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John Ingersoll and Joe Huang

December 1981

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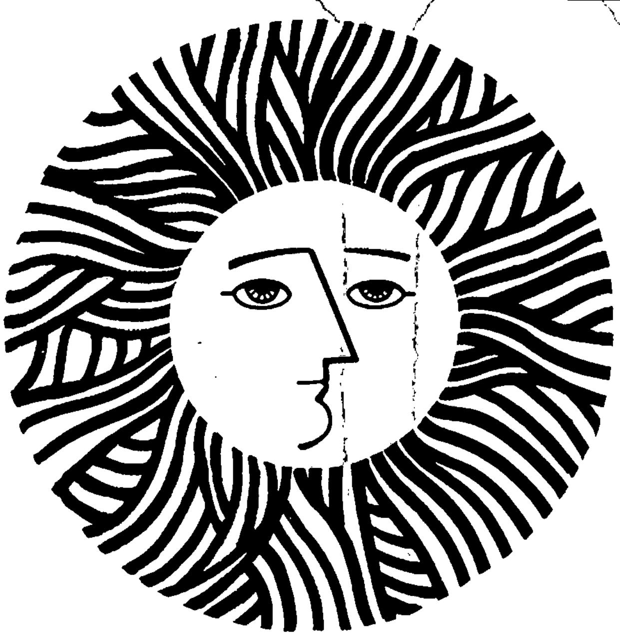

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Submitted to Energy and Buildings.

HEATING ENERGY USE MANAGEMENT IN RESIDENTIAL BUILDINGS BY TEMPERATURE CONTROL

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Berkeley, CA 94720

DECEMBER 1981

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HEATING ENERGY USE MANAGEMENT IN RESIDENTIAL BUILDINGS BY TEMPERATURE CONTROL

ABSTRACT

This paper presents the results of analytical investigations to determine the potential heating energy savings that can be achieved in residential buildings by controlling the house temperature through either night setback or night setback plus day zone setback. A typical U.S. single family house is analyzed for different levels of thermal integrity of the building envelope (i.e., levels of insulation, window glazing, and infiltration). Reduced infiltration, insulated interior walls, and various window orientations are also considered. Results are given for all four major climate zones in the U.S. - cool, temperate, hot-humid, and hot-arid. The analysis shows that both types of setbacks are most effective in loose houses, with the greatest absolute savings for the cool climate, and the greatest percent savings for the hot climates. However, the benefits from thermostat setbacks are smaller for tighter houses, and may actually be counter-productive due to corollary effects such as increased peak loads and degradation of system efficiency.

HEATING ENERGY USE MANAGEMENT IN RESIDENTIAL BUILDINGS BY TEMPERATURE CONTROL

INTRODUCTION

In the last few years, relatively inexpensive devices for automatic temperature control in residential buildings have been introduced on the market that allow for one or more temperature setback periods during the course of a day. Furthermore, new types of furnaces with thermostatically controlled registers for individual rooms in the house are about to enter the market.[1] In addition, zonally controlled buildings using electric baseboard heaters are already in use in various parts of the country. The objective of all these measures is to reduce or utilize more efficiently the energy used for space heating without adversely affecting human comfort conditions. However, up until now there has been no quantitative assessment of the effectiveness of these thermostat measures for the various climate regions of the U.S., although some work in that respect has been done in Europe.[2]

The objective of this study is to quantify the energy savings resulting from different temperature control strategies so that a comparison of their significance can be made. A typical ranch-style house of average size and construction is simulated on DOE-2.1A, a state-of-the-state computer model that can calculate the hour-by-hour performance of a building in any given climate. A large number of cases are studied to determine the relationships between temperature control strategies, the thermal integrity of the building (i.e., insulation, glazing, and infiltration levels), and the climate in which the building is located.

ASSUMPTIONS

The prototype house model used in our analysis (see Figure 1) represents a typical present-day single-family residence in the U.S. It is a one story detached frame construction ranch-style house with 1540 square feet of floor area and 154 square feet of glass area. Construction details of the house are taken from standard building practices, while important building characteristics such as infiltration rates are based on the most reliable statistical surveys of current houses.[3][4] The heating system is assumed to be either a furnace with zonal control options or zonally controlled electric baseboard heaters. When zonal controls are used, the house is assumed to be divided into two distinct zones of roughly equal size. Zone One consists of the living room, dining room, and kitchen; Zone Two consists of the three bedrooms, two bathrooms, and interior hallway. A wooden door with a glass window and good degree of air tightness connects Zone One to Zone Two. (For description of building details and simulation methodology, see Appendix A).

Whenever there is a temperature differential between the two zones, there will be additional heat transfer through air infiltration around the door which would tend to reduce the effectiveness of any zone setback measure. However, hourly computer simulations using steady state estimates of heat transfer due to infiltration around the door show that, in our case, the effects of this additional heat transfer are minimal.[5]

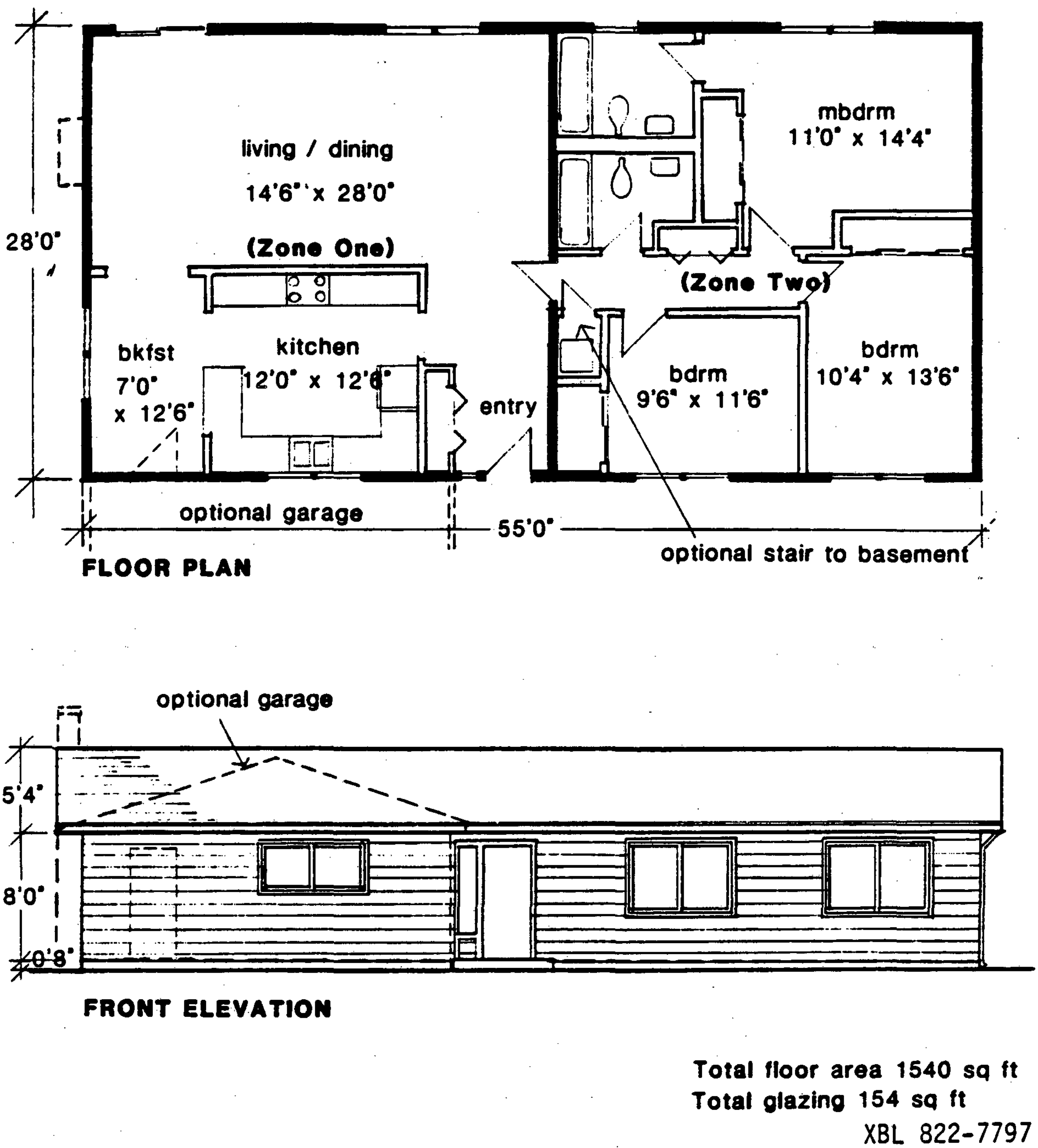


Figure 1. House plan and elevation.

Four climate zones have been considered as representative of the major climatic regions of the U.S.[6] These climate zones - cool, temperate, hot-humid, and hot-arid - are represented by weather data in the form of "test reference years" for Minneapolis, New York, Houston, and Phoenix.

For each climate zone, computer simulations were done for three levels of building envelope thermal integrity, i.e., insulation, glazing, and infiltration levels. These are listed in Table 1. The "tight house" represents a high level of thermal integrity to which additional improvements, with the exception of infiltration, would result in only marginal additional energy savings of no more than a few percent.[7] The "very tight house" has the same thermal characteristics as the "tight house" except that the infiltration rate has been reduced by 40% from 0.7 to 0.4 air changes per hour averaged over the winter months. Lastly, the "loose house" corresponds roughly to the average insulation, glazing, and infiltration levels of residential buildings built in the previous decade (1970-79).[3][8]

Thermostat Control Options

Three temperature control options have been considered in our analysis. These options are: 1) base option with the thermostat fixed at 70°F all day; 2) night setback option with the thermostat lowered from 70°F to 60°F between the hours of midnight and 6 a.m.; and 3) night setback plus zone setback option, where, in addition to the night setback, thermostat settings are also lowered to 60°F during the day for unoccupied spaces.

TABLE 1. BUILDING ENVELOPE CONDITIONS FOR THE FOUR U.S. CLIMATE ZONES

	Cool Climate		Temperate Climate		Hot-Humid Climate		Hot-Arid Climate	
	Tight & Very Tight Houses	Loose House	Tight & Very Tight Houses	Loose House	Tight & Very Tight Houses	Loose House	Tight & Very Tight Houses	Loose House
Ceiling insulation	R-49	R-19	R-38	R-19	R-30	R-19	R-30	R-19
Wall insulation	R-27	R-11	R-19	R-11	R-19	R-11	R-19	R-11
Basement/slab insulation	R-10	R-0	R-10	R-0	R-5	R-0	R-5	R-0
Window glazing	3-pane	2-pane	3-pane	2-pane	2-pane	1-pane	2-pane	1-pane
Infiltration levels	0.7, 0.4	1.0	0.7, 0.4	1.0	0.7, 0.4	1.0	0.7, 0.4	1.0

The complete schedule for the third option is shown in Table 2.

TABLE 2. ZONE SETBACK SCHEDULE

Time of Day	Zone 1 (Living Rm., Dining Rm., and Kitchen)	Zone 2 (Bedrooms and Bathrooms)
12 A.M. to 6 A.M.	60^oF	60^oF
6 A.M. to 9 A.M.	70^oF	70^oF
9 A.M. to 5 P.M.	70^oF	60^oF
5 P.M. to 6 P.M.	70^oF	70^oF
6 P.M. to 11 P.M.	70^oF	60^oF
11 P.M. to 12 A.M.	60^oF	70^oF

This schedule is based on the assumption that the bedroom spaces are not occupied from 9 a.m. to 5 p.m. and from 6 p.m. to 11 p.m., and that the living room, dining room, and kitchen are not occupied from 11 p.m. to 6 a.m. Depending on the structure, work style and living habits of a particular family, the zone control schedule will have to be modified so as to not impinge on comfort standards. Consequently, greater or less energy savings could be realized per household, even though the average savings for the entire country will not differ substantially from the results for the typical schedule used here.

Additional Conservation Measures

In addition to the three standard options, computer simulations were also made to test the effectiveness of more extreme conservation measures such as adding insulation to the interior wall separating the two zones, or lowering the thermostat setback to below 60°F.

In the base case, the two zones were assumed to be separated by an interior wall of typical gypsum board and wood stud construction, with an interconnecting door (see Figure 1). For the zonal control option, we tested the effects on energy savings when R-11 and R-19 insulation were added to the partition wall between the zones. For these cases, the resistance of the interconnecting door was also increased from R-1.6 to R-2.0.

Simulation studies were also done with the zonal control setback reduced from 60°F to 50°F, and even to 20°F, which would be the equivalent of turning off the thermostat in the unoccupied spaces during the day.

In addition, studies were made of the effects of different south window distributions on a zonally controlled house. The purpose of these simulations was to determine whether additional savings could be realized by linking zonal control schedules with that of solar radiation. Computer runs were made with the same amounts of total and south window areas, but redistributed so that the zone occupied during the day (Zone 1, i.e., living room, dining room, and kitchen) received nearly all the solar radiation.

Lastly, simulation studies were made for the following cases:

1. A day setback to 60°F from 9 a.m. to 5 p.m. for the entire house, in addition to the standard 60°F night setback from 12 a.m. to 6 a.m. This is representative of a one-zone building with both day and night setbacks.

2. Thermostat settings raised to 72°F (from 70°F), with and without night setback.

Both of these options are of limited general applicability - the former reduces comfort standards (unless the house is vacant during working hours) and the latter is unnecessary from a comfort standpoint. For the sake of comparison, these simulations were performed only on the tight house for all four climate zones.

RESULTS

The results of our analysis for all four climate zones with three levels of building envelope thermal integrity, using different thermostat options and interior wall insulations, are summarized in Tables 3 and 4. The first column in Table 3 refers to an electric baseboard system and gives energy consumption in kilowatt-hours (kWh). The other columns assume a gas furnace system with a 70% efficiency and give energy consumption in million-BTU's (MBtu).* Results for sensitivity studies for 50°F and 20°F zone setbacks, R-19 interior wall insulation,

---

Gas energy consumption can be converted to electric energy consumption by the equation: (energy consumption, kWh) = (energy consumption, MBtu) x (net seasonal furnace efficiency) x (1000/3.413). In this equation,the units of electricity consumption are at the building boundary.

and various window orientations are given in Tables 5 and 6. Results for the one-zone building day setback and raised thermostat setting are shown in Table 7. The hourly loads on the coldest day of the year for three cool climate cases are depicted in Figures 2, 3, and 4. These show the peak heating loads that must be met by the furnace or electric baseboard systems. The hourly loads on a typical winter day for a cool climate tight house is shown in Figure 5. This curve is representative of typical winter loads in both the cool and temperate climate zones. For comparison, the hourly loads on the coldest day of the year for a hot-arid climate case is depicted in Figure 6.

TABLE 3. NET ANNUAL HEATING ENERGY CONSUMPTION FOR TWO ZONE HOUSE

Climate Zone and Bldg Envelope Condition	Base Case*		Night Setback		Night Setback plus Zonal Control		Night Setback, Zonal Control, and R-11 Wall	
	Energy Consumption (kWh)	Energy Consumption (MBtu)	Energy Consumption (MBtu)	Change over Base Case (%)	Energy Consumption (MBtu)	Change over Base Case (%)	Energy Consumption (MBtu)	Change over Base Case (%)
COOL (Minneapolis)								
Very Tight House	12,291	59.93	57.70	3.7	53.94	10.0	53.79	10.2
Tight House	16,500	80.45	77.05	4.2	72.00	10.5	71.86	10.7
Loose House	35,779	174.45	164.78	5.5	153.56	11.9	153.38	12.0
TEMPERATE (New York)								
Very Tight House	6,506	31.72	29.76	6.2	27.42	13.6	27.25	14.1
Tight House	9,067	44.21	41.54	6.0	37.64	14.8	37.43	15.3
Loose House	19,324	94.22	86.45	8.2	77.55	17.6	77.29	17.9
HOT-HUMID (Houston)								
Very Tight House	2,037	9.93	9.06	8.8	8.08	18.7	8.01	19.5
Tight House	3,117	15.20	13.68	10.0	12.09	20.5	12.00	21.1
Loose House	8,518	41.53	36.06	13.2	30.94	25.5	30.74	26.0
HOT-ARID (Phoenix)								
Very Tight House	1,411	6.88	5.97	13.2	5.57	19.0	5.54	19.4
Tight House	2,398	11.69	10.02	14.3	9.20	21.3	9.14	21.8
Loose House	7,203	35.12	29.00	17.4	25.68	26.9	25.49	27.4

* Base case is with the thermostat set at 70°F all day

TABLE 4. NET AND PERCENT CHANGES FOR SETBACK OPTIONS OVER THE BASE CASE*

Climate Zone and Building Envelope Condition	Night Setback		Night Setback plus Zonal Control		Night Setback, Zonal Control plus R-11 Interior Wall	
	Net Change Over Base Case (No Setback) (MBtu)	Change Over Base Case Option (%)	Net Change Over Previous Option (MBtu)	Change Over Previous Option (%)	Net Change Over Previous Option (MBtu)	Change Over Previous Option (%)
COOL (Minneapolis)						
Very Tight House	2.23	3.7%	3.76	6.3%	0.15	0.2%
Tight House	3.40	4.2%	5.05	6.3%	0.14	0.2%
Loose House	9.67	5.5%	11.22	6.4%	0.18	0.1%
TEMPERATE (New York)						
Very Tight House	1.96	6.2%	2.34	7.4%	0.17	0.5%
Tight House	2.67	6.0%	3.90	8.8%	0.21	0.5%
Loose House	7.77	8.2%	8.90	9.4%	0.26	0.3%
HOT-HUMID (Houston)						
Very Tight House	0.87	8.8%	0.98	9.9%	0.07	0.7%
Tight House	1.52	10.0%	1.59	10.5%	0.09	0.6%
Loose House	5.47	13.2%	5.12	12.3%	0.20	0.5%
HOT-ARID (Phoenix)						
Very Tight House	0.91	13.2%	0.40	5.8%	0.03	0.4%
Tight House	1.67	14.3%	0.82	7.0%	0.06	0.5%
Loose House	6.11	17.4%	3.32	9.5%	0.19	0.5%

*Base case is with the thermostat set at 70^{o}F all day.

TABLE 5. EFFECTS OF ADDITIONAL CONSERVATION MEASURES ON ANNUAL HEATING LOADS OF A TWO-ZONE VERY TIGHT HOUSE IN MINNEAPOLIS (COOL CLIMATE) (Yearly Totals in MBtu)

Thermostat Option	R-0 Interior Wall		R-11 Interior Wall		R-19 Interior Wall	
	Energy Consumption	Net Change over Previous option	Energy Consumption	Net Change over R-0 Int. Wall	Energy Consumption	Net Change Over R-11 Int. Wall
No Setback	59.93					
60° Night Setback	57.70	-2.23				
60° Night and Zone Setbacks	53.94	-3.76	53.79	-0.15		
50° Night, and Zone Setbacks	53.75	-0.19	53.55	-0.20	53.52	-0.03
60° Night, 20° Zone Setbacks	53.76	+0.01	53.57	-0.19	53.54	-0.03

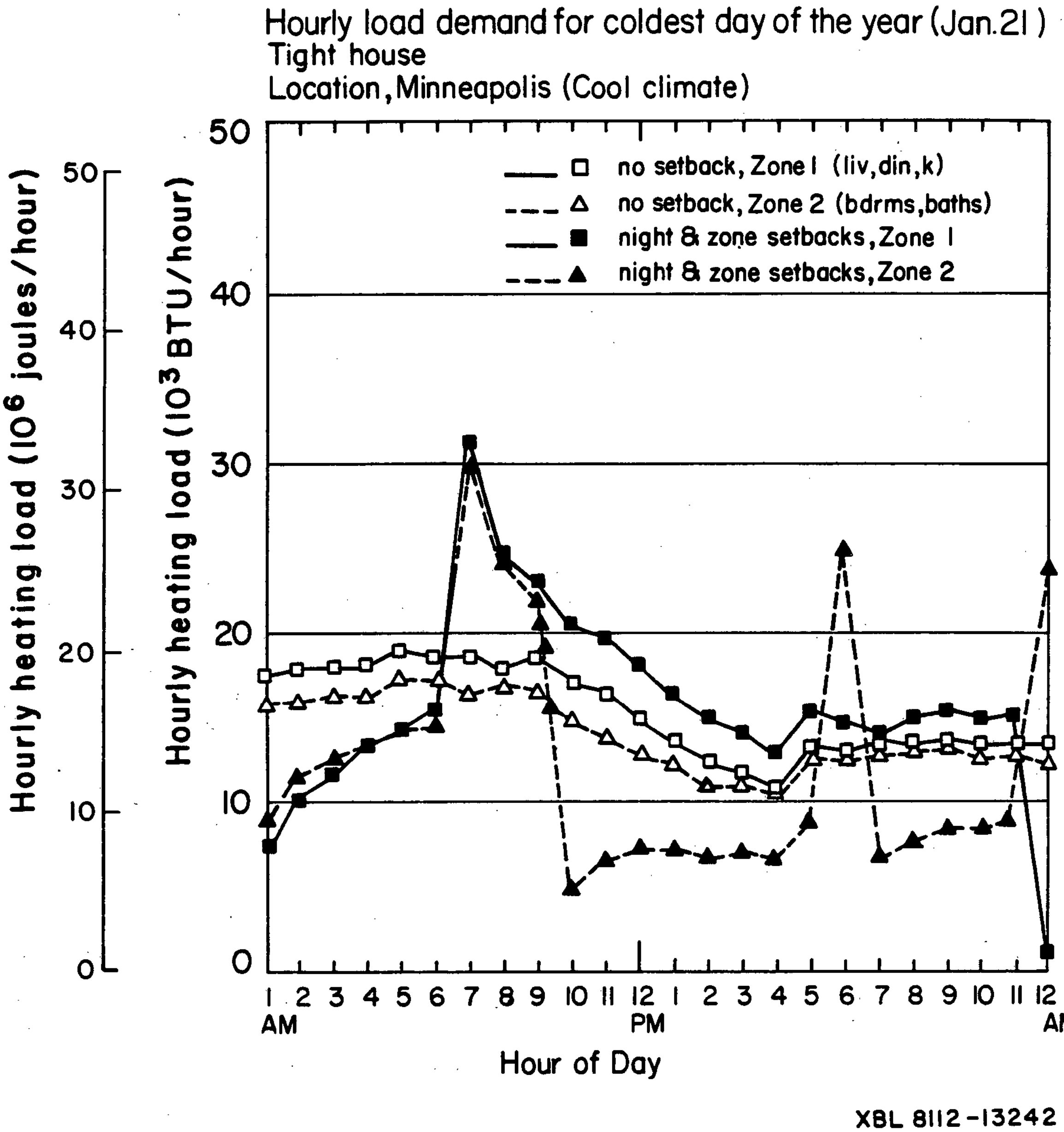
TABLE 6. EFFECTS OF VARIOUS WINDOW ORIENTATIONS ON ANNUAL HEATING LOAD OF A TIGHT HOUSE WITH 60°F NIGHT AND ZONE SETBACKS

	2.5% South-Glass		5% South-Glass	
Climate Zone	1.25% in Zone 1 1.25% in Zone 2 (Base Case w/ night setback)	2.5% in Zone 1 0% in Zone 2	2.5% in Zone 1 2.5% in Zone 2	5% in Zone 1 0% in Zone 2
	Energy Consumption in MBtu	Energy Consumption in MBtu	Energy Consumption in MBtu	Energy Consumption in MBtu
COOL (Minneapolis)	72.00	71.62	69.21	68.71
TEMPERATE (New York)	37.64	37.03	35.26	34.48

TABLE 7. COMPARISON OF ENERGY CONSUMPTION FOR ONE-ZONE SETBACK OPTIONS IN A TIGHT HOUSE TO THE BASE CASE

(Energy Consumption in MBtu)

Climate Zone	70°F All Day	70°F Setting 60°F Night Setback at night	70°F setting 60°F from 9 to 5 and	72°F All Day	72° Setting, 60°F Night Setback
	Base Case	% change from Base Case		% change from equiv. 70°F Setting	
COOL	80.45	77.05 (-4.2%)	71.80 (-10.7%)	86.27 (+7.2%)	82.41 (+7.0%)
TEMPERATE	44.21	41.54 (-6.0%)	37.76 (-14.6%)	49.87 (+12.8%)	46.77 (+12.6%)
HOT-HUMID	15.20	13.68 (-10.0%)	12.09 (-20.5%)	18.51 (+21.8%)	16.63 (+21.6%)
HOT-ARID	11.69	10.02 (-14.3%)	9.12 (-22.0%)	15.31 (+31.0%)	13.09 (+30.6%)



Hourly load demand for coldest day of the year (Jan.21)
Tight house
Location, Minneapolis (Cool climate)
no setback, Zone 1 (liv, din, k)
no setback, Zone 2 (bdrms, baths)
night & zone setbacks, Zone 1
night & zone setbacks, Zone 2
Hourly heating load (10^6 joules/hour)
Hourly heating load (10^3 BTU/hour)
0
10
20
30
40
50
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
AM
PM
AM
Hour of Day
XBL 8112-13242

FIGURE 2

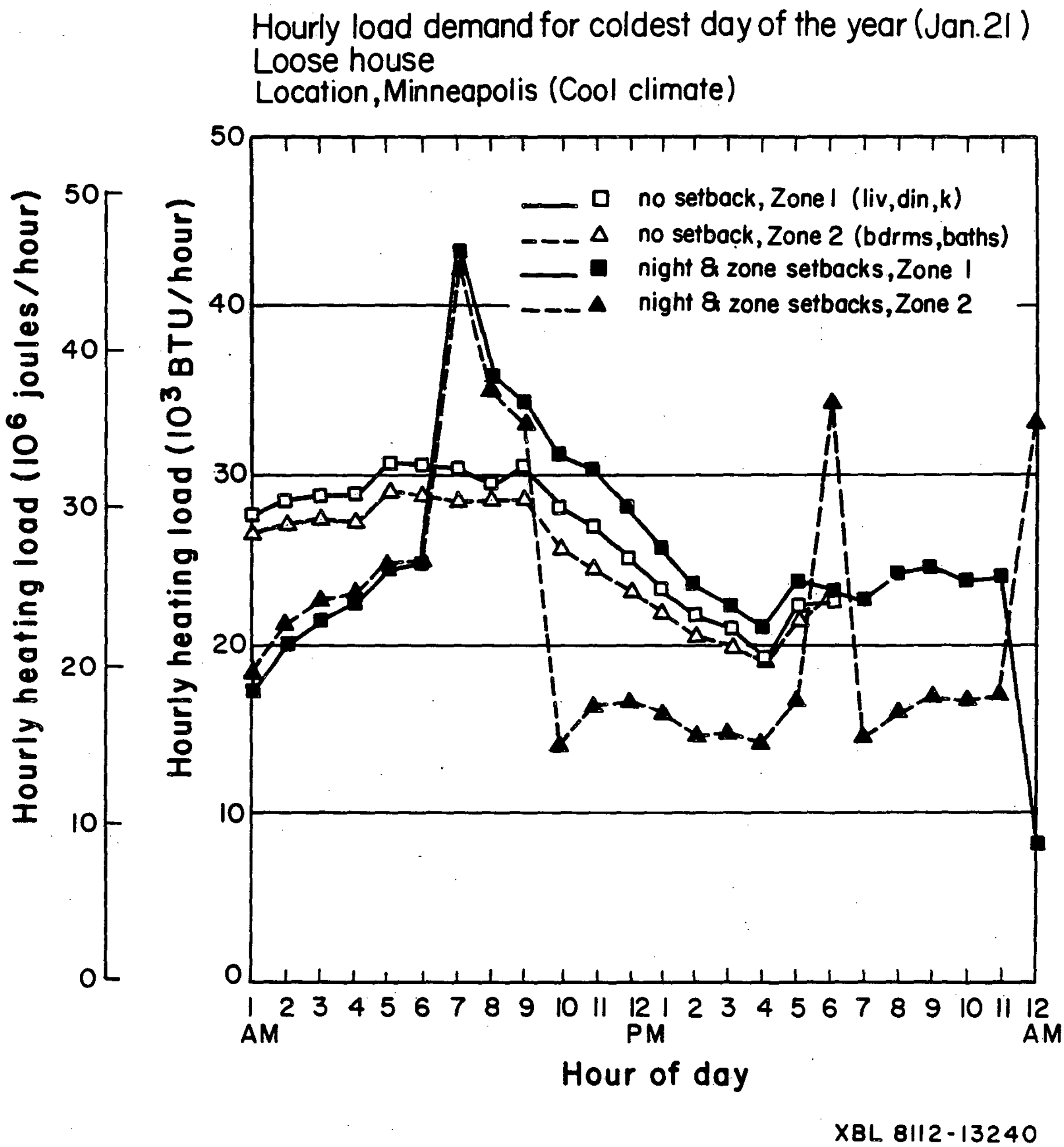

Hourly load demand for coldest day of the year (Jan.21)
Loose house
Location, Minneapolis (Cool climate)
no setback, Zone 1 (liv,din,k)
no setback, Zone 2 (bdrms,baths)
night & zone setbacks, Zone 1
night & zone setbacks, Zone 2
Hourly heating load (10⁶ joules/hour)
Hourly heating load (10³ BTU/hour)
0
10
20
30
40
50
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
AM
PM
AM
Hour of day
XBL 8112-13240

FIGURE 3

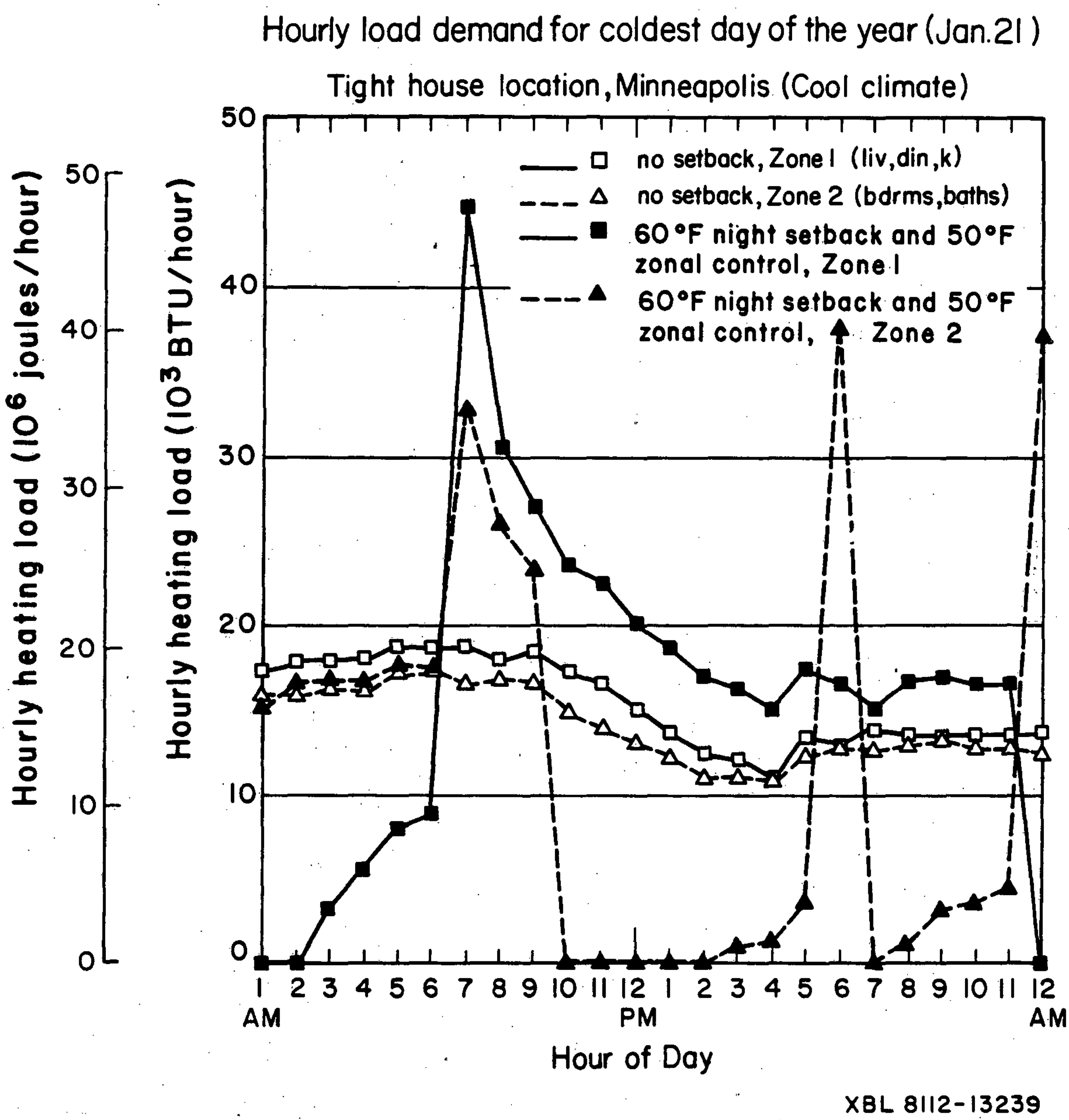
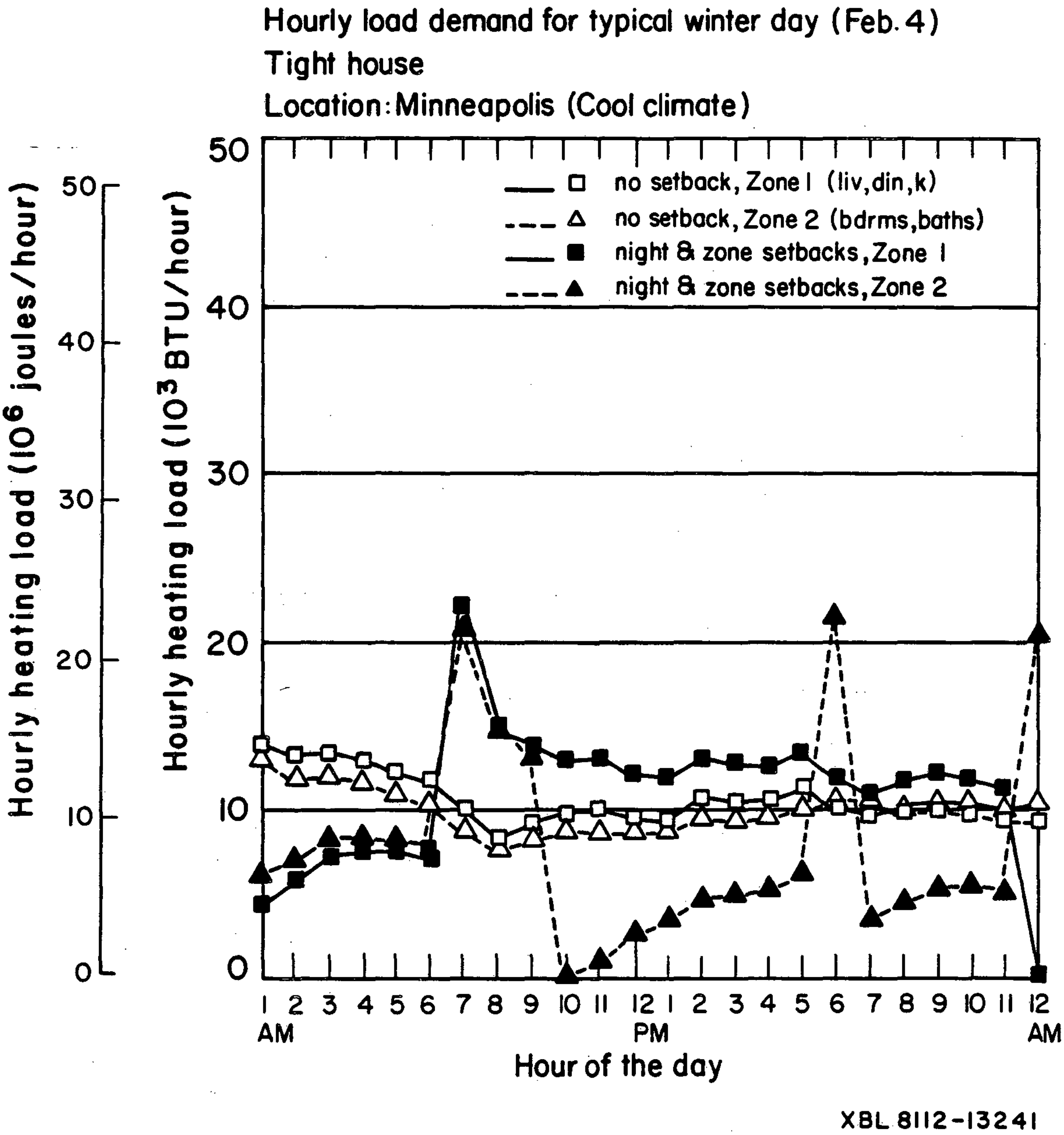
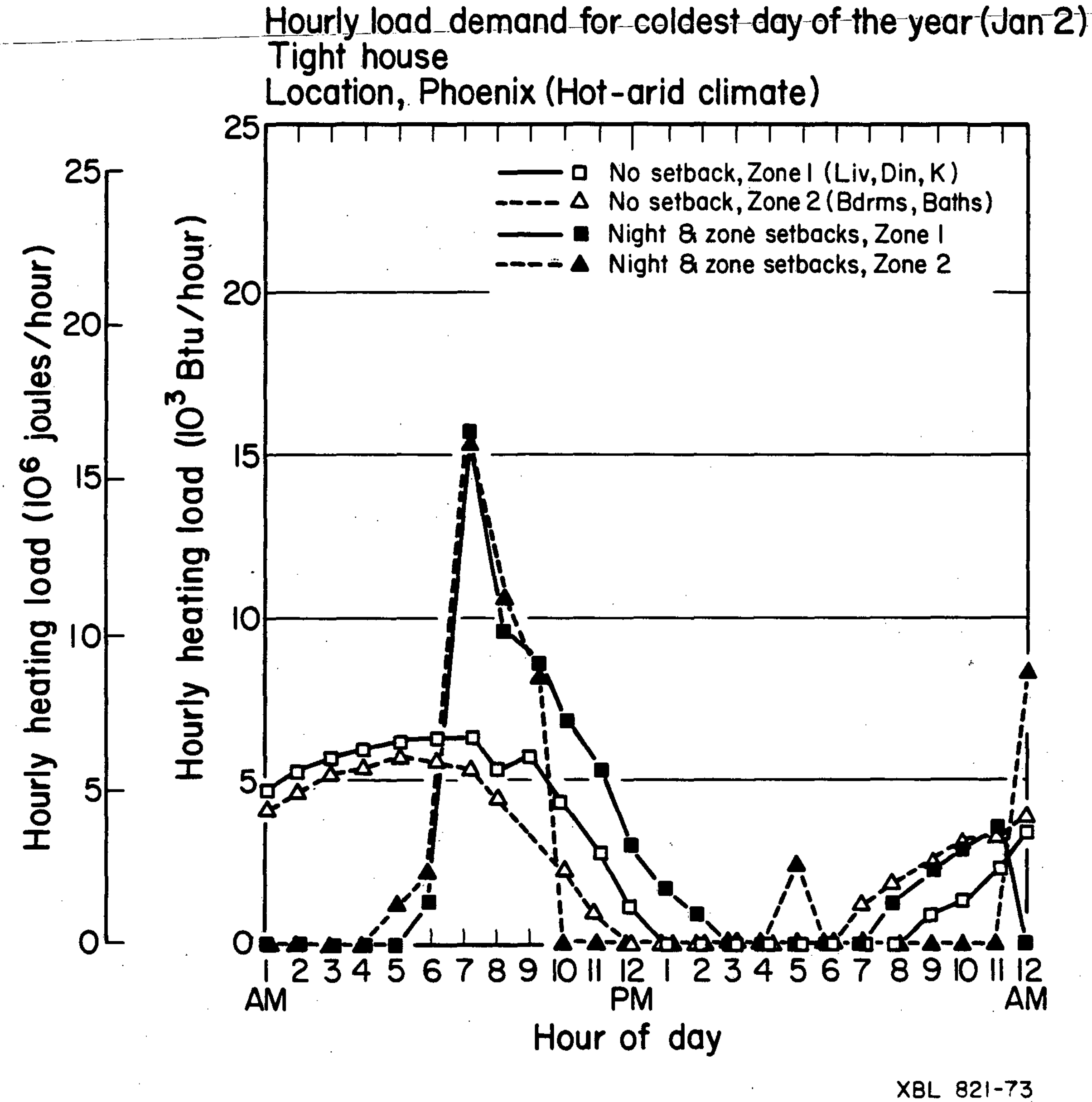

Hourly load demand for coldest day of the year (Jan.21)
Tight house location, Minneapolis (Cool climate)
no setback, Zone I (liv,din,k)
no setback, Zone 2 (bdrms,baths)
60°F night setback and 50°F zonal control, Zone I
60°F night setback and 50°F zonal control, Zone 2
Hourly heating load (10^6 joules/hour)
Hourly heating load (10^3 BTU/hour)
Hour of Day
AM
PM
AM
XBL 8112-13239

FIGURE 4



Hourly load demand for typical winter day (Feb. 4)
Tight house
Location: Minneapolis (Cool climate)
no setback, Zone 1 (liv,din,k)
no setback, Zone 2 (bdrms,baths)
night & zone setbacks, Zone 1
night & zone setbacks, Zone 2
Hourly heating load (10^6 joules/hour)
Hourly heating load (10^3 BTU/hour)
0
10
20
30
40
50
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
AM
PM
AM
Hour of the day
XBL 8112-13241

FIGURE 5



Hourly load demand for coldest day of the year (Jan 2)
Tight house
Location, Phoenix (Hot-arid climate)
No setback, Zone 1 (Liv, Din, K)
No setback, Zone 2 (Bdrms, Baths)
Night & zone setbacks, Zone 1
Night & zone setbacks, Zone 2
Hourly heating load (10^6 joules/hour)
Hourly heating load (10^3 Btu/hour)
0
5
10
15
20
25
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
AM
PM
AM
Hour of day
XBL 821-73

FIGURE 6

CONCLUSIONS

The results show that the relative effectiveness of night and zone setback measures varies with both climatic conditions and the thermal integrity of the house. Both measures are more effective for the "loose house," both in percentile and absolute terms.

For the cool and temperate climates, night setback results in energy savings on the order of 4 to 5%, while day zone setback will add another 6 to 7%. For the hot-humid climate, night and zone setbacks each result in 8 to 13% savings while in the hot-arid climate night setback results in 13-17% savings, but day zone setback adds only another 6 to 10% savings.

In absolute energy saved, however, the cool climate shows the greatest gain either through night or zone setbacks. This is to be expected as both the night and day temperatures are the lowest of the four zones. The hot-humid climate shows the least absolute energy savings, since this zone has the smallest day-night temperature variations. On the other hand, the hot-arid climate shows the least energy savings by zone setback, because daytime temperatures in this zone are higher than those in any other.

Notice that if the net furnace efficiency in a gas heated house were to be further increased (see Appendix A) the percentile savings for any level of thermal integrity and in any climate zone would remain the same whereas the absolute energy saved in each instance will be reduced proportionally.

A few other interesting conclusions can be drawn from our study. First, adding interior insulation to the partition wall between the zones produces negligible energy savings. The inter-zone heat transfer through the partition wall is insignificant compared to the total heat transfer to the outside through the building envelope. Second, reducing the temperature of one zone down to 50°F or lower also does not produce any significant savings. As shown in Table 5, the yearly difference in energy consumption in the cool climate between a 50°F and a 60°F zone setback is only 0.3%. Figures 2 and 4 showing the hourly consumptions on the coldest day of the year for these two options illustrate why there is basically no benefit from the lowered zone setback. The additional savings from the lower thermostat setting are counteracted by the much larger energies required to return the zone to 70°F once the setback is removed. For the day shown on the two graphs, the total heating load is actually higher for the 50°F zone setback option. In addition, further penalties will be incurred since the building must be equipped with a larger system in order to meet the greatly increased peak hourly loads (more than 100% in the cool and temperate climates and almost 200% in the hot climates for a "tight house" with a pick-up time of one hour). This will result not only in higher capital costs, but also in probable degradation of performance due to the oversizing if a typical furnace is used or potential increase in peak load demand if a baseboard system is used instead.[9,10]

The studies of different window orientations show that efforts to link solar radiation with occupant patterns, i.e., putting all the south-facing windows in the zone occupied during the day (Zone 1), will produce only a small improvement in energy consumption, 0.6% in the cool climate zone, and 1.6% in the temperate climate zone. This strategy is more effective for houses with more south-facing glass, but will be still only one-third as effective as moving window distribution from the north to the south, as shown in Table 6.

It has been known for some time that the energy savings resulting from the intermittent heating of a building, such as with night setback or zonal control, are less for more insulated houses.[11]. As the thermal integrity of a building increases, the importance of either setbacks or zonal control diminishes, and may in fact produce negative results in terms of energy consumption, particularly if the performance of an oversized furnace is degraded. Measurements of houses in the New York - New Jersey area with and without night setbacks have shown no statistically significant differences in energy consumption.[12] Since our analysis shows a net reduction of 6 to 8% in energy consumption for night setback in temperate climates, it is not suprising that such savings have not been reliably validated by measured data. In fact, the savings calculated here for a tight or very tight building may be negated by the roughly equal losses that have been calculated elsewhere for furnace oversizing.[9]

It appears that even though temperature controls in residential buildings may reduce energy consumption, the net energy saved by any of these controls diminishes and may become nil as both the thermal integrity of the building, including infiltration, and the efficiency of heating systems improve.

APPENDIX A

DESCRIPTION OF PROTOTYPE HOUSE METHODOLOGY

Dimensions: 28 ft. by 55 ft. by 8 ft.

Floor area: 1540 square feet Wall area: 1328 square feet

Foundation type: Basement in cold and temperate climates, slab on grade in hot-humid and hot-arid climates

Window area: 154 square feet (10% of floor area) equally distributed on all four sides. This equal distribution of glazing is not typical of most houses, but is statistically true for a large sample of houses, since street orientation is random.

Window shading: The shading coefficient used for all glass surfaces is 0.64, which corresponds to an average value for the shading effects of drapes and blinds.[13]

Internal Loads: The internal loads are entered into the program for each hour of the day and are distributed according to a typical appliance usage and occupancy schedule. The simulation model includes heat gains from the following appliances: range, refrigerator, freezer, clothes dryer, water heater, and television; and from people for an average occupancy of 2.8 persons per household. The total daily internal load consists of 56,440 Btu sensible load and 28,050 Btu latent load.[14]

Systems : The heating system of the house is assumed to be either a gas furnace or an electric baseboard heater. In the former case the net seasonal efficiency of the furnace, taking into account duct losses, is 0.70 for the tight and very tight houses, and 0.60 for the loose house. The seasonal efficiency of baseboard heaters is assumed to be 1.0. The results given in MBtu refer to the furnace system while those in kWh refer to the baseboard system. If on the other hand, a pulse combustion gas furnace with an efficiency of over 95% were to be used, a net seasonal efficiency as high as 85% to 93% may result including duct losses.[15,12] Consequently the absolute energy saved for either the tight or very tight house in any climate zone would decrease by 18% to 25% (1- (0.7/0.85) = 0.18; 1- (0.7/0.93) = 0.25) from respective figures given in Tables 3 and 4. On the positive side, however, more efficient furnaces are equipped with tight stack dampers and intermittent ignition devices so that the degradation of performance due to oversizing becomes much less significant.

Infiltration : The average infiltration for the tight house for the five winter months (November through March) is 0.7 ach (air changes per hour), of which 0.6 ach is due to weather conditions and 0.1 ach to user operations. This average infiltration rate is representative of current construction practices and has been used in our simulations for all four climatic zones. It has been found in the U.S. that houses are being built tighter in the colder climates to offset the harsher weather conditions, with the net effect that the average winter infiltration rate in any given climate remains roughly constant.[4] For the very tight house, the average winter infiltration rate has been reduced to 0.4 ach, of which 0.3 ach is due to the building envelope and 0.1 ach to building operation. The 0.3 ach can be considered as either reflecting the true building envelope integrity or a building with a better envelope quality but equipped with a mechanical ventilation system such as a heat exchanger. In the latter case, it is assumed that the building envelope results in 0.2 ach, while the ventilation system adds another 0.4 ach at a heat recovery efficiency of 75%. Under these envelope conditions, there is 0.7 ach actual infiltration, but only 0.3 ach in terms of energy consumption [(0.2) + (0.4) (1-0.75)].

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REFERENCES

1. Becker, F.E. and Searight, E.F., "Development of a Gas-fired, Heat-pipe, Warm-air Heating System." 1981 International Gas Conference, Los Angeles, September 1981.

2. Larsen, B., "Energy Savings by Using Automatic Control in Small Residential Buildings," Second International CIB Symposium on Energy Conservation in the Built Environment, Session 3, p. 291-227.

3. Single-Family Construction Practices - 1979; National Association of Home Builders (NAHB) Research Foundation, Inc, Rockville, Maryland, 1980.

4. Grimsrud, D.T., Sonderegger, R.C., and Sherman, M.H., "Infiltration Measurements in Audit and Retrofit Program," Lawrence Berkeley Laboratory Report LBL-12221, Berkeley, 1980.

5. Kimura, K.I. Scientific Basis of Air Conditioning, Chapter 6, Applied Science Publishers Ltd., London, 1977.

6. Olgyay, V. Design with Climate, Bioclimatic Approach to Architectural Regionalism, Princeton University Press, Princeton, 1973.

7. Ingersoll, J.G., unpublished computer simulation results, Lawrence Berkeley Laboratory, Berkeley, 1980.

8. Single-Family Construction Practices - 1976; NAHB Research Foundation, Inc., Rockville, Maryland, 1977.

9. Nelson, L.W., MacArthur, J.W., "Energy Savings Through Thermostat Setback", ASHRAE Transactions, Vol. 84, Part 2, pp. 319-334, New York, 1978.

10. Koenig, K., "Gas Furnace Size Requirements for Residential Heating Using Thermostat Night Setback," ASHRAE Transactions, Vol. 84, Part 2, pp. 335-351, New York, 1978.

11. Billington, N.S. Building Physics: Heat, p. 79, Pergamon Press, Oxford 1967.

12. Griffith, J.E., Public Services Electric and Gas (PSE&G) Research Corporation, Maplewood, N.J., private communication, September 1981.

13. ASHRAE Handbook, 1977 Fundamentals, Chapter 26, New York, 1977.

14. Ingersoll, J.G., Levine, M.D., Mass, J.J., "Methodology and Assumptions for the Evaluation of Energy Performance Standards for New Residential Buildings." Lawrence Berkeley Laboratory Report LBL - 13767, Berkeley, 1981.

15. "Analysis of Residential Duct Losses", Gamze-Korobhin-Caloger, Inc, prepared for the Gas Research Institute, PB-80-22800, Washington, D.C., 1980.

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