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LOW RISE MULTI-FAMILY HOUSING: PROTOTYPE DEVELOPMENT AND PRELIMINARY ENERGY ANALYSIS

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ABSTRACT

We have completed the first phase of a project to study energy use for space conditioning in new multi-family housing. We have gathered existing data on typical construction characteristics and energy use in such buildings and used them to develop an initial prototypical building. Additional prototypes, based on responses to a questionnaire, are being developed. By averaging results from individual units in these prototypical buildings, we will be able to use these average units as building blocks to analyze most multi-family structures.

Computer simulations have been performed to determine the reduction in space conditioning energy use resulting from added thermal insulation, decreased infiltration, nighttime thermostat setback, and optimal choice of building orientation and glazing. A microcomputer program is being developed to determine the cost-effectiveness of these measures in different locations.

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INTRODUCTION

The Building Energy Analysis Group at Lawrence Berkeley Laboratory has been funded by the Department of Energy to study energy use in new multi-family buildings. The major objectives of this research are to gain a better understanding of the major determinants of energy use in multi-family residences and the cost-effectiveness of conservation measures in various climates and to transfer this information to builders of such housing. The research includes collection of data on energy use and building characteristics of multi-family buildings, development of prototypical buildings, and energy and economic analyses.

The first step in our research was to collect data on multi-family housing. We are interested in both energy use and construction characeristics data. The availability of such data is limited (see below). Therefore, we met with builders of multi-family residences and developed a questionnaire to gather additional information. We are analyzing the responses we have received to date. When this analysis is complete, we will develop new prototypical buildings. We developed the prototypical building used for the analyses described in this report with information obtained from discussions with builders and from data on new single-family housing construction. A preliminary analysis of early questionnaire returns indicates that our initial building characteristics assumptions are reasonable.

The parametric analyses described below were carried out with the computer program DOE-2[1]. We performed many simulations to determine the heating and cooling loads for each apartment within our prototypical building in different climates. We tabulated the reductions in space conditioning loads achieved by employing various conservation measures (see Appendix A for an example). We expressed the results for average end- and mid-units so that these average units could serve as building blocks for most other multi-family designs. That is, one can extend the heating and cooling load reductions calculated for average end and mid-units in the six-unit, two-story prototypical building to other larger two-story buildings. For example, if we were interested in calculating the total reduction in heating load for some conservation measure in an eighteen-unit, two-story apartment building, then we would multiply the number of end-units times the delta heating load for an average end-unit and add the result to the product of the number of mid-units and the delta heating load for the average mid-unit. In addition to these typical measures (e.g., insulation and double glazing), we also studied the use of reflective glazing, movable insulation, thermostat setback, and light roof color. In the future, we plan to study the cost-effectiveness of these conservation measures in different locations across the U.S. This report gives our progress to date. It is the first in a series of reports in this study.

Housing Characterisics

We define multi-family housing to include all buildings with two or more living units. For the existing U.S. housing stock, buildings with two to four units contain 11.2% of the total residential units and buildings with more than four units contain 14.4% of the total units (see Table 1)[2].

Table 1.
Existing Housing Stock*
Total Residential Units 83.1 Million Households

	# units (millions)	% of Total Units	Average Floor Space (ft^2)
Single family detached	54.6	67.7	1742
Single family attached	3.0	3.6	1596
2 - 4 units	9.3	11.2	1054
> 4 units	12.0	14.4	816
Mobile homes	4.2	5.1	872

*1981 Residential Energy Consumption Survey
DOE/EIA-0314 (81), August 1983.

These multi-family buildings (> 1 unit) consume more than 20% (see Table 2) of the energy consumed by residential buildings (9.5 Quads for all residential buildings)[3]. Presently, about one third of all new residential units built each year are in multi-family buildings[4].

Almost half a million multi-family units are built each year. Appproximately two thirds of these units are occupied by renters and the majority of those are separately metered[5]. Thus, there is little financial incentive for builders of such units to implement energy conservation measures.

Table 2.
Energy Consumed as a Percentage of Total in Existing Residential Buildings
(1981 - 1982)

Housing Type	Percentage of total
Single family detached	72.8
Single family attached	3.4
2 - 4 units	10.6
> 4 units	9.7
Mobile homes	3.5
Total energy use- 9.5 quads	

Source: DOE/EIA/0321 September 1983, Washington D.C.
Consumption & Expenditures, April 1981 through
March 1982.

There were 467,000 multi-family units built in 1983. Table 3 illustrates that most new multi-family units were built in the south and west in 1983[6]. This trend continues today.

Table 3.

1983 Multifamily Building Construction as a Percentage of New Units*

Location	% of New units
Northeast	7
North Central	13
South	58
West	22

*HUD Construction Reports (25-83-13) June 1984

Three states (California, Florida and Texas) account for approximately 45% of all new units built in buildings with five or more units. Seventy-five percent of all multi-family units built each year are in buildings with more than four units. Low-rise buildings (1-3 stories) account for 86% of all new multi-family units[7].

Electricity is the dominant heating source for newly constructed multi-family housing units (see Fig. 1), more than twice as many new units use electric heat as all the other fuels combined. During the last decade, the use of natural gas and oil have slowly decreased as heating sources. In 1983, 89% of newly constructed multi-family units were air conditioned[8]. In that same year, electric heat pumps were installed in 28% of new multi-family units[9]. The average size of multi-family units has varied between 900 and 1000 square feet over the last few years (see Fig. 2). This is a little more than half the size of average single family units.

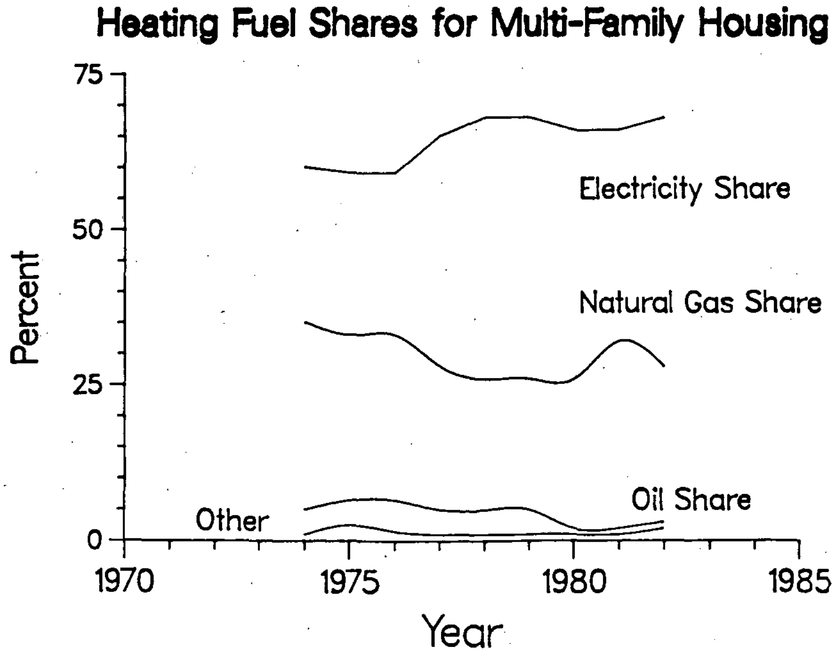

Fig. 1: Heating fuel mix in new multifamily housing units.

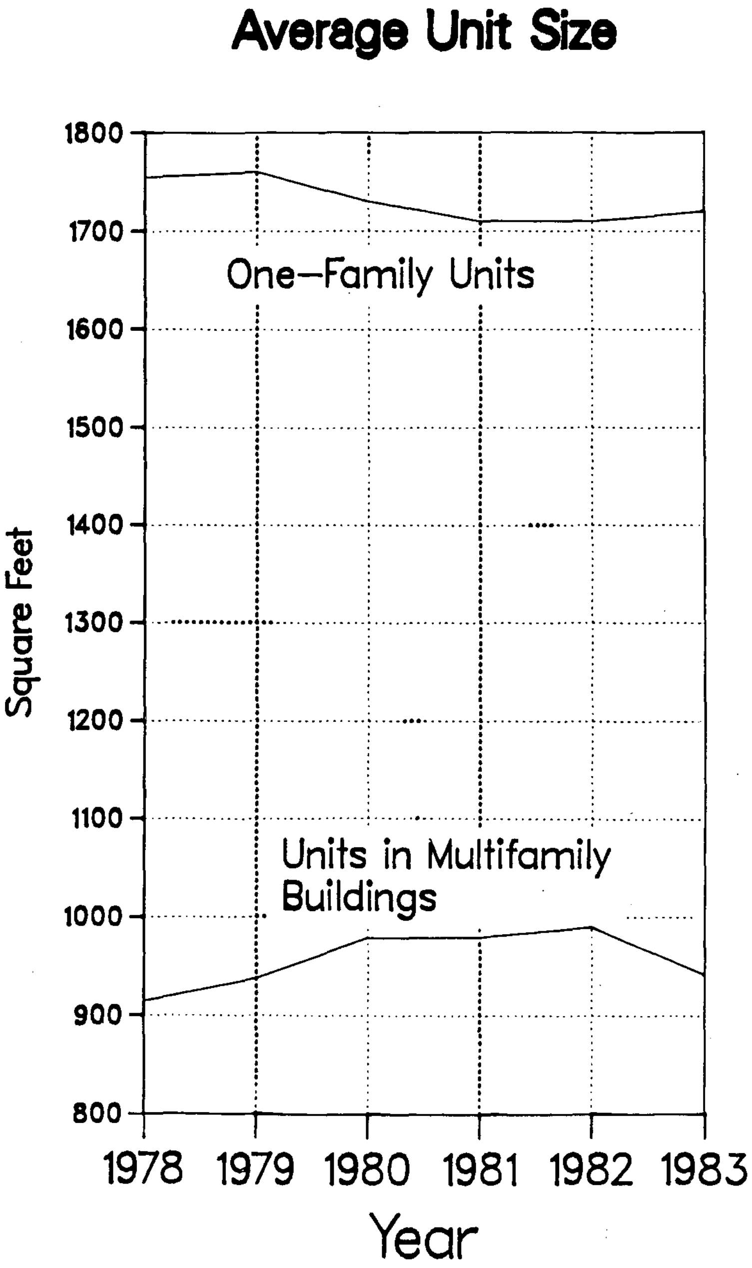

Fig. 2: The average unit size in single and multifamily buildings is shown for a six-year period.

At the present time, there are few data available on the construction characteristics of newly built multi-family buildings. In order to develop a prototypical low-rise multi-family building, we used information that was gathered on new single-family residences[10]. We are now obtaining additional information on typical architectural features and space conditioning systems from builders of multi-family housing. We will update our prototypes as needed. This paper contains a description of the prototypical building we have developed and some preliminary results of energy use analyses that have been completed to date.

PROTOTYPICAL BUILDINGS

The present research project on multi-family housing focuses on new construction. Since low-rise buildings with more than four units account for most of the new construction and most of the energy use in the new multi-family housing sector, we focused our attention on this type of structure for our initial analyses. Additionally, since much of the new construction is in the Sun Belt, it will be important to stress methods of reducing cooling energy use.

Our initial prototype is a two-story building consisting of six 1200 square foot apartment units (see Fig. 3). Some simulations were also performed for floor space areas ranging from 900 to 2000 square feet, allowing heating and cooling load reductions for a 1200 square foot apartment unit to be scaled upwards to a 2000 square foot unit or downwards to a 900 square foot unit. This prototype is representative of most two-story buildings with six or more units since the middle and end units in this six-plex will behave thermally like any similar units in a larger two-story building. We assumed a two foot fixed overhang on all four sides of the building. A four foot wide landing, which shades part of the first floor, is located on the north side of the building. We performed simulations with window area for each unit equal to 10%, 15%, and 20% of the unit floor area. Table 4 contains a description of the building construction characteristics. The external walls are stud walls with variable amounts of insulation. The ceiling insulation is also variable. We modelled three types of foundations (ventilated crawl,

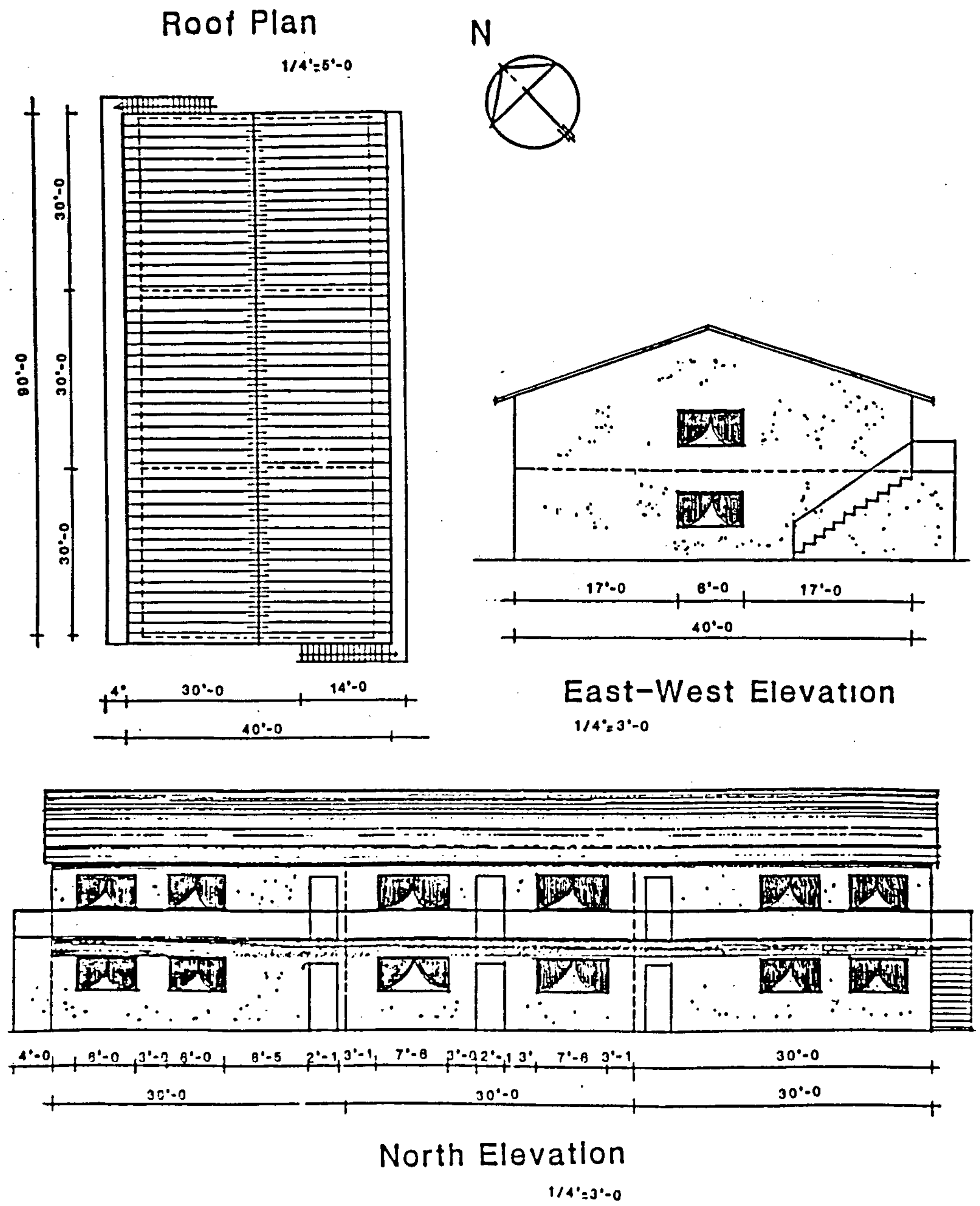

Fig. 3: Roof plan and elevations of prototypical multifamily building.

slab-on-grade, and basement). Party walls between units are composed of four layers of gypsum board and R-11 insulation. The solar absorptivity of the walls and roof is 0.70. We assumed the cooling setpoint to be 78°F and the heating setpoint to be 70°F with a nighttime setback to 60°F. Sensible internal loads are shown in Table 5. Latent loads are equal to 23% of the sensible loads at each hour. Heat released by occupants, lights and appliances are added together to produce the values shown in Table 5. We modelled infiltration to average 0.7 air changes per hour during the winter.

We performed many of the simulations with two alternate shading assumptions. The simpler assumption is that drapes with a shading coefficient of 0.63 are in place at all hours and that they do not affect the thermal conductivity of the windows. For the second assumption, we assumed that drapes with a shading coefficient of 0.63 cover all windows during half of the daylight hours during the summer. This is approximately equivalent to a constant shading coefficient of 0.82 during all the daytime hours. During winter days, drapes do not cover the windows. During both summer and winter nights, drapes cover the windows. The R-value of the drapes is assumed to be equal to 0.9, which corresponds to a dead air space between the windows and the drapes. If, in practice, convective heat flows are present between the windows and drapes, then the actual R-value will be lower. We specify the particular shading assumption used in each analysis in the results section.

Using the prototype described above, we performed a number of sensitivity analyses using the DOE-2.1 computer program. These include studies of: ceiling insulation, wall insulation, foundation types with variable insulation, infiltration rate, window area, glazing type (number of glazings and reflective/absorptive glazing), floor area, roof solar absorptivity, movable nighttime insulation, thermostat setback, and building orientation. Other conservation measures that may be modelled are the use of whole house fans, reflective barrier insulation, and sunspaces. Thus far, we have completed our analysis of insulation, infiltration, floor area, orientation, glazing type, and window area.

Table 4. Specifications for Prototypical Multi-Family Building

WALLS

Exterior Walls: The exterior walls are uniformly constructed throughout the six (6) apartment units. The layers of materials that comprise the exterior wall are different at two sections - sections at the stud and non-stud portions.

Wall at stud: aluminum siding, plywood sheathing, wood stud, and 1/2" drywall. The size of the wood stud varies with the wall insulation.

Wall at non-stud: aluminum siding, plywood sheathing, insulation, and 1/2" drywall. The insulation R-value varies from R-0 to R-27.

Party Walls: The layer of materials comprising the party walls, the walls separating units, are: 2 layers of 5/8" gypsum board, R-11 insulation, and 2 layers of 5/8" gypsum board.

FLOOR

Foundation: Three foundation types are modelled (ventilated crawl, slab-on-grade, and basement) with varying insulation levels.

Ceiling/Floor: The floor separating the upper level apartment unit from the lower level apartment units includes different layers of materials at two sections of the floor-sections at the stud and non-stud areas.

Floor at stud: Rug and pad, 1" plywood, 2"x10" wood stud, 1/2" gypsum board.

Floor at non-stud Rug and pad, 1" plywood, R-11 insulation, air space, and 1/2" gypsum board.

ROOF

The layers of materials that comprise the roof are different at two sections - sections at the stud and non-stud areas.

Roof at stud: At the stud section of the roof materials are: asphalt shingles, 1/2" plywood, attic air space, wood stud (the sizing of the stud varies with the thickness of the insulation), 1/2" plywood and 1/2" drywall, as a finishing material fo the ceiling.

Roof at non-stud: At the non-stud section of the roof the materials are: asphalt shingles, 1/2" plywood, air space, insulation, 1/2" plywood and 1/2" drywall. The insulation R-value varies from R-0 to R-38.

Table 5. Internal Loads Schedule - Apartment Prototype

Hour of Day	Load (Btu)	Hour of Day	Load (Btu)
1	1078	13	1616
2	1078	14	1348
3	1078	15	1401
4	1078	16	1401
5	1078	17	2048
6	1801	18	2209
7	2263	19	2371
8	4526	20	3718
9	2641	21	3718
10	1616	22	3880
11	1616	23	3880
12	2155	24	3503
		TOTAL	53,101

We simulated the building prototype with six separate zones, one for each apartment. Heating and cooling loads are obtained for each of the six zones. In order to reduce the quantity of data presented, the heating and cooling loads are calculated for average mid and end-apartment units. That is, the loads in the two mid-units and the four end-units are separately averaged and the results are presented separately for each. Therefore, these average results are applicable to two-story buildings only. Expressing the results as loads for average mid and end-units, allows one to calculate the loads for other larger two-story buildings by using the results of this analysis for a six unit building. As mentioned earlier, the number of mid and end-units are multiplied by the average mid and end loads, respectively and the two products are summed to give the total load for the larger building. We carried out many of the parametric studies for 45 locations throughout the United States. In some cases, we performed simulations for 11 locations and developed regression equations to extrapolate the results to all 45 locations.

RESULTS OF PARAMETRIC ANALYSES

Prior to our discussion of typical results for average end and mid apartment units, we briefly discuss some typical results when each unit is analyzed separately. Table 6 lists the annual heating and cooling loads for each of six units for our prototypical building assuming it to be located in Atlanta. The long axis of the building is oriented 45° west of north. We used the constant shading assumption. Units 1 through 3 are on the top floor and units 4 through 6 are on the bottom floor. The mid-units have the lowest heating loads when compared to the two outer units on either side. This is due to the smaller exposed wall area for the mid-units. Units 3 and 6, which have more south-facing glass, have lower heating loads than units 1 and 4, respectively. The cooling loads are slightly higher for the upper units than for the lower units but are generally less affected than the heating loads by the position of the particular unit in question. This latter result occurs because the cooling loads are less sensitive than heating loads to the amount of exposed wall area since there is a smaller temperature difference between inside and outside air during the cooling season. Using the values in Table 6, we calculate the annual heating loads for the average mid and end-units to be 15.5 and 18.7 MBtu. The annual cooling loads for the average mid and end-units are 18.3 and 18.5 MBtu.

Table 6. Apartment Cooling and Heating Loads - Atlanta*

Unit	Heating Load (MBtu)	Cooling Load (MBtu)
1	18.4	19.4
2	15.8	19.4
3	17.2	20.5
4	20.2	16.6
5	15.3	17.2
6	18.8	17.5

* We assumed: R-19 ceiling, R-11 walls, slab foundation with no insulation, infiltration 0.7 air changes per hour, glazing area is 15% of floor area, single-pane windows.

In this section, we discuss some of the preliminary results of the parametric analyses for the apartment prototype. First, we compare the energy use per square foot for apartments and single-family residences. Since the single-family simulations were done with a constant shading coefficient assumption, we also use that assumption for the apartment prototype. Tables 7 and 8 show heating and cooling loads per square foot of floor area for the end and mid-apartment units and the end and mid-townhouse units, respectively. The townhouse units are two-story apartments that are described elsewhere[11]. The townhouse and apartment units have the same floor area, volume, and window area but differ in net wall area. The mid and end-townhouse units have 476 and 956ft^2 of wall area, respectively and the mid and end-apartment units have 360 and 680ft^2, respectively. Heating loads are typically higher in the townhouse unit than in the apartment units. This is not surprising since the apartment units have less exterior wall area than the townhouse units. For cities with low cooling loads, there is little difference between the two prototypes as regards the cooling load magnitude. For cities with higher cooling loads, the apartment cooling loads are a little lower than the townhouse cooling loads. In such warmer climates, the heat gain through the walls becomes more important and is larger for the townhouses because of their larger exterior wall surface area.

Table 7. Apartment Annual Space Conditioning Loads Per Square Foot (KBtu/ft2)*

	Heating		Cooling	
City	End	Mid	End	Mid
Albuquerque	19.8	16.1	11.5	10.9
Atlanta	15.5	12.9	15.4	15.3
Birmingham	13.6	11.2	19.4	19.0
Bismarck	57.9	50.9	7.2	6.9
Boise	29.2	25.3	8.4	7.8
Boston	33.3	29.1	6.2	6.0
Las Vegas	9.4	7.6	29.2	27.0
Los Angeles	3.7	2.6	1.7	1.8
Memphis	21.7	20.1	23.3	22.4
Miami	0.3	0.3	49.6	48.1
Minneapolis	51.3	45.2	9.6	9.2

*We assumed: R-19 ceiling, R-11 walls, uninsulated foundations, infiltration 0.7, air changes per hour, glazing area is 15% of floor area, single-pane windows.

Table 8. Townhouse Annual Space Conditioning Loads Per Square Foot (KBtu/ft2)*

	Heating		Cooling	
City	End	Mid	End	Mid
Albuquerque	25.6	22.8	13.0	12.3
Atlanta	19.7	17.6	18.1	17.4
Birmingham	17.2	15.3	22.3	21.7
Bismarck	71.4	64.3	6.5	6.4
Boise	36.4	32.4	8.0	7.5
Boston	41.5	37.2	5.8	5.9
Las Vegas	19.3	17.4	28.6	27.1
Los Angeles	5.1	4.0	1.6	1.6
Memphis	23.2	20.1	26.5	25.6
Miami	0.4	0.3	55.9	54.3
Minneapolis	63.1	56.9	9.5	9.1

* We assumed: R-19 ceiling, R-11 walls, uninsulated foundations, infiltration: 0.7 air changes per hour, glazing area is 15% of floor area, single-pane windows.

We studied the effect of building orientation on heating and cooling loads by rotating the building in increments of 30 degrees. We used the variable shading assumption for these simulations. The apartment building has dimensions of 40 by 90 feet. Figures 4a & 4b show that the minimum heating and cooling loads occur when the building is oriented so that the long axis points east-west or west-east (90°). Orientation has a much smaller effect on heating loads than on cooling loads. The maximum loads occur when the long axis points either north-south or south-north (0° or 180°). At a 90° orientation, the maximum amount of window area points south thus maximizing solar gain during the winter months and reducing heating loads to a minimum. At this orientation, cooling loads are also reduced to a minimum since the amount of window area facing east and west is minimized thus reducing cooling loads from solar gain. Ninety degrees is therefore the optimum angle for reduction of both heating and cooling loads. The effect of orientation on space conditioning loads is greatest on cooling loads in warm locations. The effect of orientation is diminished somewhat because of the fixed shading and because of the use of windows on three sides of the building. It is important to keep in mind the dependence of orientation effects on these base case assumptions.

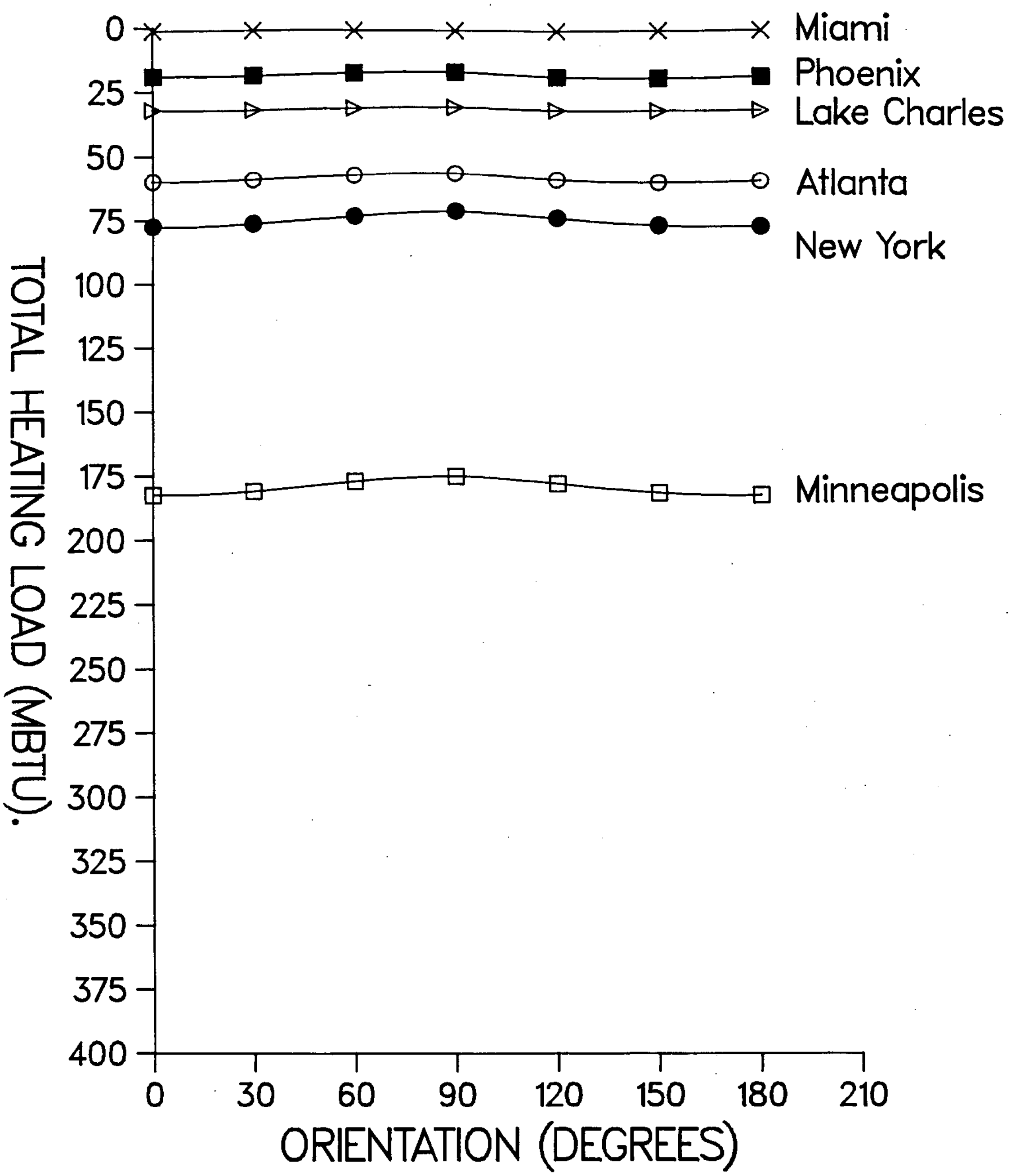

Fig. 4a: Total heating load for a six-unit apartment building as a function of building orientation for six locations.

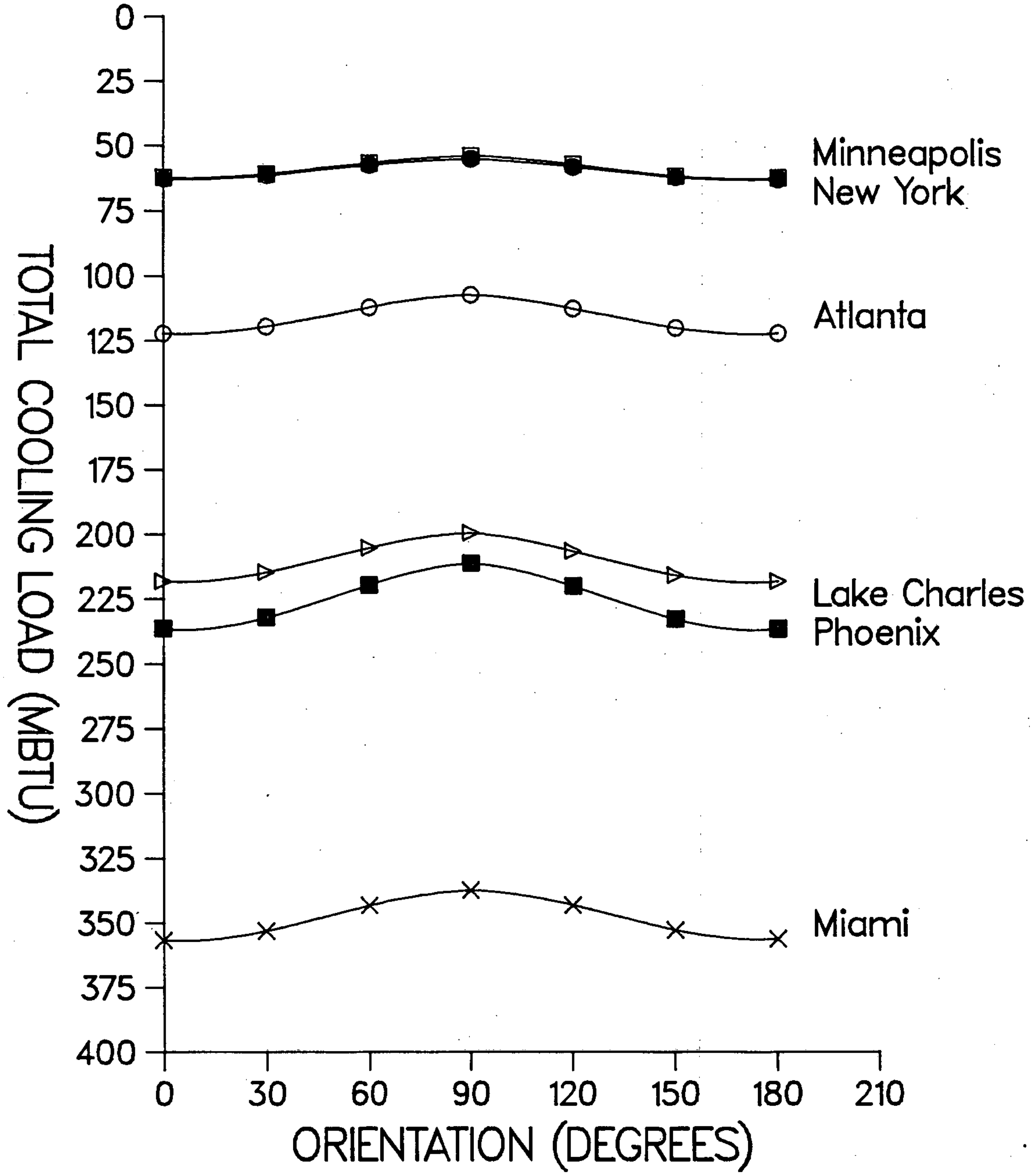

Fig. 4b: Total cooling load for a six-unit apartment building as a function of building orientation for six locations.

We also studied the effect of floor area on heating and cooling loads. We used the variable shading assumption for these simulations. As Figures 5 and 6 indicate, in Atlanta both heating and cooling loads increase linearly with floor area. Floor area simulations were performed for three cases, light insulation and single pane windows, moderate insulation and double pane windows, and heavy insulation and triple pane windows. We found similar relationships for the other four cities we studied (Chicago, Lake Charles, Minneapolis, and New York) . For cooling loads, the slope of the best fit regression line is essentially constant for all locations. For heating loads, the slope of the best fit regression line varies somewhat from one location to another. However, we discovered a strong relationship between the ratio of the heating load at any one floor area to the heating load at the base floor area (1200 ft^2) and the number of the heating degree-days at the location (see Fig. 7). Therefore, floor area multipliers for heating loads can be estimated reliably without simulations for any location where the heating degree-days are known. This is an important result because it allows a very significant reduction in simulations needed to predict heating and cooling loads for apartments of greater or lesser floor area than the base apartment (1200ft^2).

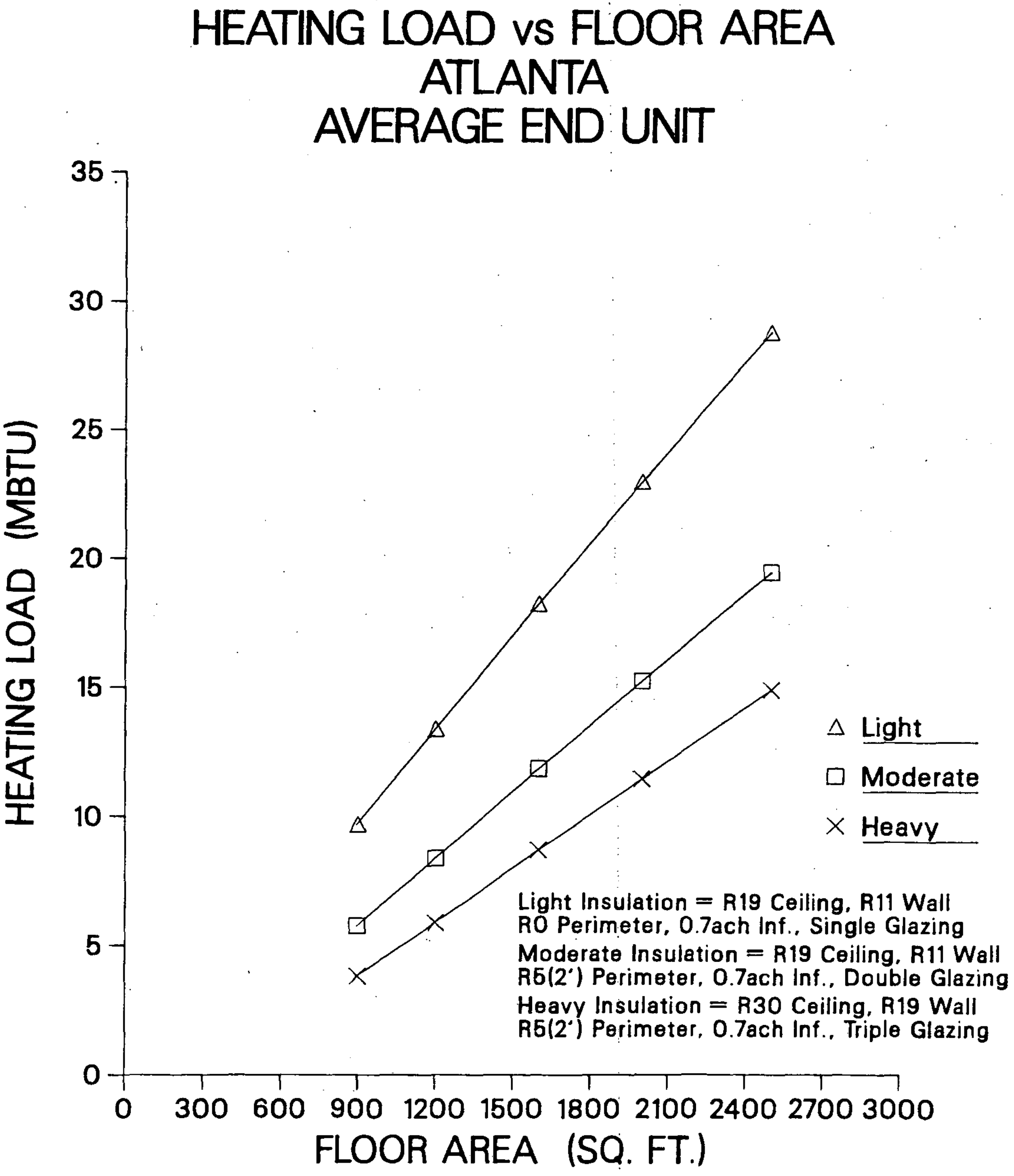

Fig. 5: Heating load versus floor area for an average end-unit apartment.

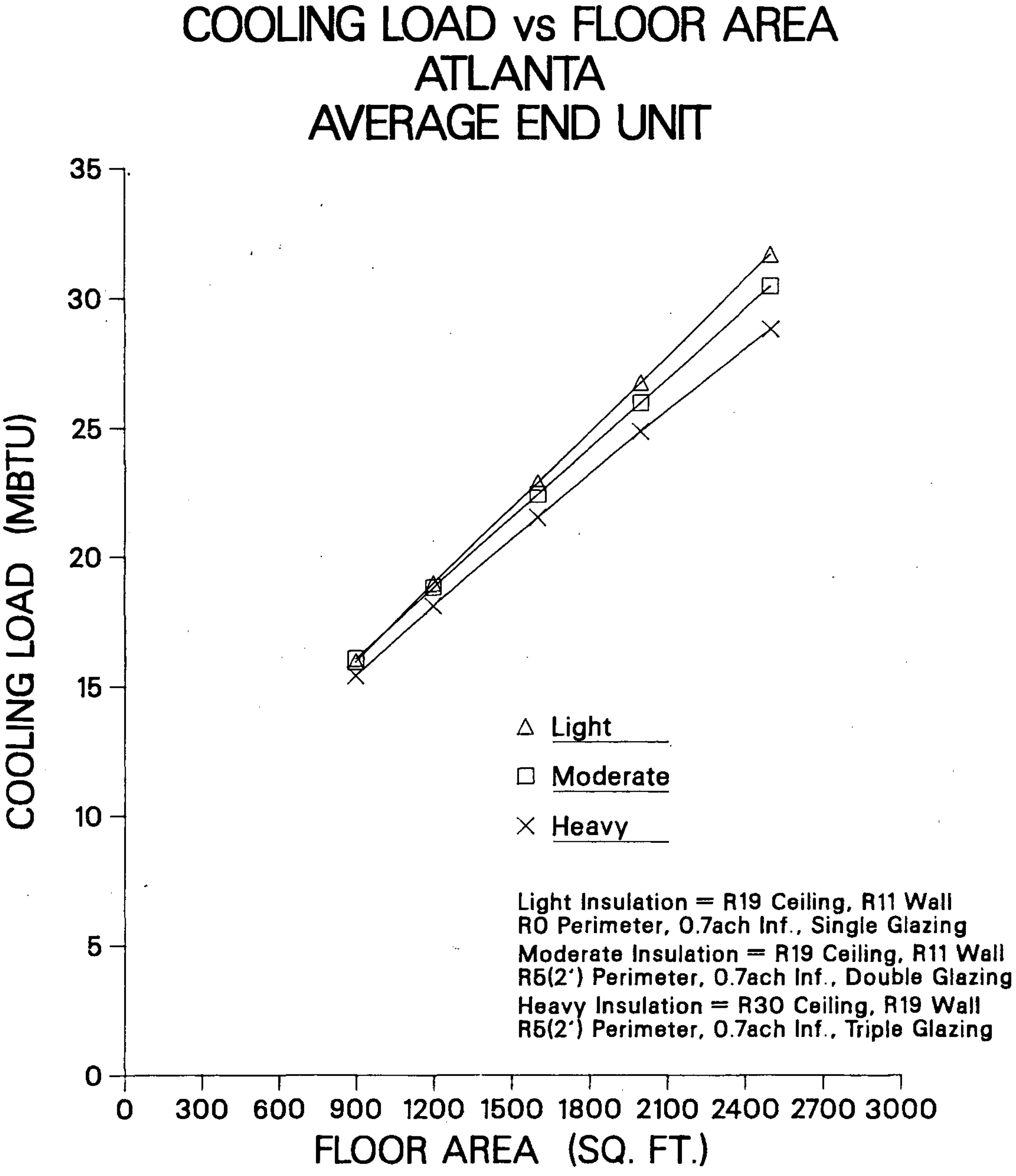

Fig. 6: Cooling load versus floor area for an average end-unit apartment.

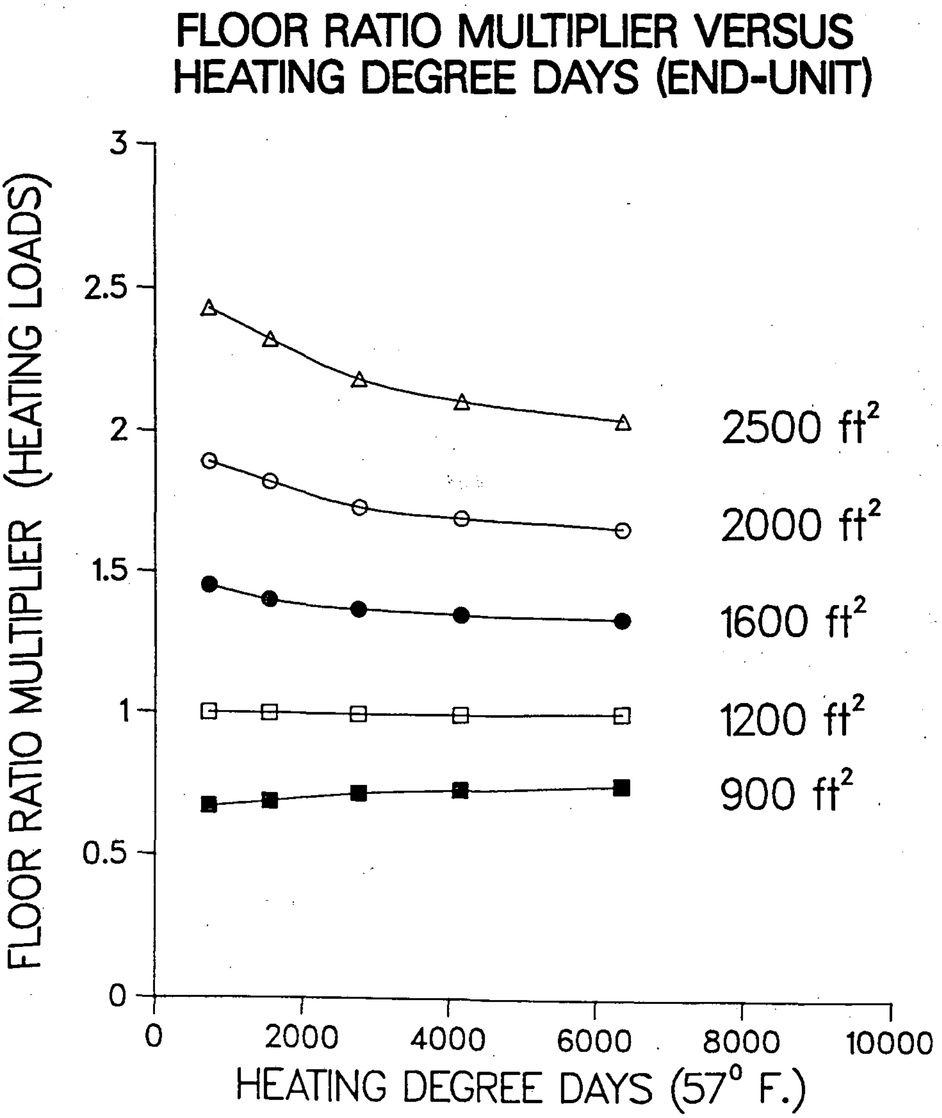

Fig. 7: Floor ratio multiplier for heating loads for five locations plotted as a function of heating degree days base 57°F.

For each of 45 cities, we developed a matrix of heating and cooling load changes that result from changes in insulation level, foundation type, infiltration level, glazing layers, and glazing area. Appendix A contains such a matrix for the end-apartment for Alburquerque. We used the variable shading assumption for these simulations. Heating load reductions resulting from increases in ceiling, wall or foundation insulation, are greatest for colder locations and for the change from no insulation to R-11. We found cooling load changes to be greatest for the warmer locations and for the initial insulation increase from zero to R-11. Heating load changes due to altered infiltration are greatest in cold climates and cooling load changes are greatest in warm, humid climates.

It is more difficult to predict trends in the window portion of the matrix than in the part just described. When window area is increased, both solar gain and conductive losses or gains are altered simultaneously. Cooling loads always increase when window area is increased. Heating loads also usually increase when window area is increased. For triple-glazed windows in Albuquerque, the increase in solar gain outweighs the increase in conductive heat loss, thus resulting in an overall decrease in heating load. The matrices can also be used to determine the effect on heating and cooling loads of employing double-or triple-pane pane windows as compared to single-pane windows. These matrices can be used as input to a program that calculates economic parameters such as benefit to cost ratio and payback period.

A final example of the type of relationships we are developing involves estimating the effect of reflective glazing on cooling and heating loads. We simulated the use of reflective glazing on all windows for 11 locations. The reflectance of this glazing was 45% compared to 6% for the standard base case single-glazing. We used the fixed shading assumption for the set of simulations described here. We regressed changes in heating and cooling loads on the average vertical insolation during the heating and cooling periods, respectively. Figures 8 and 9 illustrate the relationships between these loads and the appropriate climate variable for 11 locations. Each point in the figures represents a DOE-2 simulation for a single location. We also performed analyses for double and triple-glazed windows. Table 9 gives the 11 locations and their insolation values. The correlation coefficient varied from 0.95 to 0.99 for the reflective glazing regressions and from 0.89 to 0.99 for the absorptive glazing regressions. We can use the following regression equations obtained from these analyses to predict heating and cooling load changes in other locations for which the climate variable is known but for which computer simulations were not performed:

$$\Delta \text{Heating Load}(\text{MBtu/ft}^2) = 1.64\text{x}10^{-3} + 2.0\text{x}10^{-4} * x$$

$$\Delta \text{Cooling Load}(\text{MBtu/ft}^2) = 2.71\text{x}10^{-3} + 2.7\text{x}10^{-4} * y$$

where

x= vertical solar insolation (kBtu/ft^2) during the hours there is a heating load, and

y= vertical solar insolation (kBtu/ft^2) during the hours there is a cooling load.

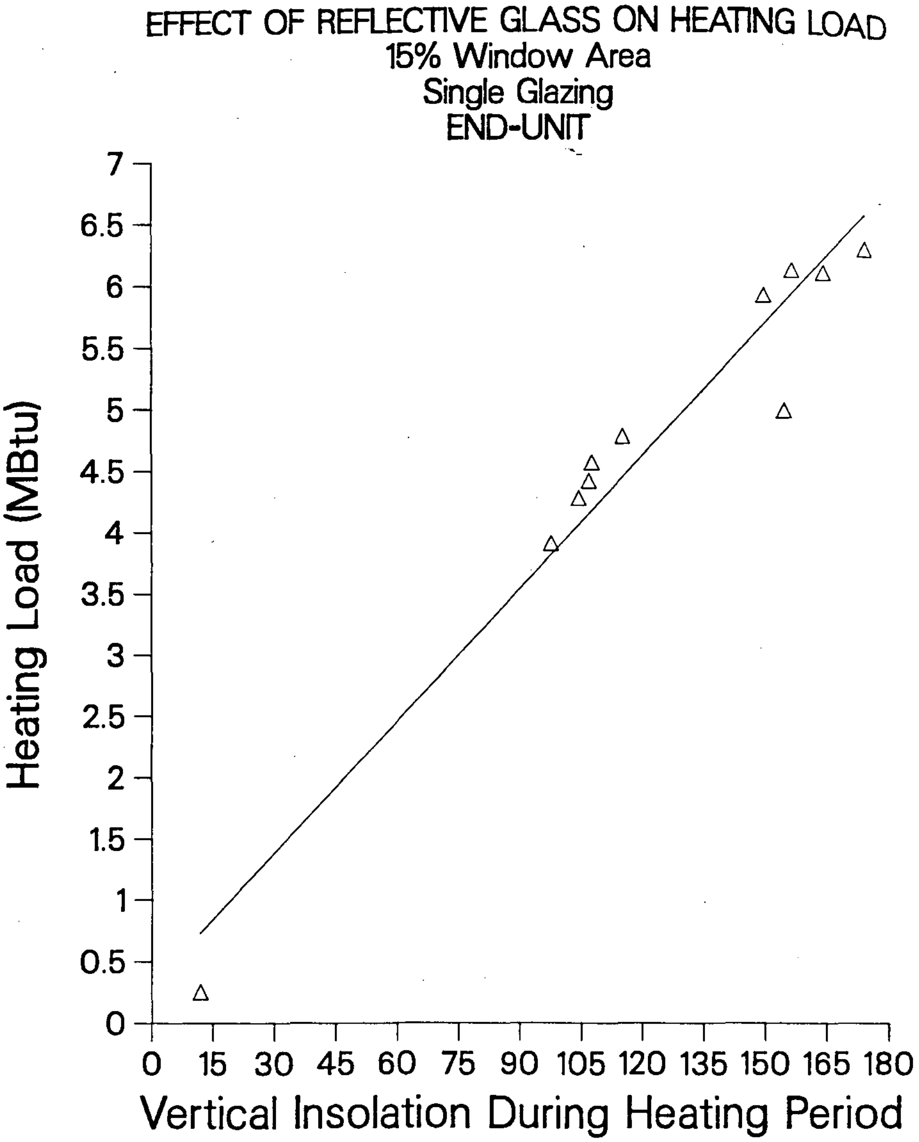

Fig. 8: The effect of reflective glazing on heating load is plotted for eleven locations as a function of average vertical insolation (KBtu/ft^2) during the heating period.

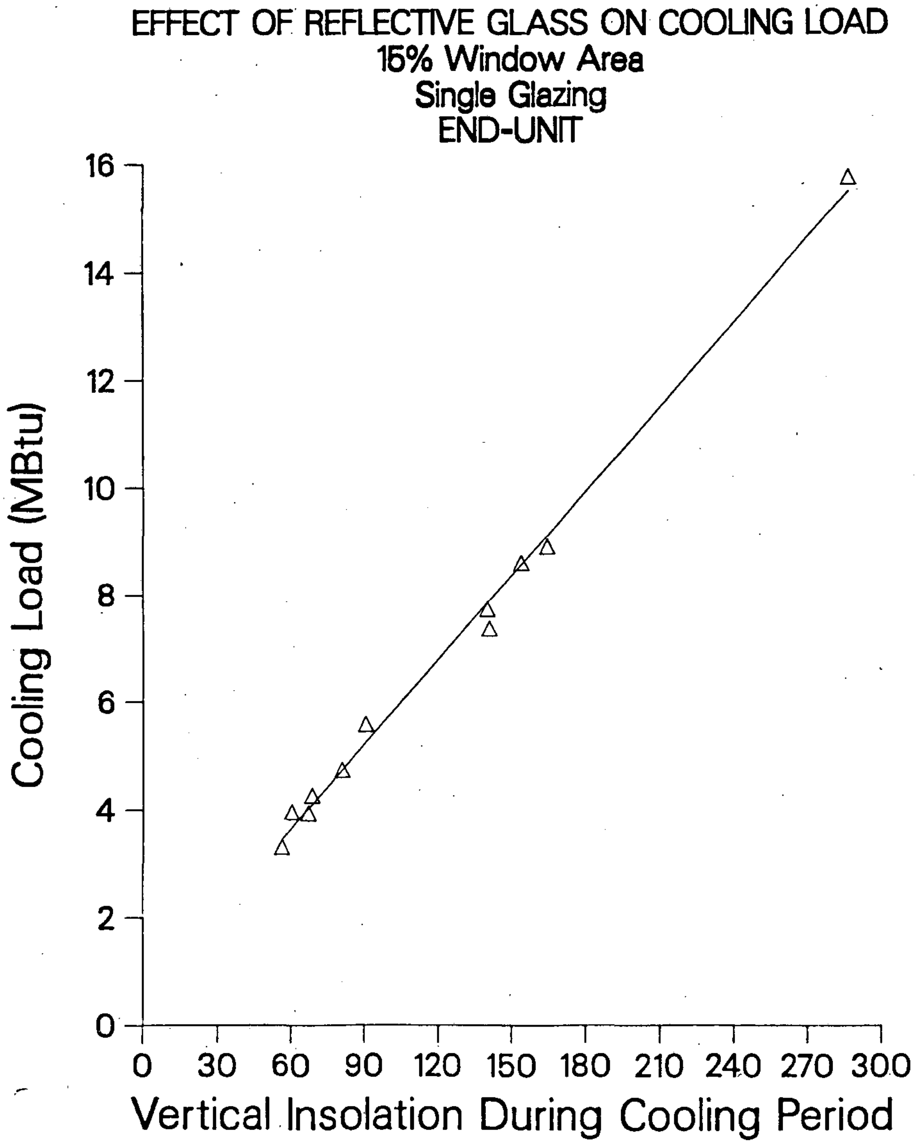

Fig. 9: The effect of reflective glazing on cooling load is plotted for eleven locations as a function of average vertical insolation (KBtu/ft^2) during the cooling period.

Table 9. Climate Data for 11 Locations

Location	Vertical Insolation During Heating Hours (KBtu/ft^2)	Vertical Insolation During Cooling Hours (KBtu/ft^2)
Albuquerque	175	91
Atlanta	105	140
Birmingham	98	154
Bismarck	157	67
Boise	155	69
Boston	164	56
Las Vegas	107	165
Medford	115	60
Memphis	108	141
Miami	12	289
Minneapolis	150	81

CONCLUSIONS

Preliminary computer simulations have allowed quantification of reduced space conditioning loads that result from added thermal insulation, nighttime thermostat setback, decreased infiltration, and proper choice of orientation and glazing. Cost-benefit analyses must be performed to determine the cost-effectiveness of specific measures in various locations. We are developing a microcomputer program that will allow such calculations to be made in an easy to use and inexpensive manner. In the next phase of our work, we will analyze additional conservation measures and additional prototypical low-rise apartments. We also plan to develop a three-story prototype in order to broaden our coverage of low-rise multifamily housing. With the addition of this prototype, we will be able to apply the building block approach to almost any low-rise multi-family building.

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APPENDIX A Heating and Cooling Load Changes For Various Conservation Measures in Albuquerque

This appendix shows the heating and cooling load changes that result from increases in ceiling, wall, and foundation insulation, reductions in infiltration rate, and changes in glazing. The simulated glazing changes are number of panes and window area as a percentage of floor area. Floor area multipliers, described in the text, are also shown. These multipliers allow one to scale the heating and the cooling loads to apartment units with floor areas other than the base case value of 1200 square feet.

The base heating and cooling loads correspond to space conditioning loads for an apartment unit with no insulation in the ceiling, walls, and foundation and 1.0 air changes per hour of average winter infiltration. the window area is 20% of the floor area and the windows are single-pane with aluminum sash. The changes in heating and cooling loads shown in the table are for an average end-unit in an Albuquerque apartment building with a slab foundation. For example, if the ceiling insulation is changed from R-11 to R-19, the heating load decreases by 1.27 MBtu and the cooling load decreases by 0.67 MBtu. Similar tables have been developed for 44 other locations.

As an example of the use of the table, consider an end-unit apartment in a two-story apartment building in Albuquerque that has 1000 square feet of floor space. and ceiling, wall and foundation insulation as follows: R-19, R-11, and R-5 perimeter insulation 2 feet down, respectively. Assume that the infiltration rate is 0.7 air changes per hour and that the window area is 10% of the floor area. Also assume that it has double pane windows with 1/2 inch air gap and wood sash. The heating load for this end-unit is equal to (44.76-11.19-6.94-3.17-3.69-10.41)x.810 = 9.36x.810 = 7.58 MBtu.

ALBUQUERQUE END UNIT SLAB

HEATING (IN MBTU-YR)

CEILING	
R-0	0.
R-11	-9.92
R-19	-11.19
R-30	-12.12
R-38	-12.46

WALL	
R-0	0.
R-11	-6.94
R-13	-7.28
R-19	-8.39
R-24	-8.99
R-27	-9.19

FOUNDATION	
R-0	0.
R-5 2FT	-3.17
R-10 2FT	-3.40
R-5 4FT	-3.53
R-10 4FT	-3.84

INFILTRATION	
HI (1 ACH)	0.
MED (.7 ACH)	-3.69
LOW (.4 ACH)	-7.38

WINDOW	SASH	10 PCT AREA	15 PCT AREA	20 PCT AREA
1 PANE	ALUM	-4.54	-2.27	0.
	ALUM+TB	-5.56	-3.80	-2.03
	WOOD	-6.07	-4.56	-3.05
2 PANE 1/4IN.	ALUM	-8.01	-7.24	-6.47
	ALUM+TB	-9.08	-8.84	-8.61
	WOOD	-9.62	-9.65	-9.68
2 PANE 1/2IN.	ALUM	-9.05	-8.80	-8.54
	ALUM+TB	-9.96	-10.16	-10.36
	WOOD	-10.41	-10.83	-11.25
3 PANE 1/4IN.	ALUM	-9.52	-9.44	-9.36
	ALUM+TB	-10.51	-10.92	-11.33
	WOOD	-11.04	-11.71	-12.39
3 PANE 1/2IN.	ALUM	-10.55	-10.99	-11.42
	ALUM+TB	-11.34	-12.16	-12.99
	WOOD	-11.77	-12.81	-13.85

BASE LOAD = 44.758 MBTU-YR

AREA	MULTIPLIERS				
900	.715	1500	1.280	2100	1.834
1000	.810	1600	1.373	2200	1.925
1100	.905	1700	1.466	2300	2.016
1200	1.000	1800	1.559	2400	2.107
1300	1.093	1900	1.651	2500	2.198
1400	1.187	2000	1.744		

COOLING (IN MBTU-YR)

CEILING	
R-0	0.
R-11	-4.13
R-19	-4.80
R-30	-5.23
R-38	-5.41

WALL	
R-0	0.
R-11	-1.58
R-13	-1.67
R-19	-1.98
R-24	-2.10
R-27	-2.14

FOUNDATION	
R-0	-1.24
R-5 2FT	-.32
R-10 2FT	-.21
R-5 4FT	-.15
R-10 4FT	0.

INFILTRATION	
HI (1 ACH)	0.
MED (.7 ACH)	-.12
LOW (.4 ACH)	-.23

10 PCT AREA	15 PCT AREA	20 PCT AREA
-6.39	-3.19	0.
-6.43	-3.25	-.06
-6.45	-3.27	-.09
-7.13	-4.18	-1.23
-7.17	-4.23	-1.29
-7.19	-4.26	-1.32
-7.17	-4.23	-1.29
-7.20	-4.27	-1.34
-7.22	-4.30	-1.37
-7.61	-4.86	-2.11
-7.65	-4.91	-2.17
-7.67	-4.93	-2.20
-7.65	-4.91	-2.17
-7.68	-4.95	-2.22
-7.70	-4.97	-2.25

BASE LOAD = 26.632 MBTU-YR

AREA	MULTIPLIERS				
900	.850	1500	1.150	2100	1.450
1000	.900	1600	1.200	2200	1.500
1100	.950	1700	1.250	2300	1.550
1200	1.000	1800	1.300	2400	1.600
1300	1.050	1900	1.350	2500	1.650
1400	1.100	2000	1.400		

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