOWLEDGMENT

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TABLE 1

HOTCAN 2.0 Computer Prediction for Milbrandt Test House with Natural Air Change Rate, No Forced Ventilation, Hot Water Energy Comsumption = 0 kWh/day (available in SI units only)

*** BUILDING PARAMETERS ***

| ELEMENT | | AREA M2 | RSI VALUE M2-DEGC/W | HT LOSS W/DEGC | % SEASONAL HT LOSS |
|---|---|---|---|---|---|
| CEILING | | 93.59 | 7 | | |
| | | 12.25 | 4.91 | | |
| | TOTAL | 105.84 | 6.67 | 15.86 | 13.17 |
| MAIN WALLS | | 84.31 | 6.91 | | |
| | | .39 | 2.51 | | |
| | | 1.61 | .55 | | |
| | TOTAL | 86.31 | 5.65 | 15.28 | 12.68 |
| DOORS | | 3.26 | 2.11 | | |
| | TOTAL | 3.26 | 2.11 | 1.55 | 1.28 |
| BASEMENT AB.GD. | | 4.72 | 3.36 | | |
| | | 8.28 | 6.66 | | |
| | | 20.7 | 6.04 | | |
| | TOTAL | 33.7 | 5.55 | 6.08 | 5.04 |
| BASEMENT 600MM. | | 24.84 | 6.04 | | |
| | TOTAL | 24.84 | 6.04 | 3.34 | 2.19 |
| BASE. TO FLOOR | | 49.68 | 4.28 | | |
| | TOTAL | 49.68 | 4.28 | 6.86 | 4.51 |
| FLOOR PERIMETER | | 37.4 | 0 | | |
| | TOTAL | 37.4 | 0 | 27.74 | 18.22 |
| FLOOR CENTRE | | 65.1 | 0 | | |
| | TOTAL | 65.1 | 0 | 14.65 | 9.62 |
| SOUTH WINDOWS | | 3.95 | .74 | | |
| | | 2.36 | .55 | | |
| | TOTAL | 6.31 | .66 | 9.63 | 7.99 |
| NORTH WINDOWS | | 3.89 | .55 | | |
| | TOTAL | 3.89 | .55 | 7.07 | 5.87 |
| EAST WINDOWS | | 0 | 0 | | |
| | TOTAL | 0 | 0 | 0 | 0 |
| WEST WINDOWS | | 0 | 0 | | |
| | TOTAL | 0 | 0 | 0 | 0 |
| AIR CHANGE | | .15/HR | 506 M3 | 23.41 | 19.43 |

DESIGN HEAT LOSS AT -34C = 5.29 KW
TEMPERATURES (DEG C) MAIN FLOOR = 22 BASEMENT = 21
SENSIBLE HEAT GAIN FROM PEOPLE (KWH/D) = 0
DAILY BASE ELECTRIC CONSUMPTION (KWH/D) = 15
DAILY HOT WATER ENERGY CONSUMPTION (KWH/D) = 0
MASS LEVEL CHOSEN IS (A)
WINDOW SHADING COEFFICIENTS: SOUTH = .63 NORTH = .71
EAST = 0 WEST = 0
SOUTH OVERHANG GEOMETRY: AVERAGE WINDOW HEIGHT = 1.18 M
AVERAGE OVERHANG WIDTH = .7 M
AVERAGE HEIGHT ABOVE WINDOW = .21 M
NATURAL INFILTRATION RATE (AC/HR) = .15
FORCED VENTILATION RATE (AC/HR) = 0

*** MONTHLY SUMMARY OF ENERGY CONSUMPTION ***

| MONTH | THERMAL LOAD KWH/D | MONTHLY SOLAR FRAC | AUX HEAT REQ KWH/D | TOT CONS KWH/D |
|---|---|---|---|---|
| JAN | 83.64 | .16 | 70.28 | 85.28 |
| FEB | 79.12 | .21 | 62.61 | 77.61 |
| MAR | 65.61 | .26 | 48.86 | 63.86 |
| APR | 42.5 | .29 | 30.27 | 45.27 |
| MAY | 25.4 | .41 | 15.02 | 30.02 |
| JUN | 17.62 | .55 | 7.85 | 22.85 |
| JUL | 11.94 | .74 | 3.12 | 18.12 |
| AUG | 11.73 | .76 | 2.81 | 17.81 |
| SEP | 20.7 | .53 | 9.67 | 24.67 |
| OCT | 34.34 | .36 | 22.04 | 37.04 |
| NOV | 56.17 | .2 | 44.99 | 59.99 |
| DEC | 72.86 | .15 | 61.68 | 76.68 |

ESTIMATED ANNUAL SPACE HEATING 41.31 GJ, OR 11474.24 KWHRS
ANNUAL SOLAR FRACTION = .27

*** ANNUAL PREDICTED FUEL COSTS ***

FUEL COSTS ARE FOR SASKATOON AS OF 1982 MAY 6

| ENERGY SOURCE | COST PER UNIT | SPACE HEATING | HOT WATER | LIGHTS AND APPLIANCES |
|---|---|---|---|---|
| ELECTRICITY | $.034/KWH | $390.12/YR EFF.= 100% | $0/YR EFF.= 100% | $186.15/YR EFF.= 100% |
| NATURAL GAS | $.1123/M3 | $177.85/YR EFF.= 70% | $0/YR EFF.= 55% | -- |
| OIL | $.26/LITRE | $393.41/YR EFF.= 70% | $0/YR EFF.= 55% | -- |
| PROPANE | $.1572/LITRE | $362.37/YR EFF.= 70% | $0/YR EFF.= 55% | -- |
| WOOD | $24.79/M3 | $399.7/YR EFF.= 50% | $0/YR EFF.= 40% | |

TABLE 2

HOTCAN 2.0 Computer Prediction for Milbrandt Test House with
0.2 ac/h Forced Ventilation, Hot Water Energy
Consumption = 15 kWh/day (available in SI units only)

*** BUILDING PARAMETERS ***

| ELEMENT | | AREA M2 | RSI VALUE M2-DEGC/W | HT LOSS W/DEGC | % SEASONAL HT LOSS |
|---|---|---|---|---|---|
| CEILING | | 93.59 | 7 | | |
| | | 12.25 | 4.91 | | |
| | TOTAL | 105.84 | 6.67 | 15.86 | 11.59 |
| MAIN WALLS | | 84.31 | 6.91 | | |
| | | .39 | 2.51 | | |
| | | 1.61 | .55 | | |
| | TOTAL | 86.31 | 5.65 | 15.28 | 11.16 |
| DOORS | | 3.26 | 2.11 | | |
| | TOTAL | 3.26 | 2.11 | 1.55 | 1.13 |
| BASEMENT AB.GD. | | 4.72 | 3.36 | | |
| | | 8.28 | 6.66 | | |
| | | 20.7 | 6.04 | | |
| | TOTAL | 33.7 | 5.55 | 6.08 | 4.44 |
| BASEMENT 600MM. | | 24.84 | 6.04 | | |
| | TOTAL | 24.84 | 6.04 | 3.34 | 1.93 |
| BASE. TO FLOOR | | 49.68 | 4.28 | | |
| | TOTAL | 49.68 | 4.28 | 6.86 | 3.97 |
| FLOOR PERIMETER | | 37.4 | 0 | | |
| | TOTAL | 37.4 | 0 | 27.74 | 16.04 |
| FLOOR CENTRE | | 65.1 | 0 | | |
| | TOTAL | 65.1 | 0 | 14.65 | 8.47 |
| SOUTH WINDOWS | | 3.95 | .74 | | |
| | | 2.36 | .55 | | |
| | TOTAL | 6.31 | .66 | 9.63 | 7.03 |
| NORTH WINDOWS | | 3.89 | .55 | | |
| | TOTAL | 3.89 | .55 | 7.07 | 5.17 |
| EAST WINDOWS | | 0 | 0 | | |
| | TOTAL | 0 | 0 | 0 | 0 |
| WEST WINDOWS | | 0 | 0 | | |
| | TOTAL | 0 | 0 | 0 | 0 |

DESIGN HEAT LOSS AT -34C = 7.01 KW
TEMPERATURES (DEG C) MAIN FLOOR = 22 BASEMENT = 21
SENSIBLE HEAT GAIN FROM PEOPLE (KWH/D) = 3.2
DAILY BASE ELECTRIC CONSUMPTION (KWH/D) = 15
DAILY HOT WATER ENERGY CONSUMPTION (KWH/D) = 15
MASS LEVEL CHOSEN IS (A)
WINDOW SHADING COEFFICIENTS: SOUTH = .63 NORTH = .71
EAST = 0 WEST = 0
SOUTH OVERHANG GEOMETRY: AVERAGE WINDOW HEIGHT = 1.18 M
AVERAGE OVERHANG WIDTH = .7 M
AVERAGE HEIGHT ABOVE WINDOW = .21 M
NATURAL INFILTRATION RATE (AC/HR) = .15
FORCED VENTILATION RATE (AC/HR) = .2

*** MONTHLY SUMMARY OF ENERGY CONSUMPTION ***

| MONTH | THERMAL LOAD KWH/D | MONTHLY SOLAR FRAC | AUX HEAT REQ KWH/D | TOT CONS KWH/D |
|---|---|---|---|---|
| JAN | 106.81 | .13 | 93.45 | 123.45 |
| FEB | 100.04 | .17 | 82.66 | 112.66 |
| MAR | 81.13 | .21 | 63.93 | 93.93 |
| APR | 49.26 | .25 | 36.94 | 66.94 |
| MAY | 26.09 | .4 | 15.68 | 45.68 |
| JUN | 16.06 | .6 | 6.5 | 36.5 |
| JUL | 8.89 | .86 | 1.25 | 31.25 |
| AUG | 9.05 | .86 | 1.22 | 31.22 |
| SEP | 21.62 | .51 | 10.49 | 40.49 |
| OCT | 40.27 | .31 | 27.83 | 57.83 |
| NOV | 70.05 | .16 | 58.76 | 88.76 |
| DEC | 92.5 | .12 | 81.32 | 111.32 |

ESTIMATED ANNUAL SPACE HEATING 52.27 GJ, OR 14520.4 KWHRS
ANNUAL SOLAR FRACTION = .23

*** ANNUAL PREDICTED FUEL COSTS ***

FUEL COSTS ARE FOR SASKATOON AS OF 1982 MAY 6

| ENERGY SOURCE | COST PER UNIT | SPACE HEATING | HOT WATER | LIGHTS AND APPLIANCES |
|---|---|---|---|---|
| ELECTRICITY | $.034/KWH | $493.69/YR EFF.= 100% | $186.15/YR EFF.= 100% | $186.15/YR EFF.= 100% |
| NATURAL GAS | $.1123/M3 | $225.07/YR EFF.= 70% | $108.01/YR EFF.= 55% | -- |
| OIL | $.26/LITRE | $497.86/YR EFF.= 70% | $238.91/YR EFF.= 55% | -- |
| PROPANE | $.1572/LITRE | $458.57/YR EFF.= 70% | $220.06/YR EFF.= 55% | -- |
| WOOD | $24.79/M3 | $505.81/YR EFF.= 50% | $238.39/YR EFF.= 40% | |

# TABLE 3

## HOTCAN 2.0 Computer Prediction for Milbrandt Tst House with 0.35 ac/h Forced Ventilation (available in SI units only)

### *** BUILDING PARAMETERS ***

| ELEMENT | AREA M2 | RSI VALUE M2-DEGC/W | HT LOSS W/DEGC | % SEASONAL HT LOSS |
|---|---|---|---|---|
| CEILING | 93.59 | 7 | | |
| | 12.25 | 4.91 | | |
| TOTAL | 105.84 | 6.67 | 15.86 | 10.46 |
| MAIN WALLS | 84.31 | 6.91 | | |
| | .39 | 2.51 | | |
| | 1.61 | .55 | | |
| TOTAL | 86.31 | 5.65 | 15.28 | 10.07 |
| DOORS | 3.26 | 2.11 | | |
| TOTAL | 3.26 | 2.11 | 1.55 | 1.02 |
| BASEMENT AB.GD. | 4.72 | 3.36 | | |
| | 8.28 | 6.66 | | |
| | 20.7 | 6.04 | | |
| TOTAL | 33.7 | 5.55 | 6.08 | 4 |
| BASEMENT 600MM. | 24.84 | 6.04 | | |
| TOTAL | 24.84 | 6.04 | 3.34 | 1.74 |
| BASE. TO FLOOR | 49.68 | 4.28 | | |
| TOTAL | 49.68 | 4.28 | 6.86 | 3.58 |
| FLOOR PERIMETER | 37.4 | 0 | | |
| TOTAL | 37.4 | 0 | 27.74 | 14.47 |
| FLOOR CENTRE | 65.1 | 0 | | |
| TOTAL | 65.1 | 0 | 14.65 | 7.64 |
| SOUTH WINDOWS | 3.95 | .74 | | |
| | 2.36 | .55 | | |
| TOTAL | 6.31 | .66 | 9.63 | 6.35 |
| NORTH WINDOWS | 3.89 | .55 | | |
| TOTAL | 3.89 | .55 | 7.07 | 4.66 |
| EAST WINDOWS | 0 | 0 | | |
| TOTAL | 0 | 0 | 0 | 0 |
| WEST WINDOWS | 0 | 0 | | |
| TOTAL | 0 | 0 | 0 | 0 |

DESIGN HEAT LOSS AT -34C = 6.19 KW
TEMPERATURES (DEG C) MAIN FLOOR = 22 BASEMENT = 21
SENSIBLE HEAT GAIN FROM PEOPLE (KWH/D) = 3.2
DAILY BASE ELECTRIC CONSUMPTION (KWH/D) = 15
DAILY HOT WATER ENERGY CONSUMPTION (KWH/D) = 15
MASS LEVEL CHOSEN IS (A)
WINDOW SHADING COEFFICIENTS: SOUTH = .63 NORTH = .71
EAST = 0 WEST = 0
SOUTH OVERHANG GEOMETRY: AVERAGE WINDOW HEIGHT = 1.18 M
AVERAGE OVERHANG WIDTH = .7 M
AVERAGE HEIGHT ABOVE WINDOW = .21 M
NATURAL INFILTRATION RATE (AC/HR) = .15
FORCED VENTILATION RATE (AC/HR) = .35
HEAT RECOVERY EFFECTIVENESS ON VENTILATION AIR = 70%

### *** MONTHLY SUMMARY OF ENERGY CONSUMPTION ***

| MONTH | THERMAL LOAD KWH/D | MONTHLY SOLAR FRAC | AUX HEAT REQ KWH/D | TOT CONS KWH/D |
|---|---|---|---|---|
| JAN | 92.57 | .14 | 79.21 | 109.21 |
| FEB | 86.87 | .19 | 70.21 | 100.21 |
| MAR | 70.53 | .24 | 53.61 | 83.61 |
| APR | 42.82 | .29 | 30.58 | 60.58 |
| MAY | 22.54 | .45 | 12.31 | 42.31 |
| JUN | 13.57 | .67 | 4.46 | 34.46 |
| JUL | 7.11 | .93 | .49 | 30.49 |
| AUG | 7.1 | .94 | .43 | 30.43 |
| SEP | 17.95 | .6 | 7.27 | 37.27 |
| OCT | 34.22 | .36 | 21.93 | 51.93 |
| NOV | 60.23 | .19 | 48.93 | 78.93 |
| DEC | 79.94 | .14 | 68.76 | 98.76 |

ESTIMATED ANNUAL SPACE HEATING 43.35 GJ, OR 12042.21 KWHRS
ANNUAL SOLAR FRACTION = .26

### *** ANNUAL PREDICTED FUEL COSTS ***

FUEL COSTS ARE FOR SASKATOON AS OF 1982 MAY 6

| ENERGY SOURCE | COST PER UNIT | SPACE HEATING | HOT WATER | LIGHTS AND APPLIANCES |
|---|---|---|---|---|
| ELECTRICITY | \$.034/KWH | \$409.44/YR EFF.= 100% | \$186.15/YR EFF.= 100% | \$186.15/YR EFF.= 100% |
| NATURAL GAS | \$.1123/M3 | \$186.66/YR EFF.= 70% | \$108.01/YR EFF.= 55% | -- |
| OIL | \$.26/LITRE | \$412.89/YR EFF.= 70% | \$238.91/YR EFF.= 55% | -- |
| PROPANE | \$.1572/LITRE | \$380.3/YR EFF.= 70% | \$220.06/YR EFF.= 55% | -- |
| WOOD | \$24.79/M3 | \$419.48/YR EFF.= 50% | \$238.39/YR EFF.= 40% | |

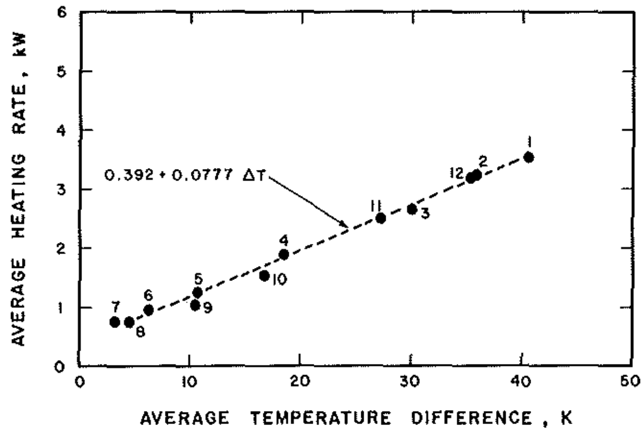


*Figure 1. Expected total energy consumption vs. average daily indoor-outdoor temperature difference (from HOTCAN prediction)*

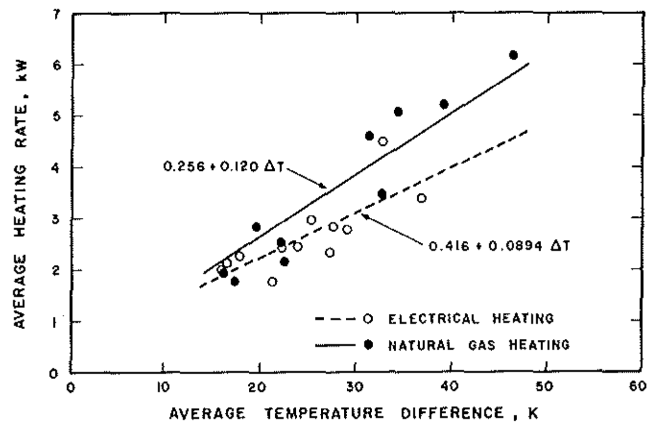


*Figure 2. Actual energy consumption vs. average indoor-outdoor temperature difference*

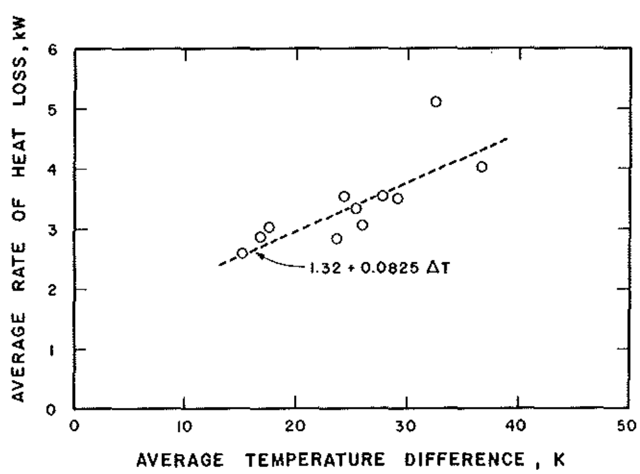


*Figure 3. Heat loss characteristics of low-energy house*

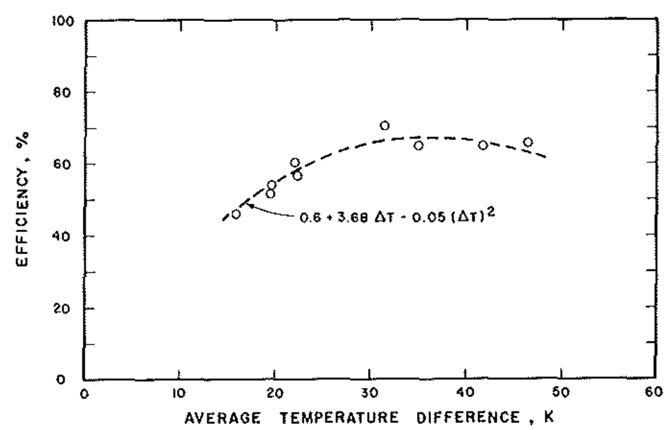


*Figure 4. Furnace efficiency vs. above-grade indoor-outdoor temperature difference*

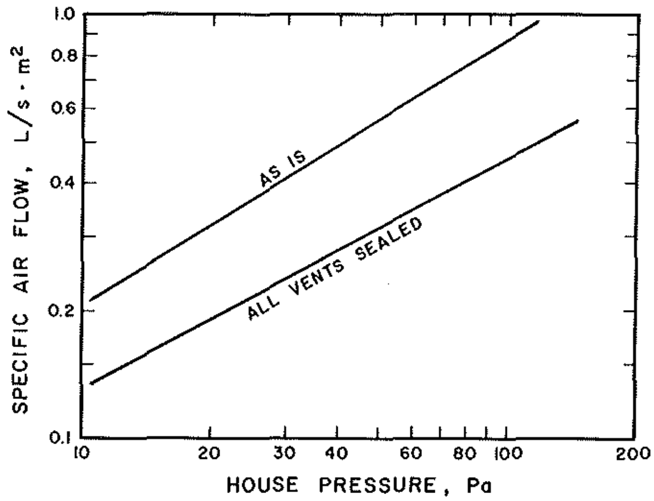


*Figure 5. Results of pressure test, August 1980*

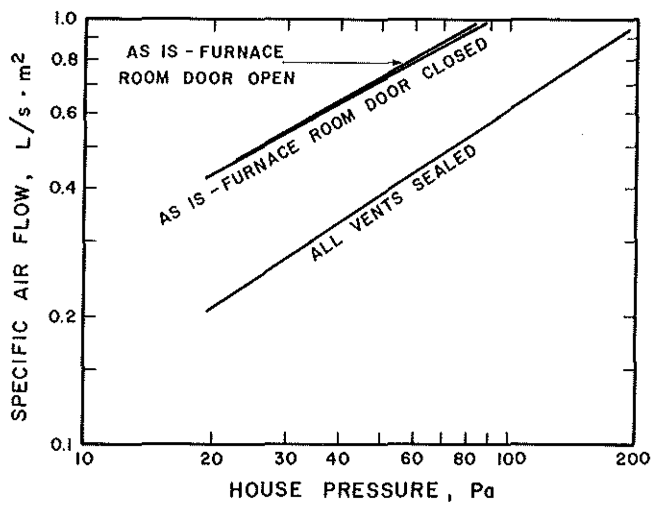


*Figure 6. Results of pressure tests, February 1981, for three conditions*

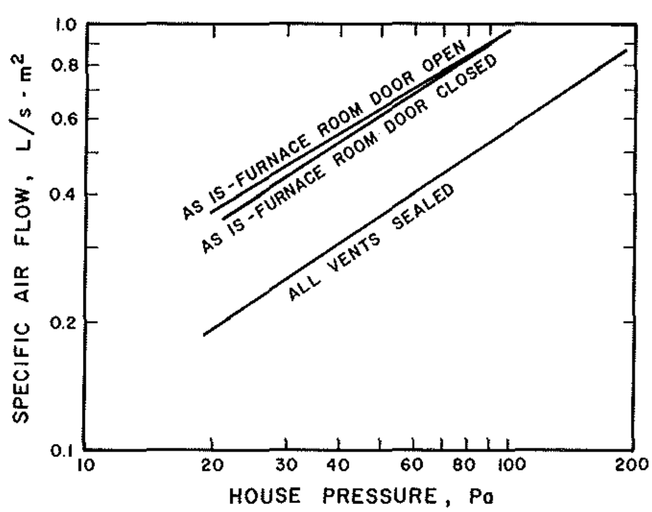


*Figure 7. Results of pressure tests, March 1981, furnace room resealed*