ASHRAE Standard 90.2P Building Envelope Requirements

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ABSTRACT

The building envelope requirements for single- and multi-family residences contained in the proposed ASHRAE Standard 90.2P were distinguished from previous versions of the standard in their development, stringency, and presentation format. The strategy for the criteria development was a combination of consumer economics and energy conservation. The advantage of this strategy was that it simultaneously produced balanced criteria among all the envelope components and was 25% more stringent than previous standards. The criteria presentation format was different for many reasons. It explicitly accounted for both heating and cooling, varied by location of the air distribution system, identified specific constructions, separated above-grade and below-grade components, determined the total fenestration area by a trade-off equation, and, for the first time, contained shading coefficient requirements. Furthermore, a procedure was developed that simplifies trade-offs among all the envelope components. All of the required weather data for the United States and Canada were included in the standard for easy reference. This paper reviews each of these significant features.

INTRODUCTION

ASHRAE has a policy of revising all standards on a five-year cycle. Standard 90 was first issued in 1975 as *ASHRAE Standard 90-75, Energy Conservation in New Building Design* (ASHRAE 1975). It was then updated on schedule in 1980 as ANSI/ASHRAE/IES 90A-1980, using the same title (ASHRAE 1980). Each of these publications contained requirements for both commercial and residential buildings.

On January 29, 1984, ASHRAE published a draft addendum for public review to revise the standard. The addendum encountered significant opposition in the public review process. Many questions were raised challenging the cost-effectiveness, consistency, application, etc.

It became clear that a new strategy was needed. As a consequence, ASHRAE decided to split the standard into two separate standards, form separate standard project committees (SPC 90.1 and SPC 90.2), and start the revision process anew. The commercial standard was officially published as *ASHRAE/IES 90.1-1989, Energy Efficient Design of New Buildings Except New Low-Rise Residential Buildings* (ASHRAE 1989a). The residential standard was designated 90.2P. The "proposed" designation (P) will be deleted when it is officially published. The title is "Energy Efficient Design of New Low-Rise Residential Buildings" (ASHRAE 1990). Two public reviews of the proposed standard have been completed, independent substantive changes have been proposed and approved, but final publication is still pending.

Background

Development of the building envelope criteria for the draft ASHRAE Standard 90.2P began with a series of SPC meetings to establish the strategy that would be used to develop the standard. Decisions were made that the prescriptive criteria were to be based on consumer economics, balanced across all envelope components, save energy relative to the existing standard, account explicitly for both heating and cooling, and be simple to understand and easy to use.

There were three compliance paths for envelopes in the standard. The simplest was a prescriptive path, but it was the least flexible. The intermediate compliance path in terms of complexity and flexibility was a complete trade-off procedure that allowed all of the envelope components to be traded among themselves. The most complex and comprehensive compliance path was an annual hour-by-hour analysis that allowed trade-offs among the envelope, water-heating, and equipment efficiencies. This paper will focus only on the prescriptive path.

Objective

The objective of this paper is to briefly review the economics and present the stringency, presentation format, requirements, and weather data associated with the development and use of the prescriptive envelope criteria contained in ASHRAE Standard 90.2P.

ECONOMIC METHODOLOGY

The fundamental economic concept was to ensure that the prescriptive criteria were economically justified. This was implemented by requiring the incremental energy savings, both heating and cooling, over some time horizon to equal or exceed the incremental costs of the energy conservation measure (ECM), both materials and labor, over some time horizon. It was assumed that the ECM

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would be totally financed as part of the home mortgage. The economic methodology can be stated as

$$\text{Incremental Energy Cost Savings Over Time} \geq \text{Incremental Costs of ECM Over Time} \tag{1}$$

In equation form, it is

$$FYS_h \cdot P_h \cdot S_h + FYS_c \cdot P_c \cdot S_c \geq \Delta FC \cdot S_2 \tag{2}$$

where

FYS_h	=	incremental first-year energy savings for heating, Btu/ft^2;
P_h	=	price of fuel for heating, \$/Btu;
S_h	=	economic scalar for heating, dimensionless;
FYS_c	=	incremental first-year energy savings for cooling, Btu/ft^2;
P_c	=	price of fuel for cooling, \$/kWh;
S_c	=	economic scalar for cooling, dimensionless;
ΔFC	=	incremental first cost of ECM, \$/ft^2;
S_2	=	economic scalar for ECM, dimensionless.

Economic scalars, S_h and S_c, are simply the "modified" uniform present-worth factors corresponding to the time horizon (life), with discount rate and fuel escalation rates assumed. ("Modified" means that the dollar value of energy savings may not be constant from year to year but increases over time at some projected rate of change.) Representative values range from 7 to 22. The economic scalar, S_2, is the present-worth factor that accounts for the financing costs (mortgage, points, and down payment) and tax savings associated with the cost of the ECM. Maintenance and replacement costs were assumed to be zero for all envelope ECM over the economic life used in the analysis. Representative values of S_2 range from 0.6 to 1.2. The distinct advantage of the economic scalar methodology is the ability to represent various cost-effectiveness criteria in a consistent set of equations.

On a unit area basis, the first-year heating savings is

$$FYS_h = \frac{\Delta U \cdot \mathrm{HLF} \cdot \mathrm{HDD65}}{\mathrm{AFUE} \cdot \mathrm{HDE}} \tag{3}$$

where

ΔU	=	incremental change in U-value for materials, Btu/ft$^2 \cdot$°F;
HLF	=	heating load factor, h/day;
HDD65	=	heating degree-days base 65°F, °F·day;
AFUE	=	annual fuel utilization efficiency, dimensionless;
HDE	=	heating distribution efficiency, dimensionless.

This equation can be modified to apply to other types of heating systems by substituting the appropriate overall coefficient of performance for the AFUE variable. For example, a heat pump could be analyzed by substituting the heating season performance factor (HSPF) for the AFUE. One would also have to incorporate the appropriate conversion factors at the same time.

On a unit area basis, the first-year cooling savings is

$$FYS_c = \frac{\Delta U \cdot \mathrm{CLF} \cdot \mathrm{CDH74}}{\mathrm{SEER} \cdot \mathrm{CDE}} \tag{4}$$

where

CLF	=	cooling load factor, dimensionless;
CDH74	=	cooling degree-hours base 74°F, °F·h;
SEER	=	seasonal energy efficiency ratio, Btuh/W;
CDE	=	cooling distribution efficiency, dimensionless.

Combining Equations 2, 3, and 4 produces

$$\frac{\Delta U \cdot \mathrm{HLF} \cdot \mathrm{HDD65} \cdot P_h \cdot S_h}{\mathrm{AFUE} \cdot \mathrm{HDE}} + \frac{\Delta U \cdot \mathrm{CLF} \cdot \mathrm{CDH74} \cdot P_c \cdot S_c}{\mathrm{SEER} \cdot \mathrm{CDE}} \geq \Delta FC \cdot S_2. \tag{5}$$

Equation 5 represents the complete equation used to set the criteria. It is simply an equation for a straight line when the inequality sign is replaced with an equal sign. Conversion factors have been intentionally omitted from all equations. Additional details on the economic development are available (McBride and Powell 1990; McBride 1991b).

Intercept Equations

Starting with a specified increase in the ECN, for example, a change in insulation levels, the first costs were fixed and the unknowns became the climates, both HDD65 and CDH74, that were necessary to satisfy Equation 5. These heating and cooling values were easily determined by solving for each variable independently. The calculated values of HDD65 and CDH74 were called intercepts and appeared on the criteria curves (CDH74 vs. HDD65) as the points where the criteria line intersects the horizontal and vertical axes. The heating intercept equation is

$$\mathrm{HDD65} = \frac{\Delta FC \cdot \mathrm{AFUE} \cdot \mathrm{HDE}}{\Delta U \cdot \mathrm{HLF} \cdot P_h \cdot \dfrac{S_h}{S_2}} \tag{6}$$

where

S_h/S_2	=	economic scalar ratio (SR_h) for heating, dimensionless,

and the cooling intercept equation is

$$\mathrm{CDH74} = \frac{\Delta FC \cdot \mathrm{SEER} \cdot \mathrm{CDE}}{\Delta U \cdot \mathrm{CLF} \cdot P_c \cdot \dfrac{S_c}{S_2}} \tag{7}$$

where

S_c/S_2	=	economic scalar ratio (SR_c) for cooling, dimensionless.

Implementation

In order to calculate the intercepts, specific values had to be substituted into Equations 6 and 7. Cost data at the consumer level were assembled for construction materials and fuels across the country. National averages were used for the standard development. Construction costs were assembled as an ASHRAE research project and then reviewed, changed, and augmented by the SPC. The fuel costs used were determined by weighting the fuel costs for 73 locations by the number of single-family housing starts. The weighted national values were \$0.527/therm for natural gas and \$0.0786/kWh for electricity.

A central forced-air gas furnace (AFUE = 0.68) and air conditioner (SEER = 8.5) were assumed as the representative equipment. Heating distribution efficiencies (HDE) were set at 75% and the cooling distribution efficiencies (CDE) at 80%.

The heating and cooling scalar ratios were both set equal to 18. This value was selected to achieve a 25% energy reduction from the current standard using a national energy model (McBride and Powell 1990). Furthermore, a scalar ratio of 18 was defendable when assuming representative economic input parameters (McBride 1991b).

The heating and cooling load factors were derived from detailed hourly computer simulations. Load factors were developed for both heating and cooling seasons and for all components above and below grade (McBride et al. 1991; Christian and Strzepek 1987).

Using all of these parameters, an optimization technique was developed and used to select the specific constructions as the criteria. Details on the optimization technique have been documented (McBride 1991a).

The final results are presented in Table 5-3 for single-family houses and in Table 5-6 for multi-family structures. Breakpoints are presented in Table 5-6 which account for the thermal impact of higher internal loads to exterior envelope areas for multi-family structures (McBride et al. 1991).

Balance

"Balance" was the term applied to the envelope requirements to mean that each component had to satisfy the same economic hurdle. The economic hurdle was that each component would meet the same scalar ratio as used in Equation 5, which represented a totally different concept than in previous versions of the standard.

Balance was an issue at two levels. One level existed between major envelope components, such as ceilings, walls, floors, and fenestration. Economic balance avoided the potential problem of requiring too stringent a level for one component while making another component's requirement too lenient.

The second level existed between options within a major component, such as frame and masonry walls. Previous versions of the standard had a single wall requirement and required equal energy performance for trade-off calculations. The economic balance concept advocated separate wall requirements, one for frame walls and another for masonry walls, because the materials and applications were different, which means their costs were different. Therefore, each wall would have to meet the same scalar ratio requirement, but the frame wall would use less energy.

STRINGENCY

The stringency issue was defined by requiring the prescriptive criteria in the new standard to be 25% more energy efficient than the existing standard. The 25% requirement was a value set by the 90.2 committee. The intent was to save a significant amount of energy. A value less than 25% was not considered worth the effort to develop a new standard, and values greater than 25% were considered too bold for a single revision.

There was a distinct relationship between the desired 25% energy savings and the scalar ratio. As expected, a low scalar ratio would not save any energy relative to the existing standard. Conversely, selecting a scalar ratio too high would not survive the consensus review process. Determining the relationship and selecting a scalar ratio of 18 was accomplished by developing a national energy model (McBride and Powell 1990). Once the scalar ratio was determined, it was used to determine the energy-saving opportunities of foundations (Christian 1988).

PRESENTATION FORMAT

The presentation format for the prescriptive envelope criteria was graphical. A typical example is Figure 5-1-A/B. The criteria figure numbers correspond directly with the draft standard. (All figures begin with the number five because they are contained in section five of the draft standard.)

The horizontal axis is heating degree-days base 65°F (HDD65) and the vertical axis is cooling degree-hours base 74°F (CDH74). This format explicitly accounts for both the heating and cooling dependence. The negative slope of the criteria lines is a direct indication of the cooling impact. Accounting for the cooling dependence represents a significant improvement over previous versions of the standard.

The diagonal lines identify the prescriptive requirements as distinct bands. The requirement is uniform within a specific band and only changes in adjacent bands. The criteria are expressed in various terms depending upon the component. Thermal transmittance (U) values were used for above-grade components, including the inside and outside air film coefficients at winter design conditions. Thermal conductance (C) values were used for below-grade components to avoid the problem of accounting for the surrounding soil. Thermal resistance (R) values were used for slab insulations.

This format had several advantages. It was easy to use, simple to understand, avoided any proprietary products as criteria, and allowed alternative materials and manufacturers to be specified in demonstrating compliance.

In each figure the first or least stringent requirement was the uninsulated base-case construction. The base case for fenestration was single glazing with an aluminum frame. Each successive band represented an increase in the stringency of the criteria until HDD65 reached a value of 10,000. Above 10,000 HDD65, the criteria were presented in tables because there was no significant cooling dependence.

Determination of Compliance

To use the figure, one simply locates the city or location of interest by the intersection of the HDD65 and CDH74 values as a single point. The point falls either within a band or on a diagonal line that defines the requirements. When the point is located clearly between the requirement lines, compliance is easily determined. However, when the point lies close to or on a requirement line, it may be difficult to graphically determine the correct requirement. Compliance can be determined by calculating the relative climate ratio (RCR) as presented in Equation 8. This applies to all requirement lines, including fenestration shading coefficients.

$$RCR = \frac{HDD65_c}{IHDD65} + \frac{CDH74_c}{ICDH74} \tag{8}$$

where

$HDD65_c$ = heating degree-days base 65°F for the city or location being evaluated,

$CDH74_c$ = cooling degree-hours base 74°F for the city or location being evaluated,

IHDD65 = heating intercept of a specific requirement line from the appropriate table (5-3 or 5-6),

ICDH74 = cooling intercept of a specific requirement line from the appropriate table (5-3 or 5-6).

Then determine which requirement the city or location shall meet using the following:

Single-Family Housing

(a) If RCR > 1.0, then the city or location is above the line.

(b) If RCR < 1.0, then the city or location is below the line.

(c) If RCR = 1.0, then the city or location is on the line and must meet the more stringent requirement.

Multi-Family Structures

(a) If RCR > 1.0, then the city or location is above the line.

(b) If RCR < 1.0 and $CDH74_c$ > BPCDH74, then the city or location is above the line.

(c) If RCR < 1.0 and $CDH74_c$ < BPCDH74, then the city or location is below the line.

(d) If RCR = 1.0, then the city or location is on the line and must meet the more stringent requirement.

where

BPCDH74 = breakpoint cooling degree-hours base 74°F.

PRESCRIPTIVE ENVELOPE REQUIREMENTS

Initially, prescriptive envelope requirements were developed for every type of component the SPC could envision. This led to 128 figures, which were deemed too many. To simplify the standard, many components were consolidated.

Examples of the consolidation include above-grade frame walls and band joists; above-grade concrete, masonry, or log walls with exterior or integral insulation; above-grade concrete, masonry, or log walls with interior insulation; concrete or masonry walls adjacent to unconditioned space; all basement walls (shallow, deep, and all-weather wood); below-grade basement walls with interior insulation; crawl space walls (concrete, masonry, and frame); and all fenestration (windows, sliding glass doors, and skylights). The consolidation was justified in many cases because the differences in the criteria were small. In other cases, the consolidation was either a judgment or political decision based on the affected industries.

The prescriptive envelope requirements also varied depending upon the type of residence: single-family houses, manufactured housing, and multi-family structures. Each will be reviewed in detail.

Mandatory Requirements

There are mandatory calculation requirements regarding thermal bridges and anomalies that all buildings must follow in demonstrating compliance. Parallel and series paths must be analyzed for wood-framing members and webs in masonry construction. Fenestration must account for the thermal performance of the center-of-glass, edge-of-glass, and frame (ASHRAE 1989). Metal framing members can be analyzed by either using the zone method (ASHRAE 1989) or Equations 9 through 11 and the parallel path correction factor from Table 5-1.

$$U_i = \frac{1}{R_t}, \tag{9}$$

$$R_t = R_i + R_e \tag{10}$$

where

U_t = total thermal transmittance of the envelope assembly, Btu/h·ft²·°F;

R_t = total resistance of the envelope assembly, h·ft²·°F/Btu;

R_i = thermal resistance of the series elements (for i = 1 to n), excluding the parallel path element(s), h·ft²·°F/Btu;

R_e = equivalent resistance of the element containing the parallel path, h·ft²·°F/Btu.

The value of R_e is defined by Equation 11:

$$R_e = (\text{R-value of insulation}) \cdot F_c \tag{11}$$

where

F_c = correction factor from Table 5-1, dimensionless.

Laboratory- or field-measured data can be substituted for the required calculations provided they are obtained from one of the following test methods:

(a) guarded hot plate (ASTM C177-85)
(b) heat flow meter (ASTM C518-85)
(c) guarded hot box (ASTM C236-87)
(d) calibrated hot box (ASTM C976-90)

Single-Family Houses

All of the envelope criteria are presented in Figures 5-1-A/B through 5-16-A/B for locations below 10,000 HDD65. For locations above 10,000 HDD65, the criteria are presented in Table 5-2. The intercepts used to prepare the figures are presented in Table 5-3.

There were several unique features of the criteria. Different criteria were developed for ceilings with attics and ceilings without attics (flat or cathedral) and accounted for the location dependence of the air distribution system. Concrete or masonry walls had different criteria depending upon the location of the insulation (exterior or integral and interior, both above grade and below grade). Criteria were developed for surfaces adjacent to unconditioned spaces (frame or masonry walls and frame floors). Separate criteria for doors were developed depending upon the materials (architectural wood or thermally insulating materials). Fenestration shading criteria were developed for the first time in the standard.

The top half (A) of each figure represents the air distribution system located within the conditioned space, while the bottom half (B) of each figure represents the air distribution system located outside the conditioned space. Houses with the air distribution system located within the conditioned space had less stringent criteria than those where the air distribution system was outside the conditioned space. The use of dual figures served two purposes. First, separate figures clearly delineated the impact of the location of the air distribution system. Second, they served as a simple trade-off system because no calculations were required.

In addition to the prescriptive thermal requirements, a limit was imposed on the amount of fenestration area that was allowed in the prescriptive compliance path. The initial value was set at 15% of the conditioned floor area, and no more than 8% could exist on any single orientation. The final criterion eliminated a prescriptive requirement and requires the trade-off procedure to be used to determine the allowed fenestration area. The basis for the trade-off analysis is that the fenestration is 18% of the conditioned floor area and uniformly distributed on the four cardinal orientations. Furthermore, no area limitations were imposed by orientation.

Manufactured Housing

Initially, criteria figures for manufactured housing were developed in the same format as for single-family houses. During the first public review, comments were received that did not support that format. Instead, the traditional format of a U_o-value for the entire envelope was preferred. The U_o would be defined for zones that follow state boundaries, similar to the procedure used by the Department of Housing and Urban Development in the federal standard (P.L. 93-383). The SPC worked with the manufactured housing industry and converted to the U_o format. The stringency developed in the initial format was retained. The final zones are presented in Figure 5-17. Hawaii and U.S. possessions are included in Zone I while Alaska is Zone III. The criteria are presented in Table 5-4.

TABLE 5-1
Wall Sections with Metal Studs—Parallel Correction Factors

Size of Studs	Gauge of Studs	Spacing of Studs, in.	Cavity Insulation R-Value	Correction Factor (F_c)
2 x 4	18 - 16	16 o.c.	R-11	0.50
2 x 4	18 - 16	24 o.c.	R-11	0.60
2 x 6	18 - 16	16 o.c.	R-19	0.40
2 x 6	18 - 16	24 o.c.	R-19	0.45

SINGLE FAMILY HOUSES

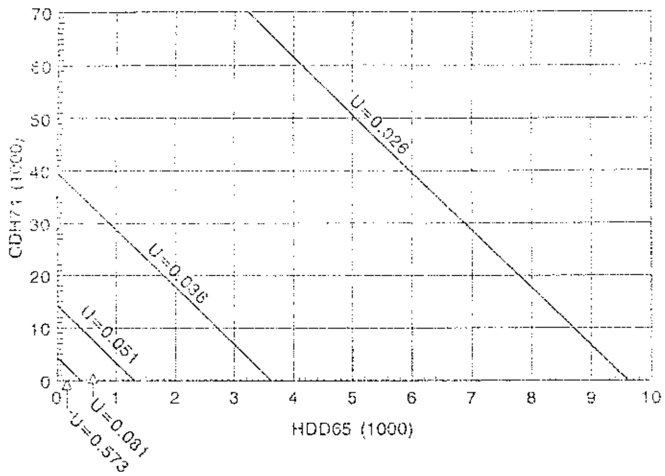

Figure 5-1-A *Ceilings with attics (ducts within conditioned space).*

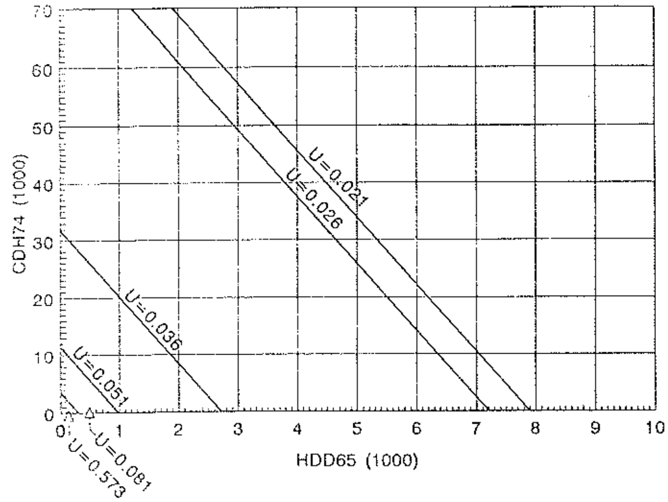

Figure 5-1-B *Ceilings with attics (ducts outside conditioned space).*

SINGLE FAMILY HOUSES

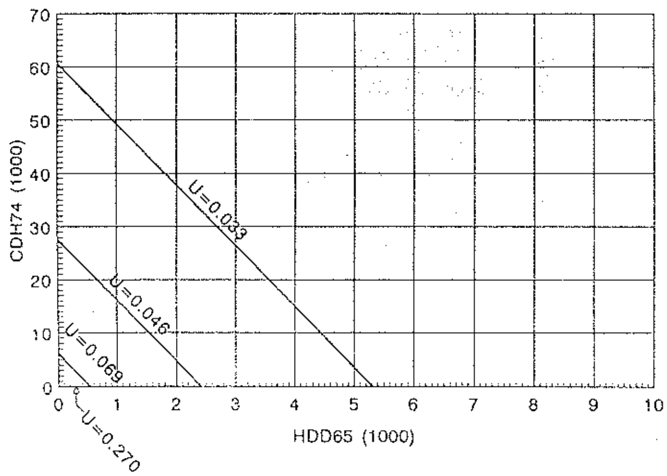

Figure 5-2-A *Ceilings without attics (ducts within conditioned space).*

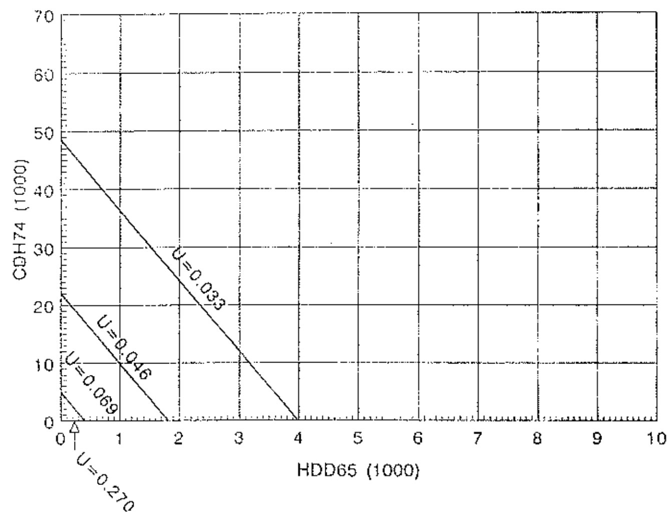

Figure 5-2-B *Ceilings without attics (ducts outside conditioned space).*

SINGLE FAMILY HOUSES

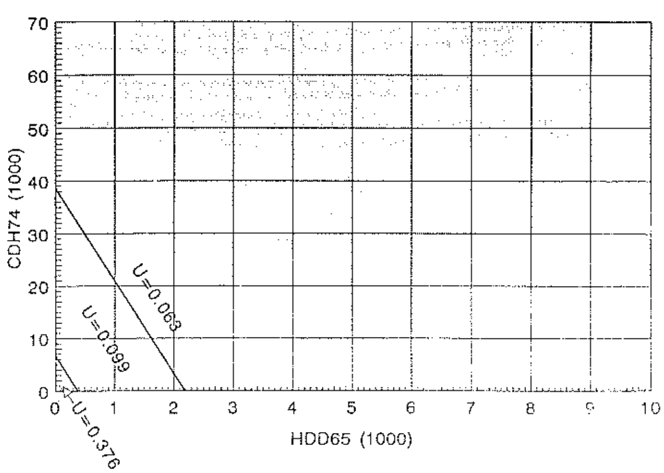

Figure 5-3-A *Above-grade frame walls and band joists (ducts within conditioned space).*

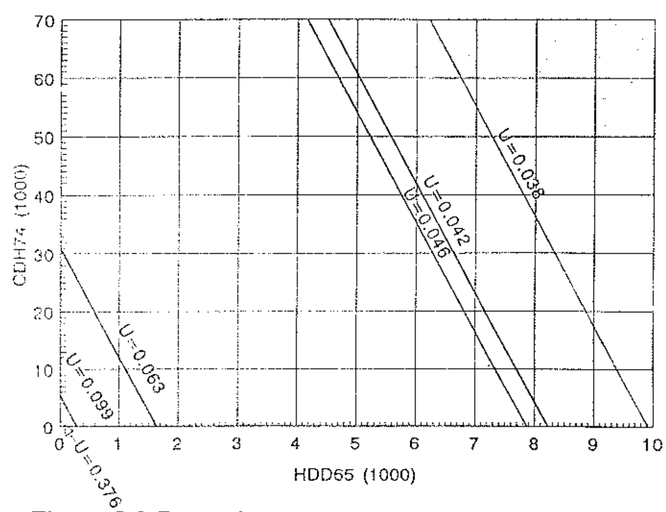

Figure 5-3-B *Above-grade frame walls and band joists (ducts outside conditioned space).*

SINGLE FAMILY HOUSES

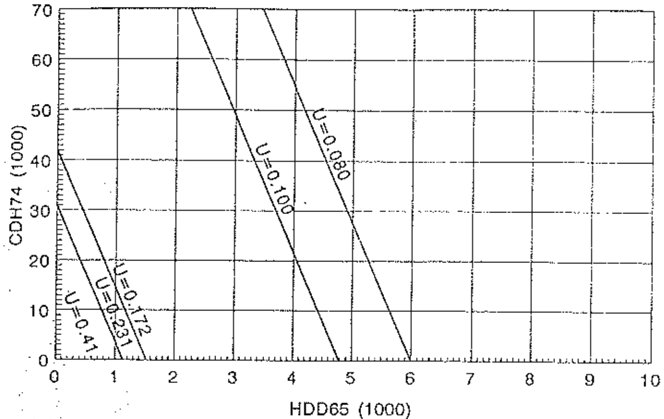

Figure 5-4-A *Above-grade concrete, masonry, or log walls with exterior or integral insulation (ducts within conditioned space).*

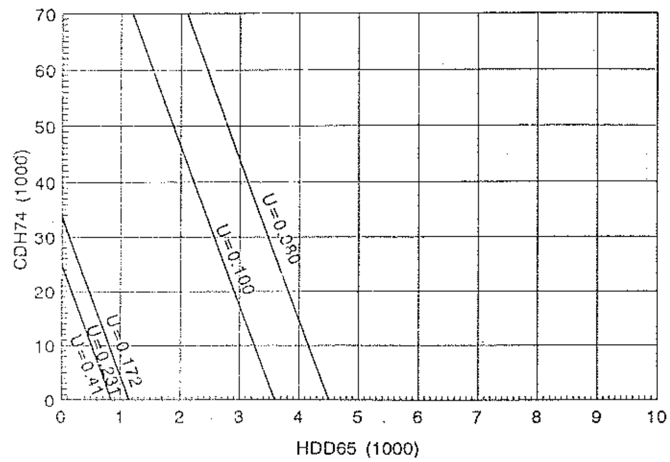

Figure 5-4-B *Above-grade concrete, masonry, or log walls with exterior or integral insulation (ducts outside conditioned space).*

SINGLE FAMILY HOUSES

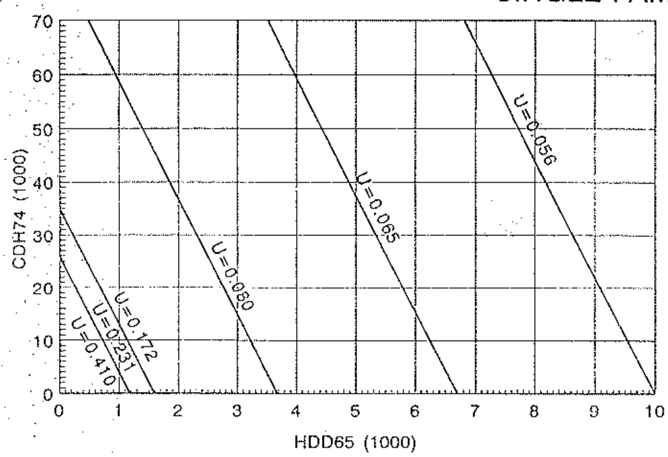

Figure 5-5-A *Above-grade concrete, masonry, or log walls with interior insulation (ducts within conditioned space).*

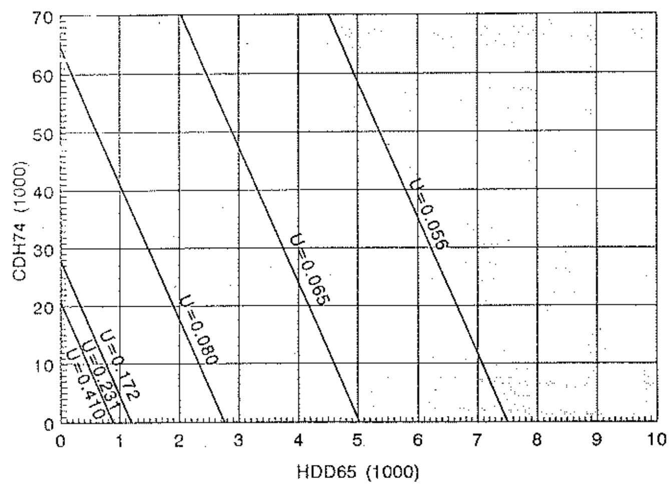

Figure 5-5-B *Above-grade concrete, masonry, or log walls with interior insulation (ducts outside conditioned space).*

SINGLE FAMILY HOUSES

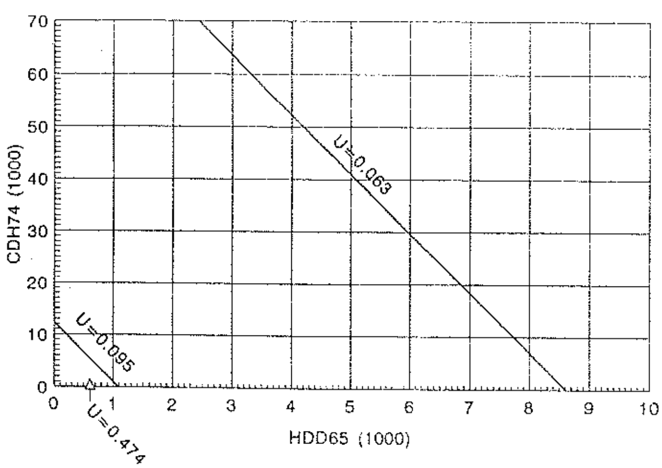

Figure 5-6-A *Wood frame walls adjacent to unconditioned space (ducts within conditioned space).*

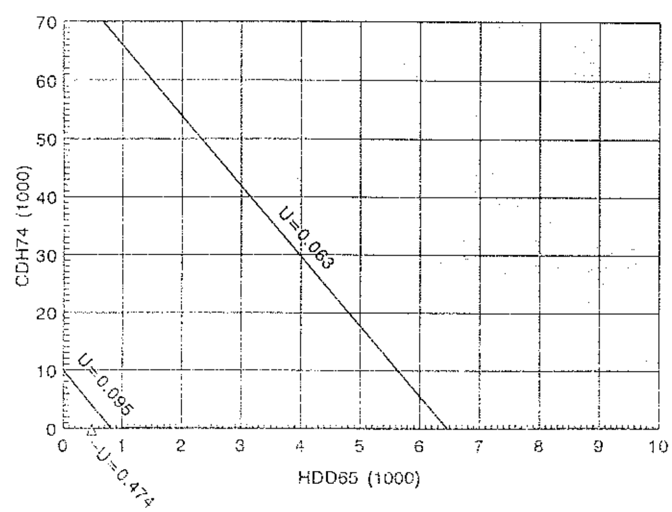

Figure 5-6-B *Wood frame walls adjacent to unconditioned space (ducts outside conditioned space).*

SINGLE FAMILY HOUSES

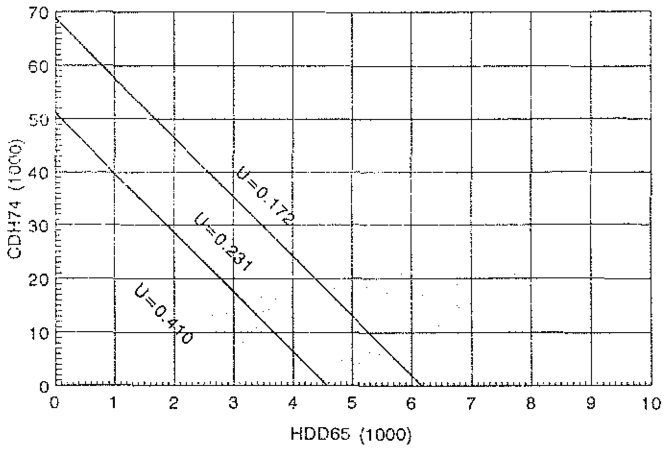

Figure 5-7-A *Concrete or masonry walls adjacent to unconditioned space (ducts within conditioned space).*

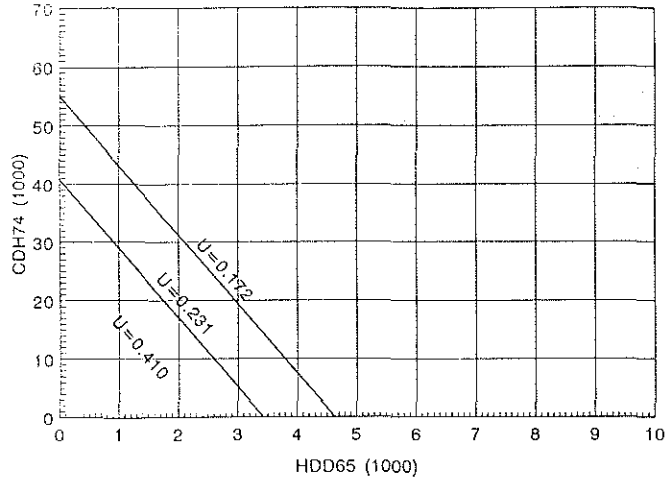

Figure 5-7-B *Concrete or masonry frame walls adjacent to unconditioned space (ducts outside conditioned space).*

SINGLE FAMILY HOUSES

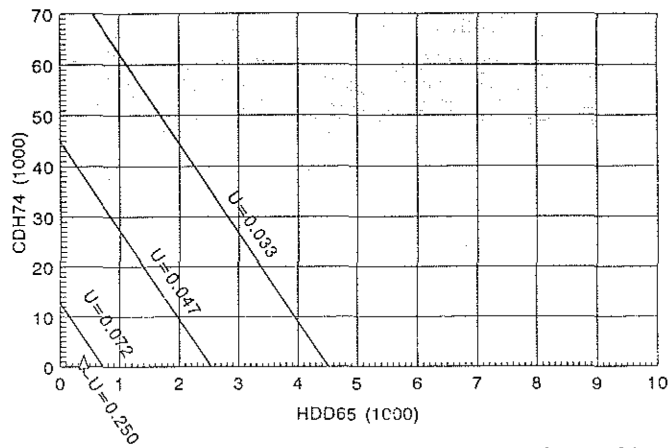

Figure 5-8-A *Wood frame floors over exterior ambient conditions—overhangs, carports, porches (ducts within conditioned space).*

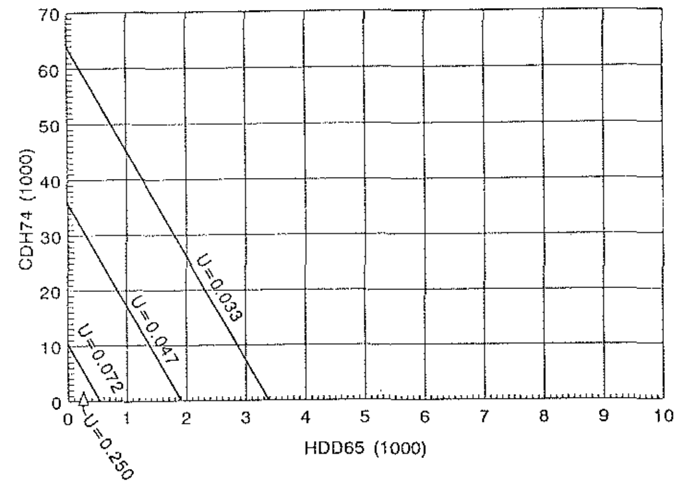

Figure 5-8-B *Wood frame floors over exterior ambient conditions—overhangs, carports, porches (ducts outside conditioned space).*

SINGLE FAMILY HOUSES

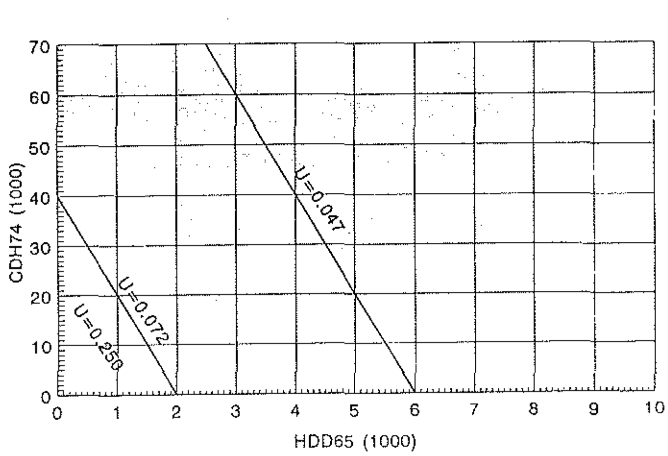

Figure 5-9-A *Wood frame floors over unconditioned space—vented crawl spaces, basements, enclosed garages, or porches (ducts within conditioned space).*

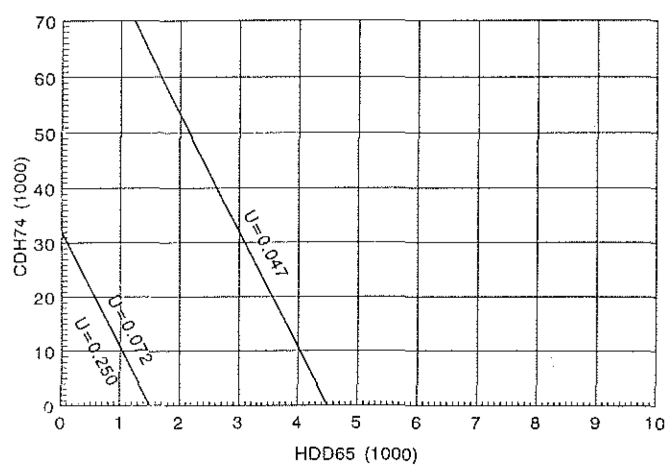

Figure 5-9-B *Wood frame floors over unconditioned space—vented crawl spaces, basements, enclosed garages, or porches (ducts outside conditioned space).*

SINGLE FAMILY HOUSES

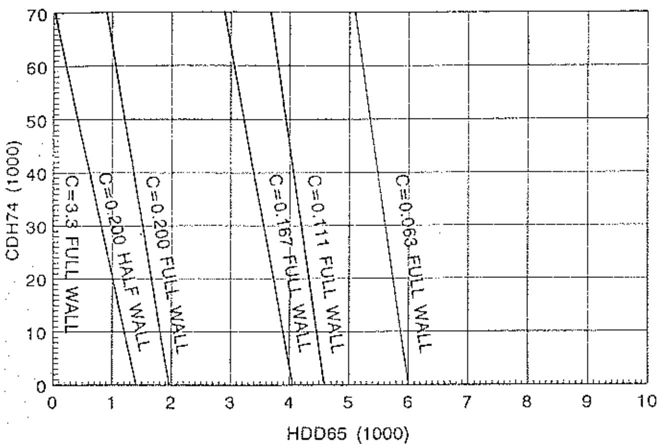

Figure 5-10-A *Below-grade basement walls with exterior or integral insulation (ducts within conditioned space).*

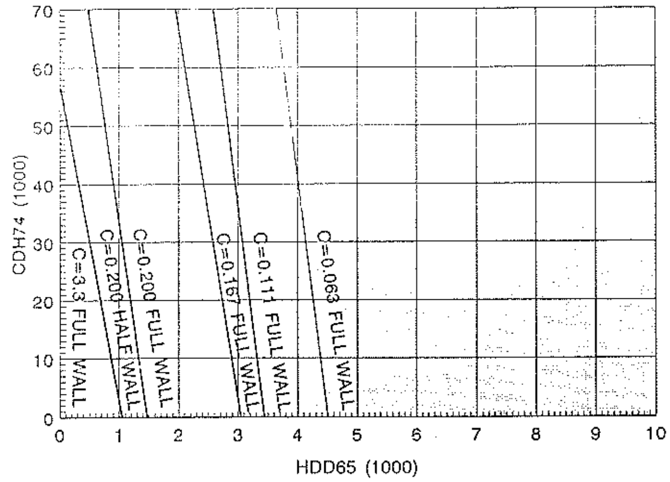

Figure 5-10-B *Below-grade basement walls with exterior or integral insulation (ducts outside conditioned space).*

SINGLE FAMILY HOUSES

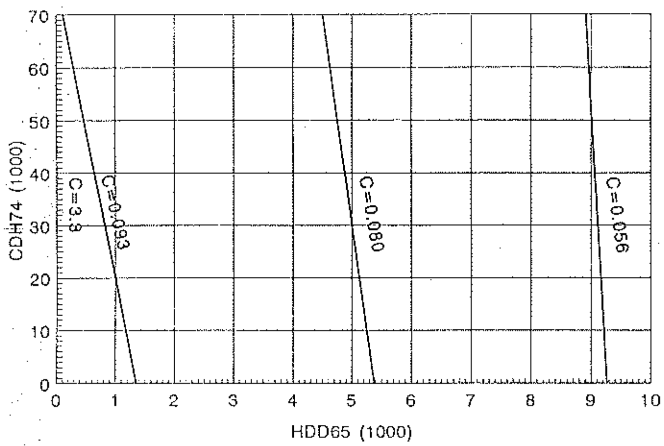

Figure 5-11-A *Below-grade basement walls with interior insulation (ducts within conditioned space).*

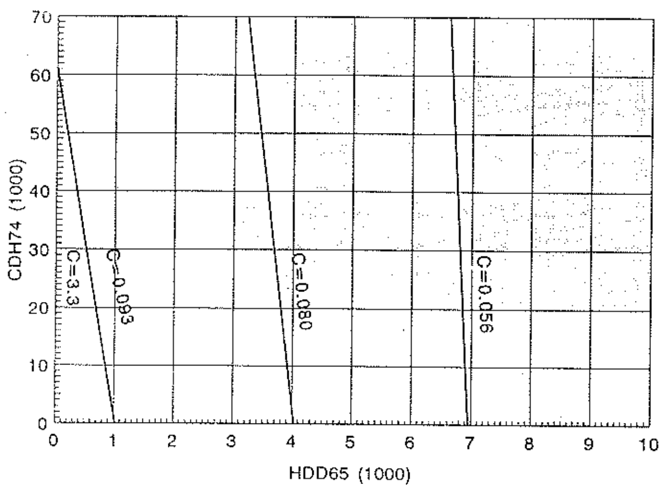

Figure 5-11-B *Below-grade basement walls with interior insulation (ducts outside conditioned space).*

SINGLE FAMILY HOUSES

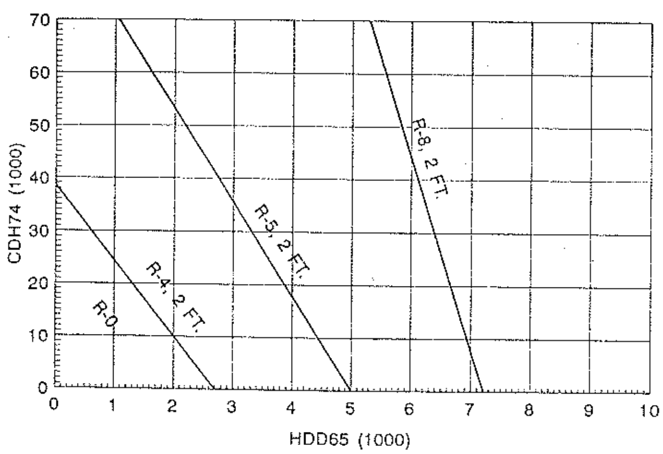

Figure 5-12-A *Slab-on-grade floors (ducts within conditioned space).*

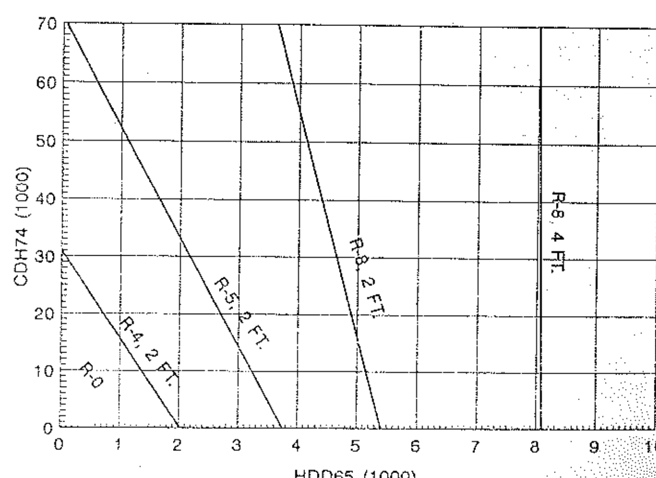

Figure 5-12-B *Slab-on-grade floors (ducts outside conditioned space).*

SINGLE FAMILY HOUSES

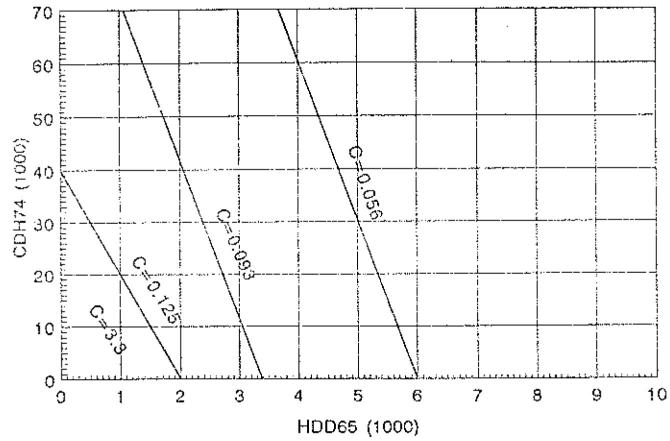

Figure 5-13-A *Crawl space walls (ducts within conditioned space).*

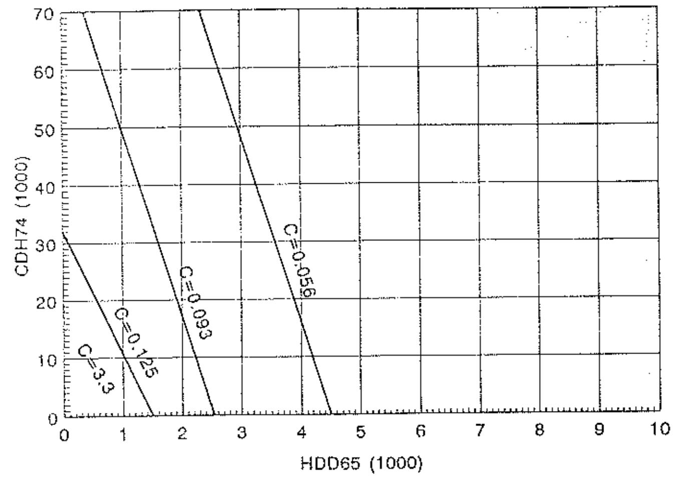

Figure 5-13-B *Crawl space walls (ducts outside conditioned space).*

SINGLE FAMILY HOUSES

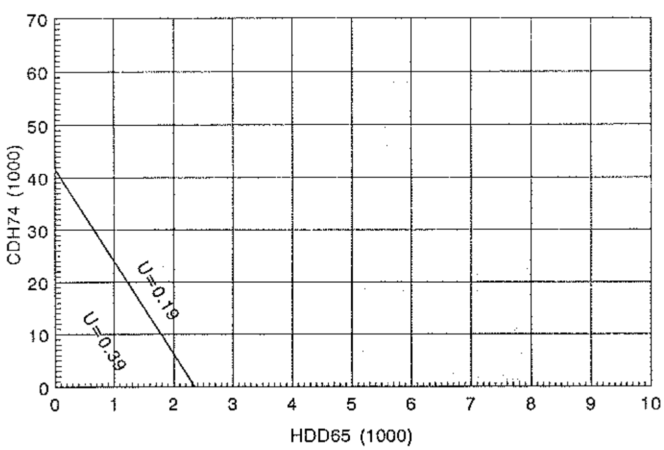

Figure 5-14-A *Nonwood doors (ducts within conditioned space).*

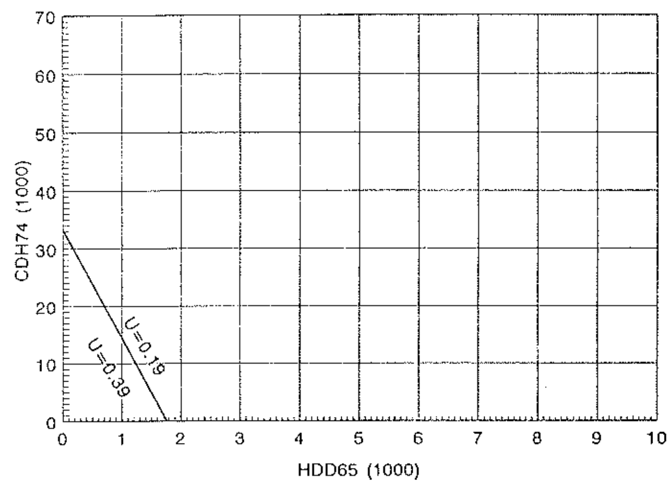

Figure 5-14-B *Nonwood doors (ducts outside conditioned space).*

SINGLE FAMILY HOUSES

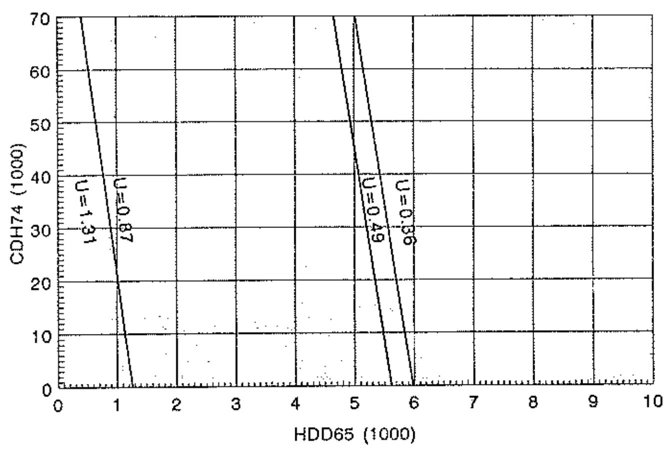

Figure 5-15-A *Fenestration U-values including framing (ducts within conditioned space).*

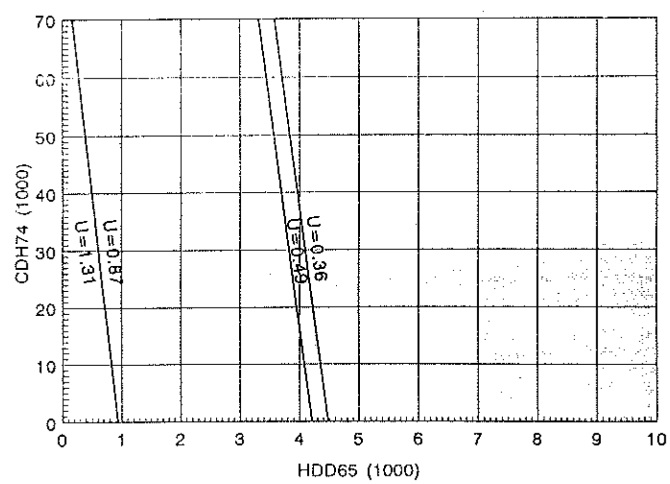

Figure 5-15-B *Fenestration U-values including framing (ducts outside conditioned space).*

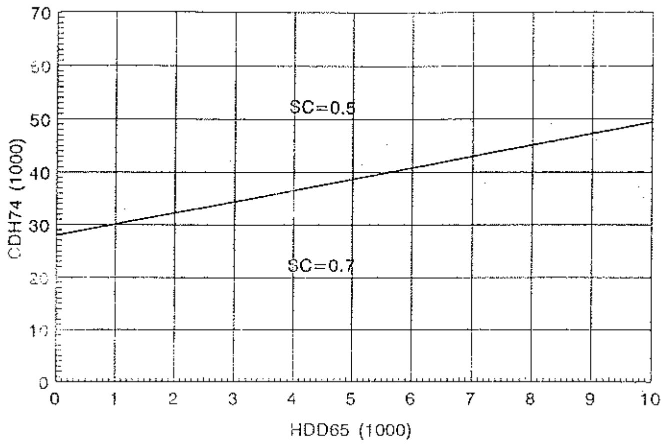

Figure 5-16-A *Fenestration shading coefficients (ducts within conditioned space).*

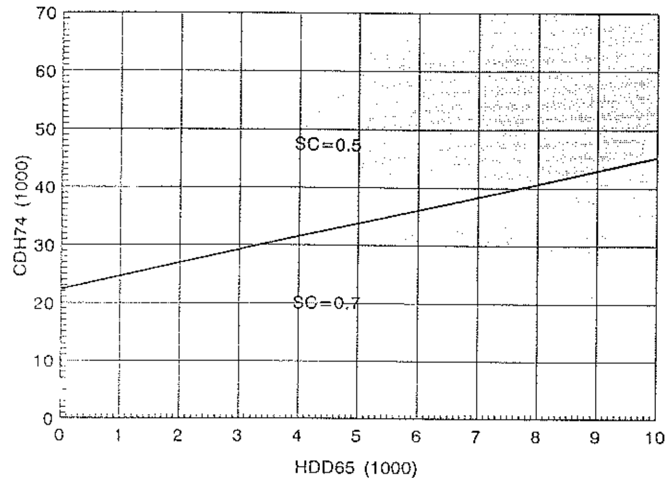

Figure 5-16-B *Fenestration shading coefficients (ducts outside conditioned space).*

TABLE 5-2
Single-Family Housing Requirements Above 10,000 HDD65

Component	Value	HDD65			
		10001 to 12000	12001 to 15000	15001 to 18000	18001 to 21000
CEILINGS					
With Attic	U	0.021	0.021	0.018	0.018
Without Attic	U	0.033	0.033	0.033	0.033
WALLS					
Above-Grade	U	0.042	0.042	0.038	0.038
Below-Grade	C	0.063	0.063	0.063	0.063
Crawl Space	C	0.056	0.056	0.056	0.056
Frame Adj. Uncon. Space	U	0.059	0.059	0.059	0.059
Mass Adj. Uncon. Space	U	0.172	0.172	0.080	0.080
SLAB	R	8	10	12	14
FLOORS					
Over Ambient Conditions	U	0.033	0.033	0.033	0.033
Over Uncon. Space	U	0.033	0.033	0.033	0.033
NON-WOOD DOORS	U	0.19	0.19	0.19	0.19
FENESTRATION	U	0.36	0.36	0.36	0.36
	SC	0.7	0.7	0.7	0.7

TABLE 5-3
Heating and Cooling Intercepts for Single-Family Houses

		DUCTS WITHIN CONDITIONED SPACE			DUCTS OUTSIDE CONDITIONED SPACE	
FIG. 5-1	CEILINGS WITH ATTICS					
	U=0.573	IHDD65	ICDH74		IHDD65	ICDH74
	U=0.081	403	4417		302	3534
	U=0.051	1305	14302		979	11442
	U=0.036	3625	39730		2719	31784
	U=0.026	9615	105372		7211	84298
	U=0.021				7898	92326
FIG. 5-2	CEILINGS WITHOUT ATTICS					
	U=0.270	IHDD65	ICDH74		IHDD65	ICDH74
	U=0.069	539	6152		404	4922
	U=0.046	2418	27623		1814	22098
	U=0.033	5311	60665		3983	48532
FIG. 5-3	ABOVE-GRADE FRAME WALLS AND BAND JOISTS					
	U=0.376	IHDD65	ICDH74		IHDD65	ICDH74
	U=0.099	378	6678		284	5342
	U=0.063	2184	38618		1638	30894
	U=0.046				7868	148406
	U=0.042				8222	155091
	U=0.038				9920	187121
FIG. 5-4	ABOVE-GRADE CONCRETE, MASONRY OR LOG WALLS WITH EXT. OR INTG. INS.					
	U=0.410	IHDD65	ICDH74		IHDD65	ICDH74
	U=0.231	1199	29889		899	23911
	U=0.172	1617	40302		1213	32242
	U=0.100	5111	127383		3833	101906
	U=0.080	6000	149540		4500	119632
FIG. 5-5	ABOVE-GRADE CONCRETE, MASONRY OR LOG WALLS WITH INTERIOR INS.					
	U=0.410	IHDD65	ICDH74		IHDD65	ICDH74
	U=0.231	1177	25829		883	20663
	U=0.172	1588	34827		1191	27861
	U=0.080	3672	80565		2754	64452
	U=0.065	6700	147000		5025	117600
	U=0.056	10000	219404		7500	175523
FIG. 5-6	WOOD FRAME WALLS ADJACENT TO UNCONDITIONED SPACE					
	U=0.474	IHDD65	ICDH74		IHDD65	ICDH74
	U=0.095	1083	12268		812	9814
	U=0.059	8617	.97577		6463	78062
FIG. 5-7	CONCRETE OR MASONRY WALLS ADJACENT TO UNCONDITIONED SPACE					
	U=0.410	IHDD65	ICDH74		IHDD65	ICDH74
	U=0.231	4577	51012	FULL WALL	3433	40810
	U=0.172	6176	68783	FULL WALL	4632	55027
FIG. 5-8	WOOD FRAME FLOORS OVER EXTERIOR AMBIENT CONDITIONS					
	U=0.250	IHDD65	ICDH74		IHDD65	ICDH74
	U=0.072	720	12764		540	10211
	U=0.047	2535	44943		1901	35954
	U=0.033	4507	79899		3380	63919
FIG. 5-9	WOOD FRAME FLOORS OVER UNCONDITIONED SPACE					
	U-0.250	IHDD65	ICDH74		IHDD65	ICDH74
	U=0.072	2000	40000		1500	32000
	U=0.047	6000	120000		4500	96000
FIG. 5-10	BELOW-GRADE BASEMENT WALLS WITH EXTERIOR OR INTEGRAL INS.					
	C=3.33	IHDD65	ICDH74	INSULATION	IHDD65	ICDH74
	C=0.200	1399	71395	HALF WALL	1049	57116
	C=0.200	1963	129784	FULL WALL	1472	103827
	C=0.167	4057	243345	FULL WALL	3043	194676
	C=0.111	4584	352500	FULL WALL	3438	282000
	C=0.063	6000	461387	FULL WALL	4500	369110
FIG. 5-11	BELOW-GRADE BASEMENT WALLS WITH INTERIOR INSULATION					
	C=3.33	IHDD65	ICDH74	INSULATION	IHDD65	ICDH74
	C=0.093	1355	76344	FULL WALL	1016	61075
	C=0.080	5372	432614	FULL WALL	4029	346091
	C=0.056	9265	1826592	FULL WALL	6949	1461273
FIG. 5-12	SLAB-ON-GRADE FLOORS					
	R=0	IHDD65	ICDH74	DEPTH	IHDD65	ICDH74
	R=4	2693	38664	2 FEET	2020	30931
	R=5	5000	88771	2 FEET	3750	71017
	R=3	7206	264375	2 FEET	5405	211500
	R=8			4 FEET	8085	VERTICAL
FIG. 5-13	CRAWL SPACE WALLS					
	C=3.33	IHDD65	ICDH74		IHDD65	ICDH74
	C=0.125	2000	40000		1500	32000
	C=0.093	3382	102145		2537	81716
	C=0.056	6000	181215		4500	144972
FIG. 5-14	NON-WOOD DOORS					
	U=0.39	IHDD65	ICDH74		IHDD65	ICDH74
	U=0.19	2349	41626		1762	33301
FIG. 5-15	FENESTRATION U-VALUES INCLUDING FRAME					
	U=1.31	IHDD65	ICDH74		IHDD65	ICDH74
	U=0.87	1258	103172		935	85121
	U=0.49	5620	408054		4207	329026
	U=0.36	5981	433279		4478	349207
FIG. 5-16	FENESTRATION SHADING COEFFICIENTS					
	SC=0.7	IHDD65	ICDH74		IHDD65	ICDH74
	SC=0.5	-13046	27980		-9785	22384

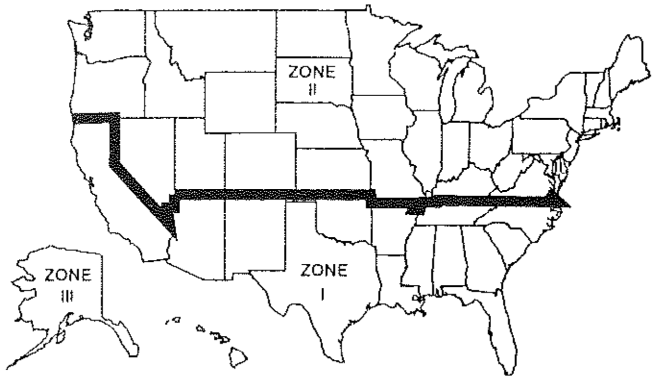

Figure 5-17 Manufactured housing zones.

TABLE 5-4
Manufactured (Mobile) Housing Requirements

Zone	Uo-value
I	0.1005
II	0.0767
III	0.0596

Multi-Family Structures

All of the envelope criteria are presented in Figures 5-18 through 5-36 for locations below 10,000 HDD65. For locations above 10,000 HDD65, the criteria are presented in Table 5-5. The intercepts used to prepare the figures are presented in Table 5-6.

Several unique features in these criteria were different from those previously cited for single-family houses. All of the above-grade components have offsets in the criteria lines to account for the difference in balance points. This difference originated because multi-family structures have lower exterior surface areas and higher internal loads per unit of floor area than single-family houses.

Furthermore, all the figures assumed that the ducts were located within the conditioned space. New criteria were developed for metal stud walls above grade and adjacent to unconditioned spaces. Concrete floors over exterior ambient conditions were also a new criterion. All of the foundation criteria (basements, crawl spaces, and slabs) were identical to those for single-family houses.

All Buildings

In addition to the thermal requirements for the envelope, requirements were also developed for air leakage, water vapor retarders and moisture barriers, and ventilation.

Mandatory air leakage requirements were included for windows, sliding doors, and swinging doors by listing specific reference standards. Also, access hatches and foundations are required to be sealed, as well as any penetration through the thermal envelope. Air infiltration retarders are recommended provided they are continuous and have a vapor permeance greater than or equal to 5.0 perm.

Water vapor retarders are required for all ceilings, all walls, over all exposed soil in crawl spaces, and below slabs with cables for radiant floor heating.

Ventilation is required in all attics. A free ventilating area of 1.0 ft^2 for each 150 ft^2 of attic floor area is recommended where no vapor retarder is provided. This becomes 300 ft^2 when a vapor retarder is present. A 1-in. ventilation space between insulating layers and roof decks in ceilings without attics (flat or cathedral) is recommended, unless the assembly is designed to be of moisture-vapor-tight construction. The ventilation requirement for crawl spaces is 1.0 ft^2 for each 1,500 ft^2 of crawl space floor area. When crawl space walls are insulated, operable vents are required.

WEATHER DATA

Complete and appropriate weather data are contained within the standard for 3,363 locations in the United States and its possessions plus 1,847 locations in Canada. The data consist of HDD65, CDH74, and annual average dry-bulb air temperature.

All of the weather data in the standard were calculated for each location using long-term (20 to 40 years) monthly average dry-bulb temperatures and the monthly average standard deviations. The United States data were supplied by the National Climatic Center of the National Oceanic and Atmospheric Administration (NOAA) in Asheville, NC. The Canadian weather data were supplied by Environment Canada, Atmospheric Environmental Services, Canadian Climate Center, Downsview, Ontario.

Various calculation methods were used to determine the required weather data from the monthly average data. Calculation of HDD65 was done by a documented method (Erbs et al. 1987). Calculation of CDH74 required development of a more sophisticated procedure. The basis for the CDH74 calculation was an assumption of gaussian or standard normal distributions but adjusted for autocorrelations. Autocorrelation means the data are a time series and related to themselves. Specifically, observations are not independent of one another if what happened in the past influences the future. Autocorrelations were developed for each month as a function of the average dry-bulb temperature using 1,212 months of hourly data from 101 locations. These autocorrelations were then applied to the monthly CDH74 calculations, and the results were summed to produce the annual totals.

The weather data were plotted to illustrate the combined domain of HDD65 and CDH74. Figure 5-37 presents the results for the United States and possessions. An inverse relationship between CDH74 and HDD65 is characterized by the broad band of the data. In general, as HDD65 increases, CDH74 decreases. There is a blank region around the origin except for the tropical locations, which have CDH74 values at HDD65 equal to zero. An upper boundary of the broad band exists but was not anticipated to be so sharp or distinct. The maximum value of CDH74 is close to 70,000. It occurs in the tropics and again in the desert Southwest. The values above 10,000 HDD65 were omitted in this figure.

Figure 5-38 presents the results for Canada. There are several points to note. The minimum value of HDD65 is 5,011, the average is 9,732, and the maximum is 24,719. The maximum CDH74 value is 7,548, while the average is 1,169. Clearly, cooling is not an issue, so it is excluded. Most of the data are clustered between 7,000 and 12,000 HDD65.

DISCUSSION OF RESULTS

The prescriptive envelope criteria proposed for ASHRAE Standard 90.2P were distinguished from previous versions by (1) the direct use of economics to establish the criteria, (2) the stringency and balance of the criteria, and (3) the graphical format that explicitly accounted for both heating and cooling. The focus of this discussion will be to summarize the major comments received during the two public review periods.

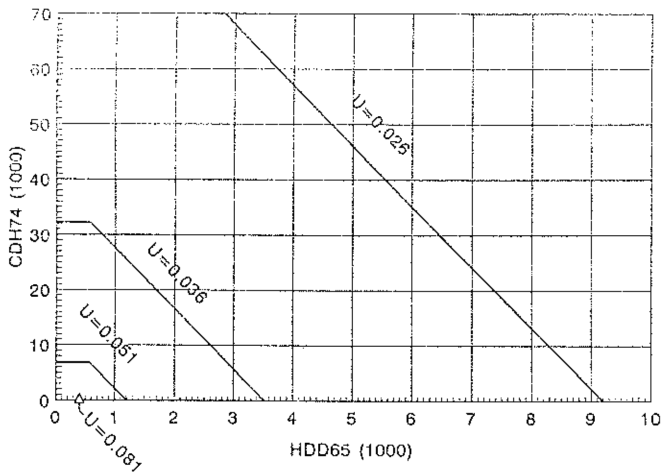

Figure 5-18 Ceilings with attics.

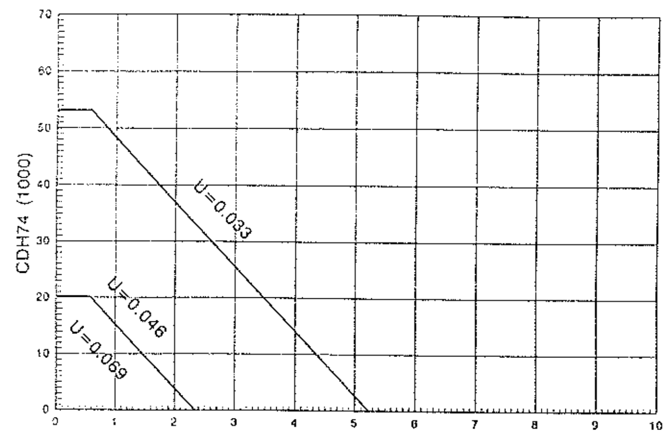

Figure 5-19 Ceilings without attics.

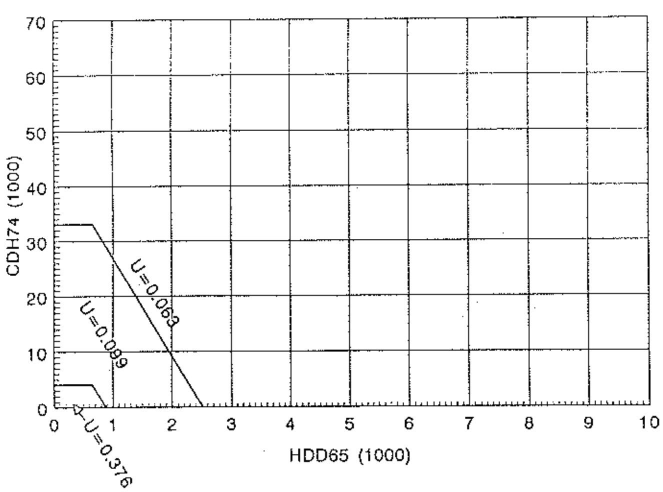

Figure 5-20 Above-grade frame walls and band joists.

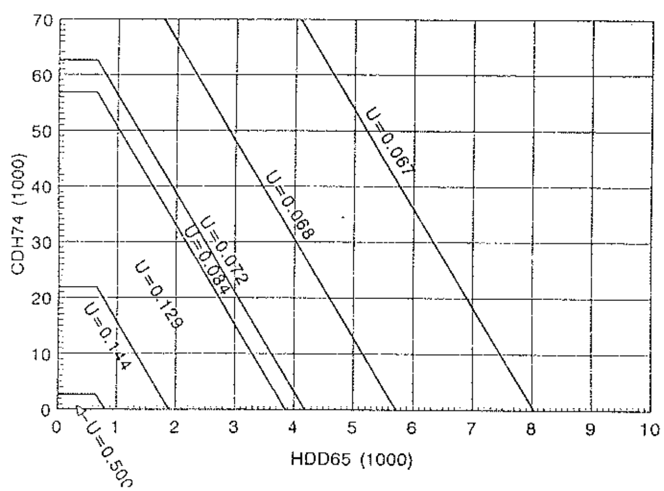

Figure 5-21 Above-grade metal frame walls.

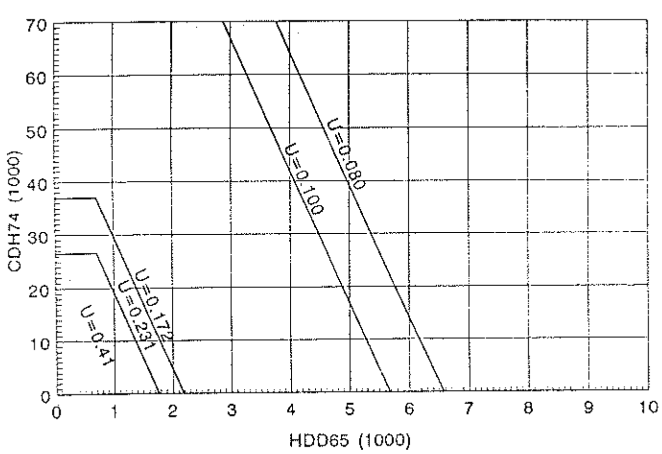

Figure 5-22 Above-grade concrete, masonry, or log walls with exterior or integral insulation.

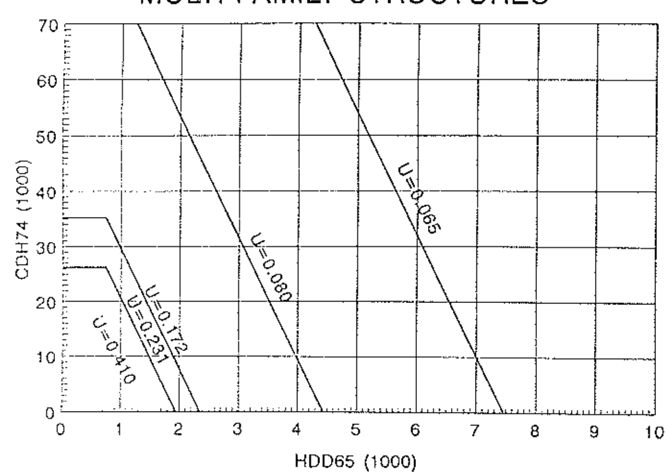

Figure 5-23 Above-grade concrete, masonry, or log walls with interior insulation.

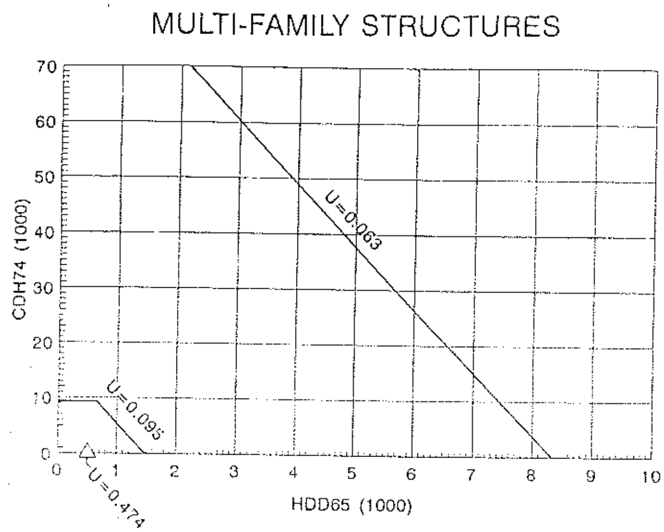

Figure 5-24 *Wood frame walls adjacent to unconditioned space.*

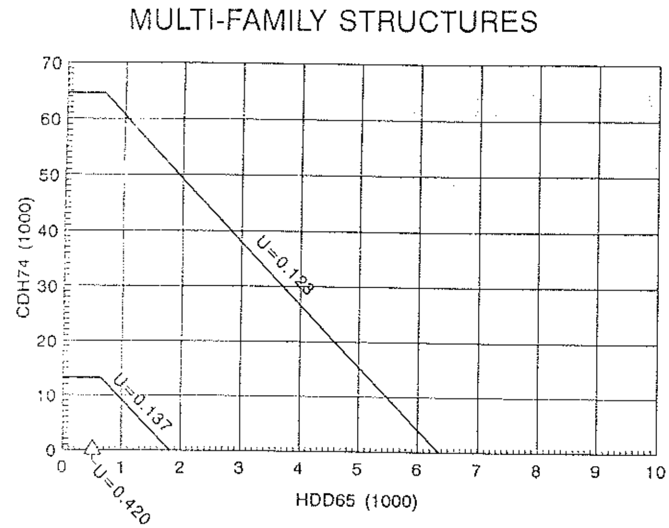

Figure 5-25 *Metal frame walls adjacent to unconditioned space.*

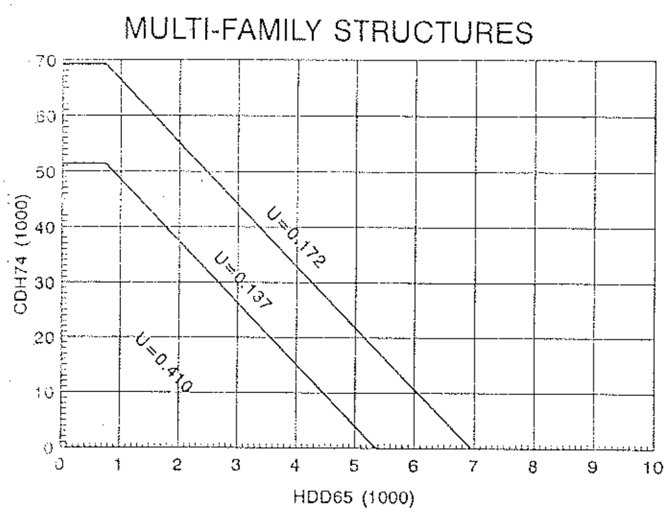

Figure 5-26 *Concrete or masonry walls adjacent to unconditioned space.*

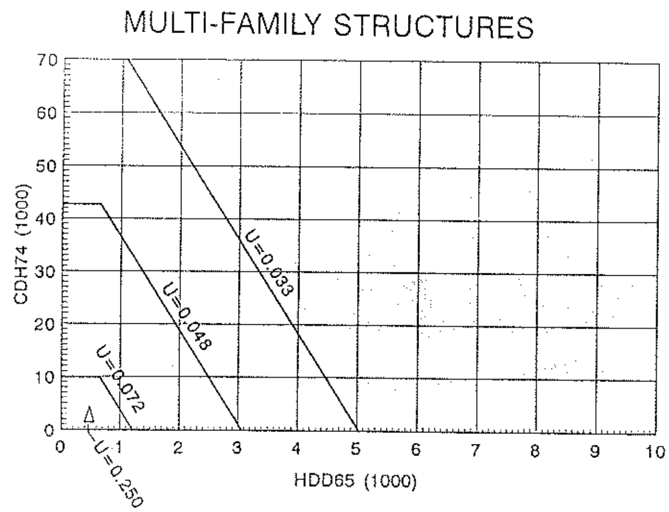

Figure 5-27 *Wood frame floors over exterior ambient conditions (overhangs, carports, porches).*

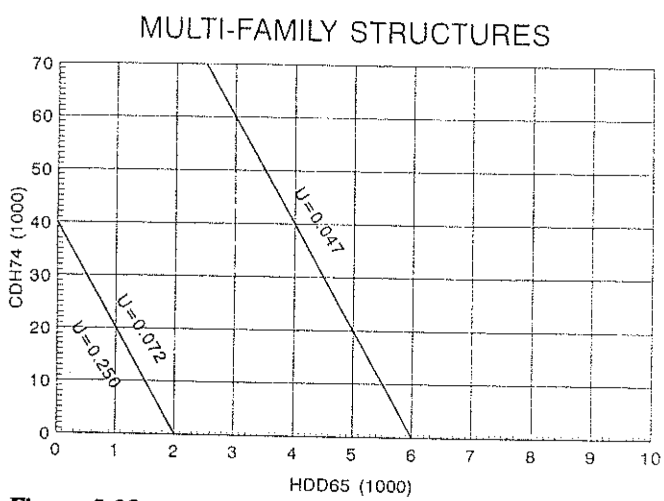

Figure 5-28 *Wood frame floors over unconditioned space (vented crawl spaces, basements, enclosed garages, or porches).*

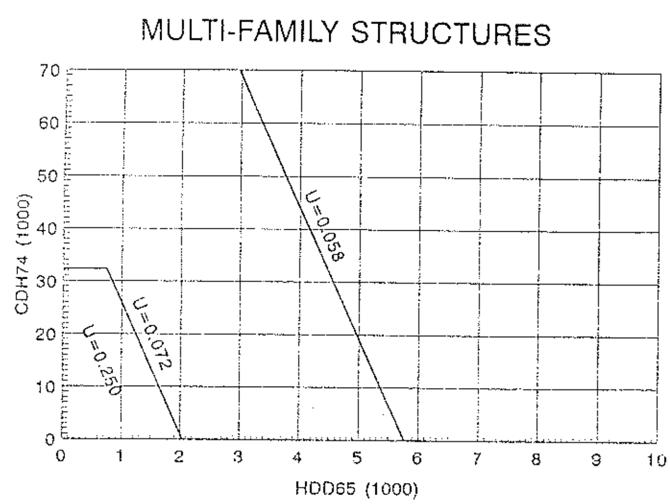

Figure 5-29 *Concrete floors over exterior ambient conditions (garages).*

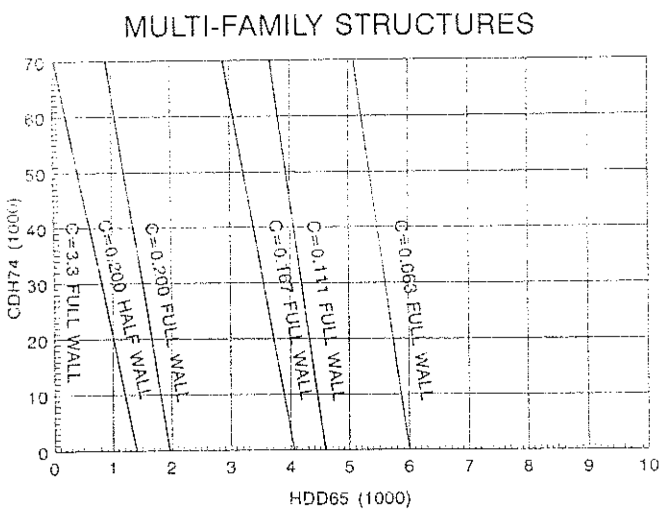

Figure 5-30 Below-grade basement walls with exterior or integral insulation.

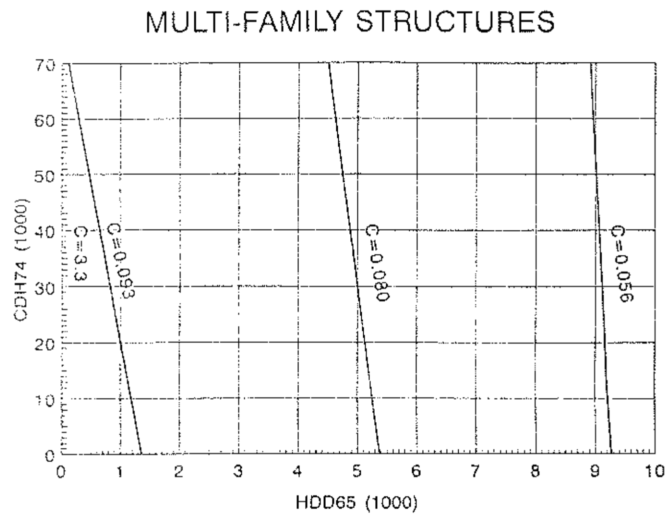

Figure 5-31 Below-grade basement walls with interior insulation.

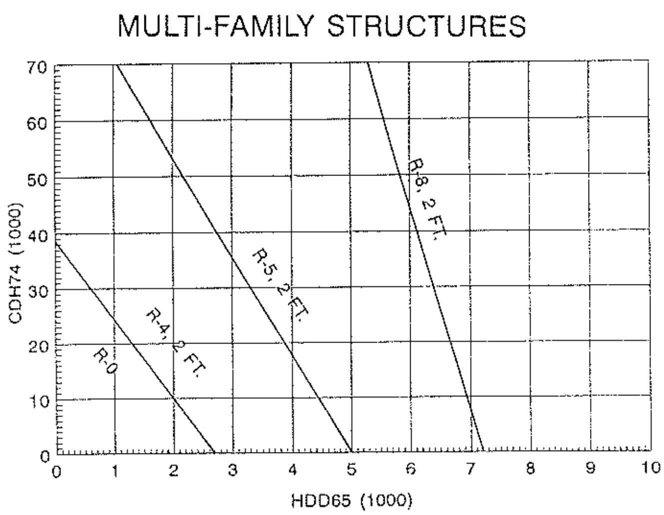

Figure 5-32 Slab-on-grade floors.

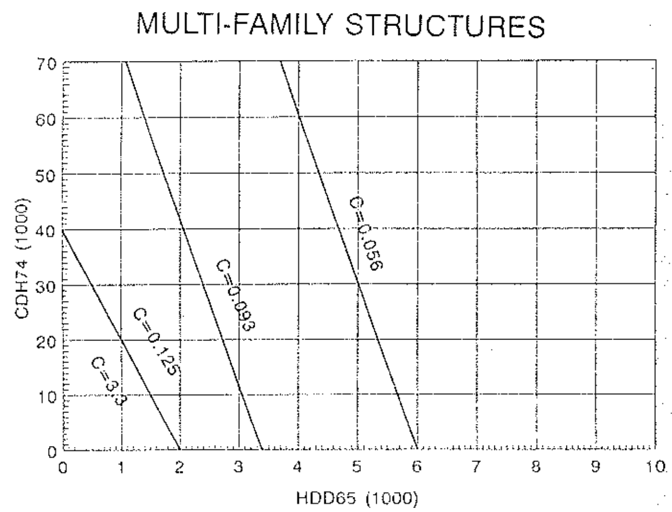

Figure 5-33 Crawl space walls.

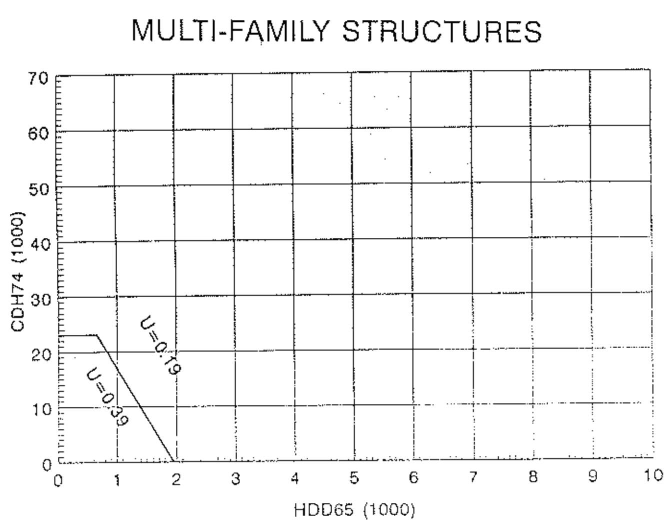

Figure 5-34 Nonwood doors.

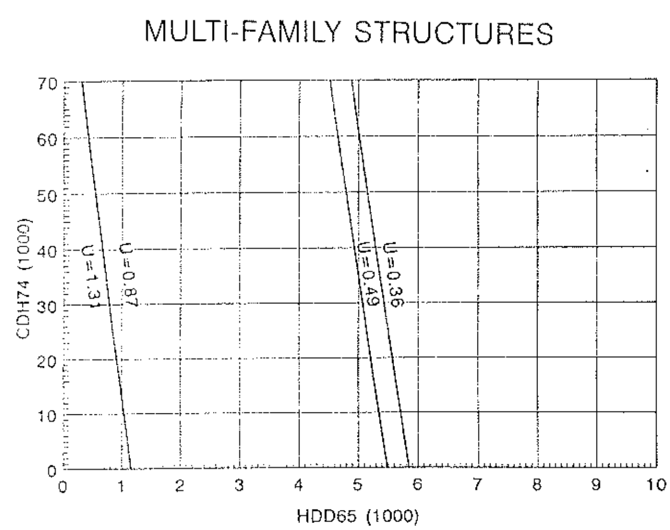

Figure 5-35 Fenestration U-values including framing.

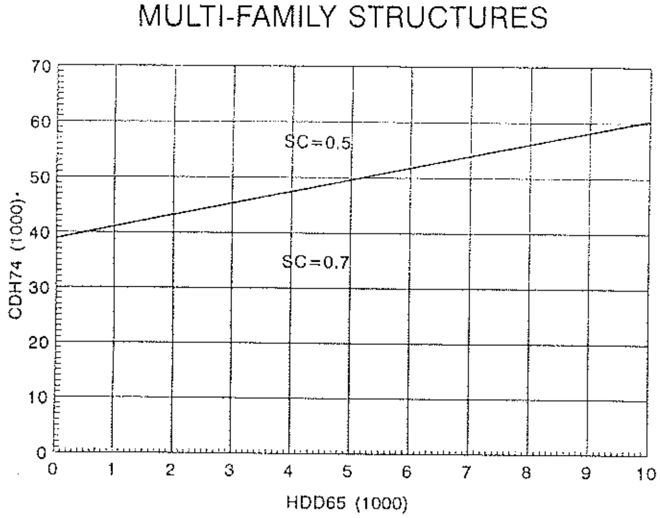

Figure 5-36 Fenestration shading coefficients.

TABLE 5-5
Multi-Family Housing Requirements Above 10,000 HDD65

Component	Value	HDD65 10001 to 12000	HDD65 12001 to 15000	HDD65 15001 to 18000	HDD65 18001 to 21000
CEILINGS					
With Attic	U	0.021	0.021	0.018	0.018
Without Attic	U	0.033	0.033	0.033	0.033
WALLS					
Wood Frame Above-Grade	U	0.042	0.038	0.038	0.038
Metal Frame Above-Grade	U	0.067	0.067	0.067	0.067
Below-Grade	C	0.063	0.063	0.063	0.063
Crawl Space	C	0.056	0.056	0.056	0.056
Wood Frame Adj. Uncon. Space	U	0.059	0.059	0.059	0.059
Metal Frame Adj. Uncon. Space	U	0.123	0.123	0.079	0.079
Mass Adj. Uncon. Space	U	0.172	0.172	0.080	0.080
SLAB	R	8	10	12	14
FLOORS					
Framed Over Ambient Cond.	U	0.033	0.033	0.033	0.033
Framed Over Uncon. Spaces	U	0.033	0.033	0.033	0.033
Concrete	U	0.058	0.058	0.058	0.058
NON-WOOD DOORS	U	0.19	0.19	0.19	0.19
FENESTRATION	U	0.36	0.36	0.36	0.36
	SC	0.7	0.7	0.7	0.7

TABLE 5-6
Heating and Cooling Intercepts and Breakpoints for Multi-Family Structures

FIG. 5-18 CEILINGS WITH ATTICS — BREAK POINTS

U-0.081	IHDD65	ICDH74	BPHDD65	BPCDH74
U-0.051	1196	13110	573	6830
U-0.036	3516	38538	573	32258
U-0.026	9206	100886		

FIG. 5-19 CEILINGS WITHOUT ATTICS

U-0.069	IHDD65	ICDH74	BPHDD65	BPCDH74
U-0.046	2337	26697	573	20151
U-0.033	5230	59738	573	53193

FIG. 5-20 ABOVE-GRADE WOOD FRAME WALLS AND BAND JOISTS

U-0.376	IHDD65	ICDH74	BPHDD65	BPCDH74
U-0.099	879	15559	648	4091
U-0.063	2520	44563	648	33104

FIG. 5-21 ABOVE-GRADE METAL FRAME WALLS

U-0.500	IHDD65	ICDH74	BPHDD65	BPCDH74
U-0.144	802	14158	648	2717
U-0.129	1887	33374	648	21914
U-0.084	3861	68294	648	56832
U-0.072	4188	74059	648	62600
U-0.068	5726	101265		
U-0.067	8037	142136		

FIG. 5-22 ABOVE-GRADE CONCRETE, MASONRY OR LOG WALLS WITH EXT. OR INTG. INS.

U-0.410	IHDD65	ICDH74	BPHDD65	BPCDH74
U-0.231	1767	44039	702	26549
U-0.172	2185	54449	702	36962
U-0.100	5679	141529		
U-0.080	6568	146200		

FIG. 5-23 ABOVE-GRADE CONCRETE, MASONRY OR LOG WALLS WITH INTERIOR INS.

U-0.410	IHDD65	ICDH74	BPHDD65	BPCDH74
U-0.231	1936	42476	739	26257
U-0.172	2347	51464	739	35255
U-0.080	4431	97209		
U-0.065	7456	163644		

FIG. 5-24 WOOD FRAME WALLS ADJACENT TO UNCONDITIONED SPACE

U-0.474	IHDD65	ICDH74	BPHDD65	BPCDH74
U-0.095	1472	16655	648	9321
U-0.059	8326	94274		

FIG. 5-25 METAL FRAME WALLS ADJACENT TO UNCONDITIOED SPACE

U-0.420	IHDD65	ICDH74	BPHDD65	BPCDH74
U-0.137	1815	20551	648	13212
U-0.123	6353	71930	648	64593

FIG. 5-26 CONCRETE OR MASONRY WALLS ADJACENT TO UNCONDITIONED SPACE

U-0.410	IHDD65	ICDH74	INSULATION	BPHDD65	BPCDH74
U-0.231	5355	59677	FULL WALL	739	51440
U-0.172	5340	94934	FULL WALL	739	69211
U-0.080	8470	375699	FULL WALL		

FIG. 5-27 WOOD FRAME FLOORS OVER EXTERIOR AMBIENT CONDITIONS

U-0.250	IHDD65	ICDH74	BPHDD65	BPCDH74
U-0.072	1208	21367	648	9906
U-0.048	3061	54135	648	42675
U-0.033	5033	89003		

FIG. 5-28 WOOD FRAME FLOORS OVER UNCONDITIONED SPACE

U-0.250	IHDD65	ICDH74
U-0.072	2000	40000
U-0.047	6000	120000

FIG. 5-29 CONCRETE FLOORS OVER EXTERIOR AMBIENT CONDITIONS

U-0.338	IHDD65	ICDH74	BPHDD65	BPCDH74
U-0.098	2037	50773	739	32353
U-0.058	5767	143733		

FIG. 5-30 BELOW-GRADE BASEMENT WALLS WITH EXTERIOR OR INTEGRAL INS.

C-3.33	IHDD65	ICDH74	INSULATION
C-0.200	1399	71395	HALF WALL
C-0.200	1963	129784	FULL WALL
C-0.167	4057	243345	FULL WALL
C-0.111	4584	352500	FULL WALL
C-0.063	6000	461387	FULL WALL

FIG. 5-31 BELOW-GRADE BASEMENT WALLS WITH INTERIOR INSULATION

C-3.33	IHDD65	ICDH74	INSULATION
C-0.093	1355	76344	FULL WALL
C-0.080	5372	432614	FULL WALL
C-0.056	9265	1826592	FULL WALL

FIG. 5-32 SLAB-ON-GRADE FLOORS

R-0	IHDD65	ICDH74	DEPTH
R-4	2693	38664	2 FEET
R-5	5000	88771	2 FEET
R-8	7206	264375	2 FEET

FIG. 5-33 CRAWL SPACE WALLS

C-3.33	IHDD65	ICDH74
C-0.125	2000	40000
C-0.093	3382	102145
C-0.056	6000	181215

FIG. 5-34 NON-WOOD DOORS

U-0.39	IHDD65	ICDH74	BPHDD65	BPCDH74
U-0.19	1952	34601	648	23117

FIG. 5-35 FENESTRATION U-VALUES INCLUDING FRAMING

U-1.31	IHDD65	ICDH74
U-0.87	1151	94420
U-0.49	5482	398041
U-0.36	5842	423244

FIG. 5-36 FENESTRATION SHADING COEFFICIENTS

SC-0.7	IHDD65	ICDH74
SC-0.5	-18154	38936

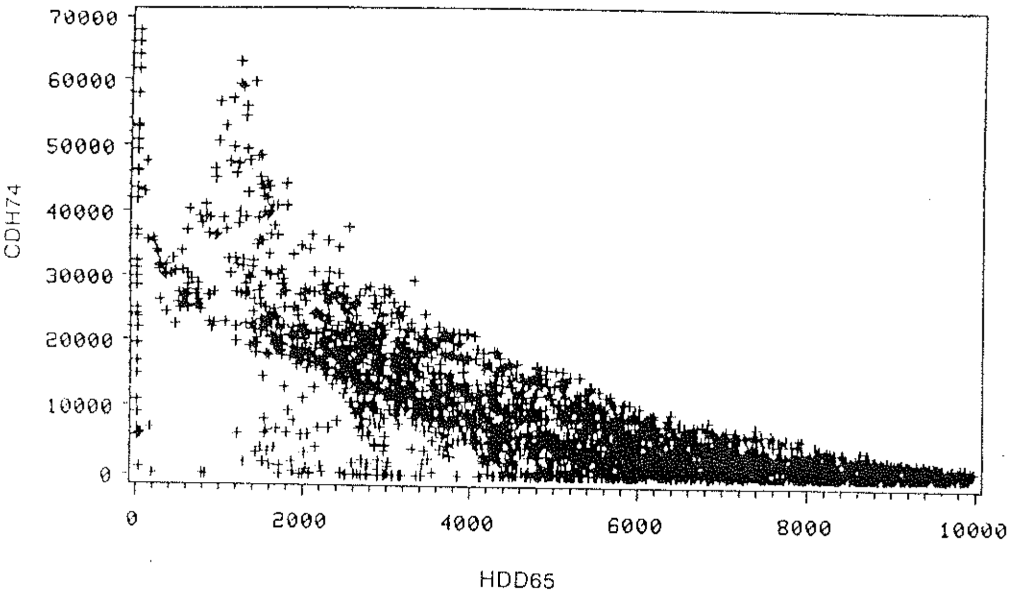

Figure 5-37 Weather data for United States and possessions.

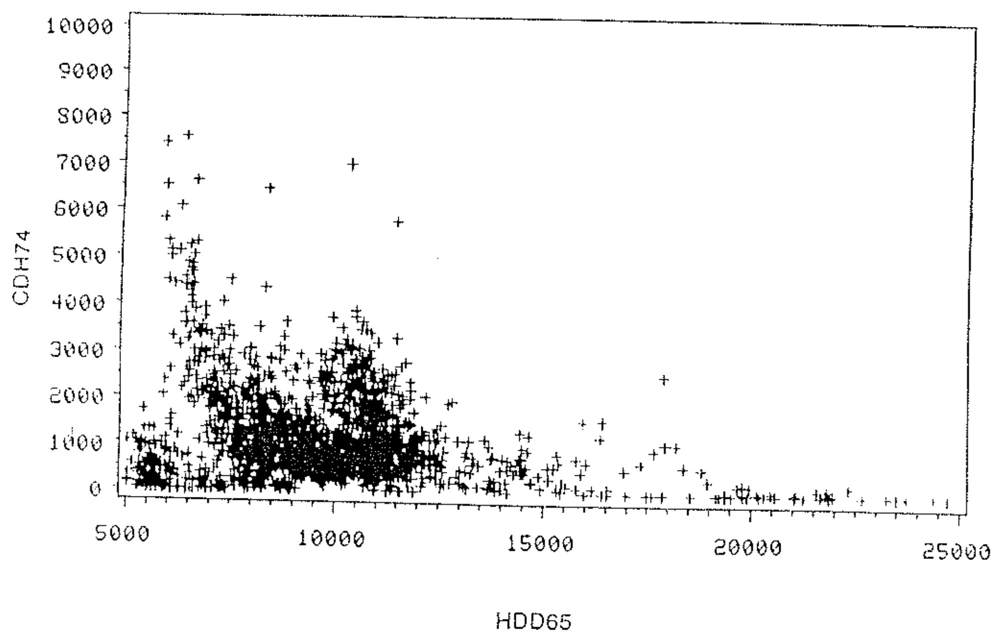

Figure 5-38 Weather data for Canada.

Economics

The concept of using economics to set the criteria was universally supported. The controversy was in the application. Critical issues were the scalar ratio of 18, the basis for the material costs, and the use of national averages for the materials and fuels. Strong and valid comments were made that the scalar ratio should be lower (10) and that it should be higher (30). The primary driving force to lower it was affordability. Conversely, societal forces in terms of incremental power generation costs, pollution, retrofit costs, and long useful lives (50 years) all advocated a higher value. The final decision was to retain the scalar ratio at 18 since it was a defendable middle ground and it achieved the desired 25% energy savings relative to the existing standard.

The basis for the material costs was challenged as not being representative. However, the SPC had initiated a formal research project that identified costs for ten regions around the country. Then the SPC augmented those costs with its own data. The final decision was to use national average values for the construction costs.

Arguments made on the construction costs were also made on the cost of fuels. Using national averages ignored the large variation that exists around the country. Determining a weighted average based on housing starts was an effort to account for the regional differences.

Achieving balance through economics was initiated to avoid problems, but some persisted. Above-grade frame and mass walls were an example. Two opposing forces govern the performance of walls. First, the load factors were different for cooling (frame walls = 1.0, mass walls with exterior or integral insulation = 0.82, and mass walls with interior insulation = 0.79). The lower cooling load factors for mass walls accounted for their thermal inertia. The heating load factors for all walls were identical (21.0). Second, the costs to insulate these walls were different, so their criteria were different. In frame walls it was easy to insulate the cavity, so it was cost-effective to have higher levels of thermal resistance than in mass walls. The net effect would be for mass walls to use more than three times the energy of frame walls in regions below 1,200 HDD65; between 40% and 80% more cooling energy in regions between 1,200 and 2,200 HDD65; and between 25% and 115% more energy in the 2,200 to 6,000 HDD65 region. Above 6,000 HDD65, all walls use the same cooling energy, but the actual values were diminished because cooling seasons were shorter.

Stringency

The stringency of a 25% energy savings in the new standard was not a controversial issue. Once the prescriptive criteria were developed, it was clear that current construction materials and practices would achieve it.

Presentation Format

The graphical format for the standard was well received. It met the goals of being easy to understand and simple to use. Explicitly accounting for the impact of cooling in the prescriptive criteria was recognized as a significant improvement. Specifying the criteria through the use of bands or regions recognized that only certain construction combinations can actually be built using currently available materials. Challenges were made to the use of dual requirements in single-family homes, depending upon the location of the air distribution system. This was intended to be a simple trade-off procedure but was interpreted as a ban on air distribution systems located outside the conditioned space.

Requirements

The prescriptive requirement on fenestration area was a major controversial issue. The basis for the criteria cannot be analytically derived—it was a judgment decision. Strong opinions were held on opposite sides. A resolution was achieved, which is the ultimate goal of a consensus standard.

Prescriptive requirements for manufactured housing were developed even though the federal law is preemptive. The levels proposed were significantly lower than the 1974 HUD Title VI levels: U_o-0.157 in Zone I, U_o-0.126 in Zone II, and U_o-0.104 in Zone III, which convert into a national average of U_o-0.145. The HUD zones matched the ASHRAE zones relative to the states included in each zone. However, the ASHRAE U_o-values (national average U_o-0.092) were very similar to those proposed by HUD in their revision that is currently in progress: U_o-0.132 for Florida as Zone 1, U_o-0.109 in Zone 2, U_o-0.096 in Zone 3, and U_o-0.079 in Zone 4, which led to a national average of U_o-0.098 (Conner et al. 1992). The four new HUD zones represent different states than the 1974 zones, but the general trend is lower U_o-values in colder climates.

There were several differences in the multi-family structure prescriptive requirements relative to single-family houses. The most significant difference was the absence of dual curves depending upon the location of the air distribution system. It was the opinion of the SPC that multi-family structures tend to have air distribution systems located in the conditioned space because of adjacent and stacked dwelling units. Other differences were the inclusion of metal studs as wall construction options and concrete floors. These are typically required to meet fire codes. Breakpoints in the above-grade components arose because of the differences in their thermal behavior. Finally, all of the below-grade criteria were identical to the single-family houses because neither data nor analytical capability were available to indicate they were different.

Weather Data

Weather data, for demonstrating compliance, were incorporated into the standard for the first time, receiving general acceptance. Inclusion of weather data for both the United States and Canada with a large number of locations eliminated any arguments that the data were too limited. Some felt the data may have been too abundant, but the SPC retained them all. Individual states that intend to adopt the standard could streamline the extensive data if necessary. However, the states would have had more difficulty in adding locations because CDH74 is not available or published elsewhere.

CONCLUSIONS

A strategy was developed and then utilized to generate the prescriptive envelope criteria for single- and multi-family residences in ASHRAE Standard 90.2P. The strategy was to economically justify the development of the criteria, achieve a 25% energy savings relative to the current standard, explicitly account for both heating and cooling, and present the criteria in a graphical format. Many of these features were instituted for the first time in the standard. After the standard was developed, it was submitted for a public review. Revisions were made in response to the comments, so the second draft was then submitted to a public review. Comments on the second draft led to development of independent substantive changes that are currently being reviewed.

Economic Development

Economics was used to serve two purposes in the development of the prescriptive envelope criteria. First, it ensured the criteria were cost-effective. Second, it ensured that all of the envelope criteria were in balance. Both of these features were considered significant and beneficial.

Stringency

The envelope criteria were developed to save 25% more energy than those in the existing standard. This was a target set by the SPC. It was achieved through development of the national energy model.

Presentation Format

The presentation format incorporated two major changes from previous versions of the standard. First, it explicitly incorporated both heating and cooling dependence, which was considered a significant improvement. Second, the criteria were presented in terms of bands rather than as a continuum. The only similarity with previous versions of the standard was that it still had a graphical approach, which was easy to understand and simple to use.

Requirements

The requirements varied depending upon the type of residence. Single-family houses had dual criteria depending upon the location of the air distribution system. The criteria were more stringent when the air distribution system was located outside of the conditioned space. Separate criteria were developed for above-grade walls and below-grade walls to avoid the problem of accounting for the surrounding soil. Shading coefficient requirements were developed for the first time in the standard.

The requirements for manufactured homes were presented in the traditional U_o-value concept with state borders acting as the division between the thermal zones.

The requirements for multi-family structures were separated from single-family structure requirements for all envelope components. Furthermore, the criteria lines contained breakpoints that accounted for the impact of smaller exposed envelope surface areas and higher internal loads.

Weather Data

Extensive tables of weather data were developed and included in the standard for the first time. A new weather variable, cooling degree-hours to base 74°F, was developed for use in the standard. The tables contained 3,363 locations in the United States and possessions. Canada was included for the first time by incorporating 1,847 locations.

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