NBSIR 75-678

Analysis of Construction Systems for the Thermal Classification of Residential Buildings

Stanley T. Liu

Center for Building Technology
Institute for Applied Technology
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Final Report

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U.S. DEPARTMENT OF COMMERCE, Rogers C.B. Morton, *Secretary*
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NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Acting Director*

Analysis of Construction Systems for the Thermal Classification of Residential Buildings

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ABSTRACT

This report is the result of a study to classify various kinds of residential buildings in relation to their thermal behavior. A collection of various building data and construction systems taken from the proposals of 18 of the 22 Housing System Producers participating in the Department of Housing and Urban Development (HUD) Operation BREAKTHROUGH Program is presented. Thermal performance parameters of buildings, such as; U-value, thermal mass, thermal time constant, and mass per unit area were computed and analyzed. The report recommends one way in which construction systems could be classified. Since the housing systems studied represented a cross section of the conventional residential construction systems in the building industry, it is felt that a realistic classification procedure for typical residential buildings can be established and based upon the parameter: mass per unit area. A more refined procedure of subdividing the building within each mass class on the basis of the building thermal time constant is also discussed.

Key Words: Building classification; building thermal mass; building thermal performance; building thermal time constant; housing systems; industrialized housing; mass per unit area; Operation BREAKTHROUGH; U-value

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Analysis of Construction Systems for the Thermal Classification of Residential Buildings

1. Introduction

It has been well established that heating/cooling loads, or energy requirements of buildings, are directly affected by the structure of the exterior walls and roof, and the type and area of windows. The role that the building thermal mass* plays with respect to the heating/cooling requirement, however, is not so well understood. Even less appreciated is the fact that the building thermal performance is influenced not only by the value of the thermal mass but also by the relative position of the thermal mass and insulation in the structure.

Because of the periodically varying solar radiation and the large fluctuation in external environment temperatures, steady-state heat transfer through the enclosing walls into the interior space of a building rarely occurs, and the heat storage effects of the walls and the internal objects must be taken into account in order to estimate accurately the cooling load or the variations of the indoor environment. The overall heat transfer coefficient (U-value) of a wall, which gives a direct indication of the resistance to heat flow under steady-state conditions, is not the only major indicator of the heat flow through the walls into the inside environment under transient conditions. The mass of the wall, which governs the energy storage capacity, is also an important parameter to be considered.

J. F. van Straaten [1]**, of the Building Research Institute of South Africa, reports the results of an experimental study wherein small 4-room single story structures of different materials and with approximately 46.45 m^2 (500 ft^2) floor area were built. These unoccupied structures were not air conditioned, but adequately instrumented to observe the indoor environment as a function of time. The experiments were conducted at Pretoria and Durban in South Africa. The climate at Pretoria was warm and dry with a daily temperature variation between 30.56 °C (87 °F) and 16.11 °C (61 °F) while the climate at Durban was warm and humid with a much smaller daily temperature variation between 28.33 °C (83 °F) and 22.22 °C (72 °F). The experiments showed that under warm arid conditions with a large daily temperature variation massive brick buildings proved to be superior in minimizing the daily variation of the indoor temperature. The reason is that the large energy storage capacity of the massive structure causes a "time lag" or "flywheel effect" on the indoor

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* In this report, the name thermal mass is defined as the thermal storage capacity per unit area of a construction component.

** Numbers in square brackets refer to bibliographical listing at the end of this report.

temperature. The indoor environment remained reasonably cool during the day (26.11 °C (79 °F) compared with 28.89 °C (84 °F) outside temperature at noon) and reasonably warm during the night (23.33 °C (74 °F) compared with 16.11 °C (61 °F) outside temperature at 5:00 a.m.). Conversely, light timber structures with essentially no "time lag" effect allowed the indoor temperature to increase significantly during the day (33.89 °C (93 °F) compared with 30.56 °C (87 °F) outside at 2:00 p.m.), and to become cool during the night (16.67 °C (62 °F) compared with 16.11 °C (61 °F) outside at 5:00 a.m.). On the other hand, under warm and humid conditions with a much smaller daily temperature variation, the experiments showed that the massive buildings were a distinct disadvantage. The wall could not cool down sufficiently during the night to provide reasonably comfortable temperatures in the enclosures during the day. The indoor temperature remained high during the night (27.78 °C (82 °F) compared with 22.22 °C (72 °F) outside temperature at 5:00 a.m.), and also high during the day (30 °C (86 °F) compared with 27.22 °C (81 °F) outside temperature at 4:00 p.m.). While the light timber structures followed the outside temperature variation closely and resulted in more comfortable indoor temperature (22.78 °C (73 °F) at 5:00 a.m. and 28.89 °C (84 °F) at 4:00 p.m.). An experiment sponsored jointly by the Department of Housing and Urban Development (HUD) and the National Bureau of Standards (NBS) was conducted at NBS, where a small test building of masonry construction was placed in a large environmental chamber and subjected to a diurnal temperature cycle from 7.22 °C (45 °F) to 38.89 °C (102 °F), showed the damping and time lag effects due to the position of insulation. The measured indoor temperature fluctuation showed a range of 5.83 °C (10.5 °F) when no insulation was placed in the wall, 3.06 °C (5.5 °F) when insulation was placed inside the masonry surface, and 1.11 °C (2 °F) when insulation was placed outside the masonry surface. It is apparent from these types of investigations that the building thermal mass and thermal time constant (to be defined later), in addition to the thermal resistance, are two of the basic parameters that govern the building thermal performance.

This report, as part of the overall effort in the HUD-sponsored research project for the determination of air-conditioning criteria, presents a collection of various building construction data relevant to the thermal performance of buildings, based on residential housing design.

The idea in the development of air-conditioning criteria is to give architectural design engineers some guidelines as to whether a building of a particular design in a specific geographical location will require air-conditioning to maintain a comfortable indoor environment. The conditions under which air-conditioning is required depend on both the outdoor weather conditions and the construction materials of the building shell. The first step in the establishment of the air-conditioning criteria is to classify the weather and the building construction into different groups so that a finite but adequate number of tables or charts containing the criteria can be prepared. Details in the development of the air-conditioning criteria will be described in another report. This report covers the study on the construction of residential buildings leading to the classification of these buildings based on their thermal performance.

Construction data were taken from the proposals of 18 of the 22 participating Housing System Producers in the HUD Operation BREAKTHROUGH program. Since the contractors involved in that program represent a cross section of the housing system producers in the building industry, data contained in their proposals would provide meaningful information about the practice, and the state of the art, in housing design. Consequently, it is felt that a realistic classification procedure based upon analysis of the thermal parameters of composite structural components of these buildings will be a realistic classification procedure applicable to typical contemporary residential buildings.

2. Type of Building Data Compiled

From the drawings and specifications submitted by the Housing System Producers in the HUD Operation BREAKTHROUGH program, two types of data were collected. The first concerned the method of construction and materials used for the exterior enclosures and interior partitions of a building, and the associated thermophysical property data of the materials. Pertinent thermal performance parameters associated with the structural components such as the U-value, mass per unit area, thermal mass, and the thermal time constant were then computed. Their computation, physical meaning and usefulness will be discussed later in this report. The second type of data was of a geometric nature and involved the following:

1. Total floor area of a dwelling unit.

2. Floor area for each of the rooms in a dwelling unit.

3. Type of walls and openings, windows, doors, and their areas for each of the rooms in a unit.

4. Total glass area of a dwelling unit.

5. Crack length of the windows and doors. These data are required in order to know air movement and infiltration characteristics.

6. Shading coefficient for the glazed area.

3. Method of Data Presentation

Data collected from the drawings and specifications were processed by the NBS UNIVAC 1108 computer and printed out in a uniform manner in tabular form. Two types of tables are presented corresponding to the two types of data discussed in Section 2. They are given as Tables 1 to 4 at the end of the report. The various building types were first classified in the following four categories related to height and number of families per structure:

1. Single Family Detached (SFD): Residential buildings consisted of a single family unit, ranging from 1- to 3-story high, with or without basement.

2. Single Family Attached (SFA): Residential buildings consisted of a group of family units with at least one side wall in each unit shared with another unit, townhouse, duplex, etc., are included in this group.

3. Multi-Family Low Rise (MFLR): Residential buildings less than 6-story high, with each floor composed of one or more family units. Occasionally a family unit may take more than one floor such as a 3-bedroom unit occupying 2 floors (2S/3-BR). Garden type apartments or condominiums are included in this group.

4. Multi-Family High Rise (MFHR): Apartment buildings or condominiums 6-story or more in height.

Table 1 gives a sample of the typical building construction and material data for the 18 HSP's surveyed. It is included as an example of the type of basic data needed for the analysis. This table contains a typical layer by layer description and the thermophysical properties of the materials used in the construction of the structural components (exterior walls, interior partition, party wall, floor/ceiling, roof/ceiling, ground floor, basement wall, basement floor, window). The order of the layers is from the outside of a room toward the inside for side walls and from top to bottom for roofs and floor/ceilings. The thermal property values were taken from the contractor's drawings and specifications and from the 1967 ASHRAE Guide and Data Book [3]. Occasionally data for the specific heat capacity (C_p) of certain materials were not available and a value of .200 was assumed. Since the value of C_p does not vary greatly for most of the building materials (on the order of .150 to .400 with a major portion of the materials in the lower range of the spectrum), the value of .200 was chosen. The surface air film resistance values were taken from the ASHRAE Guide and Data Book [3] based on summer design conditions since this project was established for the purpose of determining summer air-conditioning criteria. For those layers which had a negligible mass, such as an air space, carpet and glass, only the thermal resistance value was given.

Table 2 gives sample calculations and summaries of the four relevant parameters associated with and affecting the thermal performance of a building. They were computed from the data given in Table 1. A brief description follows:

1. U-value: The U-value is the overall heat transfer coefficient including the surface air film resistance (at 3.35 m/s (7.5 mph) wind outside and still air inside) under steady-state conditions. This is the major factor used by designers in estimating the cooling load of a building. As mentioned previously, under unsteady-state conditions the U-value is not the only controlling factor in heat flow through walls since it does not take into account the energy storage effect of the walls. However, it does give an indication of the amount of resistance the wall offers to heat flow and therefore, acts as one of the parameters in determining the overall heat transfer through the walls.

2. Thermal Mass, $\rho C_p L$: The thermal mass is a counterpart of the U-value and gives an indication of the energy storage capacity of the walls. It is computed from the following equation:

$$\rho C_p L = \sum_{i=1}^{N} \rho_i C_{pi} L_i \qquad (1)$$

   where ρ_i, C_{pi}, L_i are the density, specific heat capacity, and thickness, respectively, of the i^{th} layer in a multi-layer wall. N is the total number of layers in the wall.

3. Mass per unit surface area, ρL: Because of the small variations in the magnitude of the specific heat capacity for most building materials, the energy storage capacity of a wall is almost directly proportional to the mass per unit surface area of the wall. This parameter is, therefore, closely related to the thermal mass of the wall. It has the advantage over the thermal mass in that a knowledge of the values of the specific heat capacity, which are not available for certain materials, is not required. The mass per unit area of a wall is computed by

$$\rho L = \sum_{i=1}^{N} \rho_i L_i \qquad (2)$$

4. Thermal Time Constant (Th.T.C.): The Th.T.C. is a function of the thermal diffusivities of the layers in a multi-layer wall and is defined [4] as the heat stored per unit of heat transmitted. It is, therefore, a combination of the thermal mass and the thermal resistance of the wall. It is derived on the basis of the analogy between the heat flow represented by a thermal circuit and the time constant of an R-C electric circuit (Figure 1), and is given by Givoni [4]

$$\text{Th.T.C.} = \sum_{i=1}^{N} (\tau_i)$$

where

$$\tau_i = (R_{os} + L_1/k_1 + \ldots + L_i/2k_i) \cdot (L_i \rho_i C_{pi}) \qquad (3)$$

where R_{os} and R_{is} are the outside and inside surface air film resistance, respectively, and k_i is the thermal conductivity of the material of the i^{th} layer. In the case of an air space, L_i/k_i is substituted by the resistance of the air space.

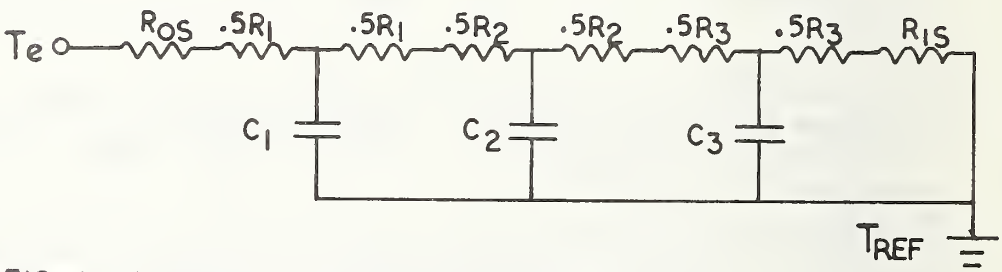

FIG. 1 A THREE-LAYER R-C CIRCUIT

Similar to the thermal diffusivity of a homogeneous single layer wall, the thermal time constant is a measure of the thermal damping capacity of a multi-layer wall on the amplitude and time lag of the inner surface temperature, or indoor air temperature, with respect to a periodically varying outdoor temperature. It should be pointed out that the TH.T.C. given by equation (3) also takes into account the order the layers of materials are arranged. A change in the order of the arrangement will change the rate of heat flow through the wall under transient conditions. This is because the outside surface temperatures of the walls with different orders of arrangement in their layers will be different during the transient states. For example, during the day, the outside surface temperature of a wall with an insulation layer next to the external surface layer will be higher than a wall constructed of the same layers of materials but with the insulation layer placed further away from the external surface layer. The former construction will result in more heat being transferred back to the external environment by convection and radiation, and consequently less heat being transferred into the interior space. It is noted that this phenomenon is not accounted for by either the U-value or the thermal mass where the order of arrangement of the layers is not considered.

Table 3 gives a sample of the typical geometrical data for one of 30 dwelling units ranging in size from 1-bedroom to 4-bedrooms. The 30 units were chosen randomly from six of the 18 HSP's in the Operation BREAKTHROUGH program, with the purpose of obtaining some average values of unit size, floor area, and window area for a normal dwelling unit. The table gives a room by room tabulation of the areas of the floor, ceiling, and the enclosing walls and openings of a room. The orientation of the unit is not specified since this is one of the factors that is influenced by site location, terrain, units group plan, etc. as much as by thermal performance considerations. For a group of attached units (single family attached, multi-family low rise or high rise), the unit at the ends, or corner, of the group was chosen since it has the largest wall area exposed to the outside environment and consequently results in the most severe indoor temperature variation, or the largest cooling load, among the group, and therefore represents the worst case as far as air-conditioning is concerned. Table 3 also gives the crack lengths of the windows and doors which are required in the air infiltration study. Data for lighting (as internal heat source) and furniture (as internal heat sink) were not available. The data for the shading coefficient on windows are assumed values for regular sheet glass with light indoor venetian blinds shading. These data would, of course, be of different values for other types of glass and shading.

Table 4 gives a summary of dimensional values and thermal properties associated with the 30 dwelling units, plus three parameters that can be used for the classification of dwelling units on a geometrical basis. These three parameters are:

1. Floor Area: The floor area represents the total amount of living space in a dwelling unit and gives an indication of the size of the unit among the same type of building.

2. Ratio of Exterior Wall Area to Floor Area: This ratio gives an indication of the complexity of the shape of the unit. For example, a simple rectangular unit will have a lower ratio than a complex geometrically shaped unit.

3. Ratio of Window Area to Exterior Wall Area: This ratio indicates the relative amount of glass area in a unit which has a direct bearing on the amount of solar radiation transmitted directly into the interior space.

It is noted that in Table 4, only U-value was given for the windows and doors since they are considered as fast response elements with negligible thermal inertia*. Also, for those constructions where a particular parameter did not apply or was not required, the spaces were filled with either blank or asterisk.

In general, data contained in Tables 1 and 3 are required by the computer program "NBSLD" [5] developed by the Thermal Engineering Section of the NBS Building Environment Division for indoor temperature or load prediction purposes.

4. Analysis of Data and Discussion

A study of the data compiled in Tables 1 thru 4 indicates the following:

1. Unit Size: The range and average size of the dwelling units in terms of total sq. meter and sq. ft. of floor area are tabulated below:

	Min. Area		Max. Area		Average		Total Units Used
	m^2	ft^2	m^2	ft^2	m^2	ft^2	
4-Bedroom Unit	98.9	1065	161	1740	124.5	1340	11
3-Bedroom Unit	84.5	910	137.5	1480	102.2	1100	16
2-Bedroom Unit	65.0	700	111.5	1200	84.1	905	15
1-Bedroom Unit	53.9	580	89.2	960	68.3	735	8

* If required, the thermal time constants of windows and doors can be computed by 1/UM where U is the overall heat transfer coefficient and M the total weight of windows or doors per unit area. Th.T.C. of windows and doors are usually less than one hour.

It is noted that the total number of units upon which the average values are based is not statistically significant. However, for the study of an air-conditioning criteria where a typical sized unit is to be used, slight variation from the above listed average values would not have any significant influence on the results.

2. Glass Area: The total glass area in a dwelling unit ranges from 10% to 26% of the total floor area (obtained by multiplying the area ratios of window to exterior wall by exterior wall to floor in Table 4), with an average value of 17% for the 50 units studied (data for 20 of the units are from the HUD Total Energy Project at the Jersey City, New Jersey Operation BREAKTHROUGH prototype site and were not included in Table 4). The variation of 10 ∿ 26% occurs in both the large and small units (FHA Minimum Property Standards requires 10% minimum for light). It can, therefore, be said that the size of a dwelling unit has no effect on the relative amount (with respect to floor area) of the glass in the design of a typical housing unit.

3. Individual Room Size: The variations in the sizes of the major rooms in the dwelling units are quite large, and are listed below for reference:

	Range, m^2	Range, sq. ft.	Average, m^2	Average, sq. ft.
Living Room	13.0 ∿ 25.1	140 ∿ 270	18.6	200
Dining Room	8.8 ∿ 11.6	95 ∿ 125	10.2	110
Kitchen	4.6 ∿ 13.9	50 ∿ 150	8.8	95
1st Bedroom	11.6 ∿ 20.4	125 ∿ 220	15.3	165
2nd Bedroom	9.3 ∿ 20.4	100 ∿ 220	12.5	135
Other Bedrooms	7.4 ∿ 16.7	80 ∿ 180	10.7	115
Bathroom	3.3 ∿ 4.2	35 ∿ 45	3.7	40

Normally, the larger living room is associated with a 3- or 4-bedroom dwelling unit. Generally the lower limits in the above list are controlled by the FHA Minimum Property Standards.

4. U-value: The U-values for the different designs of the wall and roof/ceiling constructions by the 18 HSP's are fairly uniform within each weight class of construction. The ranges and average values for the exterior wall and the roof/ceiling elements are,

   Exterior wall = .352 ∿ 1.010 J/s · m · K, average value = 0.590 (.062 ∿ .178 Btu/hr-ft^2-°F, average value = .104)

   Roof/ceiling = .233 ∿ .647 J/s · m · K, average value = .352 (.041 ∿ .114 Btu/hr-ft^2-°F average value = .062)

   In general, for the exterior wall system, the higher than average U-values are associated with the heavy type construction such as concrete wall. For light weight construction such as wood frame walls and sandwich panel walls with various cores and facings, the U-values are all comparable.

5. Mass Per Unit Area: As stated previously, the mass per unit area and the thermal mass are closely related, having an almost linear relationship because of the moderate variation in the values of the specific heat capacity for different building materials. This linear relationship is shown in Figure 2. The mass can, therefore, be used to indicate the thermal storage capacity of a wall or roof/ceiling system. For the 18 HSP's studied, the ranges of the mass of different building enclosures are,

   Exterior wall: 17.1 ∿ 478.4 Kg/m^2 (3.5 ∿ 98 p.s.f.)

   Roof/ceiling: 12.2 ∿ 336.8 Kg/m^2 (2.5 ∿ 69 p.s.f.)

   Floor/ceiling: 19.5 ∿ 419.8 Kg/m^2 (4 ∿ 86 p.s.f.)

   Ground floor: 9.8 ∿ 439.4 Kg/m^2 (2 ∿ 90 p.s.f.)

   Party wall: 24.4 ∿ 351.5 Kg/m^2 (5 ∿ 72 p.s.f.) (including load bearing interior wall)

   The type of construction of the buildings included: wood frame, sandwich panel with various cores and facings, metal frame, brick wall, and concrete wall systems. A classification based on the mass of the exterior wall system is recommended as follows:

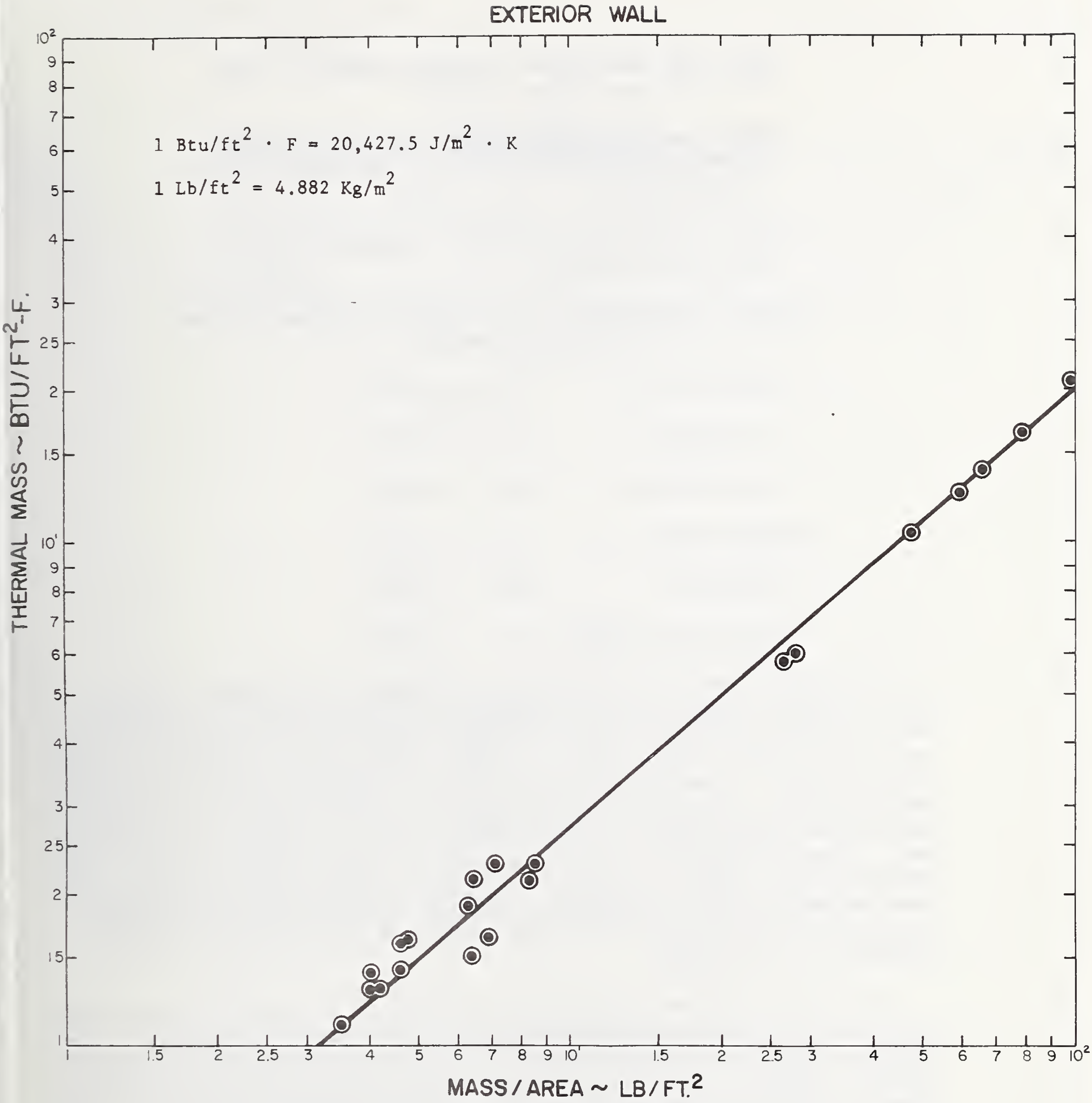

Figure 2 Relation of Thermal Mass vs. Mass (Exterior Wall)

Light mass (wood frame, sandwich panel): Less than 100 Kg/m^2 (20.5 p.s.f.)

Medium mass (wood frame with face brick, brick, light weight concrete: 100 ∿ 250 Kg/m^2 (20.5 ∿ 51.2 p.s.f.)

Heavy mass (brick, concrete): Higher than 250 Kg/m^2 (51.2 p.s.f.)

6. Thermal Time Constant: The ranges of values for the different building enclosures are,

Exterior Wall:	3.2 ∿ 115 HRS.
Roof/Ceiling:	4.1 ∿ 165 HRS.
Floor/Ceiling:	3.4 ∿ 86 HRS.
Ground Floor:	2.2 ∿ 96 HRS.
Party Wall:	6.2 ∿ 44 HRS.
Interior Partitions:	1.7 ∿ 10 HRS.

It can be seen that the range of values for the thermal time constant are quite large and are comparable with the range for the mass of the structures. Figures 3 and 4 show the relationship between the thermal time constant and the mass of exterior wall and roof/ceiling systems, respectively. As mentioned previously, the large scattering of the data points shows the effect of the arrangement of the layers of different materials and the placement of insulations and/or air spaces in a wall system. However, Figures 3 and 4 also show that even though the local scattering of data points is large, the overall trend of increasing Th.T.C. with increasing mass is preserved, and the classification of buildings by mass may be sufficient for constructions of conventional design as compiled in this report.

For a more refined classification, the Th.T.C. might be used within each mass class with designations such as low, moderate, and high. The dividing points for those designations should be determined by actually running a number of typical cases within each mass class on the computer program "NBSLD" [5] and examining the resulting indoor environment variations under identical external environment conditions*.

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* Although the discussion given in this Section deals with Th.T.C. of various subelements of the building construction, the overall or total thermal time constant of a building can be estimated by using the data developed herein. The details of the total building thermal time constant is given by Givoni and Hoffman [6].

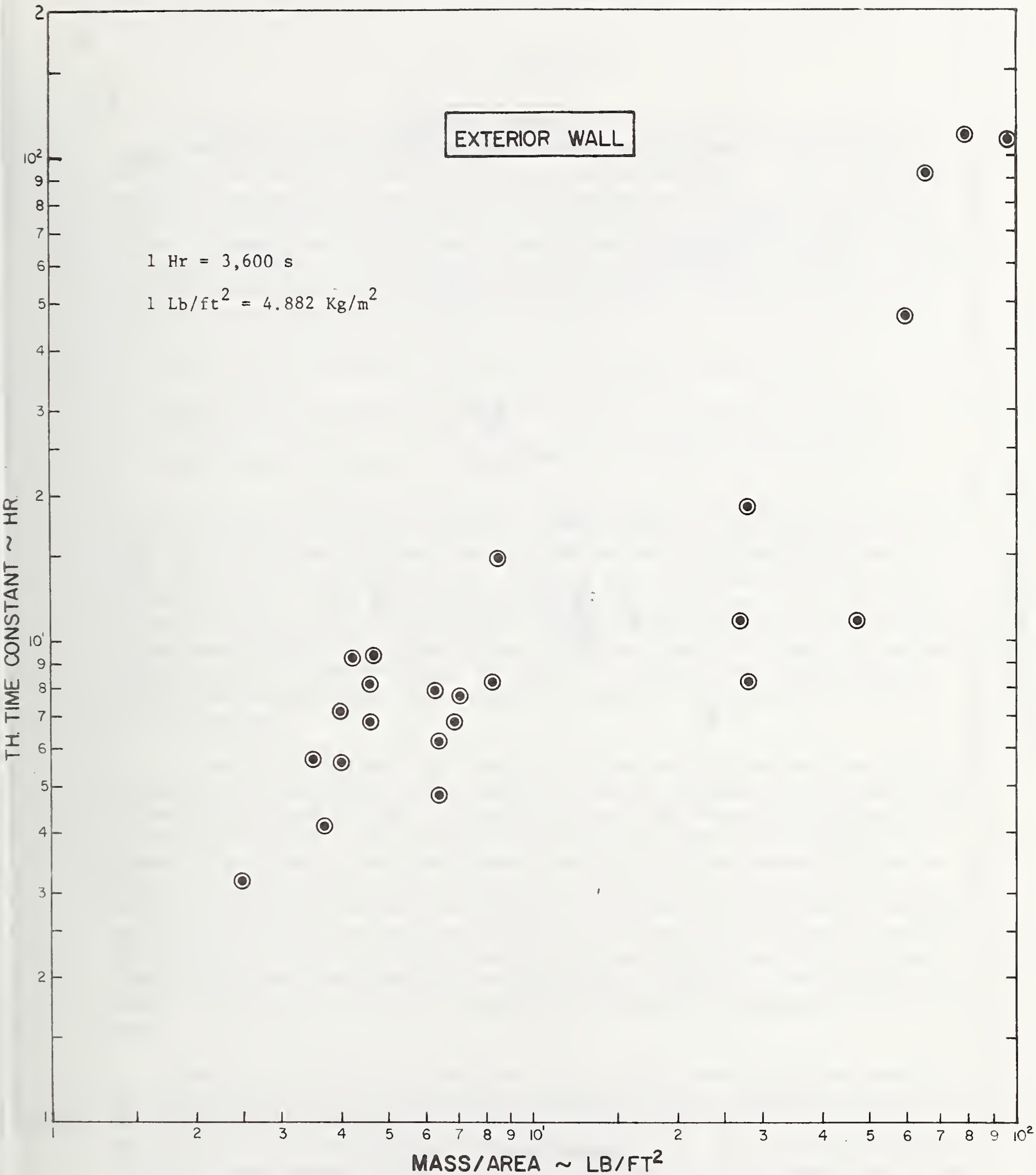

Figure 3 Relation of Thermal Time Constant vs. Mass (Exterior Wall)

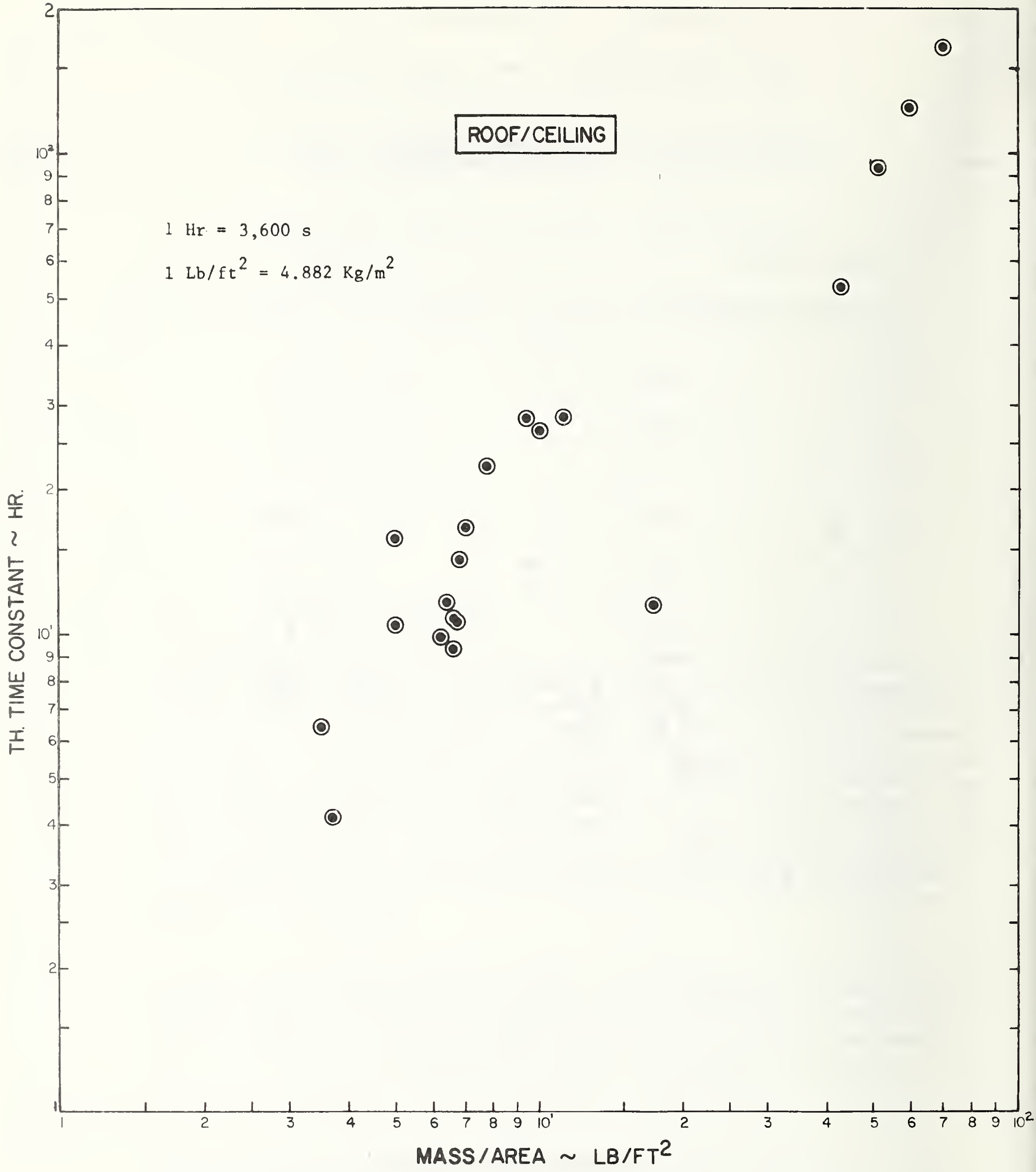

Figure 4 Relation of Thermal Time Constant vs. Mass (Roof/Ceiling System)

5. Conclusions

Through the analysis of the data presented herein, a criterion for the classification of construction system for residential buildings on the basis of their thermal performance was established. This criterion, based on the mass per unit area of a building enclosure, can be used to classify residential buildings of various structural systems according to the behavior and variations of their indoor thermal environment under identical external environmental conditions. Specifically, it is suggested that on the basis of mass per unit area of a building exterior wall, the following classification be made:

Light Mass Structure: less than 100 Kg/m^2 (20.5 lb/ft^2)

Medium Mass Structure: 100 $\sim$ 250 Kg/m^2 (20.5 to 51.2 lb/ft^2)

Heavy Mass Structure: greater than 250 Kg/m^2 (51.2 lb/ft^2)

For the HUD-sponsored research effort on the determination of a design criterion for air-conditioning of residential buildings based on some indoor comfort indices, the classification discussed above can be used as a first approximation in grouping the buildings into various classifications. The air-conditioning design criterion is to be established by studying the thermal performance of selected buildings in selected geographical locations using a thermal simulation model (computer program such as "NBSLD" [5]). In order to minimize the computational effort, the division of buildings into groups of similar constructions is a necessity.

It should be pointed out that for a more refined and accurate classification of buildings, with respect to indoor thermal environment, the thermal time constant (Th.T.C.) might be used as a second criterion within each mass class. This would particularly be true if insulation is placed in the medium and heavy mass class walls in an innovative way as shown in reference 2. Within each mass class, the designation low, medium, and high (or moderate and high) can be used. This should, however, be verified by further work, using data on a variety of selected typical residential units of different design as input to the computer program "NBSLD" [5], and comparing the results under identical external environmental conditions at various geographical locations throughout the country.

Finally, it should be mentioned that in the above suggested method of classification of buildings, the effects of glass (amount, orientation, type) with respect to conduction of heat and solar radiation on the indoor environment are not taken into account. For those buildings having a large amount of glass area, a subdivision within each mass class with respect to percentage of glass area might have to be used.

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7. Appendix

Conversion Factors to SI Units

The source data presented in graphs and tables in this report were collected from handbooks and drawings which are all in English units of measurement because of the present accepted practice in this country for building technology. In recognition of the position of the United States as a signatory to the General Conference on Weights and Measures, which gave official status to the metric SI system of units in 1960, appropriate conversion factors have been provided in the table below.

Report Units	Multiply By	To Obtain SI Units
in	0.0254	m
ft	0.3048	m
ft^2	0.0929	m^2
hr	3,600.	s
mph	0.447	m/s
lb/ft^2	4.882	Kg/m^2
lb/ft^3	16.018	Kg/m^3
Btu/lb-F	4,184.	J/Kg · K
Btu/ft^2-F	20,427.5	$J/m^2 \cdot K$
$Btu/hr-ft^2-F$	5.6744	$J/s \cdot m^2 \cdot K$
$Btu-in/hr-ft^2-F$	0.1441	J/s · m · K
$Hr-ft^2-F/Btu$	0.1762	$K \cdot m^2 \cdot s/J$

Table 1

Sample of Typical Construction and Thermal Property Data Building Enclosures

For readers interested in converting data in this table to SI units, a conversion table is provided in the Appendix.

Table 1 Sample of Typical Construction and Thermal Property Data of Building Enclosures

DWELLING TYPE -- SINGLE FAMILY ATTACHED AND DETACHED

UNIT TYPE ------ 2,3,4-BEDROOM UNITS

CONSTRUCTION --- WOOD FRAME, ALUMINUM SIDING

••••••••••••••••••••••••THERMAL PROPERTY TABLE FOR BUILDING ENCLOSURES••••••••••••••••••••

LAYER	MATERIAL DESCRIPTION	L_i THICKNESS IN.	ρ_i DENSITY LB/CU.FT.	C_{pi} SP.HEAT BTU/LB-F	k_i TH.CONDUCTIVITY BTU-IN/HR-SQ.FT-F	R_i TH.RESISTANCE. HR-SQ.FT-F/BTU
EXTERIOR WALL, FIRST TYPE						
os	AIR FILM(7.5 MPH WIND)					.250
1	ALUM. SIDINGS	.024	169.0	.208	.1415.	.000
2	PLYWOOD SHEATHING	.375	34.0	.550	.800	.470
3	R-11 GL.WOOL BATT INSUL.	3.000	3.0	.157	.270	11.000
4	AIR SPACE(5/8") W/REF S					3.280
5	GYPSUM BOARD, FOIL BACK	.500	50.0	.259	1.125	.450
is	AIR FILM(STILL AIR)					.680
INTERIOR PARTITION						
os	AIR FILM(STILL AIR)					.680
1	GYPSUM BOARD	.500	50.0	.259	1.125	.450
2	AIR SPACE(3 IN.)					.970
3	GYPSUM BOARD	.500	50.0	.260	1.125	.450
is	AIR FILM(STILL AIR)					.680
PARTY WALL						
os	AIR FILM(STILL AIR)					.680
1	GYPSUM BOARD	.625	50.0	.259	1.125	.560
2	MIN.WOOL BATT SOUND INS"	3.000	3.0	.157	.270	11.000
3	AIR SPACE(4.7 IN.)					.970
4	GYPSUM BOARD	.625	50.0	.259	1.125	.560
is	AIR FILM(STILL AIR)					.680
FLOOR/CEILING						
os	AIR FILM(STILL AIR)					.920
1	CARPET W/PAD					1.200
2	PLYWOOD SUBFLOOR	.625	34.0	.550	.800	.780
3	AIR SPACE(7.5 IN.)					1.060
4	GYPSUM CEILING	.500	50.0	.259	1.125	.450
is	AIR FILM(STILL AIR)					.920
ROOF/CEILING						
os	AIR FILM(7.5 MPH WIND)					.250
1	235 ASPHALT SHINGLES	.375	75.0	.200	.850	.440

Table 1 - continued

2	PLYWOOD SHEATHING	.375	34.0	.550	.800	.470
3	ATTIC SPACE					3.000
4	R-13 BATT INSULATION	3.625	3.0	.157	.270	13.000
5	GYPSUM BOARD	.500	50.0	.259	1.125	.450
is	AIR FILM(STILL AIR)					.920
GROUND FLOOR						
os	AIR FILM(STILL AIR)					.920
1	CARPET W/PAD					1.230
2	PLYWOOD SUBFLOOR	.625	34.0	.550	.800	.780
3	AIR SPACE(4 IN.)					.970
4	R-5 BATT INSULATION	1.375	3.0	.157	.270	5.000
is	CRAWL SPACE W/V.B.					.620
BASEMENT WALL						
1	NONE	••••••	••••••	••••••	••••••	••••••
BASEMENT FLOOR						
1	NONE	••••••	••••••	••••••	••••••	••••••
EXTERIOR WALL, SECOND TYPE						
1	NONE	••••••	••••••	••••••	••••••	••••••
WINDOW						
1	INSULATION GLASS					1.640

•NOTE --- 1. RESISTANCE VALUES FOR SURFACE AIR FILM ARE FOR SUMMER CONDITION

Table 2a

Sample Computation for the Thermal Performance Parameters in Table 2b

Data from Table 1 are used as an example for this computation. In particular, the exterior wall in the table is chosen. This wall consists of 5 (N = 5) layers excluding air films on both sides of the wall. The four pertinent thermal performance parameters are computed as follows:

1. Mass Per Unit Area:

By equation 2, $\rho L = \sum_{i=1}^{5} \rho_i L_i$

$= (.024 \times 169 + .375 \times 34 + 3 \times 3 + 0 + .50 \times 50)/12$

$=$ <u>4.23</u> LB/sq. ft. (20.65 Kg/m^2)

2. U-value:

The U-value is computed by

$U = 1/R$, where $R = R_{os} + (\sum_{i=1}^{5} R_i) + R_{is}$

R = .250 + 0 + .470 + 11.000 + 3.280 + .450 + .680 = 16.130

Therefore, U = 1/R = <u>.062</u> Btu/hr-sq. ft.-F

Where R_{os} and R_{is} are the resistance of the outside and inside air film, respectively.

3. Thermal Mass:

By equation 1, $\rho C_p L = \sum_{i=1}^{5} \rho_i C_{pi} L_i$

$= (.024 \times 169 \times .208 + .375 \times 34 \times .550 + 3 \times 3$

$\times .157 + 0$

$= \underline{1.31}$ Btu/sq. ft.-F

4. Thermal Time Constant:

By equation 3, $\text{Th.T.C.} = \sum_{i=1}^{5} \tau_i$

$\tau_1 = (R_{os} + L_1/2k_1)\ (L_i \rho_1 C_{p1})$

$= (.250 + 0)\ (.024 \times 169 \times .208)/12 = .0176$ hr.

$\tau_2 = (R_{os} + L_1/k_1 + L_2/2k_2)\ (L_2 \rho_2 C_{p2})$

$= (.250 + 0 + .375/2 \times .80)\ (.375 \times 34 \times .550)/12 = .282$ hr.

In the same manner

$\tau_3 = .740$ hr.

$\tau_4 = 0.$ hr.

$\tau_5 = 8.21$ hr.

Therefore, Th.T.C. = .0176 + .2820 + .740 + 0 + 8.21 = $\underline{9.25}$ Hrs.

Table 2b

Summary of Pertinent Thermal Performance Parameters of Various Building Enclosures

The abbreviations used in this table, besides those that are clearly defined, are:

E. Wall: Exterior wall

I. Wall: Interior wall or partition

P. Wall: Party wall (for multi-family structure)

B. Floor: Basement floor

B. Wall: Basement wall

I. Door: Interior door

E. Door: Exterior door

For readers interested in converting the data to SI units, a conversion table is provided in the Appendix. Also, in the following table, the meaning of weight per unit area is equivalent to mass per unit area.

Table 2b Summary of Pertinent Thermal Performance Parameters of Various Building Enclosures

DWELLING TYPE -- SINGLE FAMILY ATTACHED AND DETACHED

UNIT TYPE ------ 2,3,4-BEDROOM UNITS

CONSTRUCTION --- WOOD FRAME, ALUMINUM SIDING

•••••••••••••••••VALUES OF PERTINENT THERMAL PERFORMANCE PARAMETERS OF BUILDING ENCLOSURES•••••••••••••••••

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	2ND E.WALL
WT./UNIT AREA(LB./SQ.FT.)	4.234	4.167	5.958	3.854	6.396	2.115	••••••	••••••	••••••
U-VALUE(BTU/HR-SQ.FT.-F)	.062	.310	.069	.188	.054	.105			
TH.MASS(BTU/SQ.FT.-F)	1.312	1.081	1.467	1.514	1.735	1.028	••••••	••••••	••••••
TH.TIME CONSTANT(HR.)	9.249	1.748	10.540	4.703	11.658	2.819	•••••••	•••••••	•••••••

DWELLING TYPE -- SINGLE FAMILY ATTACHED AND MULTI FAMILY LOW RISE

UNIT TYPE ------ 2,3,4-BEDROOM UNITS

CONSTRUCTION --- WOOD FRAME

•••••••••••••••••VALUES OF PERTINENT THERMAL PERFORMANCE PARAMETERS OF BUILDING ENCLOSURES•••••••••••••••••

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	2ND E.WALL
WT./UNIT AREA(LB./SQ.FT.)	6.312	5.208	9.937	6.562	10.031	2.125	••••••	••••••	••••••
U-VALUE(BTU/HR-SQ.FT.-F)	.093	.290	.073	.068	.043	.270			
TH.MASS(BTU/SQ.FT.-F)	1.887	1.349	2.516	2.265	2.766	1.169	••••••	••••••	••••••
TH.TIME CONSTANT(HR.)	7.910	2.327	20.967	15.597	26.296	3.062	•••••••	•••••••	•••••••

Table 2b - continued

DWELLING TYPE -- MULTI-FAMILY HIGH RISE

UNIT TYPE ------ EFFICIENCY,1,2-BR. APARTMENTS

CONSTRUCTION --- MASONRY

*****************VALUES OF PERTINENT THERMAL PERFORMANCE PARAMETERS OF BUILDING ENCLOSURES*****************

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	2ND E.WALL
WT./UNIT AREA(LB./SQ.FT.)	65.583	4.167	51.000	46.750	50.771	42.500	******	******	78.333
U-VALUE(BTU/HR-SQ.FT.-F)	.087	.312	.266	.179	.088	.224			.082
TH.MASS(BTU/SQ.FT.-F)	13.809	1.083	10.710	9.817	10.710	8.925	******	******	16.498
TH.TIME CONSTANT(HR.)	93.388	1.739	20.135	34.950	93.192	30.880	*******	*******	116.601

DWELLING TYPE -- SINGLE FAMILY ATTACHED AND DETACHED, MULTI FAMILY LOW-RISE

UNIT TYPE ------ 1, 2, 3, 4-BEDROOM UNITS

CONSTRUCTION -- WOOD FRAME

*****************VALUES OF PERTINENT THERMAL PERFORMANCE PARAMETERS OF BUILDING ENCLOSURES*****************

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	2ND E.WALL
WT./UNIT AREA(LB./SQ.FT.)	6.437	4.167	11.167	4.604	6.594	93.333	******	******	******
U-VALUE(BTU/HR-SQ.FT.-F)	.100	.310	.060	.058	.059	.355			
TH.MASS(BTU/SQ.FT.-F)	2.132	1.079	2.818	1.631	1.905	18.667	******	******	******
TH.TIME CONSTANT(HR.)	6.620	1.743	30.328	12.337	10.677	46.359	*******	*******	*******

Table 2b - continued

DWELLING TYPE -- MULTI-FAMILY HIGH RISE

UNIT TYPE ------ EFFICIENCY,1,2,3-BEDROOM APARTMENTS

CONSTRUCTION --- MASONRY

••••••••••••••••••VALUES OF PERTINENT THERMAL PERFORMANCE PARAMETERS OF BUILDING ENCLOSURES•••••••••••••••••

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	2ND E.WALL
WT./UNIT AREA(LB./SQ.FT.)	27.812	8.740	71.875	85.917	59.354	83.333	••••••	••••••	98.646
U-VALUE(BTU/HR-SQ.FT.-F)	.151	.111	.176	.066	.051	.155			.100
TH.MASS(BTU/SQ.FT.-F)	5.983	2.230	15.354	18.120	12.567	17.500	••••••	••••••	20.856
TH.TIME CONSTANT(HR.)	18.803	10.082	43.606	86.416	123.184	78.050	•••••••	•••••••	112.800

DWELLING TYPE -- MULTI-FAMILY HIGH RISE

UNIT TYPE ------ 1-BEDROOM APARTMENTS

CONSTRUCTION --- MASONRY (PRE-CAST)

••••••••••••••••••VALUES OF PERTINENT THERMAL PERFORMANCE PARAMETERS OF BUILDING ENCLOSURES•••••••••••••••••

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	2ND E.WALL
WT./UNIT AREA(LB./SQ.FT.)	59.250	4.167	66.667	80.000	69.250	89.250	••••••	••••••	••••••
U-VALUE(BTU/HR-SQ.FT.-F)	.133	.310	.219	.200	.070	.099			
TH.MASS(BTU/SQ.FT.-F)	12.466	1.079	14.000	17.267	14.539	19.233	••••••	••••••	••••••
TH.TIME CONSTANT(HR.)	47.537	1.743	31.920	46.727	165.537	96.290	•••••••	•••••••	•••••••

Table 2b - continued

DWELLING TYPE -- MULTI-FAMILY LOW RISE

UNIT TYPE ------ 1,2,3 BR. APARTMENT

CONSTRUCTION --- WOOD FRAME

••••••••••••••••••VALUES OF PERTINENT THERMAL PERFORMANCE PARAMETERS OF BUILDING ENCLOSURES••••••••••••••••••

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	2ND F.WALL
WT./UNIT AREA(LB./SQ.FT.)	7.083	5.208	8.563	4.729	5.021	2.750	••••••	••••••	••••••
U-VALUE(BTU/HR-SQ.FT.-F)	.103	.290	.054	.223	.069	.105			
TH.MASS(BTU/SQ.FT.-F)	2.286	1.349	2.714	1.843	1.611	1.267	••••••	••••••	••••••
TH.TIME CONST.(HR.)	7.701	2.327	24.955	3.902	10.541	2.214	••••••	••••••	••••••

DWELLING TYPE -- SINGLE FAMILY ATTACHED

UNIT TYPE ------ 2-,3-,4-BEDROOM UNITS

CONSTRUCTION --- WOOD FRAME

••••••••••••••••••VALUES OF PERTINENT THERMAL PERFORMANCE PARAMETERS OF BUILDING ENCLOSURES••••••••••••••••••

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	2ND E.WALL
WT./UNIT AREA(LB./SQ.FT.)	4.604	4.167	9.833	3.854	6.802	2.521	••••••	••••••	••••••
U-VALUE(BTU/HR-SQ.FT.-F)	.075	.310	.038	.156	.046	.063			
TH.MASS(BTU/SQ.FT.-F)	1.631	1.079	2.394	1.514	1.799	1.092	••••••	••••••	••••••
TH.TIME CONSTANT(HR.)	8.125	1.743	31.730	5.280	14.214	3.603	•••••••	•••••••	•••••••

Table 2b - continued

DWELLING TYPE -- SINGLE FAMILY DETACHED

UNIT TYPE ------ 3, 4-BEDROOM UNITS

CONSTRUCTION --- WOOD FRAME

•••••••••••••••••VALUES OF PERTINENT THERMAL PERFORMANCE PARAMETERS OF BUILDING ENCLOSURES•••••••••••••••••

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	2ND E.WALL
WT./UNIT AREA(LB./SQ.FT.)	4.000	4.167	••••••	••••••	6.217	1.771	••••••	••••••	••••••
U-VALUE(BTU/HR-SQ.FT.-F)	.079	.310			.063	.282			
TH.MASS(BTU/SQ.FT.-F)	1.397	1.079	••••••	••••••	1.637	.974	••••••	••••••	••••••
TH.TIME CONSTANT(HR.)	7.154	1.743	•••••••	•••••••	9.832	2.474	•••••••	•••••••	•••••••

DWELLING TYPE -- SINGLE FAMILY ATTACHED AND DETACHED

UNIT TYPE ------ 2,3,AND 4-BEDROOM UNIT

CONSTRUCTION --- SANDWICH PANEL (POLYESTER LAMINATE)

•••••••••••••••••VALUES OF PERTINENT THERMAL PERFORMANCE PARAMETERS OF BUILDING ENCLOSURES•••••••••••••••••

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	2ND E.WALL
WT./UNIT AREA(LB./SQ.FT.)	2.545	2.545	5.090	5.937	3.458	2.458	••••••	••••••	••••••
U-VALUE(BTU/HR-SQ.FT.-F)	.078	.075	.038	.136	.052	.068			
TH.MASS(BTU/SQ.FT.-F)	.509	.509	1.018	2.057	.692	1.082	••••••	••••••	••••••
TH.TIME CONST.(HR.)	3.171	3.390	13.361	6.130	6.426	3.449	••••••	••••••	••••••

Table 2b - continued

DWELLING TYPE -- SINGLE FAMILY ATTACHED

UNIT TYPE ------ 4, 3, 2 - BEDROOM DUPLEX

CONSTRUCTION --- WOOD FRAME

••••••••••••••••••VALUES OF PERTINENT THERMAL PERFORMANCE PARAMETERS OF BUILDING ENCLOSURES••••••••••••••••••

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	IST FL.	B.FLOOR	B.WALL	2ND E.WALL
WT./UNIT AREA(LB./SQ.FT.)	3.467	4.167	9.333	4.208	6.990	2.125	••••••	••••••	••••••
U-VALUE(BTU/HR-SQ.FT.-F)	.096	.310	.056	.235	.041	.395			
TH.MASS(BTU/SQ.FT.-F)	1.104	1.079	2.315	1.708	1.828	1.169	••••••	••••••	••••••
TH.TIME CONST.(HR.)	5.691	1.743	20.792	3.358	16.604	1.683	••••••	••••••	••••••

DWELLING TYPE -- SINGLE FAMILY DETACHED

UNIT TYPE ------ 2,3 4-BEDROOM UNITS

CONSTRUCTION --- STEEL JOIST, WOOD FRAME

••••••••••••••••••VALUES OF PERTINENT THERMAL PERFORMANCE PARAMETERS OF BUILDING ENCLOSURES••••••••••••••••••

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	IST FL.	B.FLOOR	B.WALL	2ND E.WALL
WT./UNIT AREA(LB./SQ.FT.)	8.553	4.167	••••••	4.208	5.062	33.333	••••••	••••••	••••••
U-VALUE(BTU/HR-SQ.FT.-F)	.076	.312		.180	.048	.267			
TH.MASS(BTU/SQ.FT.-F)	2.299	1.292	••••••	1.710	1.627	7.000	••••••	••••••	••••••
TH.TIME CONSTANT(HR.)	14.767	2.220	•••••••	5.447	15.725	20.650	•••••••	•••••••	•••••••

Table 2b - continued

DWELLING TYPE -- SINGLE FAMILY ATTACHED

UNIT TYPE ------ 2-,3-,4-BEDROOM UNITS

CONSTRUCTION --- WOOD FRAME

•••••••••••••••••VALUES OF PERTINENT THERMAL PERFORMANCE PARAMETERS OF BUILDING ENCLOSURES••••••••••••••••••

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	2ND E.WALL
WT./UNIT AREA(LB./SQ.FT.)	4.729	4.167	5.562	4.208	6.719	3.000	••••••	••••••	••••••
U-VALUE(BTU/HR-SQ.FT.-F)	.066	.310	.065	.185	.061	.057			
TH.MASS(BTU/SQ.FT.-F)	1.651	1.079	1.351	1.708	1.927	1.306	••••••	••••••	••••••
TH.TIME CONSTANT(HR.)	9.350	1.743	9.513	5.372	10.552	4.489	•••••••	•••••••	•••••••

DWELLING TYPE -- SINGLE FAMILY DETACHED

UNIT TYPE ------ 4-BR. HOUSE

CONSTRUCTION --- HONEYCOMB PANEL (METAL PANEL)

•••••••••••••••••VALUES OF PERTINENT THERMAL PERFORMANCE PARAMETERS OF BUILDING ENCLOSURES••••••••••••••••••

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	2ND E.WALL
WT./UNIT AREA(LB./SQ.FT.)	3.726	2.809	••••••	••••••	3.726	4.025	••••••	••••••	••••••
U-VALUE(BTU/HR-SQ.FT.-F)	.084	.127			.082	.073			
TH.MASS(BTU/SQ.FT.-F)	.718	.489	••••••	••••••	.718	1.218	••••••	••••••	••••••
TH.TIME CONST.(HR.)	4.128	1.921	••••••	••••••	4.128	7.003	••••••	••••••	••••••

Table 2b - continued

DWELLING TYPE -- SINGLE FAMILY ATTACHED

UNIT TYPE ------ 2,3,AND 4-BEDROOM TOWNHOUSE W/BASEMENT

CONSTRUCTION --- WOOD FRAME, ALUMINUM SIDING

•••••••••••••••••VALUES OF PERTINENT THERMAL PERFORMANCE PARAMETERS OF BUILDING ENCLOSURES•••••••••••••••••

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	2ND F.WALL
WT./UNIT AREA(LB./SQ.FT.)	4.946	6.292	5.771	5.979	7.781	1.771	93.333	46.667	47.042
U-VALUE(BTU/HR-SQ.FT.-F)	.101	.187	.096	.134	.052	.260	.742	.798	.097
TH.MASS(BTU/SQ.FT.-F)	1.263	2.248	1.437	2.682	2.509	.974	18.667	9.333	10.312
TH.TIME CONST.(HR.)	5.642	6.000	7.545	11.773	22.334	2.474	6.225	10.141	10.434

DWELLING TYPE -- MULTI-FAMILY LOW RISE

UNIT TYPE ------ 2 AND 3 - BEDROOM APARTMENT

CONSTRUCTION --- WOOD FRAME, ALUMINUM SIDING

•••••••••••••••••VALUES OF PERTINENT THERMAL PERFORMANCE PARAMETERS OF BUILDING ENCLOSURES•••••••••••••••••

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	2ND F.WALL
WT./UNIT AREA(LB./SQ.FT.)	4.567	7.333	5.771	6.500	9.365	1.771	••••••	••••••	47.562
U-VALUE(BTU/HR-SQ.FT.-F)	.101	.159	.096	.133	.051	.282			.096
TH.MASS(BTU/SQ.FT.-F)	1.414	2.518	1.422	2.817	3.229	.974	••••••	••••••	10.444
TH.TIME CONST.(HR.)	6.792	7.941	7.506	12.655	28.038	2.474	••••••	••••••	11.443

Table 2b - continued

DWELLING TYPE -- MULTI-FAMILY HIGH RISE

UNIT TYPE ------ EFFICIENCY,1,2,3,4-BEDROOM APARTMENTS

CONSTRUCTION --- MASONRY, LIGHT WEIGHT

•••••••••••••••••VALUES OF PERTINENT THERMAL PERFORMANCE PARAMETERS OF BUILDING ENCLOSURES•••••••••••••••••

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	R.WALL	2ND E.WALL
WT./UNIT AREA(LB./SQ.FT.)	28.000	4.167	34.375	33.333	42.521	33.333	••••••	••••••	26.833
U-VALUE(BTU/HR-SQ.FT.-F)	.157	.312	.160	.214	.112	.214			.099
TH.MASS(BTU/SQ.FT.-F)	6.002	1.083	7.687	7.000	8.988	7.000	••••••	••••••	5.776
TH.TIME CONSTANT(HR.)	8.132	1.739	23.985	20.650	52.455	20.650	•••••••	•••••••	10.989

DWELLING TYPE -- MULTI-FAMILY LOW RISE AND SINGLE FAMILY ATTACHED

UNIT TYPE ------ 2S/2-BR, 3S/3-BR, 3S/4-BR AND 3S/2-BR OVER 3-BR.

CONSTRUCTION --- STEEL JOIST, METAL FRAME

•••••••••••••••••VALUES OF PERTINENT THERMAL PERFORMANCE PARAMETERS OF BUILDING ENCLOSURES•••••••••••••••••

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	R.WALL	2ND E.WALL
WT./UNIT AREA(LB./SQ.FT.)	6.387	4.167	5.979	7.500	6.594	75.417	••••••	••••••	••••••
U-VALUE(BTU/HR-SQ.FT.-F)	.176	.310	.033	.169	.068	.199			
TH.MASS(BTU/SQ.FT.-F)	1.564	1.079	1.442	1.673	1.937	15.083	••••••	••••••	••••••
TH.TIME CONST.(HR.)	[illegible]	1.743	21.567	5.659	9.310	70.013	••••••	••••••	••••••

Table 2b - continued

DWELLING TYPE -- MULTI-FAMILY LOW RISE

UNIT TYPE ------ 25/2-BR. AND 15/1-BR. UNITS ON SLS LEVEL 2

CONSTRUCTION --- STEEL JOIST, METAL FRAME

•••••••••••••••••VALUES OF PERTINENT THERMAL PERFORMANCE PARAMETERS OF BUILDING ENCLOSURES•••••••••••••••••

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	2ND F.WALL
WT./UNIT AREA(LB./SQ.FT.)	6.929	4.167	10.417	4.375	17.521	20.433	••••••	••••••	••••••
U-VALUE(BTU/HR-SQ.FT.-F)	.145	.310	.216	.182	.067	.141			
TH.MASS(BTU/SQ.FT.-F)	1.638	1.079	2.698	1.648	3.735	5.356	••••••	••••••	••••••
TH.TIME CONST.(HR.)	6.794	1.743	6.232	5.377	11.424	21.547	••••••	••••••	••••••

DWELLING TYPE -- MULTI-FAMILY LOW RISE

UNIT TYPE ------ 35/4-BR. UNIT

CONSTRUCTION --- STEEL JOIST, WOOD FRAME

•••••••••••••••••VALUES OF PERTINENT THERMAL PERFORMANCE PARAMETERS OF BUILDING ENCLOSURES•••••••••••••••••

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	2ND F.WALL
WT./UNIT AREA(LB./SQ.FT.)	4.167	4.167	6.292	4.917	20.433	19.371	••••••	••••••	••••••
U-VALUE(BTU/HR-SQ.FT.-F)	.357	.310	.195	.143	.141	.160			
TH.MASS(BTU/SQ.FT.-F)	1.079	1.079	2.248	2.098	5.356	4.772	••••••	••••••	••••••
TH.TIME CONST.(HR.)	1.279	1.743	5.775	6.109	21.547	22.709	••••••	••••••	••••••

Table 2b - continued

DWELLING TYPE -- SINGLE FAMILY ATTACHED(2-STOREY) AND DETACHED(1-STOREY)

UNIT TYPE ------ 2-,3-,4-BEDROOM UNITS

CONSTRUCTION --- HONEYCOMB PANEL (GYPSUM PANEL)

****************VALUES OF PERTINENT THERMAL PERFORMANCE PARAMETERS OF BUILDING ENCLOSURES****************

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	2ND E.WALL
WT./UNIT AREA(LB./SQ.FT.)	8.312	4.167	16.625	11.937	11.323	5.729	******	******	******
U-VALUE(BTU/HR-SQ.FT.-F)	.146	.312	.071	.042	.058	.083			
TH.MASS(BTU/SQ.FT.-F)	2.123	1.081	4.247	3.597	2.758	2.046	******	******	******
TH.TIME CONSTANT(HR.)	8.204	1.737	30.047	40.418	28.232	12.536	*******	*******	*******

Table 3

Sample of Typical Geometric Data, Room-by-Room, of a Dwelling Unit

The abbreviations used in this table, besides those that are clearly defined, are:

E. Wall:	Exterior wall
I. Wall:	Interior wall or partition
P. Wall:	Party wall (for multi-family structure)
B. Floor:	Basement floor
B. Wall:	Basement wall
I. Door:	Interior door
E. Door:	Exterior door
S1, S2, S3, S4:	Indicating the four sides of a room

For readers interested in converting to SI units, a conversion table is provided in the Appendix.

Table 3 Sample of Typical Geometric Data, Room-by-Room, of a Dwelling Unit

DWELLING TYPE -- MULTI-FAMILY LOW RISE

UNIT TYPE ------ 1-BR. APT.

CONSTRUCTION --- WOOD FRAME

FLOOR LEVEL -- 2

TYPE OF ROOM - LIVING AND DINING ROOM (LENGTH=11.0 FT. WIDTH=28.0 FT. HEIGHT= 9.0 FT.)

	TOTAL SQ.FT.	E.WALL SQ.FT.	I.WALL SQ.FT.	P.WALL SQ.FT.	OPENING SQ.FT.	WINDOW/DIMENSION SQ.FT.	FT.	SH.FAC.	E.DOOR SQ.FT.	I.DOOR SQ.FT.	FLOOR/CEILING SQ.FT.
S 1	99.	0.	0.	99.	0.	0.	.00X .00	****	0.	0.	0.
S 2	252.	0.	198.	0.	54.	0.	.00X .00	****	0.	0.	0.
S 3	99.	45.	0.	0.	0.	54.	10.80X5.00	.55	0.	0.	0.
S 4	252.	207.	0.	0.	0.	25.	5.00X5.00	.55	20.	0.	0.
TOTAL		252.	198.	99.	54.	79.			20.	0.	308.

TOTAL INTERIOR DOOR CRACK- .0 FT.
TOTAL EXTERIOR DOOR CRACK- 20.0 FT.
TOTAL WINDOW CRACK- 52.0 FT.
ROOF AREA- 308. SQ.FT.
LIGHTING= 200.0 WATTS
FURNITURE= .000

FLOOR LEVEL -- 2

TYPE OF ROOM - KITCHEN (LENGTH= 5.0 FT. WIDTH=10.0 FT. HEIGHT= 9.0 FT.)

	TOTAL SQ.FT.	E.WALL SQ.FT.	I.WALL SQ.FT.	P.WALL SQ.FT.	OPENING SQ.FT.	WINDOW/DIMENSION SQ.FT.	FT.	SH.FAC.	E.DOOR SQ.FT.	I.DOOR SQ.FT.	FLOOR/CEILING SQ.FT.
S 1	45.	0.	0.	45.	0.	0.	.00X .00	****	0.	0.	0.
S 2	90.	0.	90.	0.	0.	0.	.00X .00	****	0.	0.	0.
S 3	45.	0.	45.	0.	0.	0.	.00X .00	****	0.	0.	0.
S 4	90.	0.	54.	0.	36.	0.	.00X .00	****	0.	0.	0.
TOTAL		0.	189.	45.	36.	0.			0.	0.	50.

TOTAL INTERIOR DOOR CRACK- .0 FT.
TOTAL EXTERIOR DOOR CRACK- .0 FT.
TOTAL WINDOW CRACK- .0 FT.
ROOF AREA- 50. SQ.FT.
LIGHTING= 88.0 WATTS
FURNITURE= .000

Table 3 - continued

FLOOR LEVEL -- 2

TYPE OF ROOM - BATHROOM (LENGTH= 5.0 FT. WIDTH= 9.0 FT. HEIGHT= 9.0 FT.)

	TOTAL SQ.FT.	E.WALL SQ.FT.	I.WALL SQ.FT.	P.WALL SQ.FT.	OPENING SQ.FT.	WINDOW/DIMENSION SQ.FT.	FT.	SH.FAC.	E.DOOR SQ.FT.	I.DOOR SQ.FT.	FLOOR/CEILING SQ.FT.
S 1	45.	0.	0.	45.	0.	0.	.00X .00	****	0.	0.	0.
S 2	81.	81.	0.	0.	0.	0.	.00X .00	****	0.	0.	0.
S 3	80.	0.	65.	0.	0.	0.	.00X .00	****	0.	15.	0.
S 4	81.	0.	81.	0.	0.	0.	.00X .00	****	0.	0.	0.
TOTAL		81.	146.	45.	0.	0.			0.	15.	45.

TOTAL INTERIOR DOOR CRACK- 18.0 FT.
TOTAL EXTERIOR DOOR CRACK- .0 FT.
TOTAL WINDOW CRACK- .0 FT.
ROOF AREA- 45. SQ.FT.
LIGHTING= 240.0 WATTS
FURNITURE= .000

FLOOR LEVEL -- 2

TYPE OF ROOM - BEDROOM NO. 1 (LENGTH=11.0 FT. WIDTH=12.0 FT. HEIGHT= 9.0 FT.)

	TOTAL SQ.FT.	E.WALL SQ.FT.	I.WALL SQ.FT.	P.WALL SQ.FT.	OPENING SQ.FT.	WINDOW/DIMENSION SQ.FT.	FT.	SH.FAC.	E.DOOR SQ.FT.	I.DOOR SQ.FT.	FLOOR/CEILING SQ.FT.
S 1	99.	0.	82.	0.	0.	0.	.00X .00	****	0.	17.	0.
S 2	108.	108.	0.	0.	0.	0.	.00X .00	****	0.	0.	0.
S 3	99.	74.	0.	0.	0.	25.	5.00X5.00	.55	0.	0.	0.
S 4	108.	0.	108.	0.	0.	0.	.00X .00	****	0.	0.	0.
TOTAL		182.	190.	0.	0.	25.			0.	17.	132.

TOTAL INTERIOR DOOR CRACK- 18.0 FT.
TOTAL EXTERIOR DOOR CRACK- .0 FT.
TOTAL WINDOW CRACK- 20.0 FT.
ROOF AREA- 132. SQ.FT.
LIGHTING= .0 WATTS
FURNITURE= .000

Table 3 - continued

FLOOR LEVEL -- 2

TYPE OF ROOM - HALL (LENGTH=11.0 FT. WIDTH= 7.0 FT. HEIGHT= 9.0 FT.)

	TOTAL SQ.FT.	E.WALL SQ.FT.	I.WALL SQ.FT.	P.WALL SQ.FT.	OPENING SQ.FT.	WINDOW/DIMENSION SQ.FT.	FT.	SH.FAC.	E.DOOR SQ.FT.	I.DOOR SQ.FT.	FLOOR/CEILING SQ.FT.
S 1	99.	0.	79.	0.	0.	0.	.00X .00	****	0.	20.	0.
S 2	63.	63.	0.	0.	0.	0.	.00X .00	****	0.	0.	0.
S 3	99.	0.	82.	0.	0.	0.	.00X .00	****	0.	17.	0.
S 4	63.	0.	45.	0.	18.	0.	.00X .00	****	0.	0.	0.
TOTAL		63.	206.	0.	18.	0.			0.	37.	71.

TOTAL INTERIOR DOOR CRACK- 36.0 FT.
TOTAL EXTERIOR DOOR CRACK- .0 FT.
TOTAL WINDOW CRACK- .0 FT.
ROOF AREA- 71. SQ.FT.
LIGHTING= 75.0 WATTS
FURNITURE= .000

Table 4

Summary of Pertinent Thermal Performance Parameters and Geometric Data Associated With Various Dwelling Units

The abbreviations used in this table, besides those that are clearly defined, are:

E. Wall: Exterior wall

I. Wall: Interior wall or partition

P. Wall: Party wall (for multi-family structure)

B. Floor: Basement floor

B. Wall: Basement wall

I. Door: Interior door

E. Door: Exterior door

For readers interested in converting to SI units, a conversion table is provided in the Appendix. Also, in the following table, the meaning of weight per unit area is equivalent to mass per unit area.

Table 4 Summary of Pertinent Thermal Performance Parameters and Geometric Data Associated With Various Dwelling Units

DWELLING TYPE -- MULTI-FAMILY LOW RISE

UNIT TYPE ------ 1-BR. APT.

CONSTRUCTION --- WOOD FRAME

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	I.DOOR	WINDOW	E.DOOR
TOTAL AREA/UNIT (SQ.FT.)	578.	929.	189.	606.	606.	606.	0.	0.	69.	104.	20.
WT./UNIT AREA(LB./SQ.FT.)	7.083	5.209	8.583	4.729	5.021	2.750					
U-VALUE(BTU/HR-SQ.FT.-F)	.103	.290	.054	.223	.069	.105			.441	1.058	1.075
TH.MASS(BTU/SQ.FT.-F)	2.286	1.349	2.714	1.843	1.611	1.267					
TH.TIME CONST.(HR.)	7.701	2.327	24.955	3.902	10.541	2.214					
SOLAR ABSORPTIVITY	.350	....	....	....	.300	....	....	....	....		.400
SOLAR TRANSMITTANCE	....	....	....	....	....	....	....	....	....	.870	....

TOTAL FLOOR AREA PER UNIT = 606. SQ.FT.
AREA RATIO, EXT.WALL/FLOOR = .954
AREA RATIO, WINDOW/EXT.WALL = .180

DWELLING TYPE -- MULTI-FAMILY LOW RISE

UNIT TYPE ------ 2-BR. APT.

CONSTRUCTION --- WOOD FRAME

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	I.DOOR	WINDOW	E.DOOR
TOTAL AREA/UNIT (SQ.FT.)	729.	1165.	288.	796.	796.	796.	0.	0.	99.	129.	20.
WT./UNIT AREA(LB./SQ.FT.)	7.083	5.208	8.583	4.729	5.021	2.750					
U-VALUE(BTU/HR-SQ.FT.-F)	.103	.290	.054	.223	.069	.105			.441	1.058	1.075
TH.MASS(BTU/SQ.FT.-F)	2.286	1.349	2.714	1.843	1.611	1.267					
TH.TIME CONST.(HR.)	7.701	2.327	24.955	3.902	10.541	2.214					
SOLAR ABSORPTIVITY	.350	....	....	....	.300	....	....	....	....		.400
SOLAR TRANSMITTANCE	....	....	....	....	....	....	....	....	....	.870	....

TOTAL FLOOR AREA PER UNIT = 796. SQ.FT.
AREA RATIO, EXT.WALL/FLOOR = .916
AREA RATIO, WINDOW/EXT.WALL = .177

Table 4 - continued

DWELLING TYPE -- MULTI-FAMILY LOW RISE

UNIT TYPE ------ 3-BR. APT.

CONSTRUCTION --- WOOD FRAME

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	I.DOOR	WINDOW	E.DOOR
TOTAL AREA/UNIT (SQ.FT.)	680.	1545.	288.	912.	912.	912.	0.	0.	117.	169.	20.
WT./UNIT AREA(LB./SQ.FT.)	7.083	5.208	8.583	4.729	5.021	2.750					
U-VALUE(BTU/HR-SQ.FT.-F)	.103	.290	.054	.223	.069	.105			.441	1.058	1.075
TH.MASS(BTU/SQ.FT.-F)	2.286	1.349	2.714	1.843	1.611	1.267					
TH.TIME CONST.(HR.)	7.701	2.327	24.955	3.902	10.541	2.214					
SOLAR ABSORPTIVITY	.350	****	****	****	.300	****	****	****	****		.400
SOLAR TRANSMITTANCE	****	****	****	****	****	****	****	****	****	.870	****

TOTAL FLOOR AREA PER UNIT = 912. SQ.FT.
AREA RATIO, EXT.WALL/FLOOR = .746
AREA RATIO, WINDOW/EXT.WALL = .249

DWELLING TYPE -- SINGLE FAMILY ATTACHED AND DETACHED

UNIT TYPE ------ 3-BEDROOM UNIT .SFD.

CONSTRUCTION --- SANDWICH PANEL (POLYESTER LAMINATE)

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	I.DOOR	WINDOW	E.DOOR
TOTAL AREA/UNIT (SQ.FT.)	1033.	1044.	0.	960.	960.	960.	0.	0.	107.	207.	24.
WT./UNIT AREA(LB./SQ.FT.)	2.545	2.545		5.937	3.458	2.458					
U-VALUE(BTU/HR-SQ.FT.-F)	.078	.075		.136	.052	.068			.441	1.136	.441
TH.MASS(BTU/SQ.FT.-F)	.509	.509		2.057	.692	1.082					
TH.TIME CONST.(HR.)	3.171	3.390		8.130	6.426	3.449					
SOLAR ABSORPTIVITY	.350	****		****	.350	****	****	****	****		.350
SOLAR TRANSMITTANCE	****	****		****	****	****	****	****	****	.840	****

TOTAL FLOOR AREA PER UNIT = 960. SQ.FT.
AREA RATIO, EXT.WALL/FLOOR =1.076
AREA RATIO, WINDOW/EXT.WALL = .200

Table 4 - continued

DWELLING TYPE -- SINGLE FAMILY ATTACHED AND DETACHED

UNIT TYPE ------ 4-BEDROOM UNIT SFD.

CONSTRUCTION --- SANDWICH PANEL (POLYESTER LAMINATE)

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	I.DOOR	WINDOW	E.DOOR
TOTAL AREA/UNIT (SQ.FT.)	1189.	1022.	0.	1246.	1246.	1246.	0.	0.	106.	207.	24.
WT./UNIT AREA(LB./SQ.FT.)	2.545	2.545		5.937	3.458	2.458					
U-VALUE(BTU/HR-SQ.FT.-F)	.078	.075		.136	.052	.068			.441	1.136	.441
TH.MASS(BTU/SQ.FT.-F)	.509	.509		2.057	.692	1.082					
TH.TIME CONST.(HR.)	3.171	3.390		8.130	6.426	3.449					
SOLAR ABSORPTIVITY	.350	....		....	.350	....	....	....	....		.350
SOLAR TRANSMITTANCE	....	....		....	....	....	....	....	....	.840	....

TOTAL FLOOR AREA PER UNIT = 1246. SQ.FT.
AREA RATIO, EXT.WALL/FLOOR = .954
AREA RATIO, WINDOW/EXT.WALL = .174

DWELLING TYPE -- SINGLE FAMILY ATTACHED AND DETACHED

UNIT TYPE ------ 2-BEDROOM UNIT SFA.

CONSTRUCTION --- SANDWICH PANEL (POLYESTER LAMINATE)

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	I.DOOR	WINDOW	E.DOOR
TOTAL AREA/UNIT (SQ.FT.)	942.	704.	436.	769.	384.	384.	0.	0.	90.	156.	24.
WT./UNIT AREA(LB./SQ.FT.)	2.545	2.545	5.090	5.937	3.458	2.458					
U-VALUE(BTU/HR-SQ.FT.-F)	.078	.075	.038	.136	.052	.068			.441	1.136	.441
TH.MASS(BTU/SQ.FT.-F)	.509	.509	1.018	2.057	.692	1.082					
TH.TIME CONST.(HR.)	3.171	3.390	13.361	8.130	6.426	3.449					
SOLAR ABSORPTIVITY	.350	....	....	....	.350	....	....	....	....		.350
SOLAR TRANSMITTANCE	....	....	....	....	....	....	....	....	....	.840	....

TOTAL FLOOR AREA PER UNIT = 769. SQ.FT.
AREA RATIO, EXT.WALL/FLOOR =1.225
AREA RATIO, WINDOW/EXT.WALL = .166

Table 4 - continued

DWELLING TYPE -- SINGLE FAMILY ATTACHED AND DETACHED

UNIT TYPE ------ 3-BEDROOM UNIT SFA.

CONSTRUCTION --- SANDWICH PANEL (POLYESTER LAMINATE)

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	I.DOOR	WINDOW	E.DOOR
TOTAL AREA/UNIT (SQ.FT.)	439.	1519.	805.	1082.	541.	541.	0.	0.	90.	270.	24.
WT./UNIT AREA(LB./SQ.FT.)	2.545	2.545	5.090	5.937	3.458	2.458					
U-VALUE(BTU/HR-SQ.FT.-F)	.078	.075	.038	.136	.052	.068					
TH.MASS(BTU/SQ.FT.-F)	.509	.509	1.018	2.057	.692	1.082			.441	1.136	.441
TH.TIME CONST.(HR.)	3.171	3.390	13.361	8.130	6.426	3.449					
SOLAR ABSORPTIVITY	.350	••••	••••	••••	.350	••••		••••	••••		.350
SOLAR TRANSMITTANCE	••••	••••	••••	••••	••••	••••	••••	••••	••••	.840	••••

TOTAL FLOOR AREA PER UNIT = 1082. SQ.FT.
AREA RATIO, EXT.WALL/FLOOR = .406
AREA RATIO, WINDOW/EXT.WALL = .615

DWELLING TYPE -- SINGLE FAMILY ATTACHED AND DETACHED

UNIT TYPE ------ 4-BEDROOM UNIT SFA.

CONSTRUCTION --- SANDWICH PANEL (POLYESTER LAMINATE)

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	I.DOOR	WINDOW	E.DOOR
TOTAL AREA/UNIT (SQ.FT.)	962.	1768.	468.	1141.	570.	570.	0.	0.	104.	270.	24.
WT./UNIT AREA(LB./SQ.FT.)	2.545	2.545	5.090	5.937	3.458	2.458					
U-VALUE(BTU/HR-SQ.FT.-F)	.078	.075	.038	.136	.052	.068					
TH.MASS(BTU/SQ.FT.-F)	.509	.509	1.018	2.057	.692	1.082			.441	1.136	.441
TH.TIME CONST.(HR.)	3.171	3.390	13.361	8.130	6.426	3.449					
SOLAR ABSORPTIVITY	.350	••••	••••	••••	.350	••••	••••	••••	••••		.350
SOLAR TRANSMITTANCE	••••	••••	••••	••••	••••	••••	••••	••••	••••	.840	••••

TOTAL FLOOR AREA PER UNIT = 1141. SQ.FT.
AREA RATIO, EXT.WALL/FLOOR = .843
AREA RATIO, WINDOW/EXT.WALL = .281

Table 4 - continued

DWELLING TYPE -- SINGLE FAMILY ATTACHED

UNIT TYPE ------ 2-BEDROOM DUPLEX

CONSTRUCTION --- WOOD FRAME

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	I.DOOR	WINDOW	E.DOOR
TOTAL AREA/UNIT (SQ.FT.)	692.	980.	340.	695.	347.	347.	0.	0.	137.	85.	32.
WT./UNIT AREA(LB./SQ.FT.)	3.467	4.167	9.333	4.208	4.646	2.125					
U-VALUE(BTU/HR-SQ.FT.-F)	.096	.310	.056	.235	.041	.395			.441	1.059	.450
TH.MASS(BTU/SQ.FT.-F)	1.104	1.079	2.315	1.708	1.359	1.169					
TH.TIME CONST.(HR.)	5.691	1.743	20.792	3.358	16.384	1.683					
SOLAR ABSORPTIVITY	.280	••••	••••	••••	.930	••••	••••	••••	••••		.850
SOLAR TRANSMITTANCE	••••	••••	••••	••••	••••	••••	••••	••••	••••	.870	••••

TOTAL FLOOR AREA PER UNIT = 695. SQ.FT.
AREA RATIO, EXT.WALL/FLOOR = .996
AREA RATIO, WINDOW/EXT.WALL = .123

DWELLING TYPE -- SINGLE FAMILY ATTACHED

UNIT TYPE ------ 3-BEDROOM DUPLEX

CONSTRUCTION --- WOOD FRAME

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	I.DOOR	WINDOW	E.DOOR
TOTAL AREA/UNIT (SQ.FT.)	826.	1508.	323.	931.	465.	465.	0.	0.	150.	127.	32.
WT./UNIT AREA(LB./SQ.FT.)	3.467	4.167	9.333	4.208	4.646	2.125					
U-VALUE(BTU/HR-SQ.FT.-F)	.096	.310	.056	.235	.041	.395			.441	1.059	.450
TH.MASS(BTU/SQ.FT.-F)	1.104	1.079	2.315	1.708	1.359	1.169					
TH.TIME CONST.(HR.)	5.691	1.743	20.792	3.358	16.384	1.683					
SOLAR ABSORPTIVITY	.280	••••	••••	••••	.930	••••	••••	••••	••••		.850
SOLAR TRANSMITTANCE	••••	••••	••••	••••	••••	••••	••••	••••	••••	.870	••••

TOTAL FLOOR AREA PER UNIT = 931. SQ.FT.
AREA RATIO, EXT.WALL/FLOOR = .887
AREA RATIO, WINDOW/EXT.WALL = .154

DWELLING TYPE -- SINGLE FAMILY ATTACHED

UNIT TYPE ------ 4-BEDROOM DUPLEX

CONSTRUCTION --- WOOD FRAME

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	I.DOOR	WINDOW	E.DOOR
TOTAL AREA/UNIT (SQ.FT.)	915.	1731.	317.	1065.	533.	533.	0.	0.	200.	143.	32.
WT./UNIT AREA(LB./SQ.FT.)	3.467	4.167	9.333	4.208	4.646	2.125					
U-VALUE(BTU/HR-SQ.FT.-F)	.096	.310	.056	.235	.041	.395			.441	1.059	.450
TH.MASS(BTU/SQ.FT.-F)	1.104	1.079	2.315	1.708	1.359	1.169					
TH.TIME CONST.(HR.)	5.691	1.743	20.792	3.358	16.384	1.683					
SOLAR ABSORPTIVITY	.280	****	****	****	.930	****	****	****	****	.000	.850
SOLAR TRANSMITTANCE	****	****	****	****	****	****	****	****	****	.870	****

TOTAL FLOOR AREA PER UNIT = 1065. SQ.FT.
AREA RATIO, EXT.WALL/FLOOR = .859
AREA RATIO, WINDOW/EXT.WALL = .157

DWELLING TYPE -- SINGLE FAMILY DETACHED

UNIT TYPE ------ 4-BR. HOUSE

CONSTRUCTION --- HONEYCOMB IN PANEL (METAL PANEL)

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	I.DOOR	WINDOW	E.DOOR
TOTAL AREA/UNIT (SQ.FT.)	2395.	1520.	0.		1531.	1531.	0.	0.		328.	20.
WT./UNIT AREA(LB./SQ.FT.)	3.726	2.809			3.726	4.025					
U-VALUE(BTU/HR-SQ.FT.-F)	.088	.127			.082	.073				.610	.481
TH.MASS(BTU/SQ.FT.-F)	.718	.489			.712	1.219					
TH.TIME CONST.(HR.)	4.128	1.921			4.122	7.003					
SOLAR ABSORPTIVITY	.300	****	****	****	.300	****	****	****	****		.300
SOLAR TRANSMITTANCE	****	****	****	****	****	****	****	****	****	.800	****

TOTAL FLOOR AREA PER UNIT = 1531. SQ.FT.
AREA RATIO, EXT.WALL/FLOOR =1.564
AREA RATIO, WINDOW/EXT.WALL = .137

Table 4 - continued

DWELLING TYPE -- SINGLE FAMILY DETACHED

UNIT TYPE ------ 4-BR. HOUSE TYPE 2

CONSTRUCTION --- HONEYCOMB IN PANEL (METAL)

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	I.DOOR	WINDOW	E.DOOR
TOTAL AREA/UNIT (SQ.FT.)	2400.	1520.	0.		1531.	1531.	0.	0.		328.	20.
WT./UNIT AREA(LB./SQ.FT.)	3.726	2.809			3.725	4.025					
U-VALUE(BTU/HR-SQ.FT.-F)	.094	.127			.082	.073				.610	.481
TH.MASS(BTU/SQ.FT.-F)	.719	.489			.719	1.219					
TH.TIME CONST.(HR.)	4.125	1.021			4.129	7.003					
SOLAR ABSORPTIVITY	.300	****	****	****	.300	****	****	****	****	0.	.300
SOLAR TRANSMITTANCE	****	****	****	****	****	****	****	****	****	.800	****

TOTAL FLOOR AREA PER UNIT = 1531. SQ.FT.
AREA RATIO, EXT.WALL/FLOOR =1.568
AREA RATIO, WINDOW/EXT.WALL = .137

DWELLING TYPE -- SINGLE FAMILY ATTACHED

UNIT TYPE ------ 2-BEDROOM TOWNHOUSE

CONSTRUCTION --- WOOD FRAME (ALUMINUM SIDING)

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	I.DOOR	WINDOW	E.DOOR
TOTAL AREA/UNIT (SQ.FT.)	1176.	1201.	24.	821.	410.	410.	642.	472.	147.	114.	20.
WT./UNIT AREA(LB./SQ.FT.)	4.046	6.292	5.771	5.979	5.437	1.771					
U-VALUE(BTU/HR-SQ.FT.-F)	.101	.187	.096	.134	.052	.260	.742	.798	.441	.610	1.075
TH.MASS(BTU/SQ.FT.-F)	1.283	2.248	1.437	2.682	2.040	.974					
TH.TIME CONST.(HR.)	5.642	6.000	7.545	11.773	22.114	2.474					
SOLAR ABSORPTIVITY	.470	****	****	****	.930	****	****	****	****		.400
SOLAR TRANSMITTANCE	****	****	****	****	****	****	****	****	****	.760	****

TOTAL FLOOR AREA PER UNIT = 821. SQ.FT.
AREA RATIO, EXT.WALL/FLOOR =1.432
AREA RATIO, WINDOW/EXT.WALL = .097

Table 4 - continued

DWELLING TYPE -- SINGLE FAMILY ATTACHED

UNIT TYPE ------ 3-BEDROOM TOWNHOUSE

CONSTRUCTION --- WOOD FRAME (ALUMINUM SIDING)

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	I.DOOR	WINDOW	E.DOOR
TOTAL AREA/UNIT (SQ.FT.)	696.	1908.	632.	1037.	518.	518.	716.	587.	176.	155.	20.
WT./UNIT AREA(LB./SQ.FT.)	4.046	6.292	5.771	5.979	5.437	1.771					
U-VALUE(BTU/HR-SQ.FT.-F)	.101	.187	.096	.134	.052	.260	.742	.798	.441	.610	1.075
TH.MASS(BTU/SQ.FT.-F)	1.283	2.248	1.437	2.682	2.040	.974					
TH.TIME CONST.(HR.)	5.642	6.000	7.545	11.773	22.114	2.474					
SOLAR ABSORPTIVITY	.470	****	****	****	.930	****	****	****	****		.400
SOLAR TRANSMITTANCE	****	****	****	****	****	****	****	****	****	.760	****

TOTAL FLOOR AREA PER UNIT = 1037. SQ.FT.
AREA RATIO, EXT.WALL/FLOOR = .671
AREA RATIO, WINDOW/EXT.WALL = .223

DWELLING TYPE -- SINGLE FAMILY ATTACHED

UNIT TYPE ------ 4-BEDROOM TOWNHOUSE

CONSTRUCTION --- WOOD FRAME (ALUMINUM SIDING)

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	I.DOOR	WINDOW	E.DOOR
TOTAL AREA/UNIT (SQ.FT.)	1050.	2029.	352.	1155.	577.	577.	752.	670.	208.	156.	20.
WT./UNIT AREA(LB./SQ.FT.)	4.046	6.292	5.771	5.979	5.437	1.771					
U-VALUE(BTU/HR-SQ.FT.-F)	.101	.187	.096	.134	.052	.260	.742	.798	.441	.610	1.075
TH.MASS(BTU/SQ.FT.-F)	1.283	2.248	1.437	2.682	2.040	.974					
TH.TIME CONST.(HR.)	5.642	6.000	7.545	11.773	22.114	2.474					
SOLAR ABSORPTIVITY	.470	****	****	****	.930	****	****	****	****		.400
SOLAR TRANSMITTANCE	****	****	****	****	****	****	****	****	****	.760	****

TOTAL FLOOR AREA PER UNIT = 1155. SQ.FT.
AREA RATIO, EXT.WALL/FLOOR = .909
AREA RATIO, WINDOW/EXT.WALL = .149

Table 4 - continued

DWELLING TYPE -- SINGLE FAMILY ATTACHED

UNIT TYPE ------ 2-BEDROOM TOWNHOUSE

CONSTRUCTION --- WOOD FRAME (ALUMINUM SIDING)

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	I.DOOR	WINDOW	E.DOOR
TOTAL AREA/UNIT (SQ.FT.)	748.	892.	349.	697.	348.	348.	586.	392.	50.	119.	20.
WT./UNIT AREA(LB./SQ.FT.)	4.046	6.292	5.771	5.979	5.437	1.771					
U-VALUE(BTU/HR-SQ.FT.-F)	.101	.187	.096	.134	.052	.260	.742	.798	.441	.610	1.075
TH.MASS(BTU/SQ.FT.-F)	1.283	2.248	1.437	2.682	2.040	.974					
TH.TIME CONST.(HR.)	5.642	6.000	7.545	11.773	22.114	2.474					
SOLAR ABSORPTIVITY	.470	****	****	****	.930	****	****	****	****		.400
SOLAR TRANSMITTANCE	****	****	****	****	****	****	****	****	****	.760	****

TOTAL FLOOR AREA PER UNIT = 697. SQ.FT.
AREA RATIO, EXT.WALL/FLOOR =1.073
AREA RATIO, WINDOW/EXT.WALL = .159

DWELLING TYPE -- SINGLE FAMILY ATTACHED

UNIT TYPE ------ 3-BEDROOM TOWNHOUSE

CONSTRUCTION --- WOOD FRAME (ALUMINUM SIDING)

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	I.DOOR	WINDOW	E.DOOR
TOTAL AREA/UNIT (SQ.FT.)	892.	1507.	340.	938.	469.	469.	670.	523.	116.	167.	20.
WT./UNIT AREA(LB./SQ.FT.)	4.046	6.292	5.771	5.979	5.437	1.771					
U-VALUE(BTU/HR-SQ.FT.-F)	.101	.187	.096	.134	.052	.260	.742	.798	.441	.610	1.075
TH.MASS(BTU/SQ.FT.-F)	1.283	2.248	1.437	2.682	2.040	.974					
TH.TIME CONST.(HR.)	5.642	6.000	7.545	11.773	22.114	2.474					
SOLAR ABSORPTIVITY	.470	****	****	****	.930	****	****	****	****		.400
SOLAR TRANSMITTANCE	****	****	****	****	****	****	****	****	****	.760	****

TOTAL FLOOR AREA PER UNIT = 938. SQ.FT.
AREA RATIO, EXT.WALL/FLOOR = .940
AREA RATIO, WINDOW/EXT.WALL = .189

Table 4 - continued

DWELLING TYPE -- SINGLE FAMILY ATTACHED

UNIT TYPE ------ 4-BEDROOM TOWNHOUSE

CONSTRUCTION --- WOOD FRAME (ALUMINUM SIDING)

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	I.DOOR	WINDOW	E.DOOR
TOTAL AREA/UNIT (SQ.FT.)	393.	1756.	358.	1074.	537.	537.	744.	637.	84.	201.	37.
WT./UNIT AREA(LB./SQ.FT.)	4.046	6.292	5.771	5.979	5.437	1.771					
U-VALUE(BTU/HR-SQ.FT.-F)	.101	.187	.096	.134	.052	.260	.742	.798	.441	.610	1.075
TH.MASS(BTU/SQ.FT.-F)	1.283	2.248	1.437	2.682	2.040	.974					
TH.TIME CONST.(HR.)	5.642	6.000	7.545	11.773	22.114	2.474					
SOLAR ABSORPTIVITY	.470	****	****	****	.930	****	****	****	****		.400
SOLAR TRANSMITTANCE	****	****	****	****	****	****	****	****	****	.750	****

TOTAL FLOOR AREA PER UNIT = 1074. SQ.FT.
AREA RATIO, EXT.WALL/FLOOR = .831
AREA RATIO, WINDOW/EXT.WALL = .225

DWELLING TYPE -- MULTI-FAMILY LOW RISE

UNIT TYPE ------ 2-BEDROOM APARTMENT(1ST FLOOR)

CONSTRUCTION --- WOOD FRAME (ALUMINUM SIDING)

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	I.DOOR	WINDOW	E.DOOR
TOTAL AREA/UNIT (SQ.FT.)	384.	1303.	265.	879.	879.	879.	0.	0.	102.	104.	24.
WT./UNIT AREA(LB./SQ.FT.)	4.567	7.333	5.771	6.500	7.021	1.771					
U-VALUE(BTU/HR-SQ.FT.-F)	.101	.159	.096	.133	.051	.282			.441	.610	.500
TH.MASS(BTU/SQ.FT.-F)	1.414	2.518	1.422	2.817	2.760	.974					
TH.TIME CONST.(HR.)	6.792	7.941	7.506	12.655	27.818	2.474					
SOLAR ABSORPTIVITY	.470	••••	••••	••••	.930	••••	••••	••••	••••		.400
SOLAR TRANSMITTANCE	••••	••••	••••	••••	••••	••••	••••	••••	••••	.760	••••

TOTAL FLOOR AREA PER UNIT = 879. SQ.FT.
AREA RATIO, EXT.WALL/FLOOR = .437
AREA RATIO, WINDOW/EXT.WALL = .271

Table 4 - continued

DWELLING TYPE -- MULTI-FAMILY LOW RISE

UNIT TYPE ------ 3-BEDROOM APARTMENT (2ND FLOOR)

CONSTRUCTION --- WOOD FRAME (ALUMINUM SIDING)

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	I.DOOR	WINDOW	E.DOOR
TOTAL AREA/UNIT (SQ.FT.)	489.	1403.	379.	993.	993.	993.	0.	0.	119.	125.	20.
WT./UNIT AREA(LB./SQ.FT.)	4.567	7.333	5.771	6.500	7.021	1.771					
U-VALUE(BTU/HR-SQ.FT.-F)	.101	.159	.096	.133	.051	.282			.441	.610	.500
TH.MASS(BTU/SQ.FT.-F)	1.414	2.518	1.422	2.817	2.760	.974					
TH.TIME CONST.(HR.)	6.792	7.941	7.506	12.655	27.818	2.474					
SOLAR ABSORPTIVITY	.470	....	....	....	.930	....	....	....	....		.400
SOLAR TRANSMITTANCE	....	....	....	....	....	....	....	....	....	.760	....

TOTAL FLOOR AREA PER UNIT = 993. SQ.FT.
AREA RATIO, EXT.WALL/FLOOR = .492
AREA RATIO, WINDOW/EXT.WALL = .256

DWELLING TYPE -- MULTI-FAMILY LOW RISE

UNIT TYPE ------ 2-BEDROOM APARTMENT(1ST FLOOR)

CONSTRUCTION --- WOOD FRAME (ALUMINUM SIDING)

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	I.DOOR	WINDOW	E.DOOR
TOTAL AREA/UNIT (SQ.FT.)	353.	1074.	265.	733.	733.	733.	0.	0.	50.	100.	20.
WT./UNIT AREA(LB./SQ.FT.)	4.567	7.333	5.771	6.500	7.021	1.771					
U-VALUE(BTU/HR-SQ.FT.-F)	.101	.159	.096	.133	.051	.282			.441	.610	.500
TH.MASS(BTU/SQ.FT.-F)	1.414	2.518	1.422	2.817	2.760	.974					
TH.TIME CONST.(HR.)	6.792	7.941	7.506	12.655	27.818	2.474					
SOLAR ABSORPTIVITY	.470	....	....	....	.930	....	....	....	....		.400
SOLAR TRANSMITTANCE	....	....	....	....	....	....	....	....	....	.760	....

TOTAL FLOOR AREA PER UNIT = 733. SQ.FT.
AREA RATIO, EXT.WALL/FLOOR = .482
AREA RATIO, WINDOW/EXT.WALL = .283

DWELLING TYPE -- MULTI-FAMILY LOW RISE

UNIT TYPE ------ 3-BEDROOM APARTMENT (OR 2-BR. W/STUDY) - 2ND FLOOR

CONSTRUCTION --- WOOD FRAME (ALUMINUM SIDING)

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	I.DOOR	WINDOW	E.DOOR
TOTAL AREA/UNIT (SQ.FT.)	377.	1233.	377.	845.	845.	845.	0.	0.	67.	140.	20.
WT./UNIT AREA(LB./SQ.FT.)	4.567	7.333	5.771	6.500	7.021	1.771					
U-VALUE(BTU/HR-SQ.FT.-F)	.101	.159	.096	.133	.051	.282			.441	.610	.500
TH.MASS(BTU/SQ.FT.-F)	1.414	2.518	1.422	2.817	2.760	.974					
TH.TIME CONST.(HR.)	6.792	7.941	7.506	12.655	27.818	2.474					
SOLAR ABSORPTIVITY	.470	....	....	....	.930	....	....	....	....		.400
SOLAR TRANSMITTANCE	....	....	....	....	....	....	....	....	....	.760	....

TOTAL FLOOR AREA PER UNIT = 845. SQ.FT.
AREA RATIO, EXT.WALL/FLOOR = .446
AREA RATIO, WINDOW/EXT.WALL = .371

DWELLING TYPE -- MULTI-FAMILY LOW RISE AND SINGLE FAMILY ATTACHED

UNIT TYPE ------ 3S/2-BR OVER 3-BR (MLLR)-2-BR UNIT

CONSTRUCTION --- STEEL JOIST, METAL FRAME

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	I.DOOR	WINDOW	E.DOOR
TOTAL AREA/UNIT (SQ.FT.)	758.	1010.	419.	947.	473.	473.	0.	0.	105.	156.	20.
WT./UNIT AREA(LB./SQ.FT.)	6.387	4.167	5.979	7.500	4.250	75.417					
U-VALUE(BTU/HR-SQ.FT.-F)	.178	.310	.033	.169	.068	.199			.441	1.058	.481
TH.MASS(BTU/SQ.FT.-F)	1.509	1.079	1.442	1.623	1.469	15.083					
TH.TIME CONST.(HR.)	4.830	1.743	21.567	5.659	9.090	70.013					
SOLAR ABSORPTIVITY	.350	....	....	....	.900	....	....	....	....		.350
SOLAR TRANSMITTANCE	....	....	....	....	....	....	....	....	....	.870	....

TOTAL FLOOR AREA PER UNIT = 947. SQ.FT.
AREA RATIO, EXT.WALL/FLOOR = .800
AREA RATIO, WINDOW/EXT.WALL = .204

Table 4 - continued

DWELLING TYPE -- MULTI-FAMILY LOW RISE AND SINGLE FAMILY ATTACHED

UNIT TYPE ------ 3S/2-BR OVER 3-BR(MFLR)-3-BR UNIT

CONSTRUCTION --- STEEL JOIST, METAL FRAME

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	I.DOOR	WINDOW	E.DOOR
TOTAL AREA/UNIT (SQ.FT.)	812.	1093.	227.	886.	443.	443.	0.	0.	122.	123.	20.
WT./UNIT AREA(LB./SQ.FT.)	6.387	4.167	5.979	7.500	4.250	75.417					.000
U-VALUE(BTU/HR-SQ.FT.-F)	.178	.310	.033	.169	.068	.199			.441	1.058	.481
TH.MASS(BTU/SQ.FT.-F)	1.504	1.079	1.442	1.623	1.469	15.083					
TH.TIME CONST.(HR.)	4.830	1.743	21.567	5.659	9.090	70.013					
SOLAR ABSORPTIVITY	.350	****	****	****	.900	****	****	****	****		.350
SOLAR TRANSMITTANCE	****	****	****	****	****	****	****	****	****	.870	****

TOTAL FLOOR AREA PER UNIT = 886. SQ.FT.
AREA RATIO, EXT.WALL/FLOOR = .916
AREA RATIO, WINDOW/EXT.WALL = .151

DWELLING TYPE -- MULTI-FAMILY LOW RISE AND SINGLE FAMILY ATTACHED

UNIT TYPE ------ 2S/2-BR UNIT-SFA

CONSTRUCTION --- STEEL JOIST, METAL FRAME

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	I.DOOR	WINDOW	E.DOOR
TOTAL AREA/UNIT (SQ.FT.)	850.	661.	463.	916.	229.	229.	0.	0.	94.	138.	20.
WT./UNIT AREA(LB./SQ.FT.)	6.387	4.167	5.979	7.500	4.250	75.417					
U-VALUE(BTU/HR-SQ.FT.-F)	.178	.310	.033	.169	.068	.199			.441	1.058	.481
TH.MASS(BTU/SQ.FT.-F)	1.504	1.079	1.442	1.623	1.469	15.083					
TH.TIME CONST.(HR.)	4.830	1.743	21.567	5.659	9.090	70.013					
SOLAR ABSORPTIVITY	.350	****	****	****	.900	****	****	****	****		.350
SOLAR TRANSMITTANCE	****	****	****	****	****	****	****	****	****	.870	****

TOTAL FLOOR AREA PER UNIT = 916. SQ.FT.
AREA RATIO, EXT.WALL/FLOOR = .928
AREA RATIO, WINDOW/EXT.WALL = .163

Table 4 - continued

DWELLING TYPE -- MULTI-FAMILY LOW RISE AND SINGLE FAMILY ATTACHED

UNIT TYPE ------ 3S/4-BR(OR 3-BR W/STUDY)-SFA

CONSTRUCTION --- STEEL JOIST, METAL FRAME

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	I.DOOR	WINDOW	E.DOOR
TOTAL AREA/UNIT (SQ.FT.)	1286.	1179.	647.	1353.	451.	451.	0.	0.	154.	201.	20.
WT./UNIT AREA(LB./SQ.FT.)	6.387	4.167	5.979	7.500	4.250	75.417					
U-VALUE(BTU/HR-SQ.FT.-F)	.178	.310	.033	.169	.068	.199			.441	1.058	.481
TH.MASS(BTU/SQ.FT.-F)	1.504	1.079	1.442	1.623	1.469	15.083					
TH.TIME CONST.(HR.)	4.830	1.743	21.567	5.659	9.090	70.013					
SOLAR ABSORPTIVITY	.350	....	....	....	.900	....	....	....	....		.350
SOLAR TRANSMITTANCE	....	....	....	....	....	....	....	....	....	.870	....

TOTAL FLOOR AREA PER UNIT = 1353. SQ.FT.
AREA RATIO, EXT.WALL/FLOOR = .950
AREA RATIO, WINDOW/EXT.WALL = .157

DWELLING TYPE -- MULTI-FAMILY LOW RISE

UNIT TYPE ------ 1S-1-BR. UNIT ON LEVEL 2

CONSTRUCTION --- STEEL JOIST, METAL FRAME

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	1ST FL.	B.FLOOR	B.WALL	I.DOOR	WINDOW	E.DOOR
TOTAL AREA/UNIT (SQ.FT.)	423.	406.	502.	578.	578.	578.	0.	0.	64.	107.	20.
WT./UNIT AREA(LB./SQ.FT.)	6.929	4.167	10.417	4.375	17.521	20.433					
U-VALUE(BTU/HR-SQ.FT.-F)	.145	.310	.216	.182	.067	.141			.441	1.058	.481
TH.MASS(BTU/SQ.FT.-F)	1.638	1.079	2.698	1.648	3.735	5.356					
TH.TIME CONST.(HR.)	6.794	1.743	6.232	5.377	11.424	21.547					
SOLAR ABSORPTIVITY	.350	....	....	....	.350	....	....	....	....		.350
SOLAR TRANSMITTANCE	....	....	....	....	....	....	....	....	....	.870	....

TOTAL FLOOR AREA PER UNIT = 578. SQ.FT.
AREA RATIO, EXT.WALL/FLOOR = .732
AREA RATIO, WINDOW/EXT.WALL = .253

Table 4 - continued

DWELLING TYPE -- MULTI-FAMILY LOW RISE

UNIT TYPE ------ 25/2-BR. UNIT ON LEVEL 2

CONSTRUCTION --- STEEL JOIST (GYPSUM FRAME)

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	IST FL.	B.FLOOR	B.WALL	I.DOOR	WINDOW	E.DOOR
TOTAL AREA/UNIT (SQ.FT.)	441.	508.	1008.	1025.	512.	512.	0.	0.	94.	204.	22.
WT./UNIT AREA(LB./SQ.FT.)	6.929	4.167	10.417	4.375	17.521	20.433					
U-VALUE(BTU/HR-SQ.FT.-F)	.145	.310	.216	.182	.067	.141			.441	1.058	.481
TH.MASS(BTU/SQ.FT.-F)	1.638	1.079	2.698	1.648	3.735	5.356					
TH.TIME CONST.(HR.)	6.794	1.743	6.232	5.377	11.424	21.547					
SOLAR ABSORPTIVITY	.350	....	....	....	.350	....	....	....	....		.350
SOLAR TRANSMITTANCE	....	....	....	....	....	....	....	....	....	.870	....

TOTAL FLOOR AREA PER UNIT = 1025. SQ.FT.
AREA RATIO, EXT.WALL/FLOOR = .430
AREA RATIO, WINDOW/EXT.WALL = .463

DWELLING TYPE -- MULTI-FAMILY LOW RISE

UNIT TYPE ------ 35/4-BR. UNIT ON LEVEL 1

CONSTRUCTION --- STEEL JOIST (GYPSUM FRAME)

	E.WALL	I.WALL	P.WALL	FL./CEIL.	ROOF	IST FL.	B.FLOOR	B.WALL	I.DOOR	WINDOW	E.DOOR
TOTAL AREA/UNIT (SQ.FT.)	648.	1221.	1346.	1460.	487.	487.	0.	0.	188.	323.	22.
WT./UNIT AREA(LB./SQ.FT.)	4.167	4.167	6.292	4.917	20.433	19.371					
U-VALUE(BTU/HR-SQ.FT.-F)	.357	.310	.195	.143	.141	.180			.441	1.058	.481
TH.MASS(BTU/SQ.FT.-F)	1.079	1.079	2.248	2.098	5.356	4.772					
TH.TIME CONST.(HR.)	1.279	1.743	5.775	8.109	21.547	22.709					
SOLAR ABSORPTIVITY	.350	....	....	....	.000	....	....	....	....		.350
SOLAR TRANSMITTANCE	....	....	....	....	....	....	....	....	....	.870	....

TOTAL FLOOR AREA PER UNIT = 1460. SQ.FT.
AREA RATIO, EXT.WALL/FLOOR = .444
AREA RATIO, WINDOW/EXT.WALL = .498

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16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

This report is the result of a study to classify various kinds of residential buildings in relation to their thermal behavior. A collection of various building data and construction systems taken from the proposals of 18 of the 22 Housing System Producers participating in the Department of Housing and Urban Development (HUD) Operation BREAKTHROUGH Program is presented. Thermal performance parameters of buildings, such as; U-value, thermal mass, thermal time constant, and mass per unit area were computed and analyzed. The report recommends one way in which construction systems could be classified. Since the housing systems studied represented a cross section of the conventional residential construction systems in the building industry, it is felt that a realistic classification procedure for typical residential buildings can be established and based upon the parameter: mass per unit area. A more refined procedure of subdividing the building within each mass class on the basis of the building thermal time constant is also discussed.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)* Building classification; building thermal mass; building thermal performance; building thermal time constant; housing systems; industrialized housing; mass per unit area; Operation BREAKTHROUGH; U-value

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