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End-Use Load and Consumer Assessment Program: Heat Loss Characteristics of the Residential Sample

C. C. Connor
V. B. Lortz
R. G. Pratt

June 1990

Prepared for
the Bonneville Power Administration
under a Related Services Agreement
with the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
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Pacific Northwest Laboratory
Richland, Washington 99352

SUMMARY

The End-Use Load and Consumer Assessment Program (ELCAP) conducted for the Bonneville Power Administration by Pacific Northwest Laboratory was initiated to support both conservation assessment and load forecasting missions. This report documents a study of the heat loss characteristics of the ELCAP residential buildings. The basic objectives of this analysis are to:

- calculate theoretical residential heat loss rate based on the onsite inspection data for use in support of subsequent analyses
- determine the distribution of insulation levels and heat loss potential as a function of construction vintage and climate zone
- support use of the ELCAP Residential Standards Demonstration Program (RSDP) houses for analysis of the impact of Model Conservation Standards (MCS) by determining the degree to which their construction conforms to the design specifications
- test the specification of current code used in the RSDP experiment.

The analysis of the heat loss characteristics of the ELCAP Residential sample leads to several conclusions based on the building-level structural characteristics. These include:

- The distribution of overall residential heat loss potentials with construction vintage indicates a strong tendency toward lower heat loss potential in newer houses.
- There is a clear trend toward increasing occupied floor space in newer houses.
- The data show a steady increase in overall insulation levels in more recently constructed houses.
- Heated basements tend to be concentrated in the two colder climate zones. There is a steady decline in occurrence of crawlspaces and increase in occurrence of heated basements with severity of climate.
- The distribution of foundation types in the sample does not strongly influence the general trend to higher insulation levels in newer houses and houses in colder climates.

Conclusions can also be drawn from the analysis of the building envelope component-level structural characteristics, including:

- Heat losses through walls form the largest component of space heat in the sample for all climate zones (32%), followed by windows (23%), infiltration estimated on the basis of 0.4 air changes per hour (17%), ceilings (13%), and crawlspace and unheated basement floors (10%). These indicate the relative magnitude of residential heat losses for envelope components, which are the targets for conservation technologies and programs.

- Ceilings and walls generally exhibit the trend of increasing insulation levels in newer construction. The window, floor, door, and slab components have relatively steady effective R-values with vintage.

- Windows are the only component that show sharply increased R-values in colder climate zones. This suggests that the distributions of overall and non-foundation effective R-values are influenced primarily by vintage rather than climate. With the exception of windows, the newer vintages and basement foundation types predominant in the Zone 3 sample may be the primary cause for higher effective R-values in that part of the region.

- The window percentage of gross wall area decreases from 13.6% in Zone 1 to about 11.5% in Zones 2 and 3. Thus, decreased window areas as well as increased window R-values contribute to the lower heat loss potentials in Zone 3.

Several conclusions can be drawn regarding the ELCAP RSDP sample with respect to the purposes of the RSDP study and the intent of the MCS. These include:

- The heat loss potentials of the ELCAP MCS residences are reasonably representative of the targets set in the MCS.

- The heat loss potentials in the ELCAP RSDP Control residences are representative of the targets set for the control group as defined by the Council's current code.

- The compliance of the MCS and Control houses' insulation levels indicates that designers and builders in the Pacific Northwest can and do construct homes to standards with reasonable accuracy.

- Insulation R-values in the ELCAP Post-1978 houses are approximately equal to the Council's current code, and therefore the ELCAP Post-1978 and RSDP Control houses are a reasonable control group for the study of the MCS.

- The ELCAP MCS houses exhibit a small variation in building design from the rest of the region. The median occupied floor space for the ELCAP MCS houses is 7% less than the Post-1978 houses; they are also slightly more compact in shape. The median window percentage of gross wall area for the MCS houses is also smaller, 11% compared with 12% for the Post-1978 houses and 13% for the entire Residential Base sample.

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1.0 INTRODUCTION

Since 1985 the Bonneville Power Administration (Bonneville) has been collecting data on electrical end-use energy consumption for a large sample of residential and commercial buildings in the Pacific Northwest as part of its End-Use Load and Consumer Assessment Program (ELCAP). Over 600 residential and commercial buildings are instrumented to collect hourly electrical end-use energy consumption data as a part of ELCAP, which is conducted for Bonneville by the Pacific Northwest Laboratory(a) (Parker and Stokes 1985). In addition, each of the buildings has been inspected to determine such physical characteristics as insulation levels, wall and window areas, construction types, equipment types, etc. The occupants have also been repeatedly surveyed to collect demographic data (Windell and Klan 1985).

There are two major samples of residential buildings in the ELCAP project: the Residential Standards Demonstration Program (RSDP) and Residential Base samples, as described by Windell (1987). The Residential Base sample is designed to be roughly representative of the regional single-family housing stock with electric space heat. The ELCAP sample of houses constructed by the RSDP is designed to evaluate the energy savings and cost-effectiveness of the Model Conservation Standards (MCS), an energy conservation code proposed by the Northwest Power Planning Council (the Council) for new electrically heated houses. The MCS Code is projected to save the region large amounts of energy in the coming decades.

The fundamental purpose of this study is to analyze the heat loss characteristics of the ELCAP residential buildings to support placement of the samples in a regional context. The basic objectives of this analysis are to:

- calculate theoretical residential heat loss rates based on the onsite inspection data for use in support of subsequent analyses
- determine the distribution of insulation levels and heat loss potential as a function of construction vintage and climate zone, for the buildings as a whole and for each of the building envelope components

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- support use of the ELCAP RSDP houses for analysis of the impact of the Model Conservation Standards by determining the degree to which their construction conforms to the design specifications of the RSDP
- test the specification of current code used in the RSDP experiment, by comparing the specified baseline insulation levels with those in the ELCAP Residential Base houses built after 1978.

Unlike other larger regional surveys of residential buildings such as the Pacific Northwest Residential Survey (PNWRES) (Lou Harris and Associates 1984), the houses in the ELCAP samples all received detailed onsite inspections of their physical characteristics by experienced energy auditors (Weakley, Darwin, and Howe 1987). As a part of this characteristics data collection effort, the auditor separately evaluated each section of each building component (e.g., wall, window, door) for its construction type, insulation, and surface area. This provided a unique opportunity to examine in detail the insulation levels and heat loss potentials of a large sample of houses.

The two dimensions of the ELCAP Residential Base sample explored in this analysis are vintage and climate zone. These are of particular interest in testing the extent to which the sample supports the general perception that newer houses and houses in colder climates tend to be better insulated than older houses and houses in warmer climates. These dimensions also provide a point of reference for interpreting results from two other ELCAP Residential data analysis reports characterizing the thermal performance and electrical end-use consumption of the Residential Base sample (Pratt et al. 1989). No attempt is made here to relate the theoretical heat loss characteristics to the metered heating energy consumption data.

The distributions of overall heat loss potential and insulation levels, for the houses as a whole and for the houses excluding the foundation, are examined for the Residential Base sample. The effects of house size, shape, and foundation type on these distributions are also examined. The RSDP sample houses built to the Model Conservation Standards are included as a distinct vintage category, to place the standards in context with the trends in construction practices over time. Similarly, the distributions of effective insulation levels for each building envelope component are developed. The sample weighted average heat loss potential for each envelope component is also determined by climate zone, to provide a look at the relative heat loss through components that are the targets of energy conservation retrofit programs.

In cooperation with the state energy offices of Idaho, Montana, Oregon, and Washington, Bonneville has been conducting the RSDP to evaluate the energy savings and cost-effectiveness of the Model Conservation Standards proposed by the Northwest Power Planning Council (NPPC 1986a). There are two types of houses built for the RSDP and sampled by ELCAP (Parker and Foley 1985): the MCS houses constructed to meet the proposed requirements of the MCS and the Control houses built to current building code as defined by the Council. Analyses of metered energy and climatic data from the RSDP houses have been conducted at the Lawrence Berkeley Laboratory (Meier et al. 1986) and Pacific Northwest Laboratory (Drost et al. 1986) to determine the energy saved by the MCS. An analysis of data provided by the RSDP builders was used to determine the incremental cost of building houses to the MCS (Vine 1986). Other RSDP analyses have also been performed at Bonneville, the Council, and by the state energy offices.

Two critical assumptions are tested in this analysis about the heat loss characteristics of the RSDP houses underlying the evaluation of the MCS. First, the heat loss characteristics of the MCS and Control houses must reasonably approximate the design targets of the RSDP experiment if the differential in thermal performance of the samples can reasonably be assumed to approximate the impact of implementing the MCS. Second, the presence of a sample of houses built after 1978 in the ELCAP Residential Base sample (the Post-78 houses) provides a unique opportunity to test the validity of the Council's assumption about insulation levels of current design practices used in developing the specification of the RSDP control houses.

2.0 CALCULATION OF THEORETICAL HEAT LOSS POTENTIAL

The steady-state heat loss coefficient (UA) is a common measure of the heat loss potential of a given house or building component, expressing the rate of heat loss through the building shell per degree of indoor/outdoor temperature difference. The overall UA is computed as the sum of the UAs for each component of the building envelope, which are the product of the effective U-value and surface area of each component. The component effective U-value is the conductance of the entire component assembly, taking into account each layer of material, the inside and outside air films, and any parallel heat flow paths such as are caused by studs or joists (ASHRAE 1985). A material's resistance to heat flow is often expressed as an R-value, which is the reciprocal of the U-value. The UA estimated in this manner is theoretical (as opposed to an empirical as-operated UA derived from consumption data), and will be referred to as the nameplate UA.

Classical residential heating energy requirements are calculated based on the degree-day concept (ASHRAE 1985). The space heating energy required, to the first order, is the linear product of a measure of thermal integrity (the UA) and a measure of climate severity (the degree-days to an appropriate base temperature). The number of heating degree-days are computed for a given location as the sum of the positive daily base temperature/outdoor temperature differences over the time period of interest, typically monthly or annually. In one common variation on such methods (the variable base degree-day method) the base temperature used is the balance temperature, the average daily indoor temperature at which no heat is required due to the average levels of internal and solar heat gains. The Council's climate zones, based on the number of heating degree-days with respect to a base temperature of 65°F, are shown in Table 2.1.

In fact, the balance temperature is also a function of the UA; when the UA is decreased, the same level of solar and internal gains is then adequate to maintain a given room temperature at lower outdoor temperatures. This is

TABLE 2.1. Northwest Power Planning Council Climate Zone Annual Degree-Days at 65°F Base Temperature, °F-day/yr

Climate Zone	Council Definition	Median of Range
Zone 1	<6001	5345[a]
Zone 2	6001-8000	7000
Zone 3	>8000	8517[b]

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[a] Minimum annual 65°F degree-days for region Typical Meteorological Year data (TMY data) is 4688 for North Bend, Oregon.

[b] Maximum annual 65°F degree-days for region (TMY data) is 9033 for Cut Bank, Montana.

a second-order effect, however, and it is a useful approximation for interpreting the results presented in the following sections to assume that (given the accuracy limitations of UA/degree-day methods) the heating energy consumption is directly proportional to the UA. Similarly, steady-state heating loads can be calculated as the product of the UA and the indoor/outdoor temperature difference minus the solar and internal heat gains.

The conductive UA of each ELCAP residence is calculated using the component areas and constructions collected in onsite surveys. Each survey was performed by an experienced auditor who visited the house and reported the physical characteristics of the building based on actual inspection and measurement. The auditor separately evaluated each section of each building component (wall, window, door) for its construction type, insulation, and area (Taylor et al. 1985). For instance, a typical building includes about ten separate entries describing the different wall sections.

The procedures and material properties used to calculate the UAs are primarily based on the 1985 ASHRAE Fundamentals (ASHRAE 1985), which also forms the basis of the Standard Heat Loss Methodology used by Bonneville for residential energy audits (Bonneville Power Administration 1984). The calculations used here are modified slightly to conform to the Bonneville procedure, principally involving the thickness of certain interior and exterior sheathing materials, natural outdoor air exchange rates into crawlspaces and attics, and average seasonal wind speeds. The UA calculation method is described in detail in Appendix A.

Gaps in the inspection data are filled with default assumptions about construction (see Appendix B). In cases where a significant portion of a building's audit data is missing and no reasonable default is available, that building is removed from the analysis. It is estimated that only one-fifth of the houses in the sample have defaulted greater than 20% of the overall UA. These uncertainties and the fraction of the UA defaulted are discussed in Appendix B. Appendix C gives the UAs and estimated fraction defaulted for each house analyzed.

Although it represents a mechanism for heat loss, infiltration into the heated zones is not included in the calculated UA. This UA component in practice is a strong function of construction quality, climate, and shelter from wind for each site. Thus the infiltration rate into conditioned zones was judged to vary too much for inclusion in the analysis as a site-specific component, although the comparisons with metered data include an infiltration estimate (Miller 1988). Outside air exchange rates into attics and crawlspaces are implicitly included in the UA calculation for these components.

3.0 ELCAP RESIDENTIAL SAMPLES

There are two samples of residences in the ELCAP data base for which UAs are calculated: the houses from the Residential Base sample, and the Model Conservation Standard and Control houses from the RSDP sample. The Residential Base sample is a subset of the houses surveyed for the PNWRES survey of the regional housing stock. The Residential Base houses are all detached single-family structures, whereas the Council and Bonneville define single-family structures as containing up to four dwelling units. All the houses reported having permanently installed electric space heating equipment in the PNWRES. In addition, all the Residential Base houses are reportedly owner-occupied. Small groups of gas/oil heated houses, manufactured houses, renter-occupied houses, and attached houses are also metered by ELCAP, but their UAs are not reported here.

The RSDP sample was originally intended to consist of matched pairs of houses, with one member of each pair constructed to the MCS and the other to current code as defined by the Council. These two groups are referred to as the MCS and Control groups, respectively. However, the slower than expected rate of construction of the RSDP houses required metering of unpaired MCS houses to increase the metered sample size. To compensate for a reduced number of Control houses, the Post-78 houses (a subset of the Residential Base sample) are used in conjunction with the RSDP Control houses to evaluate the MCS and compare the Council's current code definition with actual current practice. The size of each group of houses from the samples by climate zone is shown in the Table 3.1.

As the table shows, 86 single-family detached RSDP houses are in the ELCAP data base. The conclusions in this report assume that the ELCAP Residential Base sample is reasonably representative of the regional existing single- family housing stock with electric space heat, and that the RSDP houses are typical of the full RSDP sample. Four Post-78 sites and thirteen other Residential Base sites are excluded from the following analyses because UAs could not be calculated for these sites due to erroneous or missing inspection data. The number of sites actually analyzed are included in Table 3.1 where they differ from the total available.

TABLE 3.1. ELCAP Residential Sample and Analyzed Sample Sizes (Single Family, Detached, Electric Space Heat)

Climate Zone	RSDP		Residential Base		
	MCS	Control	Post-78	Other Base	Total
Zone 1	34	14	17	159 (147)[a]	224 (212)
Zone 2	20	3	14 (11)	65 (63)	102 (97)
Zone 3	9	6	8	17	41
Total	63	23	40 (36)	241 (228)	367 (350)

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[a] Parentheses indicate number actually analyzed, where different.

The average UAs for each group of houses are given in Table 3.2 (standard deviations are given in parentheses). Because the MCS houses are an average of 22% larger than the Control houses, the floor area and the UA per unit floor area for each sample are also given. The MCS houses have the smallest average UA per unit floor area, as expected.

TABLE 3.2. Average UA and Floor Area by Sample[a]

Sample	UA, Btu/hr-°F	Floor Area, ft²	UA/Floor Area, Btu/hr-°F-ft²
MCS	298 (84)	1833 (612)	0.17 (0.04)
Control	326 (68)	1499 (360)	0.22 (0.04)
Post-78 Base	487 (205)	1970 (551)	0.25 (0.08)
Other Base	562 (225)	1754 (722)	0.35 (0.15)

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[a] Standard deviations are in parentheses.

4.0 ELCAP RESIDENTIAL REGIONAL SAMPLE HEAT LOSS CHARACTERISTICS

The two dimensions of the ELCAP sample of single-family detached residential buildings explored in this analysis of regional heat loss characteristics are vintage and climate zone. Vintage categories are used that roughly group houses into decades (Pre-1960, 1960-1969, 1970-1978, and Post-1978), as defined by the date of construction reported in the ELCAP onsite inspection data (1978 is roughly the date during which a number of energy codes were adopted in the region). The climate zones used are those defined by the Council and described in Section 2.0.

4.1 DISTRIBUTION OF THE REGIONAL SAMPLE

The sample used for analyzing the heat loss characteristics consists of all 264 sites from the Residential Base sample with available heat loss characteristics data from the onsite inspections. The 63 MCS houses are included in the vintage comparisons to illustrate the degree to which the MCS stock exceeds the general trend of increasing insulation levels over time. The MCS houses are not included in the climate zone comparisons because they are not representative of the current regional housing stock. The 327 houses are distributed among the vintage categories and climate zones as shown in Table 4.1. Nearly 70% of the sample was constructed during two of the vintage categories, pre-1960 and 1970-1978. The climate zone data indicates that nearly two-thirds of the sample is located in Zone 1.

The small number of houses in Zones 2 and 3, while generally representative of the distribution of the population in the region, are problematic for the analysis. When the sample is partitioned by both vintage and climate zone as shown in Table 4.2, the small cell sizes associated with these climate zones tends to obscure rather than enhance general trends. Therefore, the analysis of the heat loss characteristics that follows focuses on the sample partitioned by vintage and climate zone independently. In general, Table 4.2 indicates that the distribution of vintage in the sample does vary somewhat with climate zone. Compared with the average for all zones (dominated by the Zone 1 sample size), there are slightly more Pre-1960 houses and correspondingly fewer 1960-1969 houses in Zone 2. Zone 3 shows a higher fraction of

TABLE 4.1. Residential Single-Family House Cell Populations for ELCAP Regional Sample by Vintage and Climate Zone

Vintage	N	%
Pre-60	93	35%
1960-1969	46	17%
1970-1978	89	34%
Post-1978	36	14%
MCS	63	NA
Total	327	100%

Climate Zone	N	%
Zone 1	164	62%
Zone 2	74	28%
Zone 3	26	10%
Subtotal	264	100%
MCS (not used)	63	

Post-1978 houses and relatively fewer Pre-1960 houses. Thus, the Zone 2 houses appear slightly older, and the Zone 3 houses noticeably newer, than the Zone 1 houses and the sample as a whole.

TABLE 4.2. Residential Single-Family House Cell Populations for ELCAP Regional Sample by Vintage and Climate Zone Combined

	Climate Zone 1		Climate Zone 2		Climate Zone 3		All Zones	
Vintage	N	%	N	%	N	%	N	%
Pre-60	57	35%	31	42%	5	19%	93	35%
1960-1969	34	21%	8	11%	4	15%	46	17%
1970-1978	56	34%	24	32%	9	35%	89	34%
Post-1978	17	10%	11	15%	8	31%	36	14%
TOTAL (BASE)	164	62%	74	28%	26	10%	264	100%
MCS	63	54%	20	32%	9	14%	63	100%
TOTAL	198	61%	94	29%	35	11%	327	100%

4.2 BUILDING-LEVEL HEAT LOSS CHARACTERISTICS

The distribution of overall UAs in the sample is shown as a function of vintage in the box plot[a] in Figure 4.1. Note that these UAs exclude infiltration. A marked decrease in overall residential UA over time is exhibited, although the change in the medians for the 1970-1978 and Post-1978 vintages is small, indicating a possible levelling off of the trend toward lower heat loss potential. The lower extent of the interquartile range of

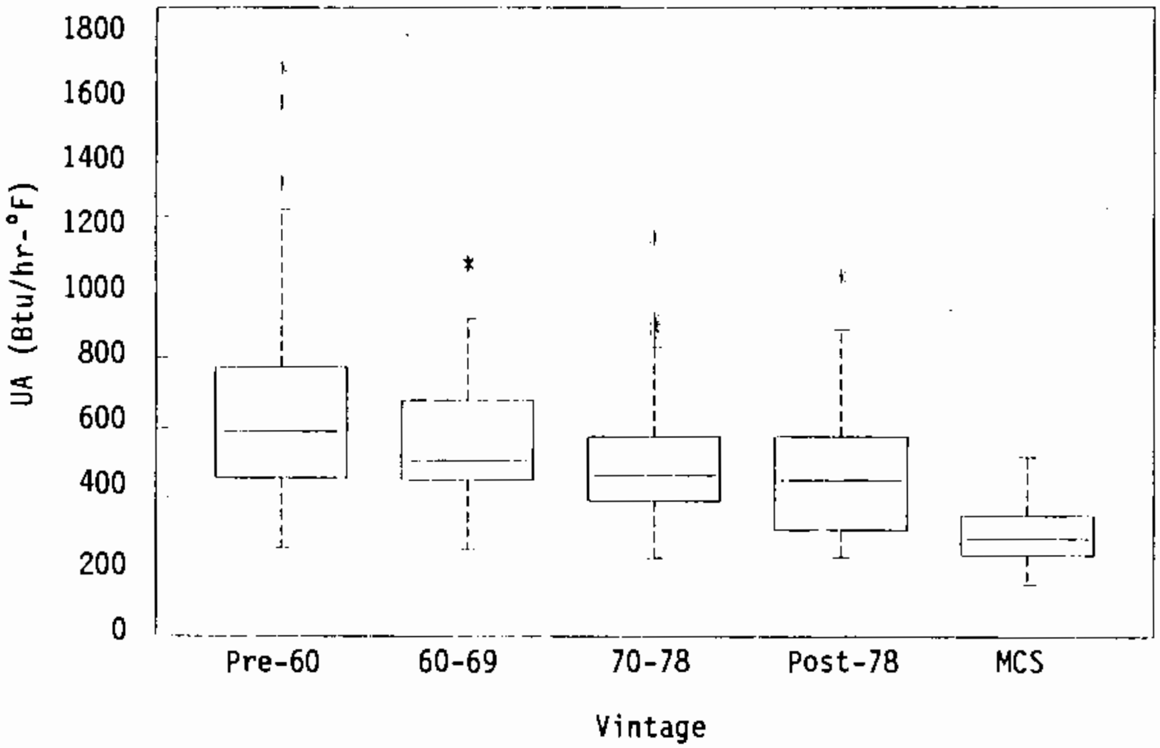

FIGURE 4.1. UA by Vintage

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[a] In this and all the box plots that follow, the box indicates the extent of the interquartile range, and the median is shown as the horizontal line splitting the box. Thus, 50% of the data lies within the horizontal range of each box, 25% above and 25% below the median. The "whiskers" above and below the boxes indicate the range of the remainder of the data up to a limit of 1.5 times the interquartile range. Data points outside the limit, if any, are indicated by the detached points beyond the whiskers.

the Post-78 houses is lower than the 1970-1978 vintage, however, indicating that many of the Post-1978 homes have substantially lower heat loss potential. The MCS houses have much lower heat loss potential than the Post-78 houses, showing the largest incremental drop in UA of any successive vintages and clearly exceeding the general trend over time. Means and medians for the distributions are shown in Table 4.3.

In Figure 4.2 the distribution of overall UAs is shown by climate zone. The median UAs for the three zones are all roughly comparable, although the upper extent of the range is less for Zone 3 than the two warmer zones, as indicated by the distribution and the lower mean UA for this zone. This may reflect increased penetration of insulation retrofits in the Zone 3 residences compared to the warmer zones, although it could also be a result of the newer sample of houses in Zone 3.

As noted previously, the overall UA for a house is the sum of the component UAs, which in turn are the product of the area and total U-value for the components. Thus the UA is a function of house size and shape as well as insulation levels. The relative contribution of size and shape and insulation levels to the distribution of overall UAs is explored by separating

TABLE 4.3. Mean and Median Total Building UAs for ELCAP Residences By Vintage and Climate Zone

	Bldg UAs-Btu/hr.°F			Bldg UAs-Btu/hr.°F	
Vintage	Mean	Median	Climate Zone	Mean	Median
Pre-1960	639	590	1	558	496
1960-1969	573	506	2	579	507
1970-1978	496	464	3	487	495
Post-1978	475	450			
MCS	298	283			

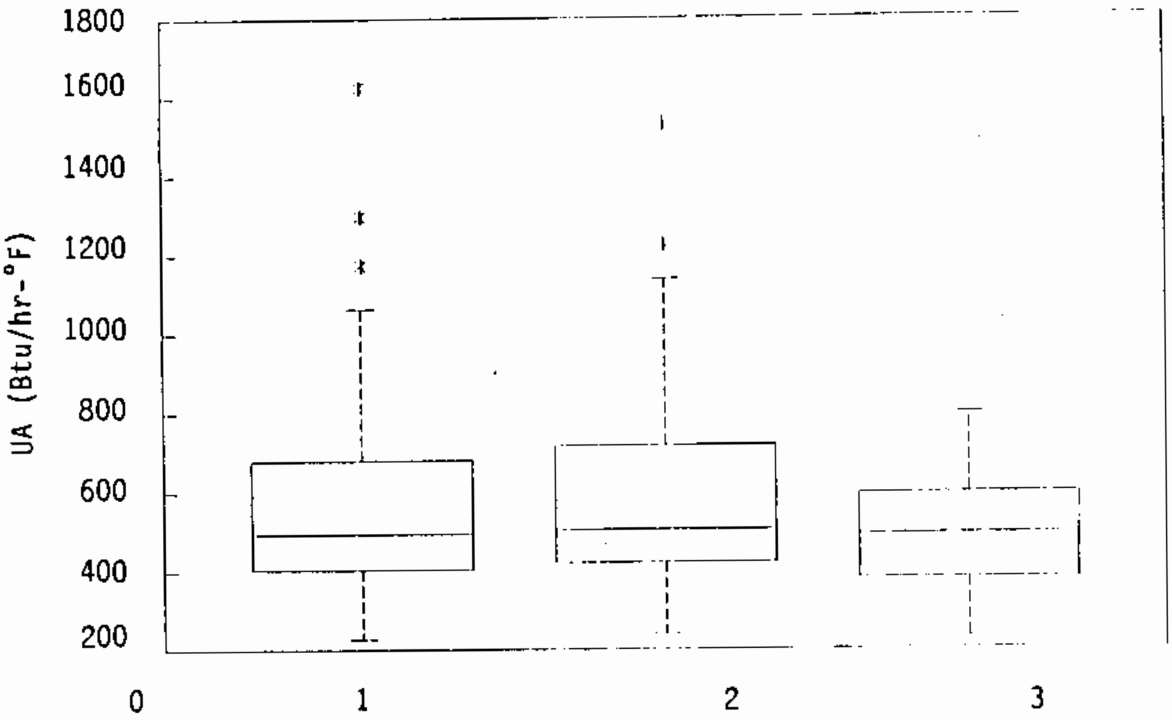

FIGURE 4.2. UA by Climate Zone

the two effects. The distributions of occupied floor space as a function of vintage and climate zone are shown in Figures 4.3 and 4.4, and the means and medians of the distributions are given in Table 4.4. There is a clear trend towards increasing median house size over time, although the sample does not include any very large Post-1978 houses. The MCS houses are somewhat smaller than the Post-1978 houses. The data also indicate a trend towards larger houses in colder climates. Floor space is not directly proportional to the surface area of all building components, however, notably the wall and window areas. To examine whether house shape influences the overall UAs, the distribution of the ratio of total surface area to occupied floor area is

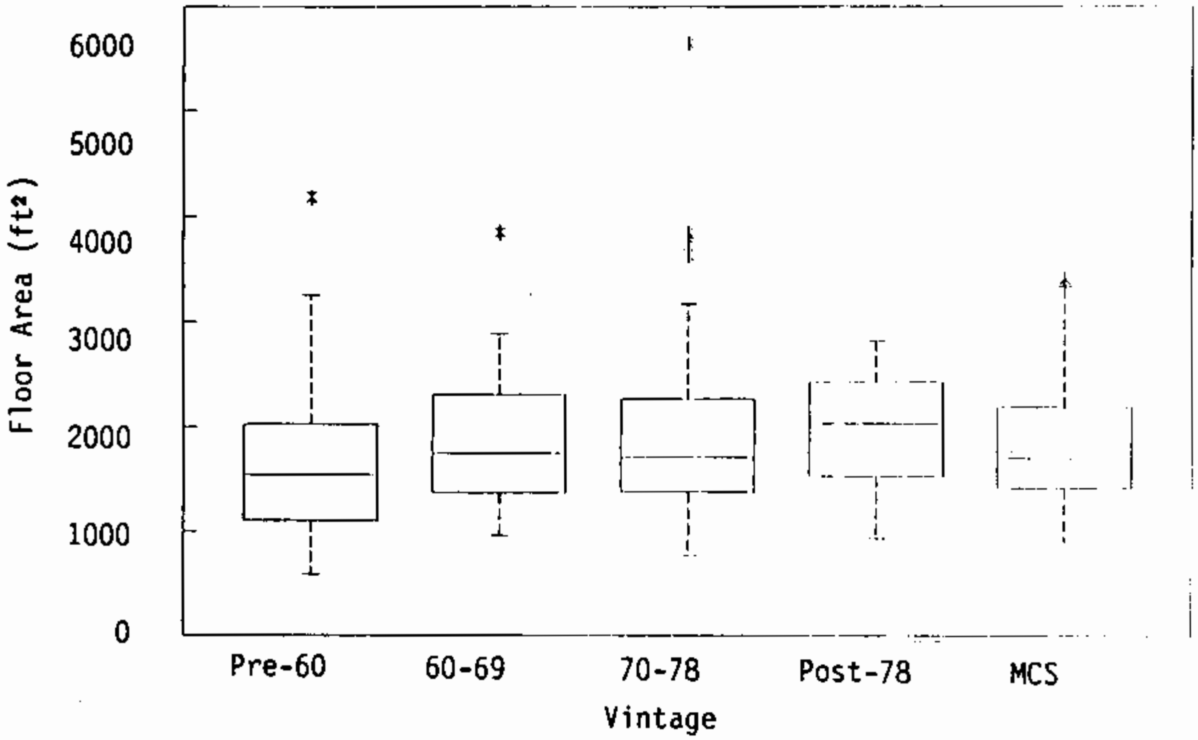

FIGURE 4.3. Occupied Floor Space by Vintage

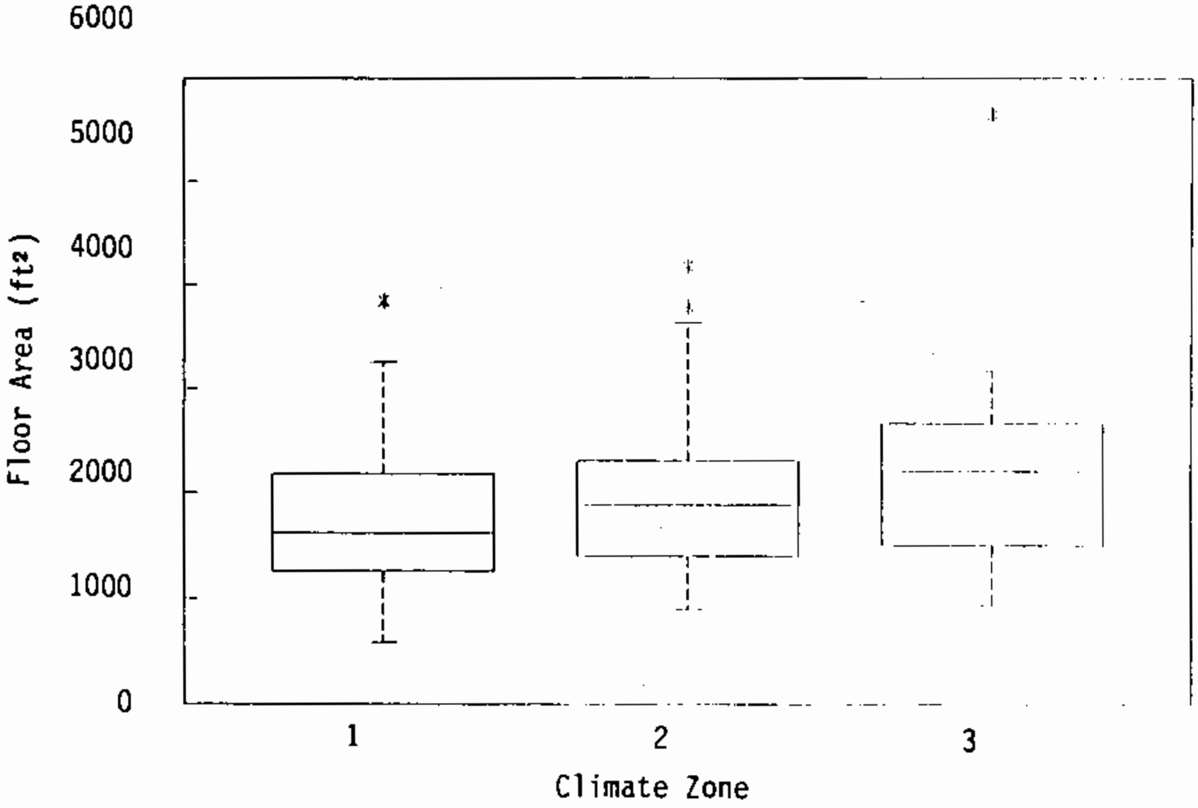

FIGURE 4.4. Occupied Floor Space by Climate Zone

TABLE 4.4. Mean and Median Occupied Floor Space for ELCAP Residences by Vintage and Climate Zone

Vintage	Floor Space, ft² Mean	Median	Climate Zone	Floor Space, ft² Mean	Median
Pre-1960	1646	1527	1	1707	1604
1960-1969	1861	1744	2	1919	1877
1970-1978	1916	1704	3	2226	2200
Post-1978	1962	2033			
MCS	1833	1700			

plotted by vintage in Figure 4.5 and by climate zone in Figure 4.6. This ratio is indicative of "compactness" and is effectively a surface/volume ratio for the houses, given that ceiling heights are relatively uniform. Note that "compactness" results from designs with larger floor areas, using multiple stories stacked vertically and minimal use of "wings" in the floor plans. The surface area used here is the total exterior surface area of the heated space, including slabs, basement floors, and walls, when present. Means and medians for the sample are shown in Table 4.5.

There is not much effect of vintage on surface/floor area ratio in Figure 4.5, except for the MCS houses which are more compact in the aggregate. The surface/floor area ratio does vary strongly with climate zone as shown in Figure 4.6. The distribution of house geometry in the sample suggests that, although the sampled houses in colder climates tend to be larger, this is at least partially offset by the their decreased surface/floor area ratio. A subsequent discussion of foundation types indicates an increasing predominance of heated basements in colder climate zones, and this may be an important cause of the observed distribution.

TABLE 4.5. Mean and Median Surface Area/Occupied Floor Space Ratio for ELCAP Regional Sample by Vintage and Climate Zone

Vintage	Mean	Median	Climate Zone	Mean	Median
Pre-1960	2.68	2.73	1	2.74	2.91
1960-1969	.72	2.87	2	2.57	2.60
1970-1978	2.62	2.79	3	2.34	2.19
Post-1978	2.62	2.72			
MCS	2.56	2.53			

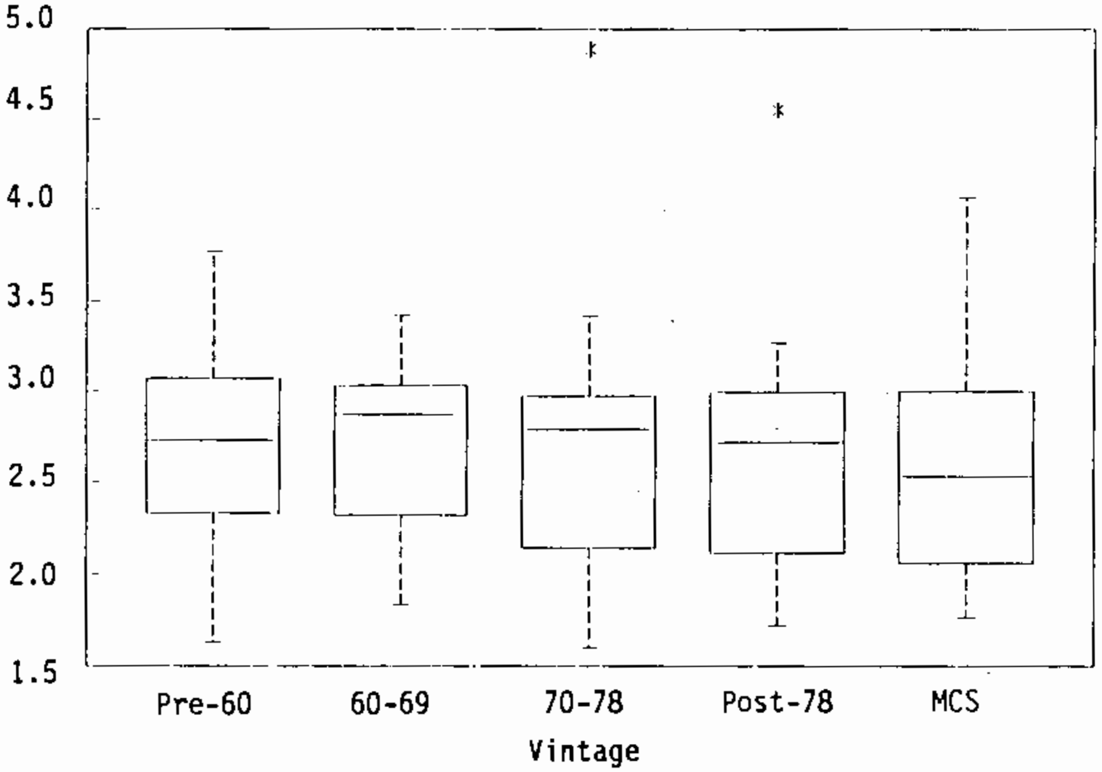

FIGURE 4.5. Surface Area/Floor Area Ratio by Vintage

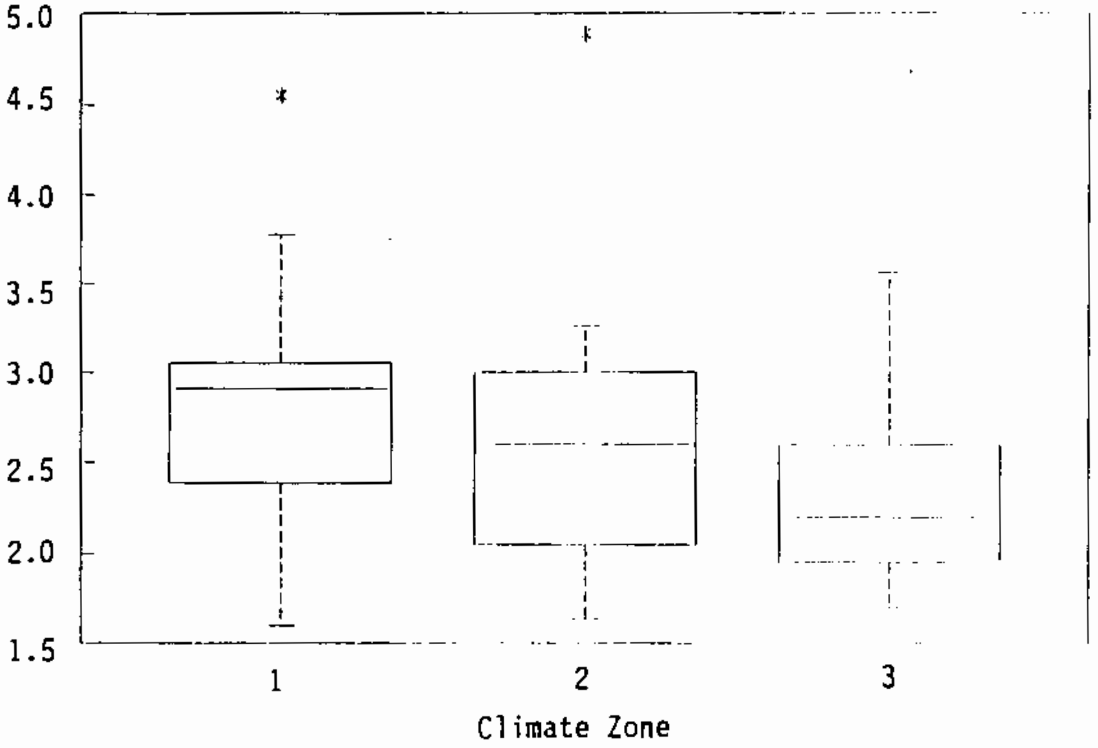

FIGURE 4.6. Surface Area/Floor Area Ratio by Vintage

The average level of insulation for a house can be evaluated using an effective R-value (R_o), calculated by dividing the surface area by the UA. The effective R-value is equivalent to a uniform R-value over the entire surface area of the house that reproduces the overall UA (literally the inverse of the average of the area-weighted component U-values). The distribution of effective R-value by vintage, illustrated in Figure 4.7, shows a steady increase in median effective R-values over time. The insulation level of the MCS houses clearly exceeds this trend. The distribution of effective R-value by climate zone is shown in Figure 4.8. Insulation levels appear to increase sharply in Zone 3, but Zone 1 and Zone 2 appear to have similar insulation levels. The means and medians for these distributions are given in Table 4.6. Note that the mean effective R-value in Zone 3 is even higher than the median (10.67 vs. 9.78), a result of the long tail of the distribution on the high end of the range.

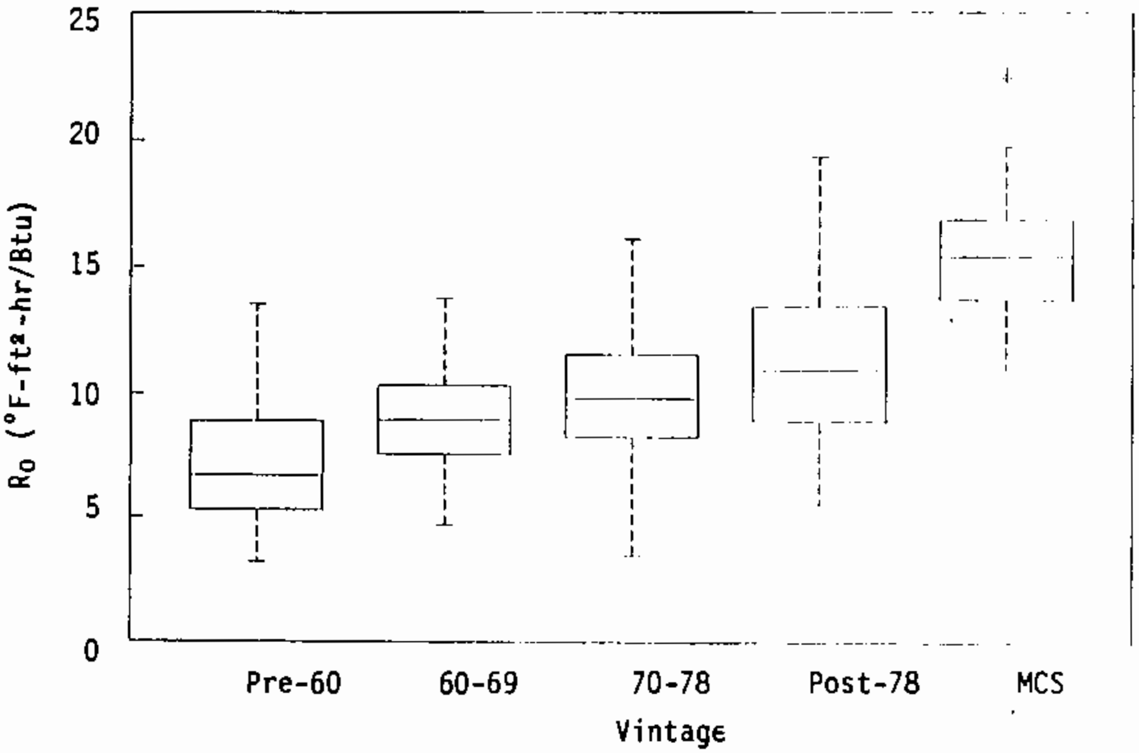

FIGURE 4.7. Total Effective R-Value by Vintage

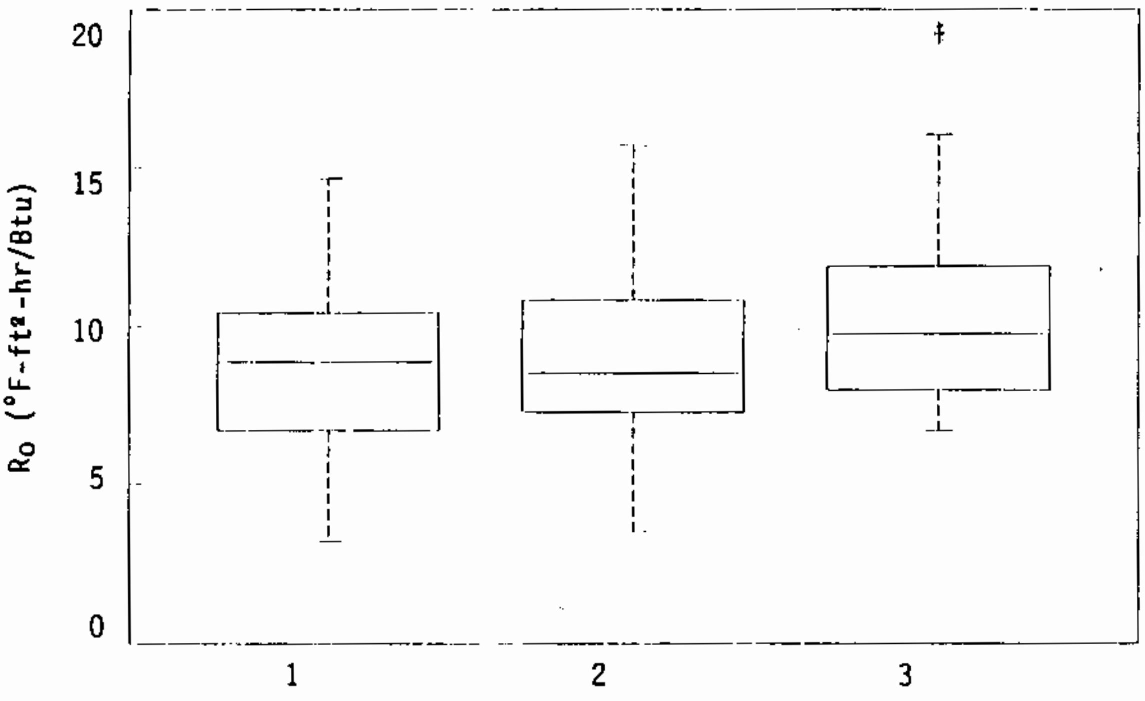

FIGURE 4.8. Total Effective R-Value by Climate Zone

One potential source of bias in the effective R-value distributions for the sample is the distribution of foundation types in the region. There are four foundation types classified in the ELCAP residential inspection data: heated basements, unheated basements, slabs, and crawlspaces. These may appear singly or in combination. The number of sites in the sample with each single and multiple foundation type are shown in Table 4.7. There is one site with an unclassified foundation type that is not used here.

TABLE 4.6. Mean and Median Total Effective R-values (°F-ft²-hr/Btu) for ELCAP Residences by Vintage and Climate Zone

Vintage	Mean	Median
Pre-1960	7.16	6.71
1960-1969	8.87	8.94
1970-1978	9.96	9.80
Post-1978	11.31	10.93
MCS	15.38	15.46

Climate Zone	Mean	Median
1	8.70	8.90
2	8.96	8.56
3	10.67	9.78

TABLE 4.7. Foundation Type Cell Populations for ELCAP Residences by Vintage and Climate Zone

	Vintage					Climate Zone			
	Pre-1960	1960-1969	1970-1978	Post-1978	MCS	Zone 1	Zone 2	Zone 3	All Houses
Single Types									
HB	15	8	21	6	11	18	32	11	61
UB	8	3	1	2	0	9	2	3	15
S	0	3	1	2	12	15	3	0	18
C	35	17	36	14	23	96	23	6	125
Multiple Types									
S/HB	1	0	7	4	6	6	3	3	18
C/HB	6	6	6	1	2	9	6	4	21
C/UB	14	1	1	1	2	10	5	2	19
C/S	6	5	11	3	5	17	7	1	30
C/S/HB	3	3	5	2	2	8	3	2	15
C/S/UB	5	0	0	0	0	2	3	0	5

Foundation Type Abbreviations:
HB = Heated Basement
UB = Unheated Basement
S = Slab
C = Crawlspace

The occurrence of each single foundation type for each vintage is shown in the histogram of Figure 4.9. Houses with multiple foundation types have more than one type of foundation used in their construction. It shows that the distribution of single foundation types over time has been relatively constant. The largest deviations occur for slab foundations, as there are no slab foundations in the Pre-1960 years, few slabs in the 1970-1978 years, and an excess of slabs for the MCS houses. There are also relatively few unheated basements in the 1970-1978 years and none in the MCS houses. The 1970-1978 houses show a slightly higher percentage of heated basements (24%) than the other vintages (18%). The percentage of each single foundation type for each climate zone is shown in Figure 4.10, which indicates that there is a steady decline in use of crawlspaces and a steady increase in use of heated

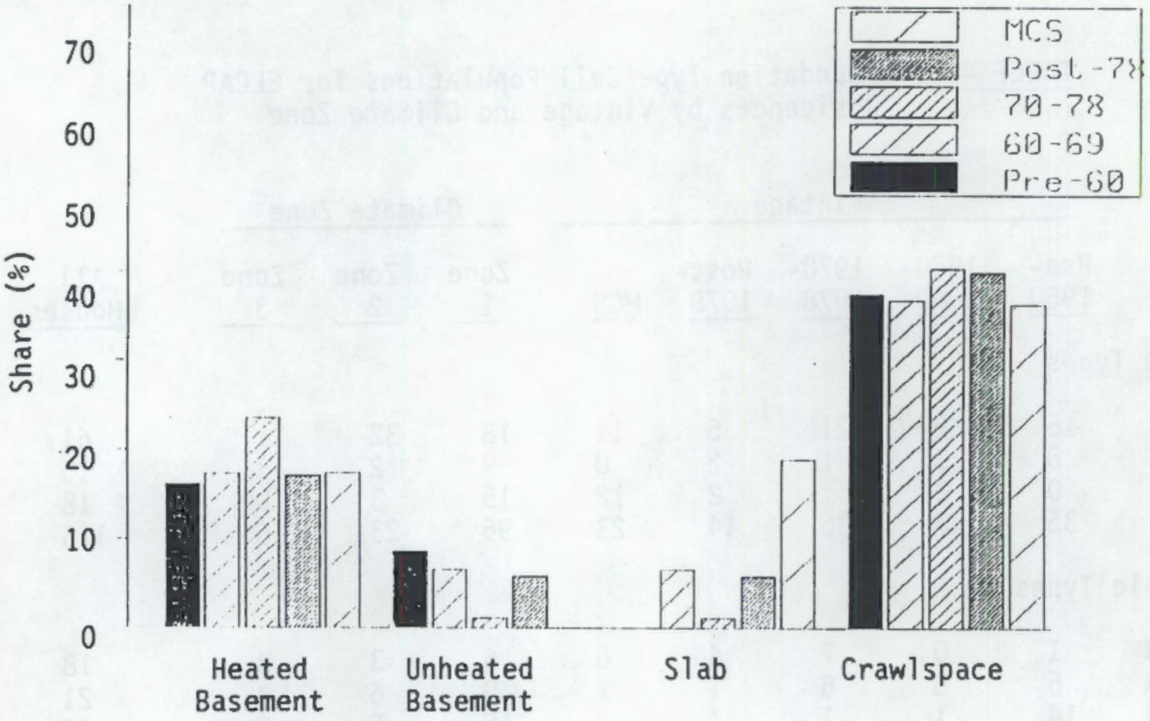

FIGURE 4.9. Share of Single Foundation Types by Vintage

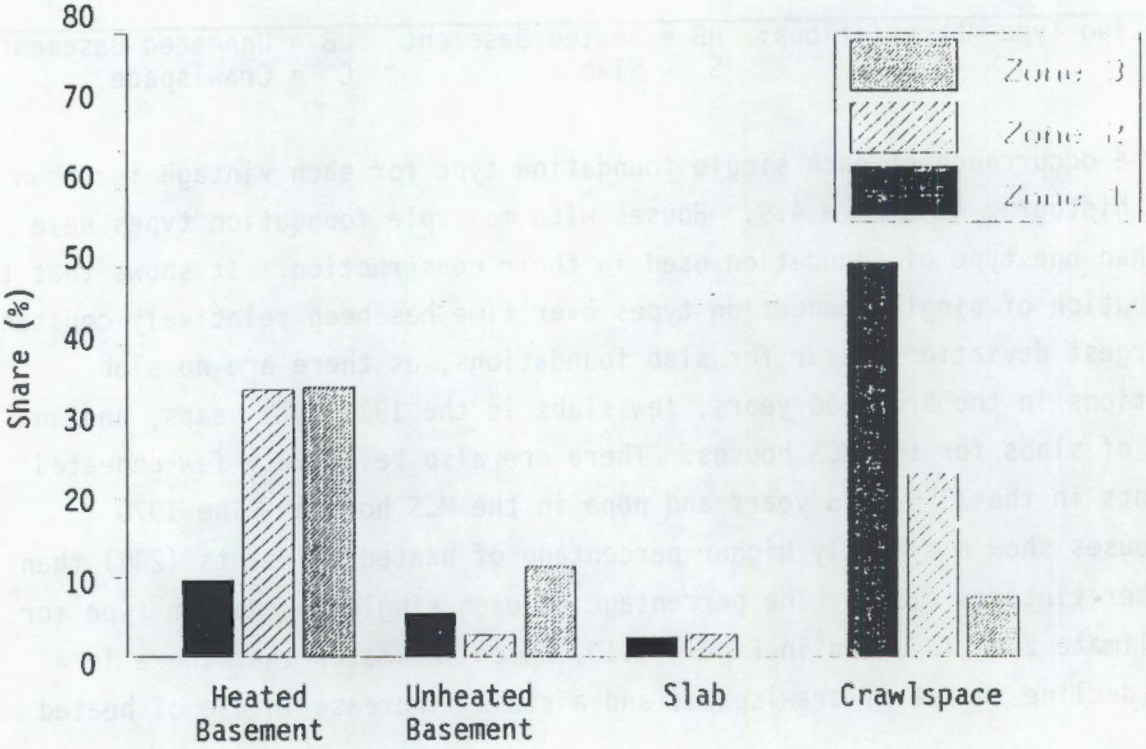

FIGURE 4.10. Share of Single Foundation Types by Climate Zone

basements in colder climate zones in the region. Crawlspaces are by far the predominant foundation in Zone 1, and heated basements predominate in Zone 3. Zone 2 appears to be intermediate in this trend. Slabs are relatively rare in the region, and none appear in the ELCAP houses located in the coldest climate zone.

Similar plots for the multiple foundation types are shown in Figures 4.11 and 4.12. The most outstanding feature of the multiple foundation types by vintage is the very high number of crawlspace/unheated basement combinations in the Pre-1960 vintage, and the absence of the crawlspace/slab/unheated basement combinations in any other vintage. This suggests that the presence of slabs may be indicative of rooms added in subsequent re-modeling of the

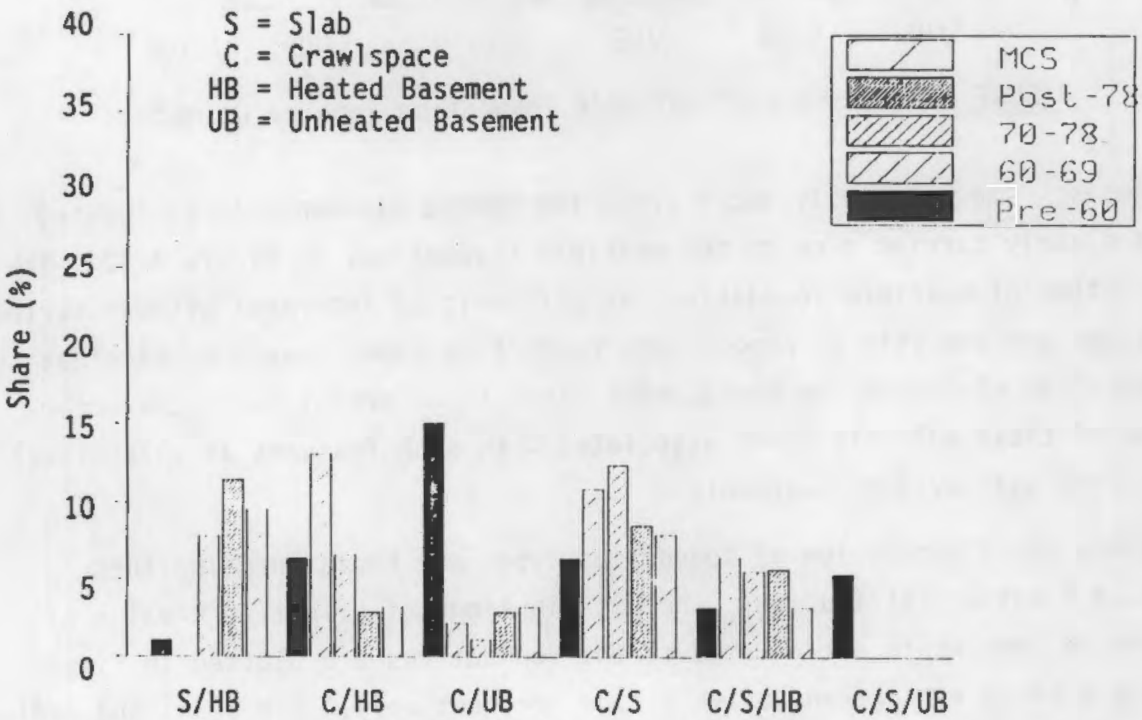

FIGURE 4.11. Share of Multiple Foundation Types by Vintage

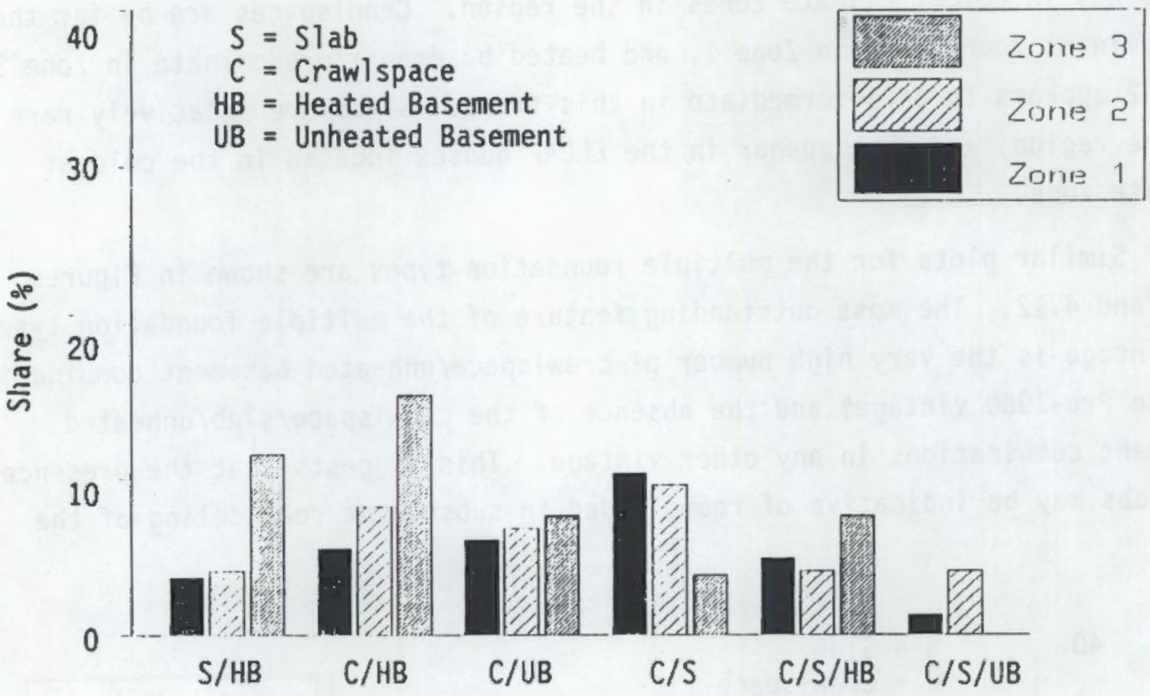

FIGURE 4.12. Share of Multiple Foundation Type by Climate

Zonehouses. The previously noted trend for heated basements to be located in Zone 3 clearly carries over to the multiple foundations in Figure 4.12. The distribution of multiple foundations is difficult to interpret without further definition and analysis of predominant foundation types (based on eliminating consideration of foundation types under minor floor areas) and a characterization of these multiple types associated with such features as split-level floor plans and daylight basements.

Since the distribution of foundation types may be influencing the effective R-value distributions, the distributions of effective R-value of only the UA components not related to the foundations are plotted in Figure 4.13 and 4.14 by vintage and climate zone, respectively. The means and medians are given in Table 4.8. Comparison on this basis indicates that the distribution of foundation types does not strongly influence the general trend to higher insulation levels in newer houses and houses in colder climates.

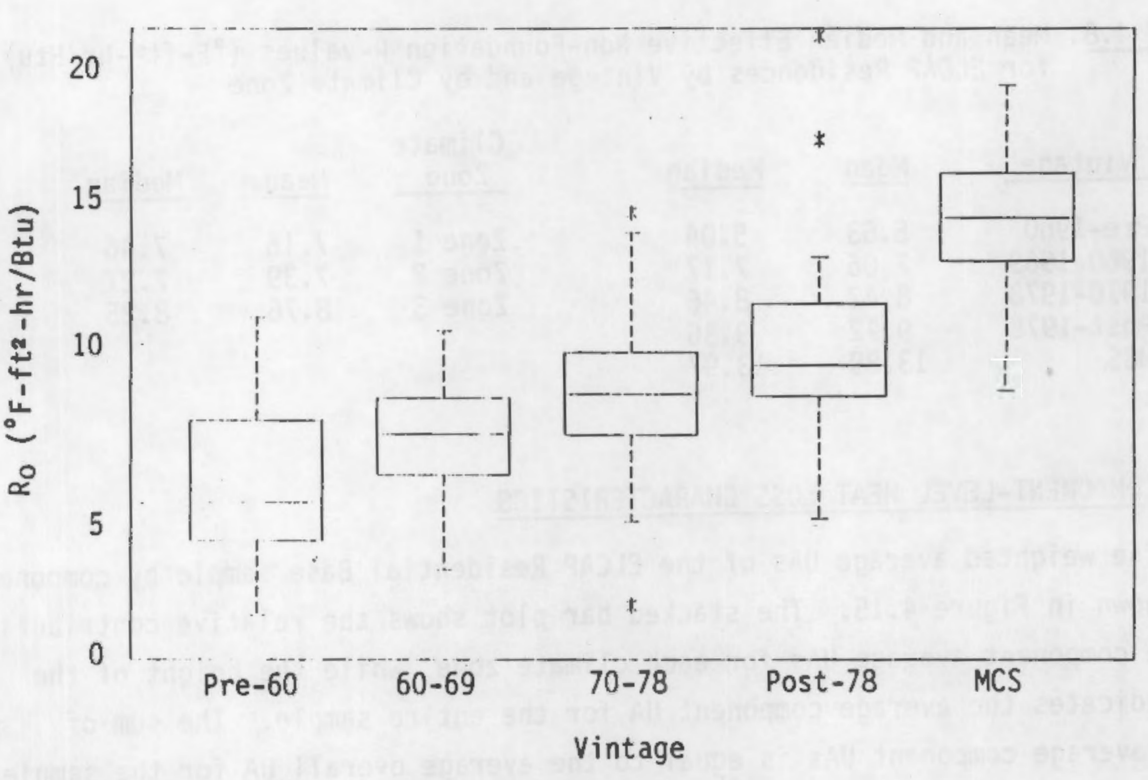

FIGURE 4.13. Effective Non-Foundation R-Value by Vintage

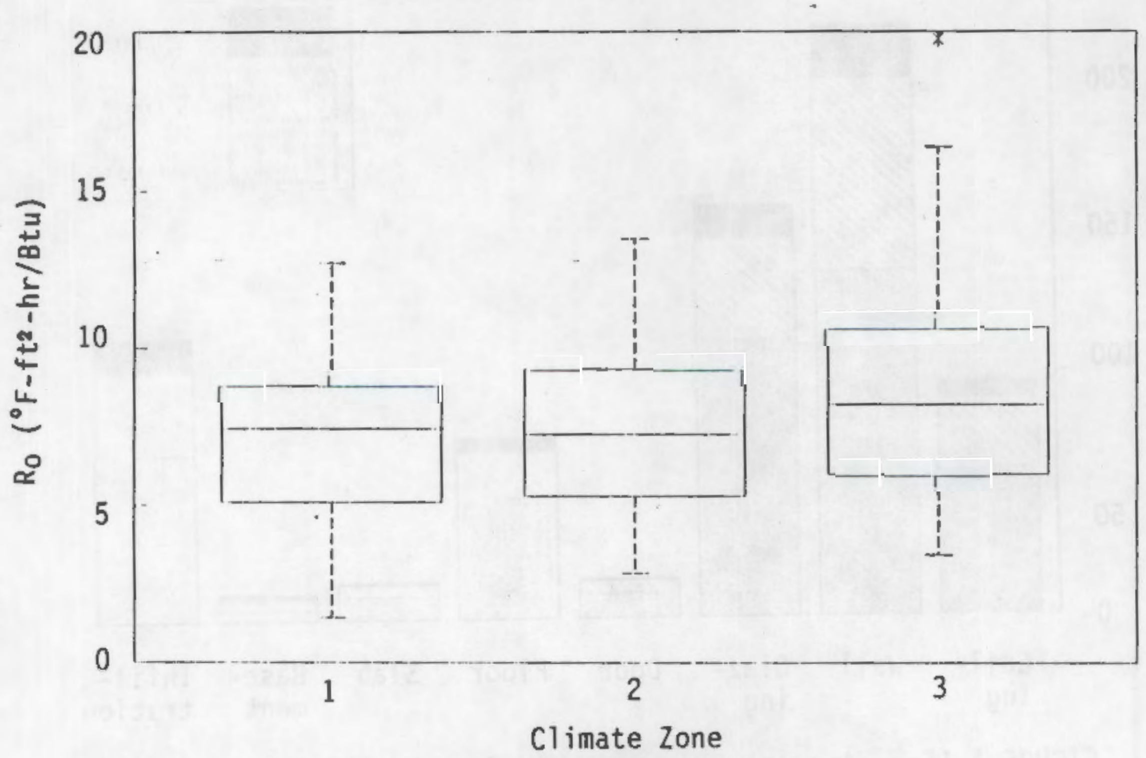

FIGURE 4.14. Effective Non-Foundation R-Value by Climate Zone

TABLE 4.8. Mean and Median Effective Non-Foundation R-values (°F-ft²-hr/Btu) for ELCAP Residences by Vintage and by Climate Zone

Vintage	Mean	Median	Climate Zone	Mean	Median
Pre-1960	5.63	5.04	Zone 1	7.16	7.46
1960-1969	7.06	7.17	Zone 2	7.39	7.27
1970-1978	8.42	8.46	Zone 3	8.76	8.25
Post-1978	9.72	9.36			
MCS	13.89	13.97			

4.3 COMPONENT-LEVEL HEAT LOSS CHARACTERISTICS

The weighted average UAs of the ELCAP Residential Base sample by component are shown in Figure 4.15. The stacked bar plot shows the relative contribution to the component average UAs for each climate zone, while the height of the bar indicates the average component UA for the entire sample. The sum of these average component UAs is equal to the average overall UA for the sample.

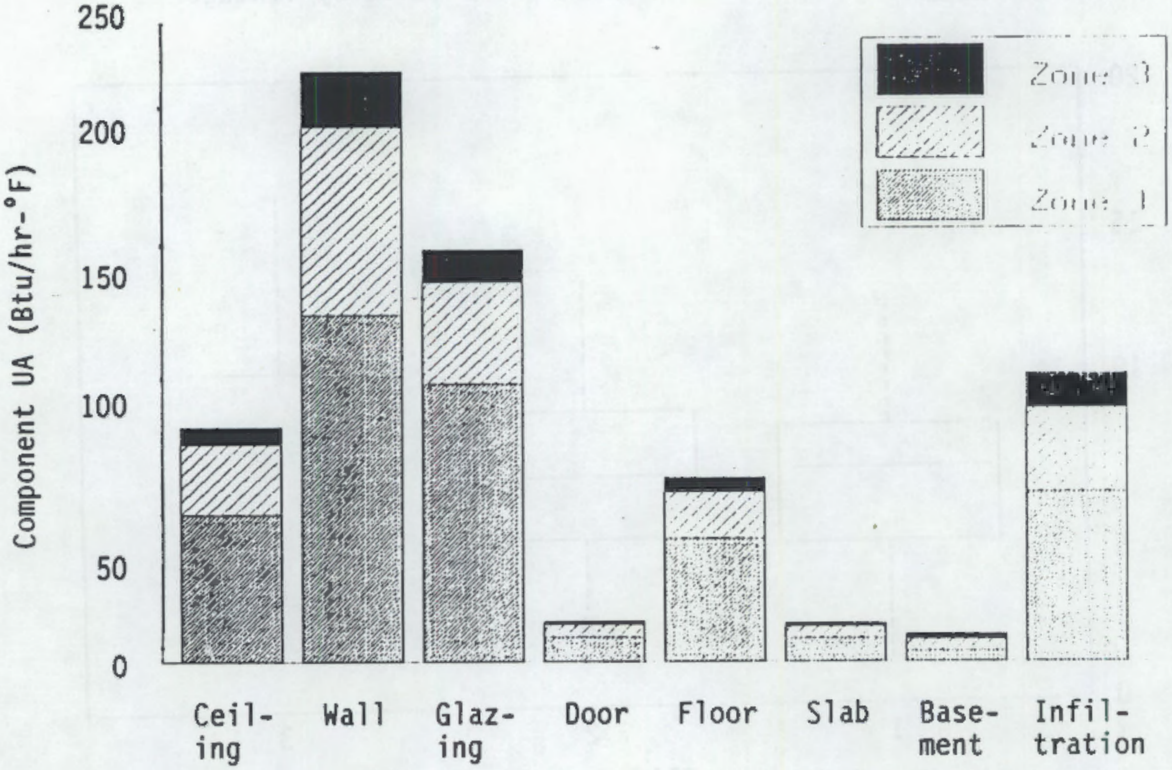

FIGURE 4.15. Average Component UAs for the ELCAP Residential Base Sample with Contributions by Climate Zone

An estimate of the infiltration component is also given here for the purpose of comparison, based on an assumed average of 0.4 air changes per hour, 8-foot ceiling heights, and sea-level air densities.

The data indicate that heat loss through walls forms the largest component of space heat in all climate zones, followed by glazing, infiltration, ceilings, and floors. The floors total includes floors over crawlspaces, unheated basements, and over other unheated areas such as garages. Doors, slabs, and basement floors are minor regional space heat loss components, principally because they comprise relatively small portions of the total surface area. Basement walls are included in the wall component, as a combination of underground walls and above-grade masonry walls in proportion to their depth below grade.

Figure 4.15 generally indicates the relative magnitude of heat loss potential for the various envelope components in residential buildings. The height of the bars does not literally indicate conservation potential, however, because factors such as current insulation levels and physical installation constraints affect the cost-effectiveness of increased insulation levels for the components. Inferences about the actual conservation potential for each component can be drawn from the examination of the distributions of effective component R-values in the discussion that follows.

4.3.1 Effects of Vintage

The distributions of effective component R-value for the sites by construction vintage are shown in Figures 4.16 through 4.21 for walls, ceilings, windows, floors, doors, and slabs, respectively. The means and medians of the distributions appear in Appendix D. The effective R-value for a component is calculated as the component surface area divided by its UA, as is the overall effective R-value in the previous section. The ceiling and wall components generally exhibit the trend of increasing insulation levels over time, as discussed in the previous section with regard to the distributions of overall and non-foundation effective R-values. The window, floor, door, and slab distributions are much less uniform.

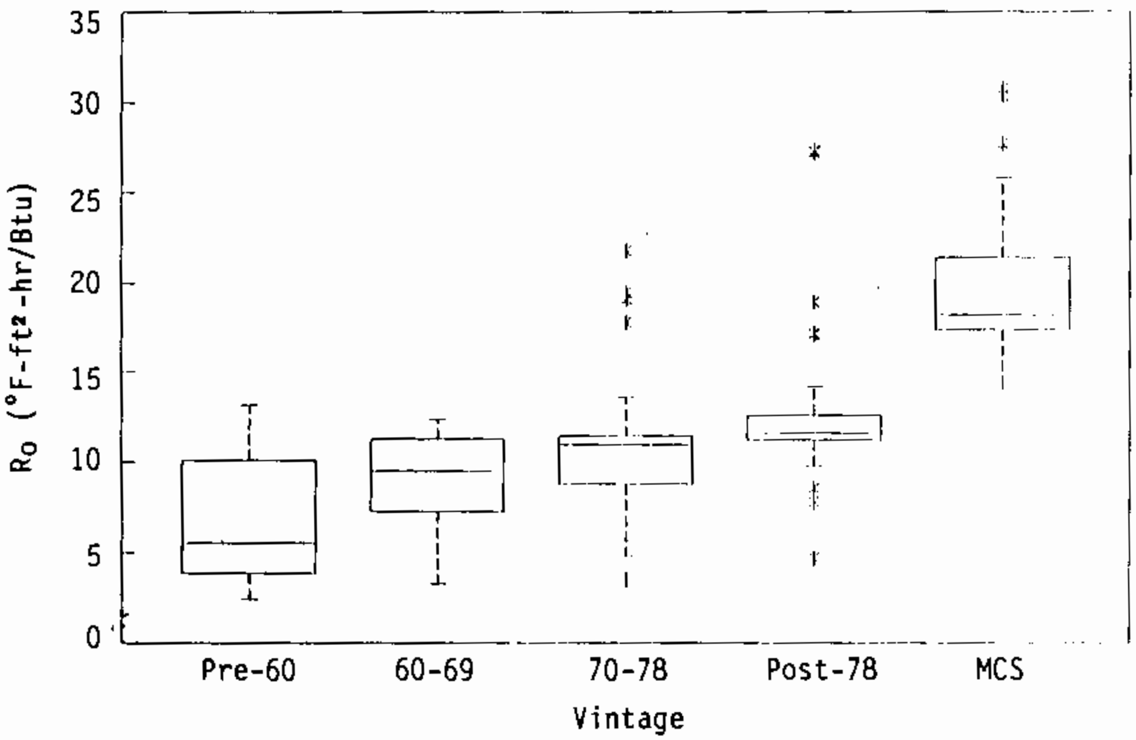

FIGURE 4.16. Effective Wall R-Value by Vintage

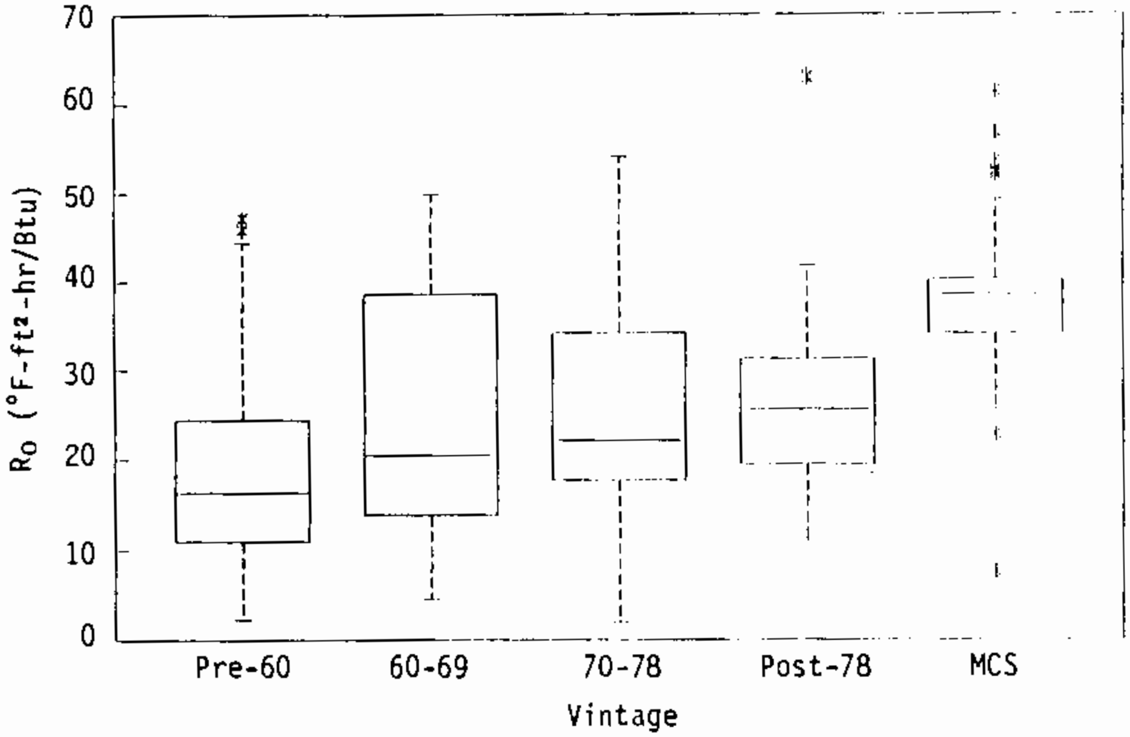

FIGURE 4.17. Effective Ceiling R-Value by Vintage

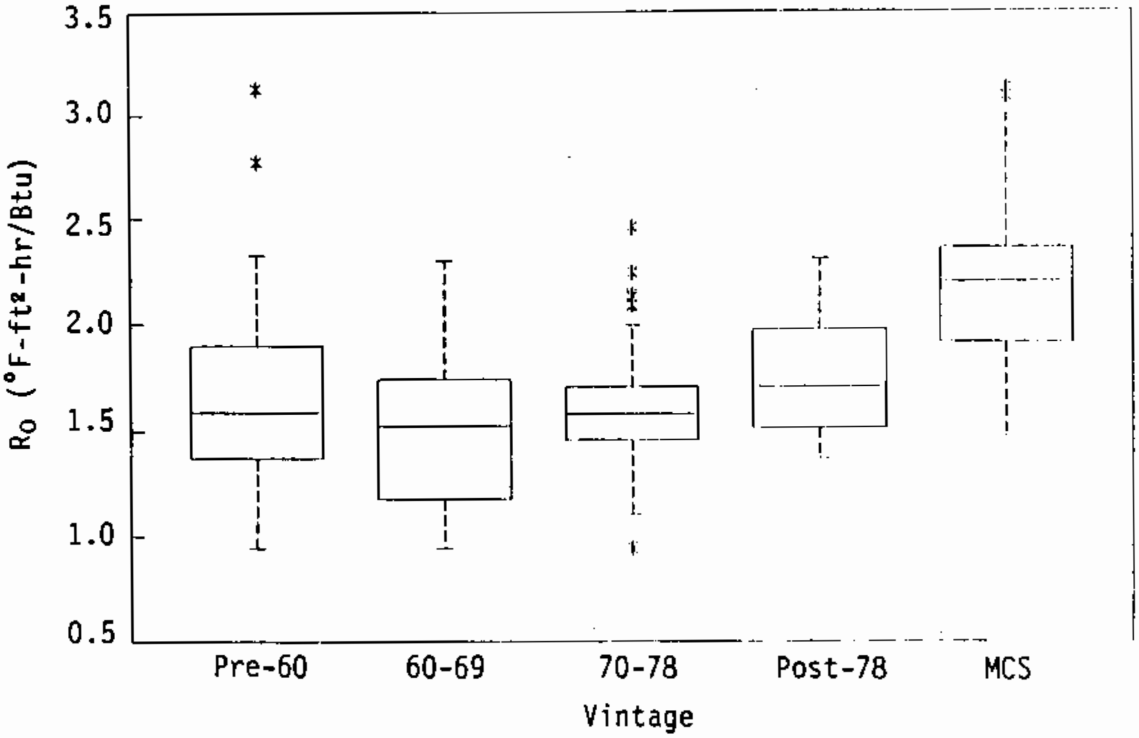

FIGURE 4.18. Effective Window R-Value by Vintage

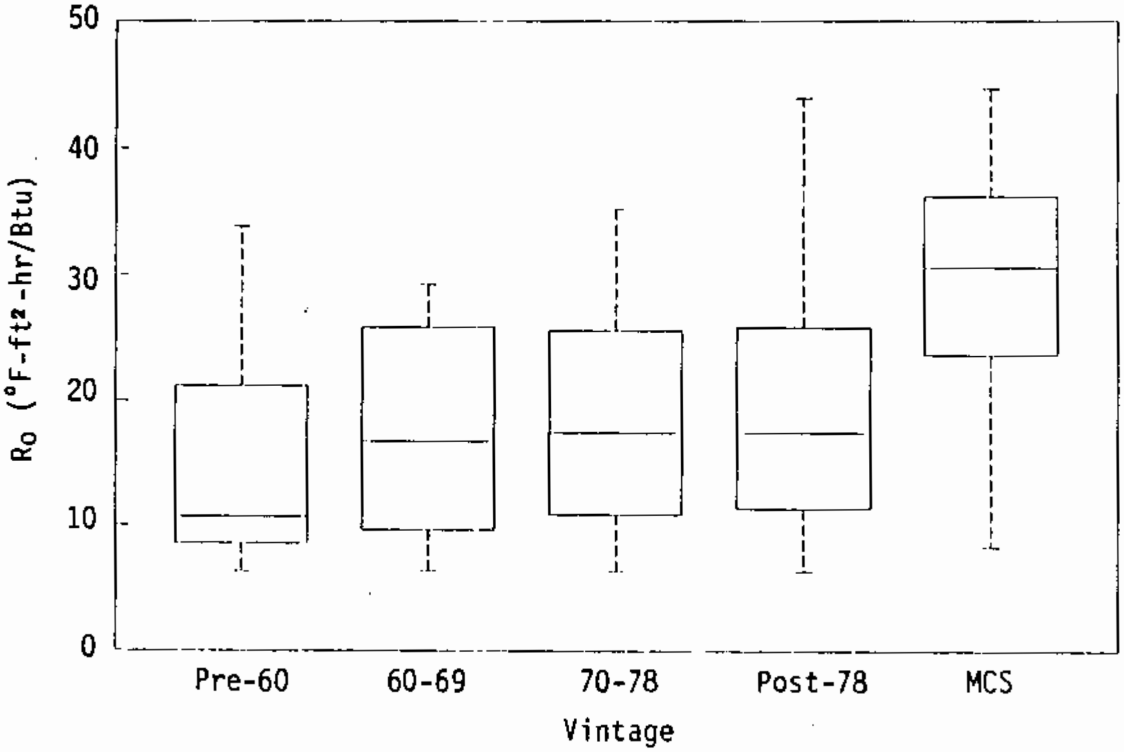

FIGURE 4.19. Effective Floor R-Value by Vintage

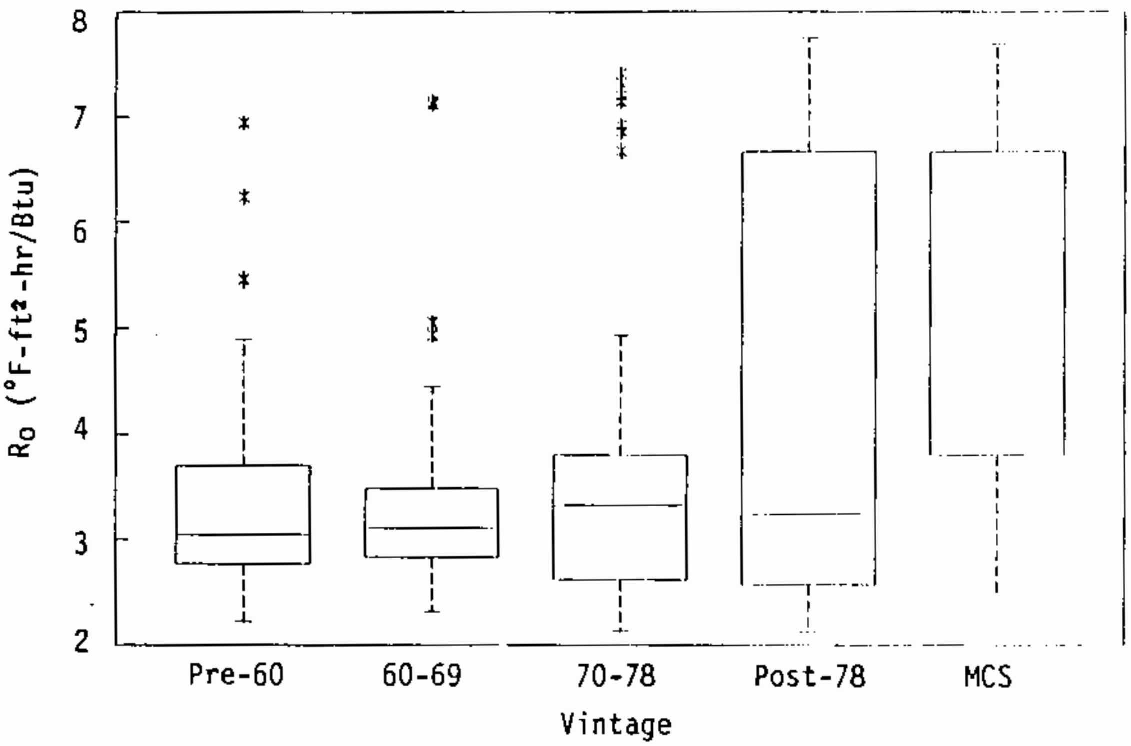

FIGURE 4.20. Effective Door R-Value by Vintage

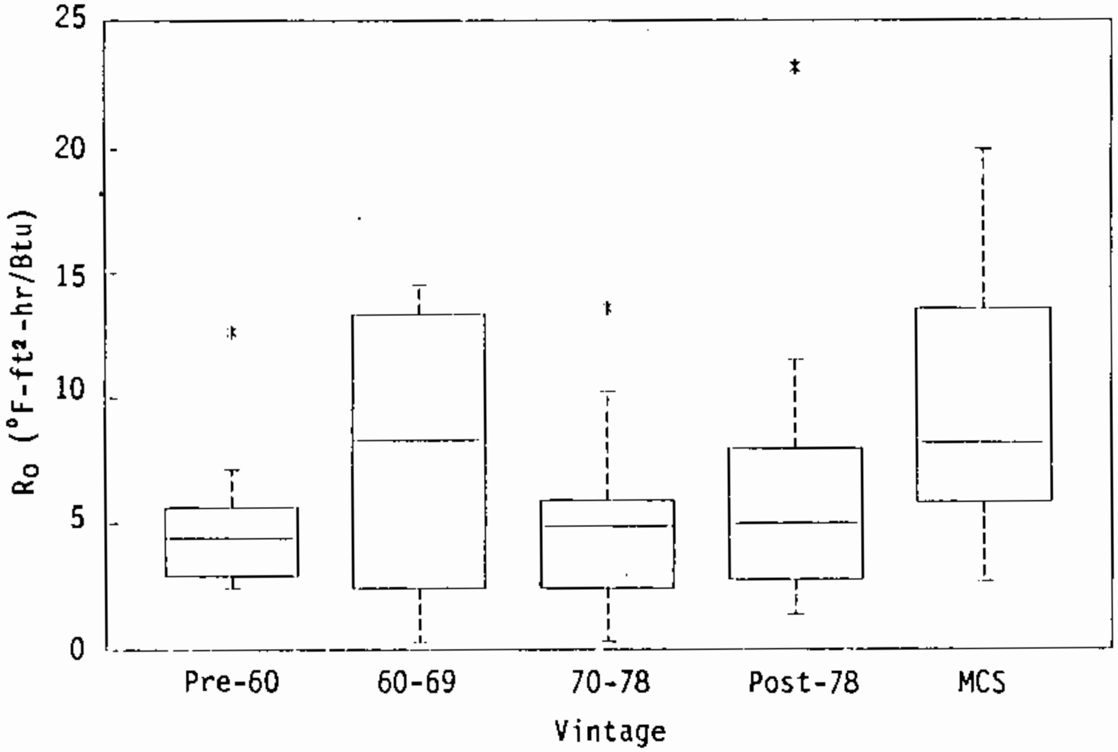

FIGURE 4.21. Effective Slab R-Value by Vintage

For all vintages except the MCS houses, wall insulation is seen to range down to uninsulated levels (approximately less than R-5), indicating the existence of uninsulated cavity and masonry wall construction at some sites. The median levels of effective wall R-value climb steadily with time, and the interquartile range also decreases dramatically. The median and mean R-values roughly double from Pre-1960 houses to Post-1978 houses. These results may be indicative of the effects of wall insulation retrofits, residential building energy codes, and increasing general awareness of energy issues by the residential design and construction industry. The frequency of low effective R-values is greatly reduced in the Post-1978 houses. The increased wall insulation levels in the MCS houses clearly exceed the trend.

The characteristics of the distribution of effective ceiling R-values with vintage is similar to that for walls, although the median and mean values increase by about 50% and the Pre-1960 distribution has a smaller interquartile range than subsequent vintages. The range of effective ceiling R-values is very large, ranging from R-3 to R-50 or more. This is probably an effect of insulation retrofits, given the relative ease of adding insulation in attics compared with walls.

The distribution of effective window R-values does not show a dramatic or steady increase of effective R-value over time as do walls and ceilings. The median and mean R-values are relatively constant in the range R-1.50 to R-1.65, until the slight increase to R-1.70 shown by the Post-1978 houses. These R-values roughly correspond to double glazing. The range of the distributions extends from R-0.94 (low quality single-glazed windows) to R-3.20 (high quality triple glazing). The best windows for each vintage through Post-1978 are about R-2.4 (low quality triple glazing), with the exception of two Pre-1960 houses that have very good windows. Windows with thicker air gaps (1/2 inch or more instead of 1/4 inch) and better sash materials (wood or thermal breaks instead of aluminum) are termed high quality here. Relatively few houses in the Post-78 vintage have single glazing compared to the earlier vintages. The use of use of higher quality windows than current practice in the MCS houses is evident.

Because windows inherently have lower R-values relative to other building components, it is important to examine distribution of window areas in the region. Figure 4.22 shows the distribution of window area as a percentage of the gross wall area. The window percentage ranges from about 5% to 25%, withthe median value around 13% for all vintages in the sample. It is interesting to note the relatively broader interquartile range for the Post-1978 houses. The MCS houses exhibit a narrower range, with a median of about 11%. Means and medians for the distributions are given in Table D.7 in Appendix D.

The patterns of the effective floor, door, and slab R-value distributions by vintage are similar to that of the windows. The general character is of relatively constant median effective R-values with vintage for these components. In all cases the MCS houses have higher insulation values than the region and the Post-1978 houses. Floor median R-values range from R-7

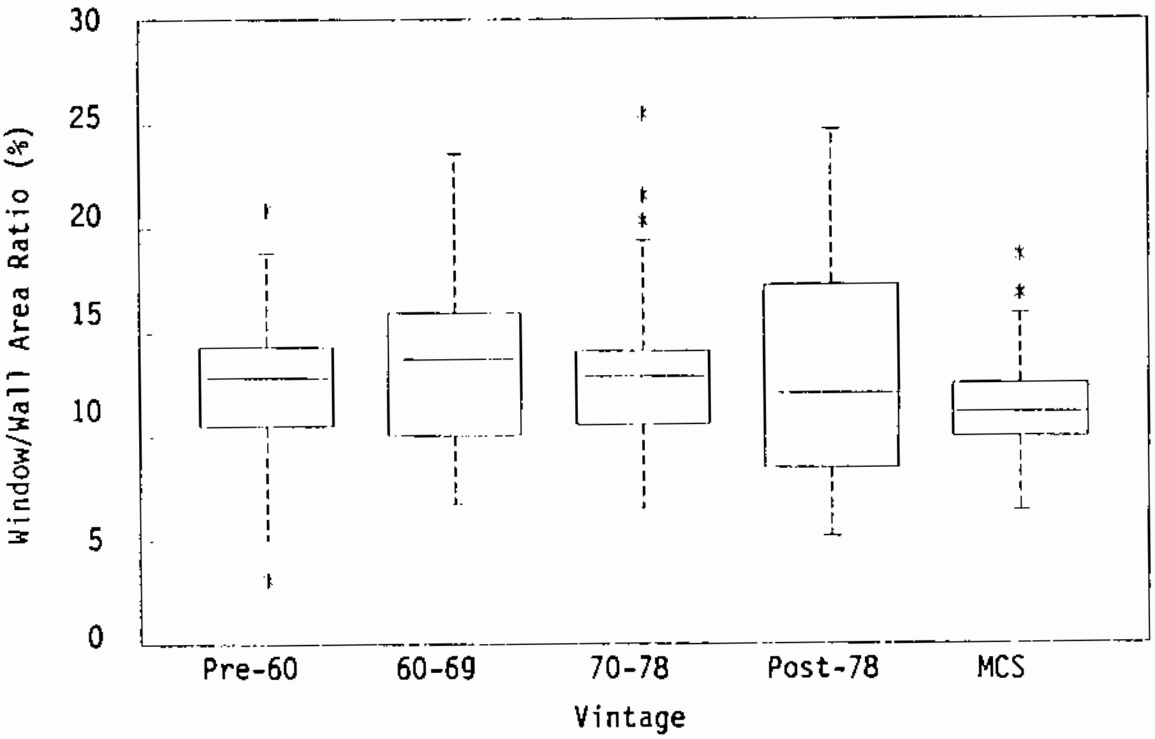

FIGURE 4.22. Window Area/Gross Wall Area Ratio by Vintage

(uninsulated) to R-45, with the medians around R-18. The distribution for Pre-1960 floors is exceptional to the general trend, with median and mean values of R-14 and R-11. Median effective door R-values through the Post-1978 vintage are roughly R-3.7, corresponding to solid wood doors with storm doors. Doors of R-6 and higher correspond to insulated doors, and are found in all vintages, most notably Post-1978. Median effective slab R-values are difficult to quantify due to the strong dependence of heat loss upon geometry. (Slab heat loss potential is calculated on the basis of perimeter instead of area, so the size and shape of the slab influence its effective R-value as defined here.)

4.3.2 Effects of Climate Zone

The distributions of effective component R-value for the sites by climate zone are shown in Figures 4.23 through 4.28 for windows, ceilings, doors, walls, floors, and slabs, respectively. The means and medians of the distributions appear in Appendix D. In contrast to the effect of vintage, the effective component R-values do not in general show strong dependence on climate zone except for windows. This indicates that the distribution of overall and non-foundation effective R-values is primarily influenced by vintage rather than climate. With the exception of windows, the newer vintages and basement foundation types in the Zone 3 sample may be the primary cause for higher effective R-values in that part of the region.

The distribution of effective window R-values by climate zone shows the strongest increase with climate coldness of any of the components. The median R-values rise from R-1.51 in Zone 1 (low quality double glazing), to R-1.73 in Zone 2 (high quality double glazing or storm windows), to R-1.95 in Zones 3 (very high quality double or low quality triple glazing). This may be indicative of the combined effects of retrofits, codes, and moisture condensation.

Due to the low R-value of windows relative to other building components, it is important to examine the distribution of window areas by climate zone. Figure 4.29 shows the distribution of window area as a percentage of the gross wall area. The median window percentage decreases from 13.6% in Zone 1 to about 11.5% in Zones 2 and 3. The high end of the range of window percentage is noticeably decreased in Zone 3. This can be interpreted as a climatically

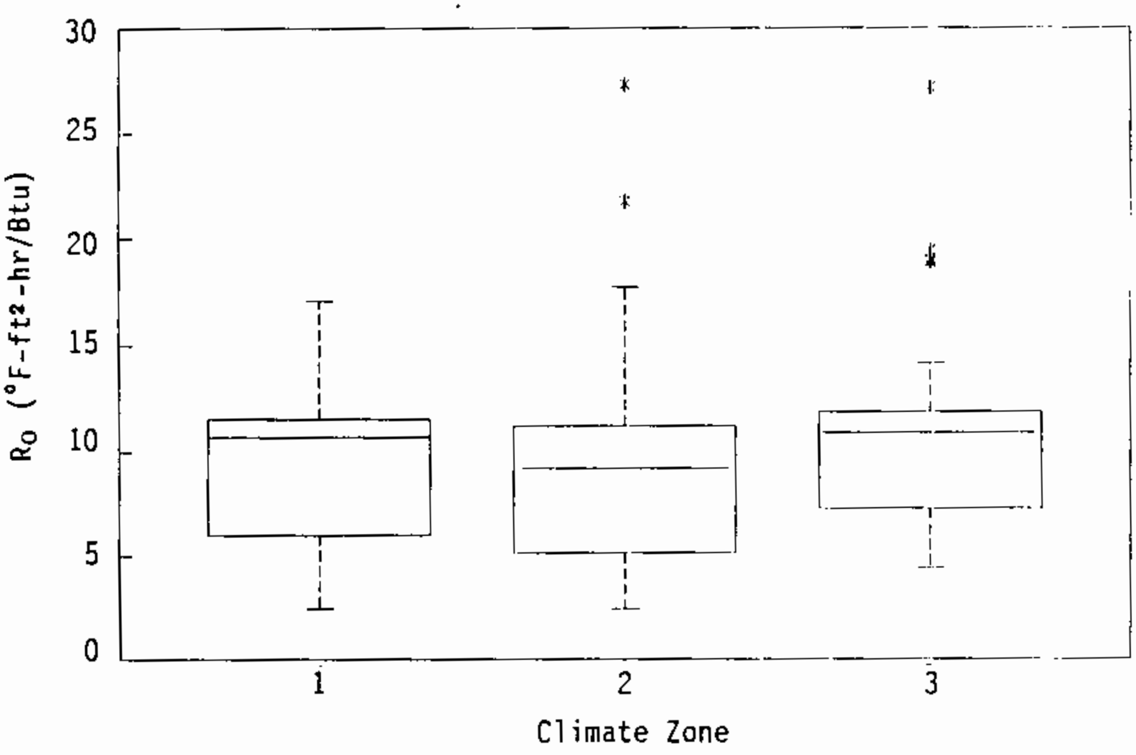

FIGURE 4.23. Effective Wall R-Value by Climate Zone

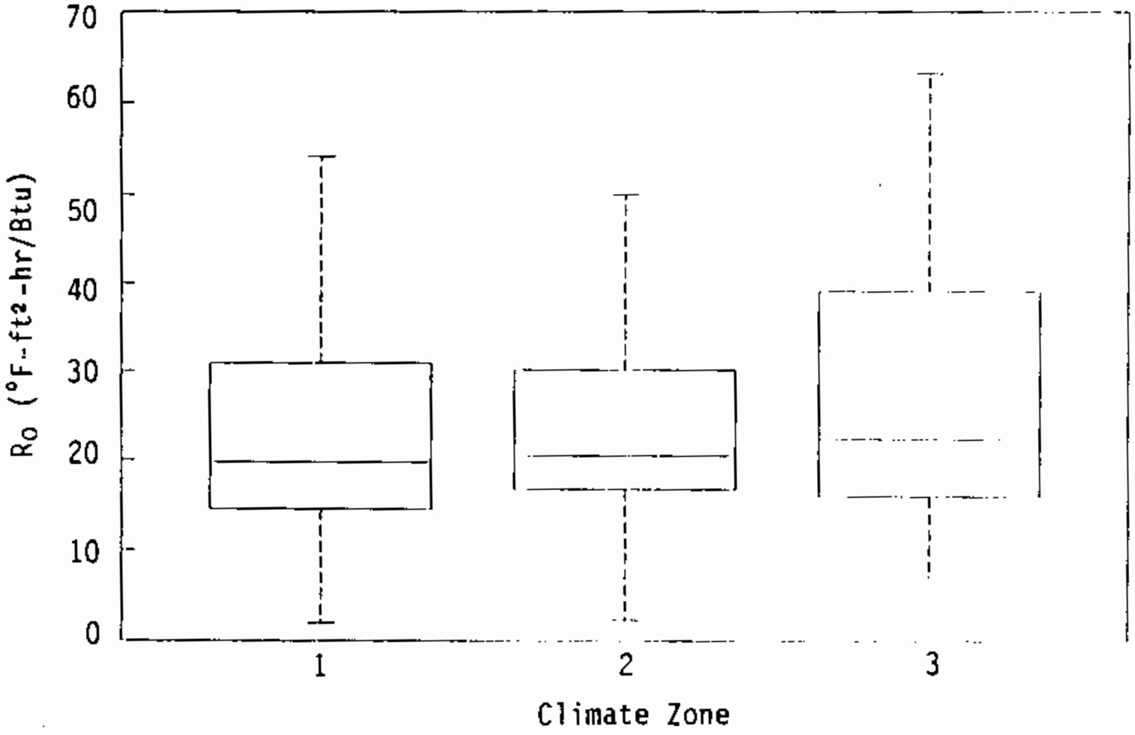

FIGURE 4.24. Effective Ceiling R-Value by Climate Zone

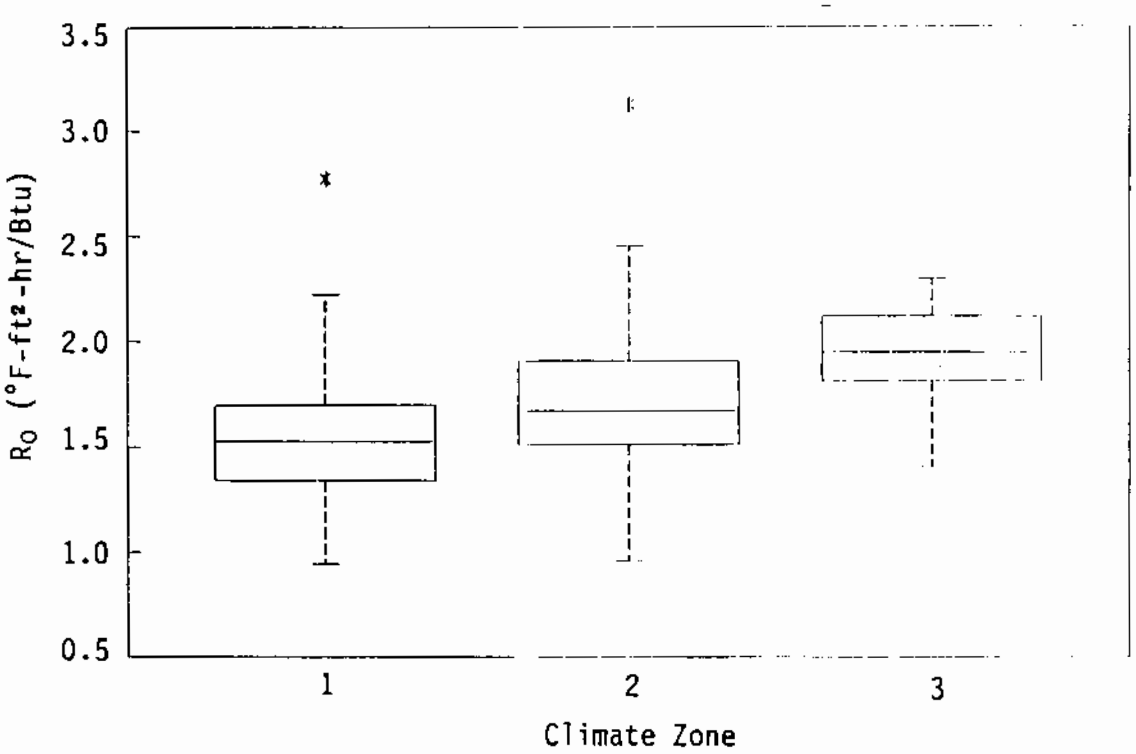

FIGURE 4.25. Effective Window R-Value by Climate Zone

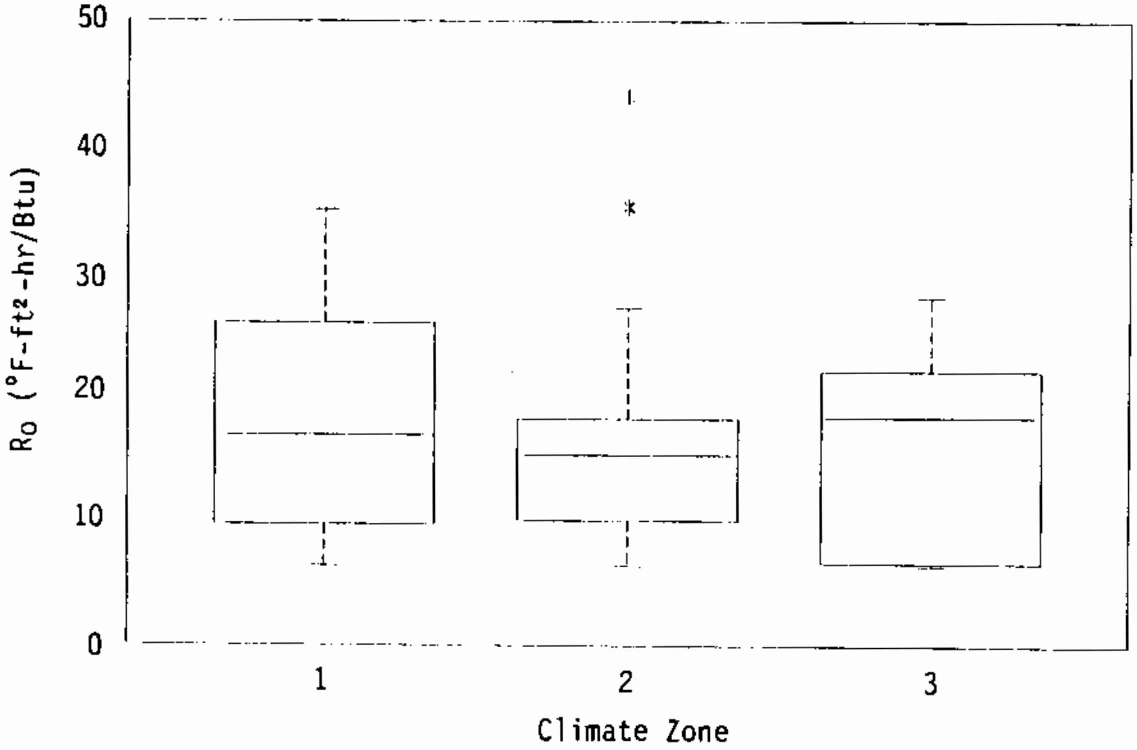

FIGURE 4.26. Effective Floor R-Value by Climate Zone

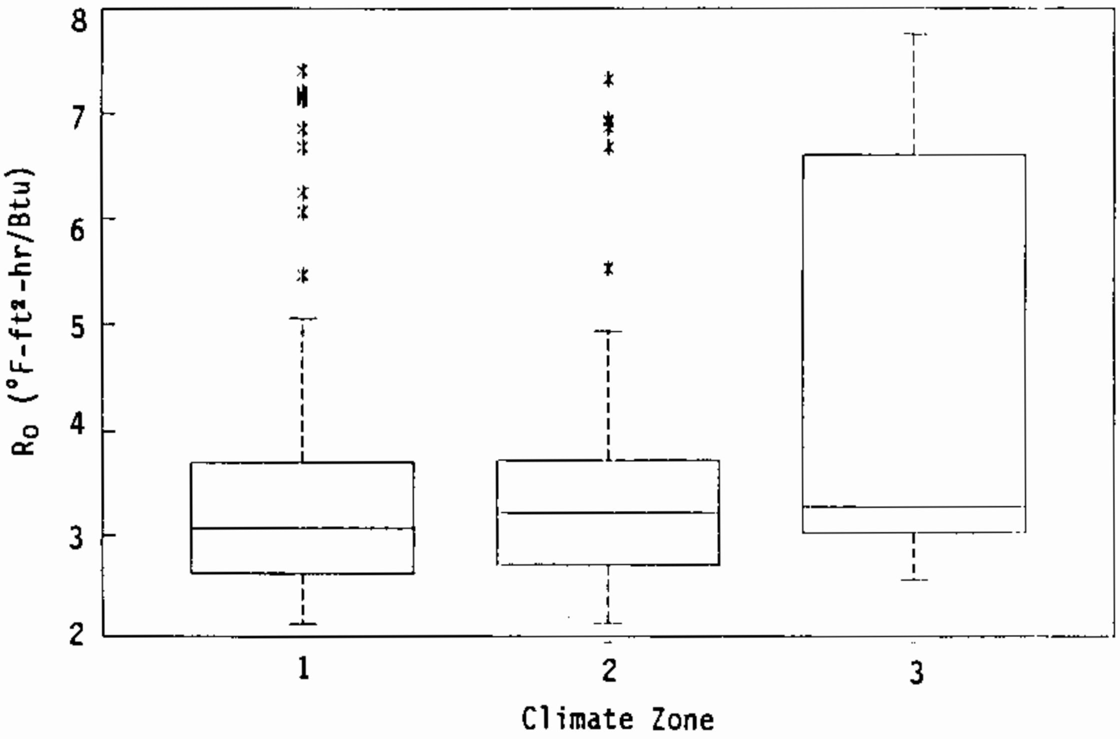

FIGURE 4.27. Effective Door R-Value by Climate Zone

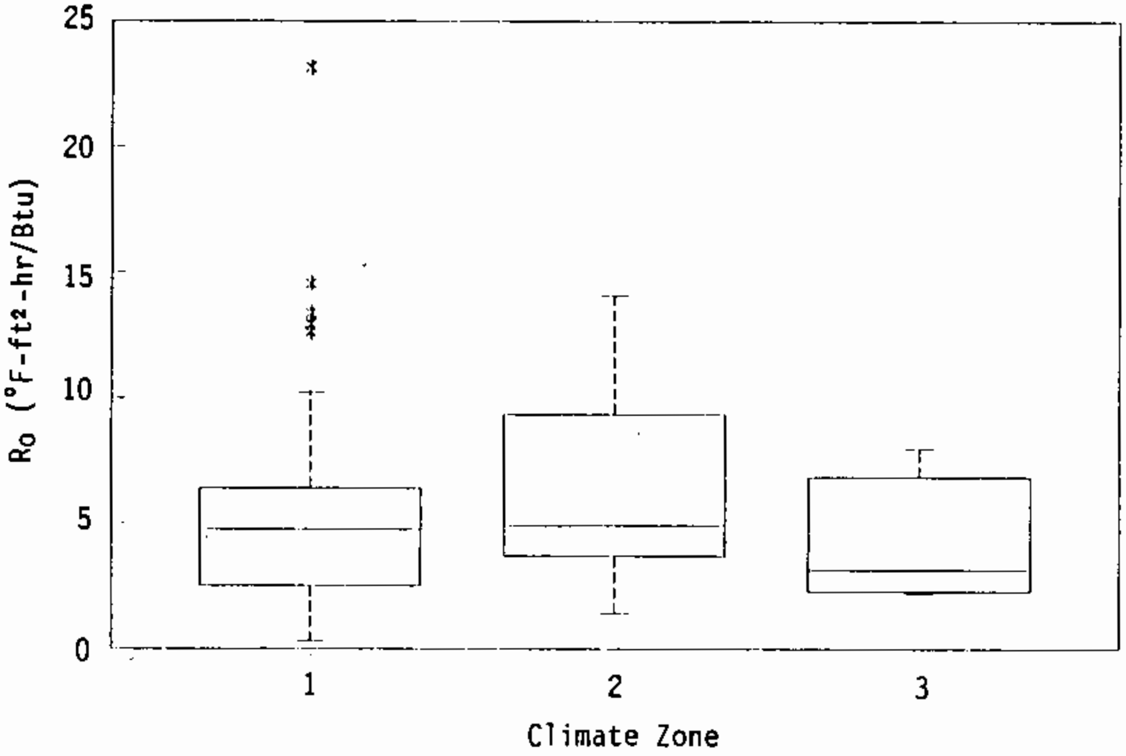

FIGURE 4.28. Effective Slab R-Value by Climate Zone

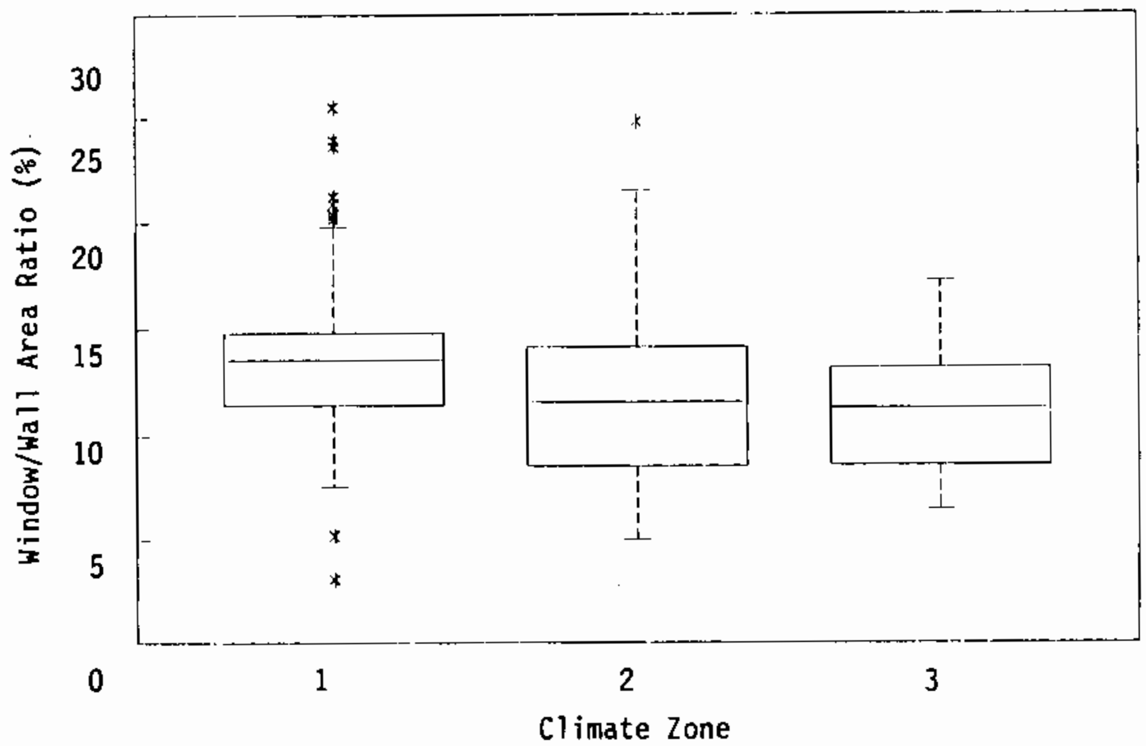

FIGURE 4.29. Window Area/Gross Wall Area Ratio by Climate Zone

induced design specification that large window areas are inappropriate in cold climates. The predominance of heated basements in colder climates probably has an effect as well. Thus, decreased window areas as well as increased window R-values contribute to the lower UAs in Zone 3. Means and medians for the distributions are given in Table D.7 in Appendix D.

The distributions of effective R-value by climate zone for ceilings and doors both show a slight, steady increase in R-value with coldness. Median R-values increase 13% and 7% from Zone 1 to Zone 3, for ceilings and doors, respectively. These are overshadowed by the magnitude of the vintage dependence for these components. The higher extent of the interquartile range for both of components is increased in Zone 3, indicating more diversity in utilization of high R-value components in this zone than in Zones 1 and 2.

The distributions of effective wall, floor, and slab R-values do not show a pattern with respect to climate zone. In Zone 2 both floors and walls have lower mean and median effective R-values than Zone 1, with higher values in Zone 3. The total variation in median R-value in both cases is about 10%. The distribution for effective slab R-values shows an opposite relationship, with the highest R-values in Zone 2 and the lowest in Zone 3. The variation here is larger, although the geometric influence on effective slab R-values makes interpretation difficult.

5.0 ELCAP RSDP SAMPLE HEAT LOSS CHARACTERISTICS

The analysis reported here focuses on a comparison of the actual insulation levels in the ELCAP RSDP houses with the levels targeted by the RSDP for single-family detached houses (most of the RSDP houses). The general question is whether the houses actually constructed by the ELCAP RSDP are sufficiently close to the characteristics targeted by the study to represent a valid source of data for study of the MCS. If the sample deviates significantly from the targets in the RSDP, then conclusions based on the analysis of ELCAP data can be called into question.

The target for the MCS houses is the Model Conservation Standard (Northwest Power Planning Council 1986a) defined by the Council. The target for the control houses is the current code, a description of the current building practices in the region developed by the Northwest Power Planning Council (1986b). The ELCAP inspection data is used to calculate the thermal integrity of the houses for comparison to the targeted UA levels. A separate set of builder-reported construction data was also collected for all of the RSDP MCS houses (Vine 1986). However, the ELCAP data is used in this analysis since it is significantly more detailed. Some variation from the exact target is to be expected. For instance, the MCS builders were allowed to exceed the MCS. There is some evidence that the MCS builders failed to meet the MCS criteria, as determined by the ELCAP residential inspection data.

A secondary goal of the analysis is a comparison of the MCS and Control buildings with the existing residences in the Northwest, as represented by the ELCAP sample. For the Control buildings, this permits a comparison with the houses they are designed to represent (the new houses in the region) to determine if they are a reasonable control group for the RSDP study of the impact of the MCS. This also permits a determination of the extent to which the conservation measures required by the MCS exceed those in the existing stock of buildings.

5.1 METHODOLOGY

The residential MCS and the Council's current code primarily define insulation values for the building envelope. That is, they specify insulation R-values and component U-values. Therefore, for each RSDP building there is a target UA specific to that building, which is a function of both the MCS or current code and that building's size and shape. Each building must be compared to its own target MCS or current code UA. In particular, the MCS and current code do not limit the area allowable for each component, except in sometimes specifying a limit on window area.

To permit this comparison, three types of UAs were calculated for each RSDP house. All UAs were calculated using the physical dimensions of the building components as reported by the auditors. The UAs differ in the insulating values used. The nameplate UA is calculated for the house as it exists, using insulation levels reported by the auditor. The MCS UA is computed by replacing the existing insulation R-values with those specified by the MCS. The current code UA assumes insulation R-values equal to the Council's current code.

A further complication in computing the MCS UA is that four different methods are allowed for proving compliance with the standards, some with several variations (Northwest Power Planning Council 1986a). The Energy Budget Method allows simulations and/or calculations to show that a building meets a required space heating energy budget. The Component Prescriptive Points Method gives houses positive or negative points depending on the conservation features used, and allows a trade-off between conservation features. The Component Performance Method specifies an overall U-value for each building component. The Prescriptive Requirements Methods prescribes the insulating values for each component of the building. There are also several variations of some of the methods; for instance, the Prescriptive Requirements Method has five paths to choose from.

Fortunately, the analysis is simplified by the fact that all of the MCS methods are designed to meet the same climate-specific space-heating energy use budgets. Therefore, from a thermal standpoint, each of the MCS methods produces a roughly equivalent building. This analysis compares the MCS houses to three of the possible methods of meeting the standard, Paths A, B, and C of the Prescriptive Requirements Method. Therefore, three MCS UAs are computed for each house.

5.2 COMPARISON OF ELCAP MCS HOUSES TO THE MCS REQUIREMENTS

Figures 5.1, 5.2, and 5.3 compare the nameplate UAs for the MCS houses to the UAs they must meet using compliance Paths A, B, and C, respectively. Each point represents one MCS house. All ELCAP MCS houses are included on each graph. Any houses falling on the diagonal line in each figure have nameplate and MCS UAs that are exactly the same. Figure 5.1 shows that the ELCAP MCS houses are near the MCS UA for Path A, although there is a tendency for the nameplate UAs to be somewhat higher than the UA allowed by Path A. Figures 5.2 and 5.3 show that the MCS UAs are closer to the requirements of Paths B and C. The mean of the nameplate UAs exceeds the MCS UAs by 11%, 9%, and 4% for Paths A, B, and C, respectively(a). The tendency for the nameplate UAs to be slightly higher than those allowed by the three paths is reasonable, because some of the MCS paths have energy-saving features (like heat pumps or properly oriented glazing) which are not reflected in the UA but which allow a higher UA in compensation. Therefore, the thermal integrity of the MCS portion of the ELCAP RSDP sample is roughly as targeted in the MCS.

The MCS Prescriptive Requirements Paths place upper limits on glazing area. The limits ranged from 12% to 19% of the gross floor area, depending on the path chosen(b). The UAs for each path described above are calculated with the glazing area actually reported by the auditor. Since there are buildings both above and below the MCS glazing area limits, calculation of the MCS target UAs using glazing areas equal to the limits specified by each path does not change the results significantly and leaves the conclusions of this report unchanged.

(a) The mean of the absolute differences for UA are 29, 24, and 12 Btu/hr-°F for Paths A, B, and C respectively. The standard deviations are 36, 36, and 37 Btu/hr-°F, respectively.

(b) Paths A and B limit glazing to 15% of the gross floor area. Sixteen percent of the MCS houses were over this limit. Path C limits glazing to 12%. Fifty-three percent of the houses were over this limit. The average glazing area for the MCS sample was 12% of the floor area.

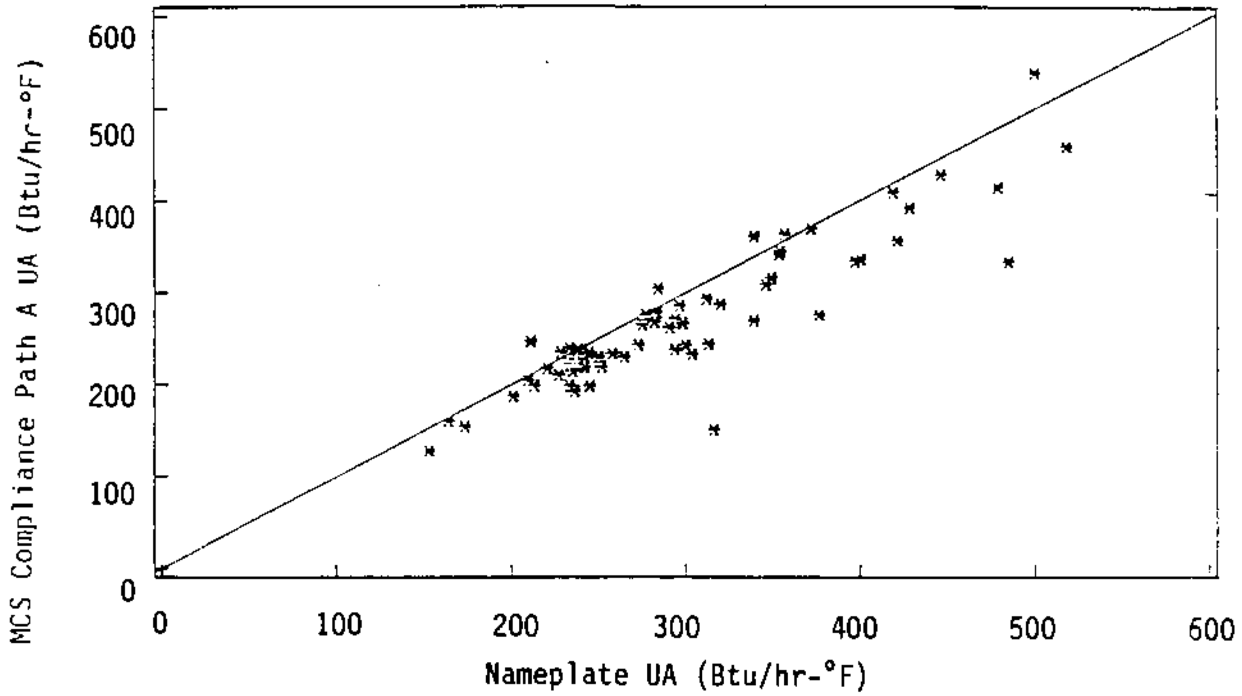

FIGURE 5.1. MCS House Nameplate UAs vs. Compliance Path A UAs

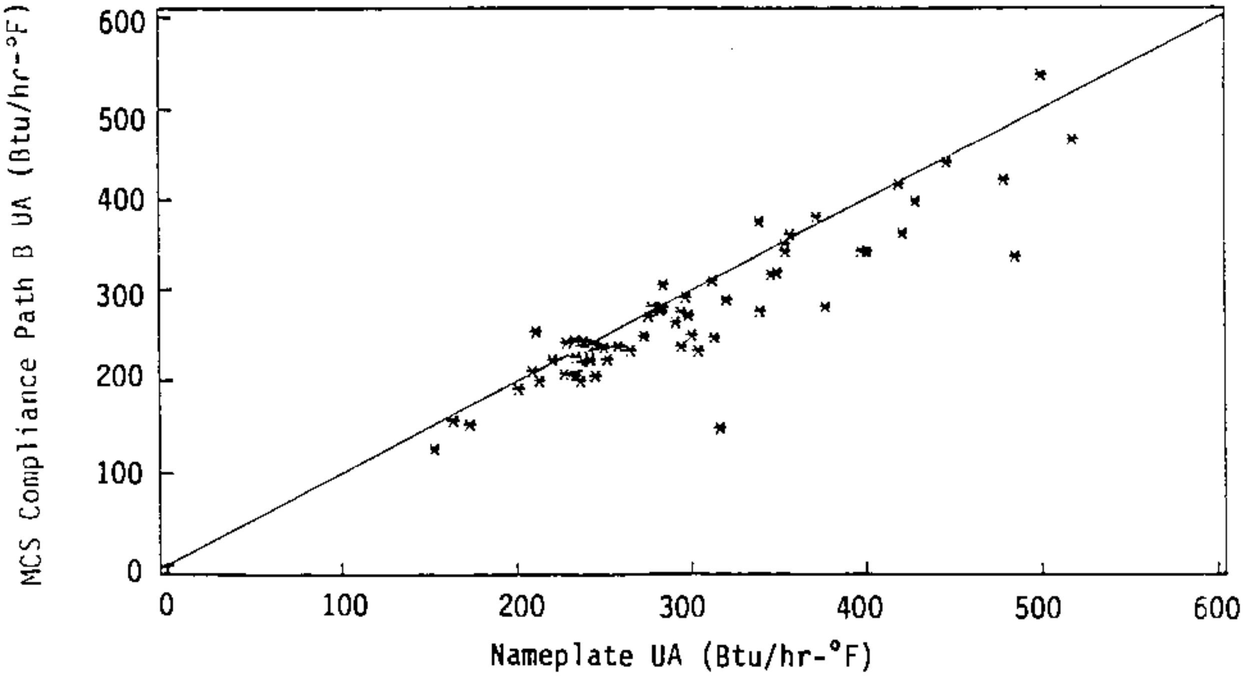

FIGURE 5.2. MCS House Nameplate UAs vs. Compliance Path B UAs

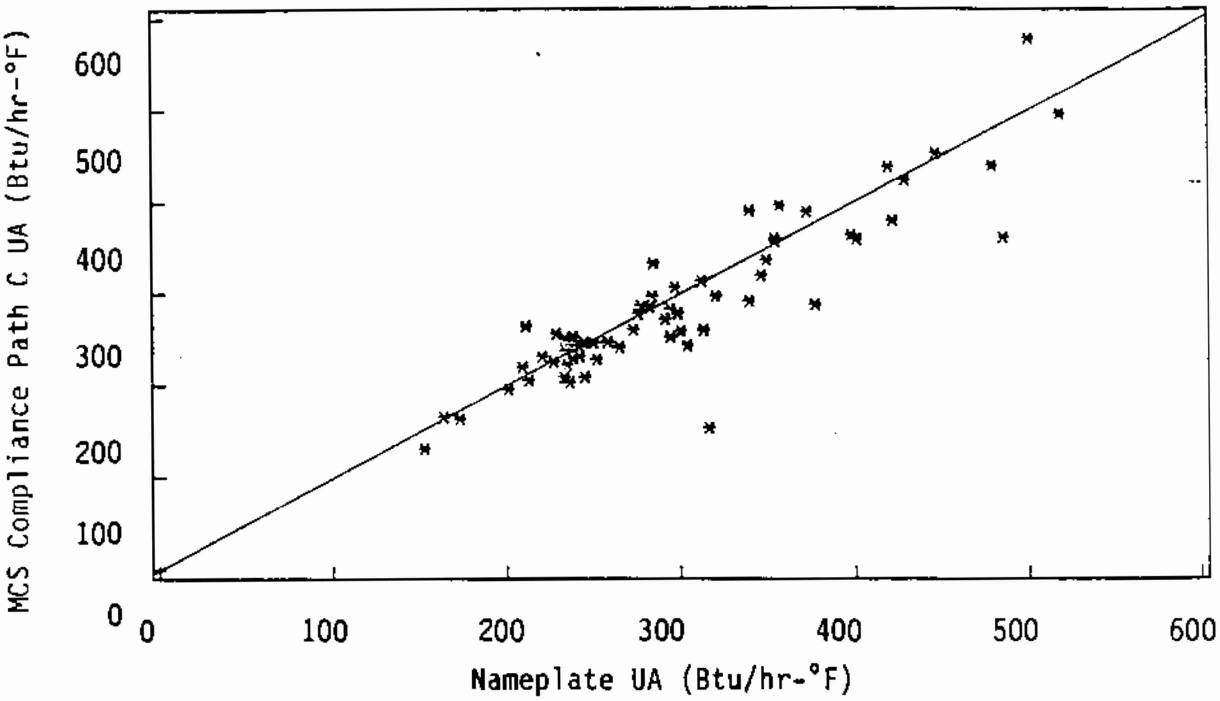

FIGURE 5.3. MCS House Nameplate UAs vs. Compliance Path C UAs

5.3 COMPARISON OF CONTROL TO CURRENT CODE

Unlike the MCS houses, where there are several possible targets in the MCS, the Control houses have only one target, the current code as prescribed by the Council. Figure 5.4 compares the Control houses' nameplate UAs to their target, the current code UA. Although the Control houses show some variation from the current code, the points are generally grouped around the line. In fact, the average values for the Controls' nameplate UAs and current code UAs differ by less than 3%[a]. Therefore, the ELCAP Control houses are a good representation of the current code targeted by the RSDP. The compliance of the MCS and Control houses' insulation levels indicates that designers and builders in the Pacific Northwest can and do construct homes to standards with reasonable accuracy.

(a) The difference of the Control as-built UA and the current code UAs averages 8 Btu/hr-°F. The standard deviation of the difference is 52 Btu/hr-°F.

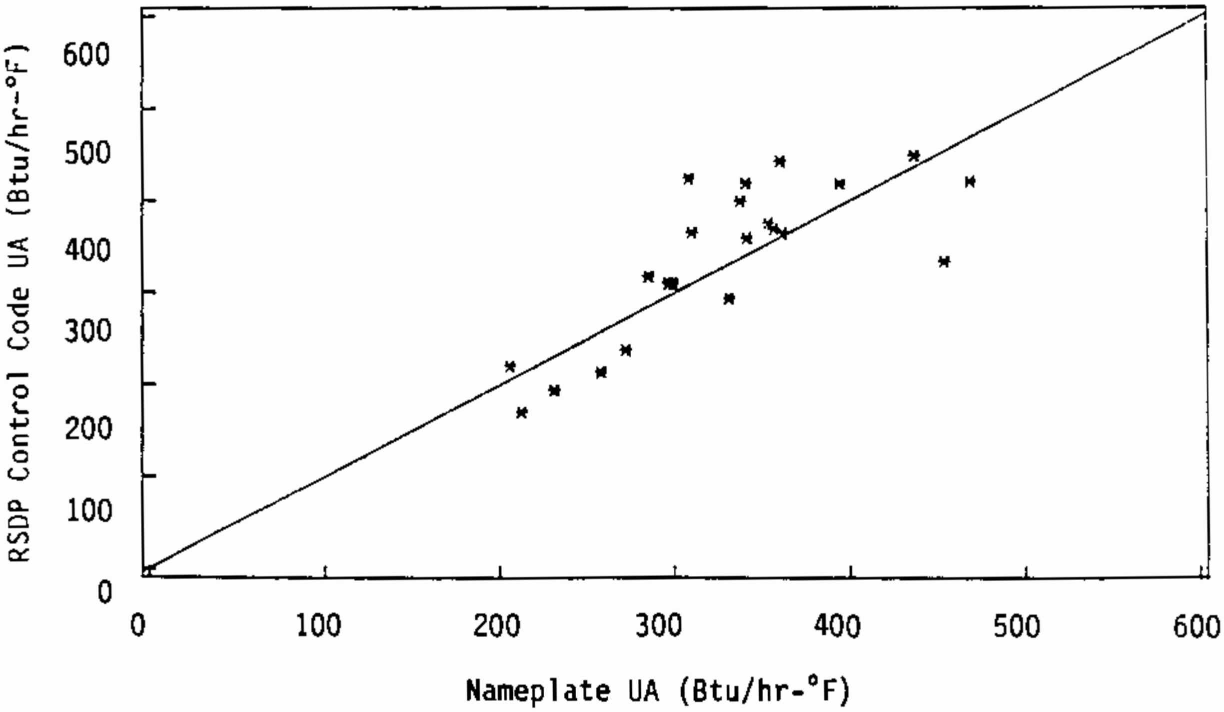

FIGURE 5.4. RSDP Control House Nameplate UAs vs. Control Code UAs

5.4 CURRENT CODE AS A DESCRIPTION OF A CONTROL GROUP

Figure 5.5 compares the nameplate UAs for Post-78 houses (the Residential Base sample houses built after 1978) with the current-code UAs for the same houses. Most of the points group around the line where the two UAs are equal with a mean difference of 8%(a). The tendency for the Post-78 nameplate UAs to be similar to the RSDP Control house UAs suggests that the RSDP current code is indeed representative of new construction in the region.

5.5 COMPARISON OF MCS PATH A AND REGIONAL UA BY VINTAGE

Figure 5.6 compares the non-RSDP houses in the ELCAP sample with the MCS Path A by vintage. The vertical axis shows the difference between the nameplate UA and the UA for the same structure as if built to the MCS Compliance Path A. This difference is the amount the nameplate UA would have to be reduced to achieve the MCS. The values in this figure reflect insulation levels reported by the inspector and, therefore, will include any retrofit

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(a) The difference of the Post-78 home as-built UAs and the current code UAs averages 36 Btu/hr-°F. The standard deviation of the difference is 123 Btu/hr-°F.

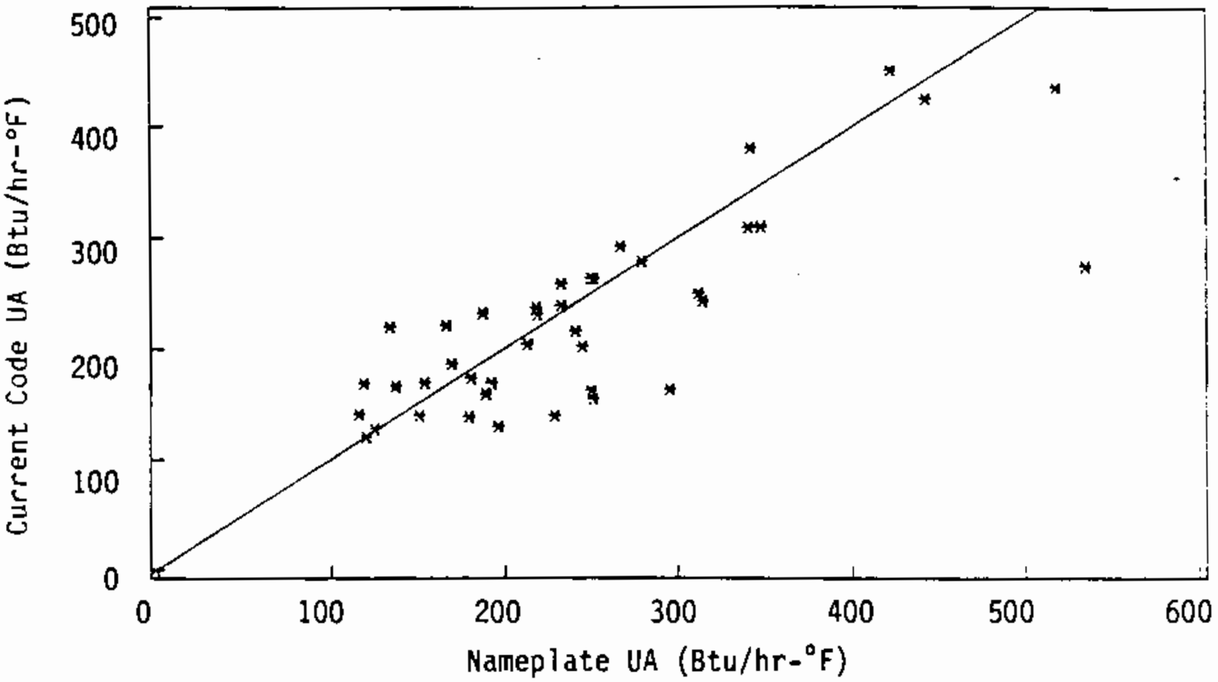

FIGURE 5.5. Post-78 Nameplate UAs vs. RSDP Control Code UAs

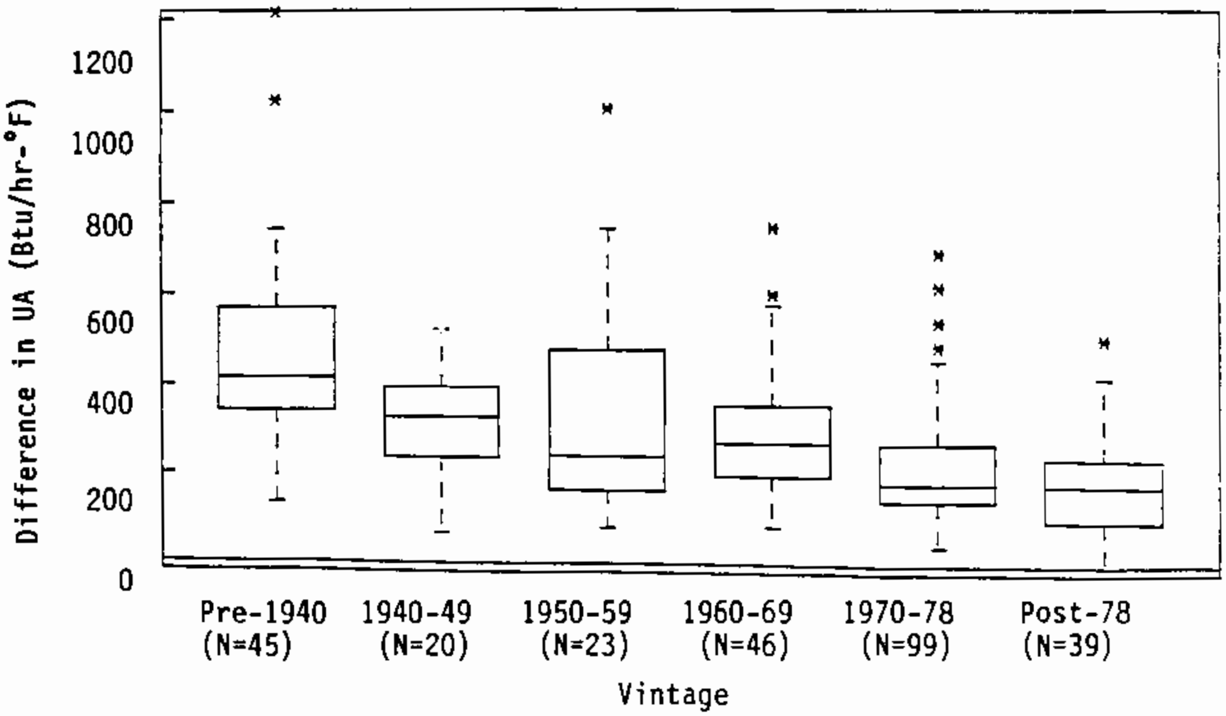

FIGURE 5.6. Difference Between ELCAP Residential Base House Nameplate UAs and MCS Compliance Path A UAs by Vintage

improvements in insulation since the houses were built. This figure shows a clear trend of improving insulation levels (approaching the MCS) in the existing housing stock with vintage. However, this figure also shows that newer buildings have heat loss potentials well above those of the MCS(a)

(a) For comparison, the average difference between the path A UA and the current code UA for these houses was 132 Btu/hr-°F.

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APPENDIX A

DETAILS OF THE UA CALCULATION

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DETAILS OF THE UA CALCULATION

The standard measure of the thermal performance of a building, or of a particular component (wall, door, etc.) in a building, is the UA. The UA is the product of the U-value and the surface area, where the U-value is the thermal transmittance of a building component (the reciprocal of the more familiar R-value, the thermal resistance). The UA of the entire building is simply the sum of the individual UAs of its components. Thus, the UA is the steady-state rate of heat flow through a structure driven by a unit of temperature differential across the building shell.

This appendix details the method of UA calculation. The UA of each component (ceiling, wall, window, door, floor) is calculated and summed into the total UA of the house. Each component is made up of several sections. For instance, the wall component is made up of an average of eight wall sections. The calculation relies on the information in the ELCAP residential inspection database. Interested readers are encouraged to study the survey procedures manual (Taylor et al 1985) in order to gain insight into the information detail available in the ELCAP data. Constants and R-values for materials are taken from the ASHRAE Fundamentals Handbook (ASHRAE 1985). The R-values of insulation were reported by the on-site auditors and based on insulation characteristics established by Taylor et al. (1985). These are shown in Table A.1.

TABLE A.1. R-Values Per Inch of Insulation (°F-ft^2-hr/Btu-inch)

Cellulose Loose Fill	3.70	Urea Formaldehyde Foam (UFFI)	4.17
Mineral Wool/Fiber Batt	3.33	Expanded Polystyrene	4.17
Mineral Wool Loose Fill	3.09	Expanded Polyurethane	6.26
Preformed Mineral Board/Rigid	3.47		

In cases where insulation levels are unknown, default insulation levels are chosen according to the ELCAP sample and climate zone of the house as shown in Table A.2. For the RSDP sample, MCS houses are assigned default insulation levels according to the Prescription Requirements Method Path-A MCS standard (Northwest Power Planning Council 1986a). Control and Post-78 houses are assigned the current practice insulation levels as defined by the Northwest Power Planning Council (1986b). The Residential Base house defaults are estimates.

TABLE A.2. Default Insulation Levels for the Samples in the UA Calculations

Component	Climate Zone	MCS	Control & Post-78	Base
Unknown Ceiling Insulation	1,2	R38	R30	R19
	3	R38	R38	R19
Unknown Door Type	All	R7	R2.6	R2.6
Unknown Wall Insulation	1	R19	R11	R11
	2	R25	R11	R11
	3	R31	R19	R19
Unknown Window Type	All	R2.5	R1.8	R1
Unknown Slab Perimeter Insulation	1	R10	R4	R0
	2	R12	R4	R0
	3	R15	R4	R0
Unknown Crawlspace Perimeter Insulation	All	R10	R0	R0
Unknown R for Floor Above Unconditioned Zone	1	R19	R11	R11
	2	R30	R11	R11
	3	R30	R11	R11
Unknown R for Floor Above Crawlspace or Outside	1	R30	R11	R11
	2	R38	R11	R11
	3	R38	R11	R11

A.1 CEILING

The ceiling UA calculation is based on the type of roofing material, the presence or absence of an attic, the slope of the roof, the attic ventilation, the type of interior ceiling finish, the ceiling insulation, and the type of joists. The heat flow is assumed to be a combination of parallel paths through joist and cavity, in series with a path through the roof. The interior ceiling finish is assumed to be gypsum board.

The roof R-value equations are shown below. The variables are not formally defined, since they are expressed as descriptive character strings in the equations. If an attic is present, a ventilation rate of 0.05 cfm/ft^2 is assumed, providing a heat flow path is parallel with the roof. An area correction is also required to correct for the difference in the roof area and the ceiling area. Note that the ceiling R-value equations combine the ceiling and roof R-values, correcting for the roof slope by multiplying the R-value of the attic by the cosine of an assumed roof slope of 27°. The insulation is included in the ceiling R-value calculation.

```
Roof R-value (No_attic) = Roofing_material + outside_air_film + 1/2"_plywood

Roof R-value = 1 / { [ 1 /(Roofing_material + outside_air_film +
 (Attic)                    1/2"_plywood + inside_air_film + R_of_2X6) *
                                                    Rafter_fraction ] +
                     [ 1 / (Roofing_material + outside_air_film +
                             1/2"_plywood + inside_air_film) *
                                            ( 1 - Rafter_fraction ) ] +
                     [ Attic_vent_rate * 1.08 * cos(arctan(roof_slope)) ]   }

Roof R-value  =        ( Same as attic but 2X10 instead of 2X6, zero
 (Decked ceiling)         Attic_vent_rate, and zero inside_air_film )
```

The ceiling R-value is a parallel summation of the path through the ceiling cavity and the path through the ceiling joist. Each of these paths is in series with the resistance of the path through the roofing material. The joist is assumed to be a 2X6 which is covered by that amount of cavity insulation greater than R19 (R19 is the amount of fiberglass which will fit into a 6" cavity). Rafter and joist fractions are assumed to be 10%. If the ceiling does not have an attic above it, the roof slope is set equal to zero. The ceiling R-value, U-value, and UA equations are shown below. Table A.3

shows the R-values used for the various structural materials comprising the roof and ceiling construction.

```
R_of_joist_path  = [ Roof_R * cos(arctan(roof_slope)) ] + Joist_R_value
                     + R_of_ceiling_insulation_covering_joist
                     + R_of_ceiling_material + Inside_air_film

R_of_cavity_path = [ roof_R * cos(arctan(roof_slope)) ] + Cavity_insulation +
                   R_of_ceiling_material + inside_air_film

U_of_ceiling     = { [ 1/(R_of_joist_path) ] * joist_fraction +
                     [ 1/(R_of_cavity_path) ] * (1 - joist_fraction) }

UA_of_ceiling    = U_of_ceiling * Area_of_ceiling
```

TABLE A.3. R-Values Used for Roof and Ceiling Materials ($^\circ F\text{-}ft^2\text{-}hr/Btu$)

Material	R-Value
Inside air film	0.61
Outside air film	0.25
Asphalt roofing material	0.30
Wood shingles	0.94
1/2" plywood	0.62
Gypsum board	0.45
2X4 wood deck ceiling	1.54
2X6 rafters or joists	6.77
2X10 joists	11.38

A.2 DOORS

The UAs of doors are calculated using the U-values from ASHRAE (1985). Winter U-values are used. If a storm door is indicated in the database, the mean between the wood and metal storm door U-values is used. The door thicknesses are assumed to be the same as used in ASHRAE (1985). If the core of a wood door is unknown, it is assumed to be solid. If the type of door is unknown, it is assumed to be solid wood. A foam core wood door is assumed to be R-7, as this type of door is not mentioned by ASHRAE (1985). Glazing in doors is separately accounted for as a window by the surveyors, so only the opaque door surface is considered. All metal doors are assumed to have foam cores. The door U-values used are shown in Table A.4.

A.3 WALLS

The UA of a wall depends upon its construction and whether it is an above or below grade wall. If the wall contains studs, the UA is the sum of the path through the studs and the path through the cavity. If the wall does not contain studs, there is a single path that includes inside and outside materials and air films, and any insulation which may be present. If the wall is a below grade (basement) wall, the UA includes the path through the ground to the outside in series with the wall path.

A.3.1 Above-Grade Walls

For above-grade wall with studs, the R-value equations for the stud and cavity paths in structural stud walls are shown below. For masonry or other walls without structural studs (eg. log walls), the R-value equation for the cavity path is modified to use the inspection variable "insulation_R" instead of "cavity_R". The UA equation for above-grade walls is also indicated below.

```
R_of_stud_path   = outside_air_film + outside_material_R + sheathing_R
                     + stud_R + gypsum_board + inside_air_film

R_of_cavity_path = outside_air_film + outside_material_R + sheathing_R
                     + cavity_R + gypsum_board + inside_air_film

UA_of_above_grade_wall = Wall_area * [ 1/(R_of_stud_path) * stud_fraction +
                                       1/(R_of_cavity) * (1-stud_fraction) ]
```

TABLE A.4 Door U-Values (Btu/hr-ft^2-°F)

Door Type	No Storm Door	With Storm Door
Hollow Wood	0.47	0.31
Solid Wood	0.39	0.27
Foam Core Wood	0.14	0.13
Unknown Core Wood	0.39	0.27
Metal Door	0.15	0.14

A.3.2 Below-Grade Wall

The total resistance of a below grade wall at any depth is a sum of the series resistance of the wall R-value and the R-value of the soil at that depth below grade. The wall R-value is found in a similar manner as for above-grade walls, except that the outside air film resistance is zero and the wall is assumed to consist of 4 inches of concrete with no outside finish. Additionally, if insulation is found in the wall, an interior stud wall is assumed if the insulation is not board-type insulation. If the insulation is board-type, the wall is assumed not to contain studs.

The R-value of the soil is a function of the path length through the soil and the conductivity of the soil. The path through the soil is assumed to be an arc with radius equal to the depth of the wall at any given point (ASHRAE 1985). In these calculations, the soil conductivity is assumed to be 9.6 Btu-in/hr-ft^2-°F (the soil R-value/foot path length is then 12/9.6 = 1.25 °F-ft^2-hr/Btu-ft). Note that this is a median value; in reality soil conductivity varies with soil composition and moisture content.) Defining the UA/ft as the total UA per lineal foot of below grade wall, it can be calculated by integrating the Total_wall_U as shown. The total UA of a below grade wall is then the UA/ft times the length of the wall (determined by dividing the gross area by the below grade depth). The R-values used for the various structural materials in walls are shown in Table A.5. The equations used to define the UA from below grade walls are shown below.

$$\text{Soil\_R} = \text{resistance\_of\_soil} * \text{path\_length\_of\_soil}$$

$$\text{Path (1/4 circle)} = (1/4 * 2 * \pi * D) \qquad \text{;at any depth } D$$

$$\text{Soil\_R} = 1.25 * \text{Path} = 1.9635 * D \qquad \text{;at any depth } D$$

$$\text{Total\_wall\_U} = 1/\text{Soil\_R} + 1/\text{Wall\_R} \qquad \text{;averaged over the below grade depth of the wall}$$

$$\text{UA/ft} = \int_{D=0}^{\text{DEPTH}} 1/\left[(1.9635 * D) + \text{Wall\_R} \right] dD$$

$$\text{UA/ft} = 1 / 1.9635 \left\{ \left[\ln(1.9635 * \text{depth}) + \text{Wall\_R} \right] - \left[\ln(1.9635) + \text{Wall\_R} \right] \right\}$$

$$\text{Wall\_UA} = (\text{Wall area}/\text{Below\_grade\_depth}) * \text{UA/ft}$$

A.3.2 Miscellaneous Features of the Wall UA Calculation Method

Brick exterior veneers over a wood frame wall are assumed to be one layer of four inch brick. A brick wall, however, is assumed to be two layers of brick with a one-inch air space between them. Wood frame walls with less than R19 cavity insulation are assumed to be 2 x 4 stud construction. Wood frame walls with R19 or greater cavity insulation are assumed to be 2 x 6 stud construction. The stud fraction of a wall with 2 x 4 studs is assumed to be 25% unless the wall is a masonry wall, in which case the stud fraction is

TABLE A.5. R-Values of Materials Used in Walls (°F-ft^2-hr/Btu)

Material	R-Value	Comment
Inside air film	0.61	
Outside air film	0.25	
One inch air space	1.02	(assumed between two layers of brick)
2X4 stud	4.31	
2X6 stud	6.77	
Gypsum board interior	0.45	(assumed as interior of all walls)
Wood siding	1.05	
Vinyl siding	1.82	(assumes 0.375 in. backing)
Brick	0.44	(one layer of 4" brick)
Stone	0.44	
Stucco	0.20	
Concrete	0.44	(assumes 4" of concrete)
Concrete block	1.04	(assumes 8" block)
Tar shingles	0.44	
Metal siding	1.82	(assumes 0.375 in. insulating backing)
Asbestos	0.06	(assumes 0.25 in.)
1/2" plywood	0.62	(assumed as sheathing on wood walls)
Logs	10.0	(assumes 10" solid log)

assumed to be 20% (that is, the studs are present to hold insulation and are not structural). Walls with 2X6 studs are assumed to have a stud fraction of 20%. The below grade depth of a basement wall is determined by taking the average below grade depth of all basement entries. The database requires this because the depth of a below grade wall is not recorded.

A.4 WINDOWS

Window U-values are derived from the ASHRAE Fundamentals Handbook (1985). The winter design condition U-values are first scaled to a 7.5 mph average wind speed, as shown in Table A.6. The U-values are multiplied by the mean of the range of sash adjustment factors to arrive at the U-value used by the UA calculation, as indicated by Table A.7. If the glazing type is unknown, the program assumed single glazing for the Residential Base sample (except Post-78), double-pane aluminum sash for the Control and Post-78 houses, and triple-pane thermal break sash for the MCS houses. If the sash type is unknown, the program assumed 1.0 as the adjustment factor. The UA equation for windows is shown below.

UA_of_window = U-value @ 7.5 MPH * sash factor * window area

TABLE A.6. Glazing U-values for Windows at 15 and 7.5 MPH Wind Speeds (Btu/hr-ft²-°F)

Glazing Layers	Air Gap Width	U-Value at 15 MPH Wind	Adjustment Ratio	U-Value at 7.5 MPH Wind
single		1.10	0.92	1.01
double	≤3/16"	0.62	0.95	0.59
double	≥3/16" & ≤1/4"	0.58	0.95	0.55
double	> 1/4"	0.49	0.96	0.47
triple	≤ 1/4"	0.39	0.95	0.37
triple	≥ 1/4"	0.31	0.97	0.30
single w' storm		0.50	0.96	0.48
double w' storm	≤ 3/16"	0.37	0.96	0.36
double w' storm	≥ 3/16" & ≤ 1/4"	0.35	0.96	0.34
double w' storm	> 1/4"	0.31	0.96	0.30
triple w' storm	≤ 1/4"	0.27	0.98	0.26
triple w' storm	≥ 1/4"	0.23	0.99	0.23

A.5 FOUNDATION

The derivation of the foundation UA is complicated somewhat by the structure of the inspection data. The data contain multiple record entries for a given foundation. A single basement may be entered as four different basement records, each representing portions of the foundation wall with different below grade depth. Similarly, separate physical crawlspaces (for example) can not be distinguished in the database from different records referring to the same crawlspace. Floors above the separate crawlspaces also can not be matched to their respective crawlspaces. These distinctions can be garnered from detailed examinations of the floor plan sketches made for

Table A.7. Sash U-Value Adjustment Factors for Windows

Glazing Type	Wood	Metal	Thermal Break
single	0.90	1.05	0.95
double	0.95	1.25	1.05
triple	0.97	1.40	1.13
single + storm	0.95	1.30	1.05
double + storm	0.97	1.40	1.10
triple + storm	0.97	1.40	1.10

each dwelling, however this level of detail is outside the scope of this analysis. To keep these calculations at a high level of automation and consistency, the UA calculations assume that a house has one and only one of any listed foundation types. This allows simplifying assumptions to be made regarding the relationship between the areas and perimeters of these compo-onents, as discussed in the following sections.

A.5.1 Basement Floor UA

The UA of a below grade floor is a function of the width and area of the floor and the depth below grade of the floor. (Note that basement walls are already accounted as below grade walls in the section on walls.) The depth of the floor is given in the inspection data. The UA calculation averages the depths of all basement records for a house and uses the average for the depth of the floor. The width and the area, however, are not recorded in the database. The UA calculation estimates these factors using the perimeter length of the basement.

The UA of the basement floor is derived by assuming the length of the heat loss path to the outside ground surface is (on average) the length of an arc from a point equal to one fourth of the width of the basement to the outside (ASHRAE 1985). The width of a basement is assumed to be equal to one-fifth of the total perimeter length. This gives the correct area for geometries which are in proportion to a 3X5 rectangle. The soil conductivity is assumed, as described in the section on underground walls. These equations are as shown.

```
path_length_of_soil = [ 1/4 * 2 * pi * (depth + width/4) ] +
                      [ 1/4 * 2 * pi * width/4 ]

R_basement_floor = resistance_of_soil * path_length_of_soil

R_basement_floor = 1.9635 * (depth + width/2)     ;see walls for devel-
                                                    opment of constant

estimated_area = (total_perimeter * 3/16) * (total_perimeter * 5/16)

estimated_area = total_perimeter * total_perimeter * 0.06

UA = estimated_area / R_basement_floor
```

A.5.2 Slab Floor UA

In the calculation of the UA for slab floors, the perimeter length of the slab is multiplied by a coefficient determined by a linear equation fit to the three points in Table VI of the Standard Heat Loss Methodology (Bonneville 1984), which in turn are derived from the 1977 ASHRAE Handbook of Fundamentals (ASHRAE 1977). For R0 (no-insulation), R4 and R8 insulation levels, this equation yields U-values of 0.81, 0.62, and 0.55 Btu/hr-ft^2-°F, respectively. The function and UA equations are shown below.

```
U/ft = 0.3825 + 2.137 / (5.0 + R_value_of_slab_perimeter_insulation)

UA_of_slab_floor = perimeter_length_of_slab * U/ft
```

A.5.3 Crawlspace UA

Crawlspaces contribute an added R-value in series with the R-value of the floors above them. To determine the effective R-value of a crawlspace, one must determine the area of the crawlspace and divide by the UA of the crawlspace. The inspection database does not contain information about the area of crawlspaces, but it does contain the area of the floors above crawlspaces. This area is used as the crawlspace area.

The UA of a crawlspace is the sum of the conductances of the above-grade crawlspace footer, the below grade crawlspace footer, the crawlspace air exchange (infiltration) rate with the outside air, and the ground loss of the crawlspace. The UA of the above and below grade crawlspace footer is computed in an identical manner as for the above and below grade walls. The UA of the crawlspace infiltration is computed using an air exchange rate that is a function of the area of open vents in the crawlspace. The UA of the ground loss is computed in the same manner as for the basement floor, except that the width of the crawlspace is assumed to be 28 feet.

The height of a crawlspace is assumed to be 2.5 feet. The inspection data contains the below grade depth of a crawlspace, so the difference between 2.5 feet and the below grade depth is assumed to be the height of the above-grade footer. If the crawlspace is deeper than 2.5 feet, the UA calculation assumes all of the footer is below grade in this case.

To calculate the infiltration rate in the crawlspace, the procedure adds up the areas of all vents in the crawlspace and then multiplies by the ratio of the number of open vents to total vents to obtain an estimate of the net open vent area. The UA calculation then adds 0.5 to this number (to make the air changes of an unvented crawlspace at least 0.5/hr), and takes the minimum of this number and 4.0 as the number of air changes per hour. For example, a crawlspace with one square foot of open vent area will be assumed to have 1.5 air changes per hour. This method is simple and yields infiltration rates similar to rates implicit in the Standard Heat Loss Methodology (Bonneville 1984). The total UA of the crawlspace is the sum of the infiltration losses, perimeter losses, and ground losses. These equations are shown below:

air_changes/hr = MIN [0.5 + total_vent_area * number_open/number_vents, 4]

infiltration_UA = volumetric_heat_capacity_of_air * volume * (air_changes/hr)

crawlspace_UA = footer_UA + infiltration_UA + ground_UA

effective_crawlspace_R = crawlspace_area/crawlspace_UA.

A.6 FLOORS

The floor calculation method described in this section pertains only to those floors over crawlspaces, unconditioned zones, or over the outside. The UA calculation uses the foundation data to calculate heat loss from slab and basement floors. Floor UAs are calculated assuming parallel heat flow through floor joists and cavities. If a crawlspace is underneath the floor, both paths are in series with the effective crawlspace R-value. The floor insulation is assumed never to cover the floor joists, and 2X8 joists are assumed for less than R-30 insulation and 2X10 joists for more than R-30 insulation.

Floors over unconditioned zones (garages, for example) are treated as if they are exposed to the outside, as the inspection data contains no information about areas or insulation levels of unconditioned zones. The identification of what the unconditioned zones actually consist of are not digitized, but rather require direct manual examination of floor plan sketches for each site. Therefore, since it is not known if a floor is over a garage or unheated basement, or over some other unheated room, the conservative assumption that the floor is over a zone as cold as the outside is made.

The floors calculation assumes that the upper floor layer contributes an R-value of 4.94 to the series R-value of the floor. This assumption includes: an R-value of 2 * 0.92 for air layers, R1.23 for carpet, R0.94 for subflooring, and R0.93 for plywood. The R-value of the cavity in the equation is the R-value of the insulation plus R1.22 for the air space. The joist fraction is 10%. The R-value of the joist is 8.92 for 2X8 and 11.38 for 2X10 joists. If there is no crawlspace under the floor, the effective_crawlspace_ R is zero. The equations used are shown below.

```
floor_R = 1 / { [ joist_fraction * I/R_of_joist ] +
                [ (1 - joist_fraction) * I/R_of_cavity] } +
          R_of_upper_floor_layer

total_floor_UA = floor_area  / ( floor_R + effective_crawlspace_R )
```

A.7. REFERENCES

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ASHRAE 1977. ASHRAE Handbook 1977 Fundamentals. American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Atlanta, Georgia.

Northwest Power Planning Council. 1986a. Model Conservation Standards Equivalent Code. Portland, Oregon.

Northwest Power Planning Council. 1986b. Northwest Conservation and Electric Plan, Vol. II, Chapter 5. Portland, Oregon.

Taylor, Z. T. 1985. Procedures Manual for ELCAP Residential Building Characteristics Survey. DOE/BP/13795-9, Bonneville Power Administration, Portland, Oregon.

APPENDIX B

UNCERTAINTIES IN THE UA CALCULATION

APPENDIX B

UNCERTAINTIES IN THE UA CALCULATION

Uncertainties in the UA calculation arise from several different sources. Part of the uncertainty is due to simplifications inherent in the thermal model, part results from incomplete survey data such as unknown ceiling insulation or window type, part comes from deviations in the R-values of actual materials from assumed values, and part is due to errors made in the data collection process (although the data entry software and techniques attempted to minimize this source of errors). The overall methods and assumptions in the UA calculation are discussed in Appendix A.

Any UA calculation method involves approximation. The most important approximations are probably involved in the computation of UAs for basements and slab floors. An exact calculation of heat loss to the ground from slabs and basements is difficult for several reasons, including thermal mass effects. Fully 58% of the houses in the sample have at least a partial slab or basement. A breakdown of foundations types is given in Table B.1. The UA calculation for the floors uses the ASHRAE model which assumes semicircular heat loss paths through the ground. Because through-the-ground heat loss is less understood than above ground heat loss, a greater uncertainty in the calculated UAs is expected for those houses with basements and slabs. Also, any unknown fraction of houses with both slabs and heated basements actually have daylight basements where the slab represents the side of the basement which is at ground level.

There are two categories of incomplete data. One category is information which the survey did not attempt to collect. In general, the ELCAP characteristics database, which contains the information used for the UA calculation, contains a very detailed description of the houses. Still, the UA calculation procedure makes many minor assumptions about materials and construction configurations. These assumptions are necessary since not all of the parameters required by the heat flow model are explicitly available in the database. For example, gypsum board is assumed as the interior finish material in walls

TABLE B.1. Distribution of Foundation Types

	Total	Percentage
Heated Basement Only	64	17
Unheated Basement Only	16	4
Slab Only	25	6
Slab and Heated Basement	19	5
Slab and Unheated Basement	1	0
Crawlspace Only	159	42
Crawlspace and Heated Basement	23	6
Crawlspace and Unheated Basement	22	6
Crawlspace and Slab	33	9
Crawlspace, Slab, Heated Basement	15	4
Crawlspace, Slab, Unheated Basement	5	1

and ceilings, and a likely stud fraction in the walls is assumed according to the wall construction type and insulation thickness.

The other category of incomplete data is information that was asked for by the survey but not provided by the auditor. For instance, although the auditors actually removed electrical outlets and light switches and climbed down into crawlspaces in the attempt to accurately report insulation levels, in some cases they were unable to determine the insulation in part of a house. The UA calculations attempt to minimize the problem of unknown insulation by defaulting according to the sample and climate zone of a house. (The defaults are listed in Appendix A). For instance, in MCS houses, unknown insulation levels are assumed to meet the Path A MCS standard. A considerable effort was made for the MCS houses to ensure that if the house is found to be below the MCS standard, that this was not because of default assignments. It should be noted that there is a tendency for the defaults to bias results towards the preconception of the sample from which the defaults are derived. It should also be noted that the defaults apply only to the nameplate UAs.

In most cases, several database entries are used to describe the components of the different buildings. For example, on the average, 8.2 separate entries are used to describe the walls of each building, each entry with a separate insulation level, construction and area. Windows use an average of 9.8 entries. Doors, ceilings, and floors average 1.9, 1.7, and 1.6 entries respectively. In some cases, similar elements of a structure are aggregated into one database entry. For instance, several doors with the same construction are aggregated into the same database entry with an area which is the sum of their individual areas.

When the UA calculations assign a default, a warning is generated so that the number and types of defaults are recorded. Table B.2 contains a summary of the frequency of warnings generated. The most frequent warning in the table below is unknown wall insulation (occurring 160 times). However, since there are multiple wall entries for each building, this represented only 5% of the total wall entries in the database.

The uncertainty resulting specifically from the defaults, is estimated by assuming that the uncertainty resulting the default of a component should be approximately equal to the average percentage of the house UA contributed by that type of component. (This may be a conservative estimate.) For instance, since the walls in a house generally represent 30% of the UA of a house and since on the average there are about eight walls entire per house in the database, each warning for an unknown wall R-value added 4% to the estimated uncertainty of the total house UA. Each additional wall entry with an unknown R-value would add another 4% to the uncertainty. The estimates of the uncertainty are by nature somewhat subjective and are intended only to give an approximate rating of the uncertainty of the UA computation for each house. Figure B.1 is a histogram of the distribution of estimated uncertainty computed by this technique. As Figure B.1 shows, only about 15% of the sample has an estimated uncertainty in the total UA of greater than 20% resulting from defaulted data. The average uncertainty is 7%. The values for each house are given in Appendix C.

Table B.2 is ordered according to the estimated uncertainty contributed to the whole building sample. This is simply the number of times a flag occurred (Column 2) times the estimated uncertainty contributed by each warning. Using this criteria, most of the certainty is associated with the first three warnings in the table. Therefore, of the average 7% per building, 3/4 is contributed by unknown floor, ceiling, and wall insulation.

When the UA calculations assign a default, a warning is generated so that the number and types of defaults are recorded. Table B.2 contains a summary of the frequency of warnings generated. The most frequent warning in the table below is unknown wall insulation (occurring 160 times). However, since there are multiple wall entries for each building, this represented only 5% of the total wall entries in the database.

The uncertainty resulting specifically from the defaults, is estimated by assuming that the uncertainty resulting the default of a component should be approximately equal to the average percentage of the house UA contributed by that type of component. (This may be a conservative estimate.) For instance, since the walls in a house generally represent 30% of the UA of a house and since on the average there are about eight walls entire per house in the database, each warning for an unknown wall R-value added 4% to the estimated uncertainty of the total house UA. Each additional wall entry with an unknown R-value would add another 4% to the uncertainty. The estimates of the uncertainty are by nature somewhat subjective and are intended only to give an approximate rating of the uncertainty of the UA computation for each house. Figure B.1 is a histogram of the distribution of estimated uncertainty computed by this technique. As Figure B.1 shows, only about 15% of the sample has an estimated uncertainty in the total UA of greater than 20% resulting from defaulted data. The average uncertainty is 7%. The values for each house are given in Appendix C.

Table B.2 is ordered according to the estimated uncertainty contributed to the whole building sample. This is simply the number of times a flag occurred (Column 2) times the estimated uncertainty contributed by each warning. Using this criteria, most of the certainty is associated with the first three warnings in the table. Therefore, of the average 7% per building, 3/4 is contributed by unknown floor, ceiling, and wall insulation.

TABLE B.2. Warnings Generated by the UA Calculation Program

Houses	Entries	Estimated % of Total UA Per Warning	Warning (and Result)
84	107	7%	floor with unknown insulation (defaulted)
93	121	6%	ceiling with unknown insulation (defaulted)
52	160	4%	wall with unknown insulation (defaulted)
39	42	5%	slab with unknown insulation (defaulted)
17	17	5%	unknown below grade basement depth (assumed 6 feet)
18	20	4%	unknown crawlspace perimeter insulation (defaulted)
23	100	0.7%	unknown fraction wall insulation over studs (assumed likely fraction)
2	9	7%	insulation type not in tables (defaulted)
20	25	0.2%	unknown roofing material (assumed only plywood)
13	16	0.3%	door with unknown U-value (defaulted)
16	39	1%	unknown window sash type (assumed an average value)
3	11	3%	unknown number of panes in window (defaulted)
30	57	0.5%	unknown window air space (assumed 1/4 inch)
2	4	7%	unknown if floor faces house exterior or interior (assigned UA=0)
80	126	0.2%	unknown below grade crawlspace depth (assumed 1.5 feet)
7	21	1%	unknown wall construction type (assumed single wall, wood siding)
1	1	15%	unknown foundation type (foundation ignored)
5	6	2%	unknown if wall faces outside air (assumed UA=0)
2	4	3%	floor with area of 0 (assumed UA=0)
9	13	0.5%	unknown depth of below grade wall (assumed 4 feet)
27	64	0.1%	unknown wall outside finish (assumed plywood or brick)
8	9	2%	unknown ceiling type (assumed no attic)
4	4	1%	unknown crawlspace perimeter length (assumed length = 0)
1	2	7%	no crawlspace found under floor (assigned crawlspace R=0)
1	2	1%	door with unknown area (assumed area = 0)

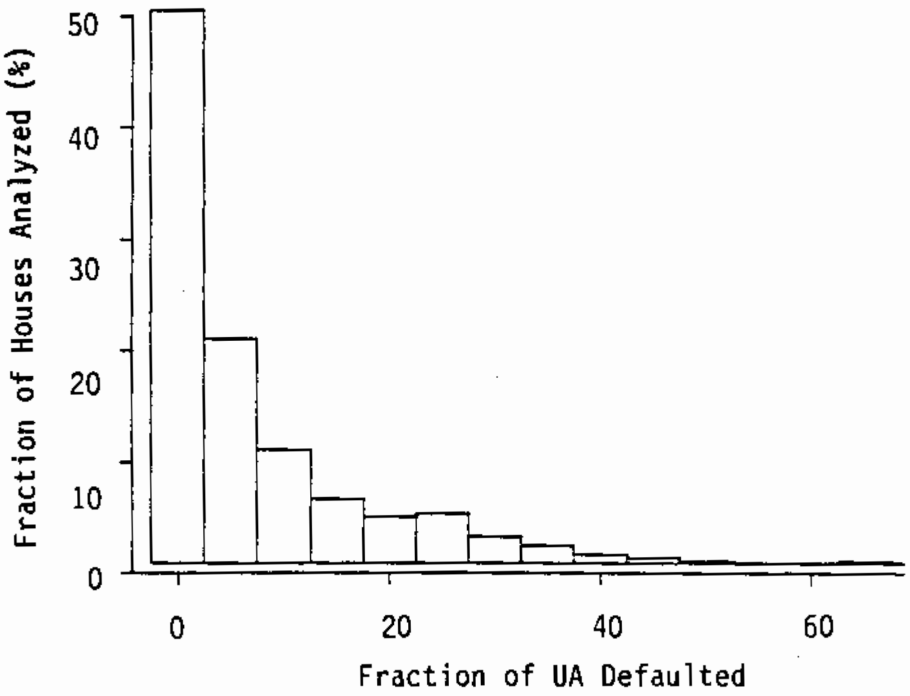

FIGURE B.1. Distribution of Estimated Fraction of UA Defaulted

Overall, although the UA calculation contains many assumptions, it is believed that the high level of detail and quality present in the survey is such that ASHRAE heat loss calculation procedure can be closely followed, and the calculated UAs should be reasonably close the UAs that would be result given perfect information about the building. Based on the uncertainty estimate, the UAs that have been calculated are not affected by the uncertainties due to defaulted information to an extent which would significantly change the results of the analysis.

APPENDIX C

UAs BY SITE

APPENDIX C

UAs BY SITE

Table C.1 contains the UAs for each site used in the analysis. The first column is the ELCAP site number, used in most of the ELCAP work to identify individual houses. The asterisks indicate houses that are not single family detached sites, and are not used in the reported analysis. The second column is the RSDP ID number, which occurs only for the RSDP homes. Note that a few Residential Base homes have RSDP numbers because they are moved from the RSDP to the non-RSDP samples in the ELCAP database. The third column is the ELCAP residential sample group from which the building is drawn: Residential Base (other than Post-78), Post-78, MCS, or Control. The next column is the estimated fraction of the UA defaulted, which is discussed in Appendix B.

The last five columns are the five different UAs calculated for each house. The nameplate UA is the as-built UA, based on the inspection data component areas and R-values. The current code UA is based on the as-built component areas, but R-values as if the house is constructed to the Council's current code. Similarly, the three MCS UAs assume R-values based on MCS compliance Paths A, B and C. See the main body of the report for a more detailed discussion of the meaning of each UA.

TABLE C.1. UAs by Site

			Estimated	UA, Btu/hr-°F				
Site	RSDP ID	Sample	% of Total UA Defaulted	Name-Plate	Current Code	MCS Path A	MCS Path B	MCS Path C
3		Res Base	0%	251	275	167	173	178
4		Post-78	1%	267	438	269	270	296
6		Res Base	1%	471	502	328	331	349
17*		Res Base	11%	416	433	269	277	287
19		Post-78	3%	237	336	241	241	256
20		Post-78	3%	231	280	205	204	216
21		Res Base	3%	439	444	277	286	293
22		Res Base	0%	389	393	239	248	260
23		Res Base	31%	374	367	229	239	241
24		Res Base	0%	446	291	177	183	189
25		Res Base	7%	407	361	234	239	249
26		Res Base	10%	518	489	324	332	345
27		Res Base	0%	358	292	182	187	189
28		Post-78	3%	843	901	569	577	613
29		Res Base	40%	485	457	279	291	299
31		Res Base	18%	742	531	328	332	360
32*	32321-836	Post-78	12%	456	415	256	256	272
33		Res Base	21%	844	280	166	169	172
34	31121-218	Control	4%	310	365	230	233	238
35	31111-218	MCS	4%	291	405	261	264	271
42		Res Base	16%	709	472	316	325	318
44	32321-844	Post-78	0%	333	440	263	270	284
47	32321-835	Post-78	4%	250	254	162	163	166
49		Res Base	22%	535	289	174	179	187
50		Res Base	10%	551	324	206	209	216
51		Res Base	0%	503	304	190	193	197
52		Res Base	12%	500	353	209	214	226
53		Res Base	32%	550	462	279	288	297
55		Res Base	0%	287	257	155	157	164
56		Res Base	0%	398	285	170	171	181
57		Res Base	0%	440	325	211	212	222
58		Res Base	0%	430	267	172	174	176
60		Res Base	10%	651	520	315	324	334
61	42321-820	Post-78	0%	489	402	254	260	264
62	41321-823	Post-78	0%	384	338	208	214	221
63	41121-151	Control	0%	394	417	264	271	278
64	41111-151	MCS	0%	275	417	264	271	278

---

* Indicate houses that are not single-family detached sites; are not used in the analysis.

TABLE C.1. (contd) UAs by Site

				UA, Btu/hr-°F				
Site	RSDP ID	Sample	Estimated % of Total UA Defaulted	Name-Plate	Current Code	MCS Path A	MCS Path B	MCS Path C
65		Res Base	18%	557	425	269	271	282
66		Res Base	0%	259	221	133	135	137
67		Res Base	0%	571	277	181	183	186
69		Res Base	0%	421	419	254	254	266
70		Res Base	0%	376	265	162	163	171
71	42321-821	Post-78	0%	1069	548	322	319	324
72		Res Base	0%	508	308	189	188	199
73		Res Base	1%	363	247	145	148	151
75		Res Base	0%	291	407	250	257	260
76		Res Base	0%	228	174	104	106	108
77		Res Base	21%	799	381	238	244	248
83	13321-814	Post-78	6%	308	338	217	221	226
84		Res Base	11%	452	356	222	227	230
85	13321-815	Post-78	2%	339	371	241	245	248
86		Res Base	0%	589	382	236	237	248
87		Res Base	3%	490	411	259	263	274
88		Res Base	0%	504	332	214	217	224
89	11111-106	MCS	26%	304	381	232	233	243
90	11121-106	Control	26%	337	399	250	254	265
91	42321-813	Post-78	12%	275	332	209	214	222
92		Res Base	0%	381	346	211	211	219
93		Res Base	7%	456	300	219	219	229
94	41111-028	MCS	38%	320	454	287	289	297
95	41121-028	Control	33%	356	369	232	235	243
97	41121-239	Control	27%	437	448	278	285	297
98	41111-237	MCS	6%	242	355	218	223	231
99	41311-186	MCS	23%	312	476	293	310	313
100	41311-189	MCS	1%	346	493	308	316	319
102	41111-045	MCS	23%	220	355	217	223	231
103	41121-209	Control	13%	285	317	202	208	211
106	41111-2D9	MCS	0%	245	310	198	205	208
107	41121-213	Control	3%	299	309	197	204	208
108	41111-217	MCS	0%	233	310	198	205	208
109	41111-215	MCS	0%	236	304	192	199	202
110	41111-213	MCS	0%	233	310	198	205	208
111	41121-215	Control	0%	296	309	197	204	207
112	41121-217	Control	0%	296	310	198	205	208
113	23111-573	MCS	0%	316	202	150	148	154
114	23111-574	MCS	0%	294	317	237	238	252
115	23121-574	Control	3%	454	333	248	250	264
116	23121-573	Control	0%	231	195	141	141	150
117	23111-521	MCS	0%	153	176	127	126	131
119	13321-803	Post-78	0%	240	239	142	144	149
121		Res Base	6%	973	643	396	402	430

TABLE C.1. (contd) UAs by Site

Site	RSDP ID	Sample	Estimated % of Total UA Defaulted	UA, Btu/hr-°F				
				Name-Plate	Current Code	MCS Path A	MCS Path B	MCS Path C
122*		Res Base	7%	370	326	206	207	218
123		Res Base	0%	610	399	256	258	269
124		Res Base	1%	1224	349	220	226	225
125		Res Base	0%	610	536	326	326	339
126		Res Base	23%	422	353	222	230	235
129		Res Base	7%	424	377	235	241	251
131		Res Base	0%	423	367	232	235	243
132		Res Base	0%	1141	823	527	536	568
133*		Res Base	0%	385	352	222	223	236
134		Res Base	3%	679	371	215	227	235
135		Post-78	14%	1034	872	534	539	576
136		Res Base	0%	613	583	358	357	384
137*		Res Base	2%	620	411	258	260	276
138		Res Base	7%	724	461	304	307	313
139		Res Base	0%	735	276	165	168	170
141	23311-550	MCS	8%	227	291	209	208	225
142	23121-521	Control	0%	213	171	126	125	130
144		Res Base	0%	795	367	223	224	236
145		Res Base	0%	401	369	226	228	247
147		Res Base	6%	912	358	226	222	241
150		Res Base	5%	505	565	354	355	390
151		Res Base	0%	886	670	405	413	429
152		Post-78	0%	497	525	318	322	337
154		Res Base	24%	480	422	264	271	281
155		Res Base	25%	1529	530	314	326	328
156		Res Base	2%	1029	573	372	373	390
157	41121-237	Control	0%	341	359	220	225	233
158	12311-133	MCS	0%	238	362	218	221	229
159	42111-021	MCS	47%	244	373	233	240	246
160	42311-224	MCS	7%	428	634	392	397	423
161	11311-136	MCS	3%	421	573	356	361	379
162		Res Base	0%	422	402	246	251	263
163		Res Base	1%	440	452	285	293	301
165		Res Base	0%	728	664	437	441	460
166	12121-117	Control	3%	331	293	176	178	183
168		Res Base	0%	590	325	209	212	217

---

* Indicate houses that are not single-family detached sites; are not used in the analysis.

TABLE C.1. (contd) UAs by Site

Site	RSDP ID	Sample	Estimated % of Total UA Defaulted	UA, Btu/hr-°F				
				Name-Plate	Current Code	MCS Path A	MCS Path B	MCS Path C
169	31321-846	Post-78	11%	464	515	337	343	358
170	31321-847	Post-78	23%	435	472	292	297	315
172	31321-839	Post-78	14%	532	583	352	366	388
173		Res Base	0%	873	784	493	505	534
174	31321-845	Post-78	7%	501	524	348	348	375
175	31311-338	MCS	0%	228	384	235	242	256
176		Res Base	0%	455	497	328	328	343
177	31321-848	Post-78	0%	557	556	370	376	392
178	31311-107	MCS	3%	211	398	246	254	264
179		Res Base	1%	598	670	405	412	453
180*		Res Base	0%	451	396	242	241	252
181	31311-399	MCS	45%	201	294	187	191	195
184	31321-843	Post-78	14%	436	461	286	298	299
185		Res Base	14%	848	430	274	283	285
186	31321-842	Post-78	0%	361	346	212	217	226
190	42121-144	Control	12%	361	364	228	233	244
191		Post-78	10%	622	499	320	330	345
192		Res Base	0%	423	290	180	181	192
199	23111-512	MCS	0%	173	210	154	152	163
200	23121-523	Control	0%	272	237	175	173	183
201	23311-549	MCS	0%	485	452	334	336	361
202	23311-558	MCS	2%	284	415	304	306	332
203		Res Base	0%	469	508	309	321	331
204		Res Base	0%	279	319	196	201	208
205		Res Base	0%	415	226	137	144	146
206		Res Base	0%	545	350	216	217	233
207		Res Base	0%	834	612	381	395	418
208		Res Base	7%	594	494	308	316	338
209*		Res Base	30%	313	293	181	185	194
210		Res Base	6%	646	222	137	142	144
211		Res Base	0%	450	341	210	216	225
212		Res Base	0%	373	409	256	256	270
213	12311-148	MCS	12%	282	434	267	277	284
214		Res Base	1%	559	265	161	170	175
215		Res Base	0%	461	453	280	286	302
216		Res Base	0%	709	308	187	199	201
217*		Res Base	33%	290	285	176	182	187
218		Res Base	7%	486	360	220	225	233
219		Res Base	16%	481	459	280	291	295

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* Indicate houses that are not single-family detached sites; are not used in the analysis

TABLE C.1. (contd) UAs by Site

Site	RSDP ID	Sample	Estimated % of Total UA Defaulted	UA, Btu/hr-°F				
				Name-Plate	Current Code	MCS Path A	MCS Path B	MCS Path C
220	31321-841	Post-78	0%	379	318	195	199	209
221		Res Base	0%	370	347	212	220	224
222		Res Base	16%	838	517	321	329	345
223		Res Base	14%	569	537	330	340	356
224		Res Base	1%	454	517	314	320	349
225		Res Base	25%	380	379	252	251	260
226		Res Base	1%	690	323	196	205	210
227		Res Base	0%	364	258	158	164	167
228	42311-242	MCS	19%	273	384	242	248	259
229		Res Base	3%	526	264	158	160	165
230		Res Base	0%	319	297	176	178	186
232		Res Base	0%	823	276	168	179	177
233		Res Base	0%	525	532	330	350	353
234		Res Base	7%	616	322	201	202	212
235		Res Base	14%	731	423	257	257	274
236		Res Base	0%	473	404	249	257	260
238	31321-838	Post-78	0%	682	761	476	475	511
239		Res Base	0%	727	411	285	282	297
240		Res Base	0%	312	231	142	148	151
241		Res Base	22%	352	229	145	154	147
242		Res Base	6%	501	534	336	339	364
243		Res Base	0%	434	339	207	214	216
244		Res Base	0%	256	184	112	118	119
245		Res Base	0%	212	247	152	158	160
246		Res Base	12%	623	380	236	239	253
247		Res Base	0%	309	285	181	190	183
248		Res Base	0%	500	241	149	152	158
249		Res Base	12%	610	620	387	398	410
250		Res Base	6%	338	287	180	183	186
251		Res Base	0%	226	286	175	181	186
252	23121-514	Control	0%	206	221	163	162	171
253		Res Base	11%	775	576	378	384	394
254		Res Base	0%	554	337	215	213	223
255		Res Base	0%	498	321	205	199	215
256		Res Base	0%	437	318	195	201	211
258	23111-514	MCS	0%	164	218	159	157	166
259		Res Base	12%	327	314	200	207	214
260		Res Base	0%	493	360	247	251	256
261		Res Base	0%	375	284	175	180	187
262		Res Base	0%	679	536	328	364	350
263		Res Base	3%	876	462	285	304	297
264		Res Base	0%	405	363	225	231	240

TABLE C.1. (contd) UAs by Site

Site	RSDP ID	Sample	Estimated % of Total UA Defaulted	UA, Btu/hr-°F Name-Plate	Current Code	MCS Path A	MCS Path B	MCS Path C
265		Res Base	6%	737	363	232	231	239
266		Res Base	2%	717	724	472	475	506
267		Res Base	11%	462	364	220	221	229
269		Post-78	9%	464	476	287	286	302
271		Res Base	0%	250	266	160	161	168
272		Res Base	1%	710	509	323	323	345
276		Res Base	3%	488	438	263	270	278
277	42111-144	MCS	12%	234	356	221	226	237
278	31311-341	MCS	1%	500	848	538	537	579
279	31311-327	MCS	0%	258	366	232	237	246
280	32311-299	MCS	1%	372	622	369	379	388
301	42211-145	MCS	8%	300	385	242	249	258
302	42211-304	MCS	19%	250	372	229	236	245
303	41311-112	MCS	0%	235	343	213	216	222
304	41311-258	MCS	0%	238	378	237	243	252
305	41111-174	MCS	0%	313	395	243	247	259
306	41111-235	MCS	13%	209	333	203	210	219
308	41111-239	MCS	19%	296	457	284	291	306
309	41311-676	MCS	26%	397	537	334	341	363
312	31311-403	MCS	0%	518	735	458	466	495
313		Res Base	12%	1003	415	261	267	272
315		Res Base	0%	659	461	290	293	307
316		Res Base	0%	282	283	170	170	175
317		Res Base	9%	876	539	337	353	352
318	31311-253	MCS	0%	446	690	427	440	453
319		Res Base	0%	686	610	367	375	399
320	23121-512	Control	0%	258	214	158	156	168
321	23311-510	MCS	0%	356	506	363	360	395
323	31311-113	MCS	0%	400	509	336	341	358
324	32311-423	MCS	6%	353	559	341	349	360
326	12311-132	MCS	11%	283	435	278	280	296
327	12111-117	MCS	3%	233	384	239	245	250
330		Res Base	30%	497	216	137	137	140
331		Res Base	13%	477	436	302	299	311
332		Res Base	7%	227	258	159	166	169
333		Res Base	10%	508	534	346	354	367
334		Res Base	6%	825	590	360	366	384
335		Res Base	0%	456	334	199	202	212
336		Res Base	3%	544	548	374	367	387
337	32311-427	MCS	0%	237	384	226	237	243
338	41311-205	MCS	67%	419	616	409	416	437
339	41311-04T	MCS	12%	339	593	361	374	390

TABLE C.1. (contd) UAs by Site

Site	RSDP ID	Sample	Estimated % of Total UA Defaulted	UA, Btu/hr-°F				
				Name-Plate	Current Code	MCS Path A	MCS Path B	MCS Path C
340	41311-02T	MCS	16%	277	434	275	280	286
341	41311-01T	MCS	1%	265	372	229	233	241
342	41311-03T	MCS	6%	354	508	344	341	356
343		MCS	0%	471	368	221	223	229
344		Res Base	16%	892	862	532	539	586
345		Res Base	8%	353	325	198	204	217
346		Res Base	0%	700	484	325	331	332
348		Res Base	0%	529	470	294	300	307
350		Res Base	7%	596	642	468	467	502
351	23321-809	Post-78	7%	302	277	207	210	222
352		Res Base	6%	600	484	310	319	322
353		Res Base	27%	717	704	439	446	475
355		Res Base	20%	1032	465	310	311	319
356	31311-311	MCS	0%	339	442	269	276	291
357		Res Base	1%	393	370	226	228	237
358		Res Base	0%	470	432	290	288	302
359	42321-805	Post-78	0%	679	618	387	393	411
361	12311-149	MCS	14%	252	357	218	223	227
362	12311-147	MCS	11%	213	321	197	199	205
363		Res Base	14%	719	567	415	415	460
364*		Res Base	29%	272	272	170	175	182
365	23321-810	Post-78	12%	501	308	233	231	253
366	23321-812	Post-78	11%	498	323	244	242	265
367		Res Base	0%	328	361	225	226	240
368		Res Base	0%	676	499	336	331	354
369	23321-808	Post-78	1%	425	406	287	288	309
370	23321-811	Post-78	8%	627	485	358	358	384
372		Res Base	6%	563	286	211	208	222
373		Res Base	0%	578	289	212	211	223
375		Res Base	4%	495	245	176	174	186
376		Res Base	0%	639	370	276	278	301
378		Res Base	0%	380	392	282	285	316
379		Res Base	0%	370	301	223	221	235
381		Res Base	4%	665	522	376	373	406
383		Res Base	5%	641	539	381	384	423
384		Res Base	20%	400	256	164	166	165
385		Res Base	0%	534	380	266	262	275
386		Res Base	0%	488	290	179	184	190
387		Res Base	0%	1066	878	567	569	603

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* Indicate houses that are not single-family detached sites; are not used in the analysis.

TABLE C.1. (contd) UAs by Site

				UA, Btu/hr-°F				
Site	RSDP ID	Sample	Estimated % of Total UA Defaulted	Name-Plate	Current Code	MCS Path A	MCS Path B	MCS Path C
388		Post-78	14%	694	620	390	390	416
390		Res Base	10%	507	425	311	311	335
391		Res Base	7%	679	529	344	349	366
392		Res Base	16%	353	357	248	246	254
393		Res Base	32%	471	374	241	244	254
394*		Res Base	33%	408	405	252	258	268
395		Res Base	1%	797	407	300	301	322
396		Res Base	16%	256	307	189	191	202
398	23321-807	Post-78	0%	457	278	209	212	234
399		Res Base	0%	403	327	234	235	254
400		Res Base	29%	514	491	300	300	312
401		Res Base	0%	645	357	219	224	234
402		Res Base	0%	285	327	201	205	214
405		Res Base	0%	1298	426	274	273	284
406		Res Base	5%	628	388	257	250	264
407		Res Base	6%	572	385	239	238	253
409	41311-178	MCS	0%	349	490	316	318	336
410	41121-174	Control	7%	353	375	231	236	245
411		Res Base	0%	1174	668	431	439	466
412		Res Base	18%	601	412	261	262	275
413		Res Base	0%	464	527	324	329	344
414		Res Base	17%	915	635	383	396	424
415		Res Base	0%	782	387	260	262	278
416		Res Base	4%	247	281	171	177	182
417		Res Base	7%	628	325	212	218	223
419		Res Base	27%	921	386	244	242	260
420		Res Base	0%	1052	661	408	419	442
421		Res Base	20%	379	299	181	188	198
422		Res Base	0%	639	211	130	135	137
423		Res Base	0%	750	740	468	472	498
424		Res Base	0%	723	358	246	243	260
425		Res Base	0%	413	390	241	245	252
426		Res Base	0%	773	505	313	319	330
427		Res Base	25%	650	606	374	392	395
428		Res Base	12%	457	272	167	174	179
429		Res Base	36%	432	201	148	149	163
430*		Res Base	10%	439	369	235	233	254
431		Res Base	23%	876	573	359	361	381
432		Res Base	10%	792	407	254	251	275

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* Indicates houses that are not single-family detached sites; are not used in the analysis.

TABLE C.1. (contd) UAs by Site

				UA, Btu/hr-°F				
Site	RSDP ID	Sample	Estimated % of Total UA Defaulted	Name-Plate	Current Code	MCS Path A	MCS Path B	MCS Path C
433		Res Base	0%	421	444	277	280	288
434		Res Base	0%	478	460	284	283	303
435*		Res Base	7%	459	336	210	212	220
436		Res Base	0%	548	493	313	325	340
437		Res Base	0%	1625	531	338	333	349
438		Res Base	3%	629	516	324	323	351
439		Res Base	6%	509	416	255	267	271
440		Res Base	6%	348	365	239	239	256
452	42321-816	Post-78	3%	884	850	523	530	578
461		ResBase	15%	773	462	293	307	315
462*		Res Base	2%	344	247	150	161	157
463		Res Base	7%	414	369	248	251	261
464		Res Base	0%	333	359	222	227	237
465		Res Base	0%	394	429	265	269	281
466		Res Base	0%	536	358	219	224	233
467		Res Base	0%	419	275	168	174	179
468		Res Base	6%	574	523	359	362	380
469		Res Base	0%	867	391	269	267	279
470		Res Base	0%	468	294	183	188	190
471		Res Base	6%	466	521	317	318	348
472		Res Base	35%	804	603	383	376	400
473		Res Base	0%	431	329	204	213	215
474		Res Base	6%	1014	450	273	282	295
475*		Res Base	12%	411	395	252	256	272
476	11321-153	Control	7%	308	425	276	282	293
478	11111-142	MCS	21%	298	422	266	271	278
479	11111-140	MCS	13%	377	438	275	280	287
481		Res Base	51%	772	483	299	300	327
482	41321-826	Res Base	0%	303	328	206	212	217
483		Res Base	6%	857	510	323	327	352
484		Res Base	0%	466	523	318	325	349
485	41321-825	Res Base	8%	665	570	372	373	401
486		Res Base	0%	275	348	214	217	227
487		Res Base	35%	468	332	211	212	228
488		Res Base	0%	488	368	236	231	242
489	23321-801	Post-78	4%	359	276	208	211	226
490		Res Base	6%	498	405	249	258	268
491		Res Base	6%	621	383	238	244	252
492		Res Base	3%	494	405	292	294	315
493		Res Base	24%	444	444	274	286	291
494	32311-110	MCS	3%	242	377	228	234	242

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* Indicate houses that are not single-family detached sites; are not used in the analysis.

TABLE C.1. (contd) UAs by Site

			Estimated	UA, Btu/hr-°F				
Site	RSDP ID	Sample	% of Total UA Defaulted	Name-Plate	Current Code	MCS Path A	MCS Path B	MCS Path C
495		Res Base	11%	363	373	229	230	250
496	41321-833	Post-78	0%	375	463	283	291	303
497*		Res Base	30%	225	241	155	162	166
500	12121-152	Control	0%	469	420	268	273	282
501	12111-152	MCS	0%	294	425	270	275	282
502		Res Base	7%	536	473	289	288	304
503		Res Base	6%	494	366	225	230	241
504		Res Base	0%	246	246	151	157	158
505	42321-818	Post-78	0%	392	257	165	167	163
507	41321-828	Post-78	0%	481	431	283	286	311
508		Res Base	0%	750	415	271	287	278
509		Res Base	0%	765	615	381	383	408
510		Res Base	0%	432	334	208	212	223
511		Res Base	6%	306	247	161	162	170
512		Res Base	7%	400	364	224	228	238
514		Res Base	0%	400	398	244	257	259
515		Res Base	5%	469	420	268	274	278
516		Res Base	26%	468	454	295	300	314
518	42311-270	MCS	19%	479	685	414	421	438
520	11121-140	Control	6%	340	419	265	268	277
521		Res Base	10%	390	313	194	198	207
522	11121-142	Control	28%	360	443	280	282	293
526		Res Base	20%	275	319	196	200	208

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* Indicate houses that are not single-family detached sites; are not used in the analysis.

APPENDIX D

MEAN AND MEDIAN EFFECTIVE BUILDING ENVELOPE COMPONENT R-VALUES

APPENDIX D

MEAN AND MEDIAN EFFECTIVE BUILDING ENVELOPE COMPONENT R-VALUES

TABLE D.1. Mean and Median Effective Ceiling R-Values (°F-ft^2-hr/Btu) for ELCAP Residences by Vintage and Climate Zone

Vintage	Mean	Median	Climate Zone	Mean	Median
Pre-1960	18.3	16.3	Zone 1	22.9	19.7
1960-1969	24.6	20.5	Zone 2	22.6	20.4
1970-1978	25.8	22.1	Zone 3	26.6	22.4
Post-1978	27.4	25.6			
MCS	38.1	38.4			

TABLE D.2. Mean and Median Effective Wall R-Values (°F-ft^2-hr/Btu) for ELCAP Residences by Vintage and Climate Zone

Vintage	Mean	Median	Climate Zone	Mean	Median
Pre-1960	6.68	5.53	Zone 1	8.97	10.68
1960-1969	9.02	9.52	Zone 2	8.95	9.18
1970-1978	10.34	11.00	Zone 3	10.88	10.87
Post-1978	12.78	11.64			
MCS	19.64	18.20			

TABLE D.3. Mean and Median Effective Window R-values (°F-ft^2-hr/Btu) for ELCAP Residences by Vintage and Climate Zone

Vintage	Mean	Median	Climate Zone	Mean	Median
Pre-1960	1.65	1.59	Zone 1	1.51	1.53
1960-1969	1.50	1.52	Zone 2	1.73	1.67
1970-1978	1.58	1.58	Zone 3	1.95	1.95
Post-1978	1.75	1.70			
MCS	2.21	2.2			

TABLE D.4. Mean and Median Total Floor R-values (°F-ft^2-hr/Btu) for ELCAP Residences by Vintage and Climate Zone

Vintage	Mean	Median	Climate Zone	Mean	Median
Pre-1960	14.12	10.71	Zone 1	16.97	16.71
1960-1969	16.90	16.73	Zone 2	15.43	15.11
1970-1978	18.10	17.46	Zone 3	15.53	18.18
Post-1978	18.00	17.43			
MCS	29.39	30.52			

TABLE D.5. Mean and Median Effective Door R-values (°F-ft^2-hr/Btu) for ELCAP Residences by Vintage and Climate Zone

Vintage	Mean	Median	Climate Zone	Mean	Median
Pre-1960	3.27	3.04	Zone 1	3.43	3.06
1960-1969	3.34	3.11	Zone 2	3.66	3.22
1970-1978	3.68	3.32	Zone 3	4.22	3.27
Post-1978	4.38	3.24			
MCS	5.63	6.67			

TABLE D.6. Mean and Median Total Slab R-values* (°F-ft^2-hr/Btu) for ELCAP Residences by Vintage and Climate Zone

Vintage	Mean	Climate Zone	Mean
Pre-1960	4.71	Zone 1	5.77
1960-1969	7.98	Zone 2	6.11
1970-1978	4.87	Zone 3	4.26
Post-1978	6.70		
MCS	9.46		

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*Medians not shown due to small cell sizes.

TABLE D.7. Mean and Median Window Area/Gross Wall Area Ratios (%) for ELCAP Residences by Vintage and Climate Zone

Vintage	Mean	Median	Climate Zone	Mean	Median
Pre-1960	12.5%	12.8%	Zone 1	13.6%	13.6%
1960-1969	13.4%	13.7%	Zone 2	11.6%	11.6%
1970-1978	12.6%	12.9%	Zone 3	11.0%	11.3%
Post-1978	13.0%	12.0%			
MCS	11.2%	11.1%			

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