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THE ECONOMICS OF RETROFITTING

EXISTING HOMES IN WESTERN CANADA

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SUMMARY:

This paper presents the results of an energy-efficiency survey of 25 homes located in Saskatoon, Saskatchewan. Insulation levels in the walls, ceilings and basements were measured and the economics of adding insulation to these areas was investigated. Air infiltration rates were measured and a pamphlet was prepared to assist homeowners in sealing and weatherstripping their homes.

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THE ECONOMICS OF RETROFITTING EXISTING HOMES IN WESTERN CANADA

INTRODUCTION

This paper presents the results of an energy efficiency survey of twenty-five homes located in Saskatoon, Saskatchewan, including the economics of retrofitting these homes to conserve energy. A wide range of house styles and years of construction was included in the study with most homes falling into two age categories: those built prior to 1945 and those built in the years 1960-1970.

Each house was examined to determine the existing insulation levels in the walls, ceiling, and basement. In addition, air infiltration rates were measured by closing all windows and doors and generating a negative pressure within the house. Furnace efficiencies and monthly natural gas and electrical consumption were recorded.

A heat loss distribution profile was then charted for each house and the economics of retrofitting the house was calculated. Each area of heat loss including the walls, ceiling, basement and air infiltration were considered separately. The economics of retrofitting these areas was determined by calculating a payback period based upon the actual cost of retrofitting and the potential savings in energy costs.

THE SURVEY

Owners of about thirty-five homes in various parts of the city were contacted by mail and asked if they would be interested in participating in the study. They were told that they would each be provided with the results of the study as well as the particular results for their own home. The response to the request was very good with twenty-five affirmative replies. A team of two people visited each home for about an hour. During this time they measured the areas of the walls, windows, ceiling, basement walls, basement floors, etc. and measured the insulation levels existing in these areas. The air infiltration test was conducted and, in addition, the homeowner was asked to provide general information about the house and about their life styles with respect to energy consumption.

ESTIMATION OF INFILTRATION RATE

The actual air infiltration rate is dependent upon house tightness as well as the pressure difference across the exterior house envelope. Although this pressure difference can vary from day to day (being dependent upon wind velocity, chimney stack action, and stack action caused by the difference between indoor and outdoor temperatures), an estimate of typical air infiltration rates can be made from a measurement of house tightness. For this study, house tightness was measured by placing a panel mounted fan unit in a doorway and measuring the air flow required to create a 50 Pa negative pressure within the house. The relative house tightness was then calculated as cubic meters of air per hour, per unit area of envelope enclosure. For the 25 homes, these values ranged from 2.9 to 17.2 $m^3/hr/m^2$. These values of house tightness were plotted against infiltration rates as measured by the tracer gas technique for four selected houses. From this graph (upper line in figure 1), it was possible to set a quick estimate of the expected air infiltration rate under design conditions for the 25 homes included in the study. This technique has been previously used by Kronvall[1] with good results for a group of houses under typical weather conditions in Sweden (lower line in figure 1). The advantage of the technique is that an estimate of the infiltration rate can be obtained for each house in less than an hour, compared to several days for the tracer gas technique.

HEAT LOSS CALCULATIONS

Using the methods and values given in the ASHRAE 1977 Handbook of Fundamentals, the heat loss of each house was calculated. Table I shows the average values for groups of houses based on their year of construction and number of stories. Heat losses were calculated based on a design temperature difference of 100°F (55.5°C) for the following areas: ceiling, walls, above-grade basement walls, below-grade basement walls, windows, doors, and air infiltration. The percentage of total heat loss is given for each component. As can be seen from the table, infiltration accounts for the largest portion (30-35%) of the heating requirements of the houses surveyed, particularly for the homes of older construction. Ceiling, wall, window and door losses, and basement wall losses were smaller. It should be noted that, although not all of the houses surveyed were fully insulated, all were fitted with double-paned windows.

One factor that became apparent during the study was that many homes did not fit into standard house styles. This was particularly true of the homes built prior to 1945, many of which had unusual styles or had been modified or added to. Standard calculating procedures could not be used for these houses. Instead, each house had to be analyzed on an individual basis to obtain accurate results. This factor would suggest that many of the computer programs that apply standard calculating procedures are of limited value for analyzing heat loss characteristics of older homes. Rather, it is necessary to calculate the heat losses for these homes on an individual basis (or at least pre-process the data for use in a computer program) in order to realistically estimate the energy savings that could be achieved through retrofits.

CALCULATED ENERGY SAVINGS

Table II shows the calculated energy savings for retrofitting five houses from Table I. Savings were calculated separately for adding insulation to various parts of the houses, as well as retrofitting to reduce infiltration.

It has been demonstrated by Sowcolow[2] that calculated energy savings are reasonably accurate when based upon the increased thermal resistance of a component of the structure. If anything, the calculations tend to underestimate the savings because the reference temperature (the outdoor temperature above which no heating is required because of solar and internal house heat gains) is lowered with added insulation. However, the energy savings that may be achieved by reducing air change rates by sealing cracks and weather-stripping doors and windows is more difficult to estimate. One might overlook a possible major air leak (or not be able to seal it), and thus the

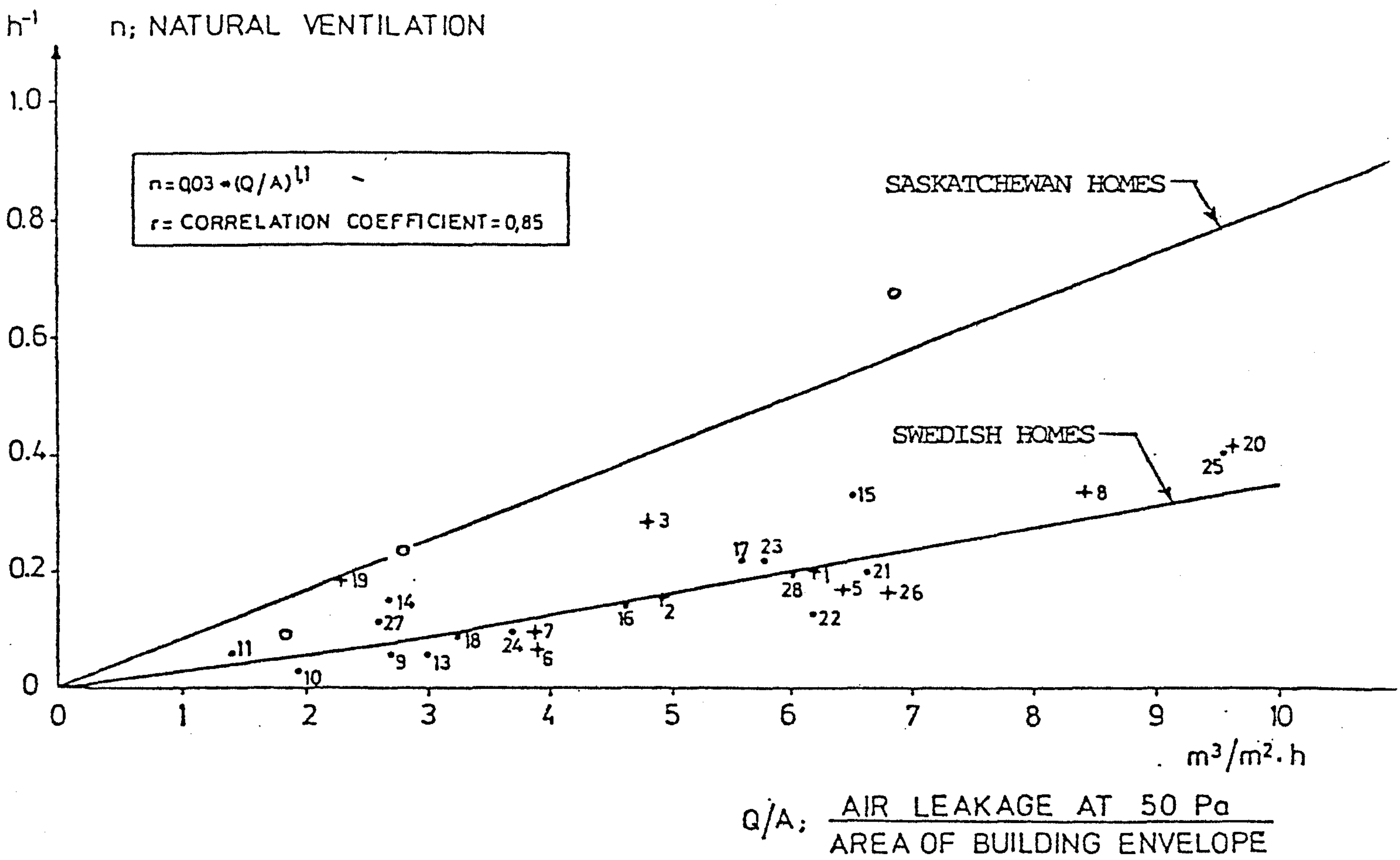

Figure 1.

PRESSURIZATION AND NATURAL VENTILATION RATES IN SWEDISH AND SASKATCHEWAN HOMES

TABLE I

MEAN VALUES OF CALCULATED HEAT LOSSES

	HOUSE STYLE					
	Pre-1945 Bungalow	Pre-1945 1½ storey	Pre-1945 2 storey	1960-70 Bungalow	1960-70 2 storey	Mean for All Houses
Av. Floor Area (ft^2)	1,155	1,548	1,595	1,075	1,723	1,384
Av. Envelope Area (ft^2)	4,405	4,003	4,651	4,110	4,716	4,414
Design Heat Loss (BTU/h)	75,873	68,250	87,680	45,577	57,472	71,640
Des. Heat Loss/Floor Area	65.6	43.9	55.5	42.3	33.4	51.8
Des. Infiltration Rate (h^{-1})	1.05	1.16	1.17	0.67	0.74	1.00
Per cent of Total Design Heat Loss: Attic	14.0	12.6	11.8	11.9	14.0	12.4
Walls	24.1	13.7	25.8	15.9	23.5	21.8
Windows & Doors	11.9	13.0	13.9	21.2	19.9	15.6
Basement	16.4	24.3	10.9	20.4	5.6	15.3
Infiltration	29.6	36.6	35.6	30.5	36.5	33.4

TABLE II

EXAMPLE CALCULATED SAVINGS FROM RETROFITTING

	HOUSE STYLE				
	Pre-1945 Bungalow	Pre-1945 1½ storey	Pre-1945 2 storey	1960-70 Bungalow	1960-70 2 storey
Attic Retrofit:					
R original	10	-	12	14	22
R added	20	-	20	20	20
Material cost ($)	267	-	219	345	211
*Annual saving ($)	62	-	40	51	20
*Payback period (yr.)	4.3	-	5.5	6.8	10.4
Basement Wall Retrofit:					
R original	2	2	3	9	14
R added	8	8	8	8	8
Material Cost ($)	400	304	290	302	290
*Annual saving ($)	135	104	98	21	8
*Payback period (yr.)	3.0	2.9	3.0	14.4	36
Infiltration Retrofit:					
Old air change rate (h^{-1})	1.04	1.2	1.26	.67	.74
**New air change rate (h^{-1})	.78	.9	.95	.5	.56
Material cost ($)	50	50	50	50	50
*Annual saving ($)	58	82	75	40	69
*Payback period (yr.)	0.9	0.6	0.7	1.25	.72

* Based on heating oil prices of 60¢/Imp. Gal. (50¢/U.S. Gal.)

** Assuming air infiltration is reduced by 25% after retrofit.

net savings would be smaller. We estimate that the average homeowner who applied his own weather-stripping would be able to reduce the rate of infiltration by approximately 25%. A very conscientious person with some experience could conceivably reduce infiltration by a greater percentage and consequently achieve greater savings. The dollar savings shown in Table II are based upon a heating oil price of 50¢ per U.S. gallon.

Once again, it was not possible to generalize the calculations of possible savings because each house studied had various areas insulated to different resistance values which contributed to different percentages to the overall energy required for heating. Each house required its own independent calculation.

COSTS OF RETROFITTING

a) Reducing Infiltration

Retrofitting to reduce infiltration was considered most important because infiltration accounted for the largest component of heat loss. The cost of materials to seal and weatherstrip houses is quite low, generally around $50.00, but the labour component is so variable that no contractor would do the work except on a cost-plus basis. Even if the work were done on this basis, we have no assurance that the desired reduction in energy consumption would occur as it is possible to overlook a major source of infiltration or find a source of infiltration that is impossible to seal. However, for the do-it-yourself homeowner who is willing to take the time to seek out and seal the points where cold air enters into the house, the savings in energy costs compared to his material costs would be considerable. This is particularly true in older homes that were constructed prior to 1945. Homes constructed in the 1960-1970 period were somewhat better sealed and the possible savings from retrofitting against infiltration would be smaller.

b) Attic and Ceiling Insulation Retrofit

An accessible attic is generally the easiest place to add insulation. Typical material costs per square foot of attic are indicated below:

Insulation	R12	R20
Fibreglass	18¢	29¢
Celufibre	14¢	25¢

Estimates for a contractor to blow in R20 of cellulose fibre range from 30 to 40 cents per square foot for accessible attics. For attic spaces with no attic hatch a hole is generally cut in the roof to allow insulation to be blown in. Roof vents can then be put in place to cover the holes. Detailed estimates must be obtained from a contractor to insulate these more difficult areas.

To avoid possible condensation problems, it is important to insure that the attic space is well sealed from house vapors before additional insulation is added to the attic.

c) Basement Insulation

Although the portion of the basement wall above grade is the greatest contributor to the heat loss of the basement, the basement wall should be insulated to well below grade level. The basement wall may be insulated on the outside by digging the earth away from the foundation to facilitate installation of insulation. If the basement walls are unfinished, insulation can easily be added to the inside. In this case it is best to carry the insulation to the floor level. The material cost for installing R8 insulation including studs, fibreglass insulation, and polyethylene vapor barrier is about 30¢ per square foot. The savings given in Table II are based upon this cost.

d) Window and Door Retrofit

All the houses included in the study were fitted with double pane windows. The cost of adding a third pane cannot be justified at present day fuel prices. his situation will change as fuel prices increase. It is, however, advisable to install weatherstripping around all windows and doors and, if practical, basement windows can be fitted with a layer of polyethylene or even stuffed completely with fibreglass insulation to reduce heat loss.

e) Retrofitting Wall Insulation

Of the 22 homes surveyed, 5 had no insulation in the walls and could have insulation blown into place. Although none of the 5 had vapor barriers, this does not preclude adding insulation. The plaster and paint on the interior walls generally forms a sufficient seal that insulation can be added to the walls without condensation problems.

Blown insulation is best installed by an insulation contractor and only he can give an accurate cost estimate. Estimates were obtained for one house for blowing insulation into the exterior walls. The estimates ranged from $600 - $900 for the same job including patching the holes in the stucco surface.

COST-BENEFIT RELATIONSHIPS

The real costs of retrofitting to the homeowner are a function of the interest rate as well as the availability of homeowner grants and loans for the purpose of adding insulation. These factors were not considered in preparing the figures for Table II. In addition, secondary benefits such as the increased warmth and comfort of the home are not reflected in Table II. The figures simply show the material costs of retrofitting and the associated fuel cost savings based on an oil price of 50¢/U.S. gal., as well as the required number of years to pay back the investment.

The cost-benefit relationship of insulating accessible attics was reasonably easy to determine. For homes with less than R10 existing in the attic the payback period ranges from 3 to 5 years. Ten homes fell into this category. For homes with R10 to R20 existing in the attics the payback period ranged from 5 to 10 years. Those homes that already has in excess of R20 in the attic had payback periods in excess of 10 years. It was not possible to calculate the cost-benefit relationships for attics with difficult access without knowing the depth of insulation that could be installed and without obtaining an actual contractor's estimate for the work.

Estimates for blowing insulation into the wall cavities were only obtained on one house. The payback period was calculated to be 5 years for the low estimate of $600 and 8 years for the high estimate of $900. Blowing insulation into walls that already have some insulation is not usually economical or effective. If you already have insulation in the wall cavity, it is best to wait until you are making major repairs (new siding, new plasterboard, etc.) and add insulation at that time. When you do add insulation, be generous; the extra added insulation is certain to pay for itself with rising fuel costs.

For homes with uninsulated basements, the installation of studs, fibreglass insulation, and vapor barrier to the inside of the basement walls returned the homeowner's investment for materials in 3 - 5 years. The heat loss through the basement floor was not large enough to warrant the construction of a second raised floor and the insulation of this area.

The retrofit of windows and doors is usually associated with the installation of new units when the older windows and doors are worn out. Replacement units based on energy saving benefits alone are difficult to justify at present day fuel costs. All windows and doors should, however, be weather-stripped to reduce infiltration.

Cost-benefits of sealing and weather-stripping homes to minimize infiltration produced the highest return on investment. The figures given in Table II are only approximate, as it is difficult to estimate the extent to which infiltration will be reduced after retrofitting, but one year payback is typical.

All of the homes included in the study were fitted with gas furnaces. The efficiency of these furnaces ranged from 75 to 80 per cent indicating that the furnaces were operating properly. With oil furnaces, however, it is important that the furnace be checked annually to assure that it is operating at peak efficiency. It should be noted that for all types of furnaces an electronic ignitor is superior to a pilot light as a significant amount of energy is required to maintain the pilot light operation in the furnace as well as hot water heater.

CONCLUSIONS

Based on a study of 25 Saskatoon homes the following conclusions were reached:

1. The major portion of heat loss (30-40%) in the average home was due to excessive air infiltration. Proper sealing of the home by the homeowner with the use of weather-stripping and caulking compound was found to be very cost effective (payback 1 - 2 years) in terms of energy savings.

2. The insulating of presently uninsulated basement walls and the addition of insulation to attics with less than R10 (3 inches) were also found to be very cost effective (payback 3 - 5 years).

3. The addition of insulation to attics with between R10 and R20 presently existing, and the blowing of insulation into uninsulated wall cavities were found to be somewhat less cost effective (payback 5 - 10 years).

4. Adding insulation to presently insulated walls is cost effective only when done in conjunction with other major repairs (new siding, replastering, etc.).

5. To obtain an accurate indication of the costs and benefits of retrofitting it is often necessary to do a detailed calculation for each individual house. This is because many homes do not fit the standard house styles provided by the various computer programs that are available for heat loss analysis.

The Saskatchewan Science Council, upon reviewing the results of the study, felt that not enough attention was being paid to the problem of air leakage as a source of heat loss. Although many publications explain how to add insulation to existing homes, few stressed the importance of sealing a house before the insulation is added. Consequently, the Council commissioned the authors to prepare a pamphlet for distribution to Saskatchewan homeowners stressing the importance of sealing and weather-stripping the home. A copy of this pamphlet is included with the paper.

REFERENCES

1. Kronvall, Johnny. Testing Houses for Air Leakage using a Pressure Method. ASHRAE Transactions, Vol. 84, Part 1, 1978.

2. Sowcolow, Robert H. The Twin Rivers Program on Energy Conservation in Housing. Energy and Buildings, Vol. 1, No. 3, 1978.