Concrete Block Insulating Systems

Thermally Insulating Masonry Walls to Meet Mandated Energy Codes

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NATIONAL CONCRETE MASONRY ASSOCIATION

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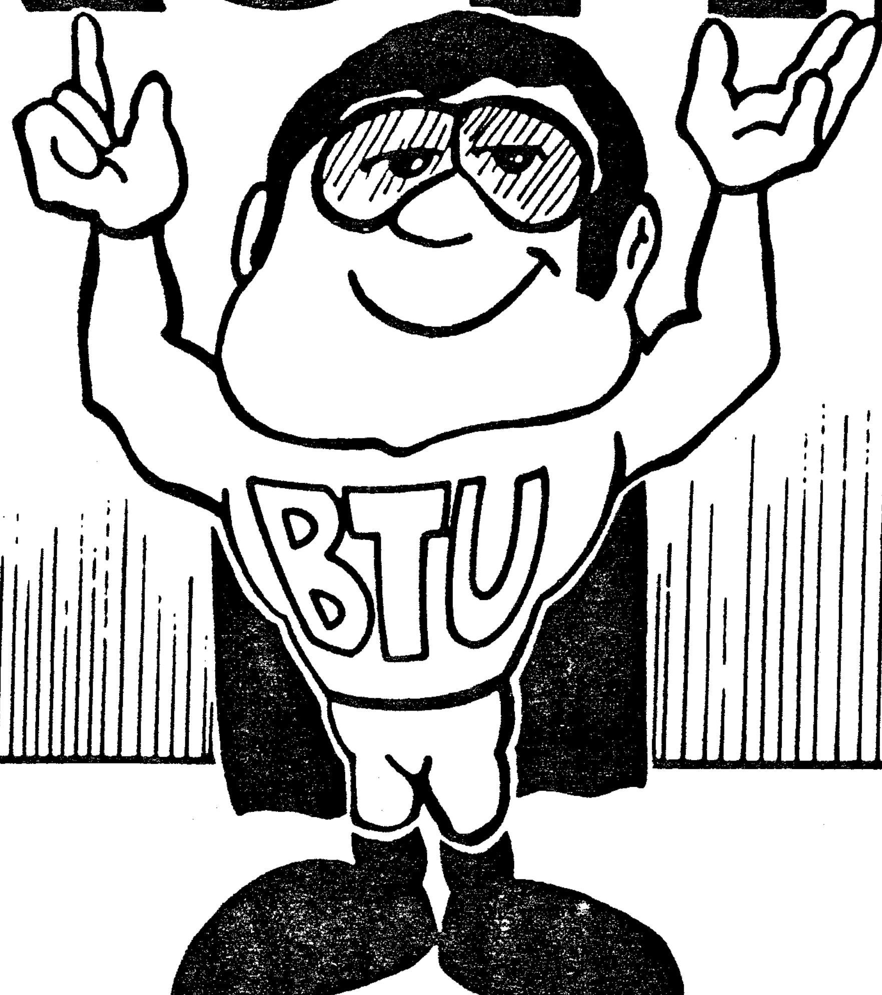
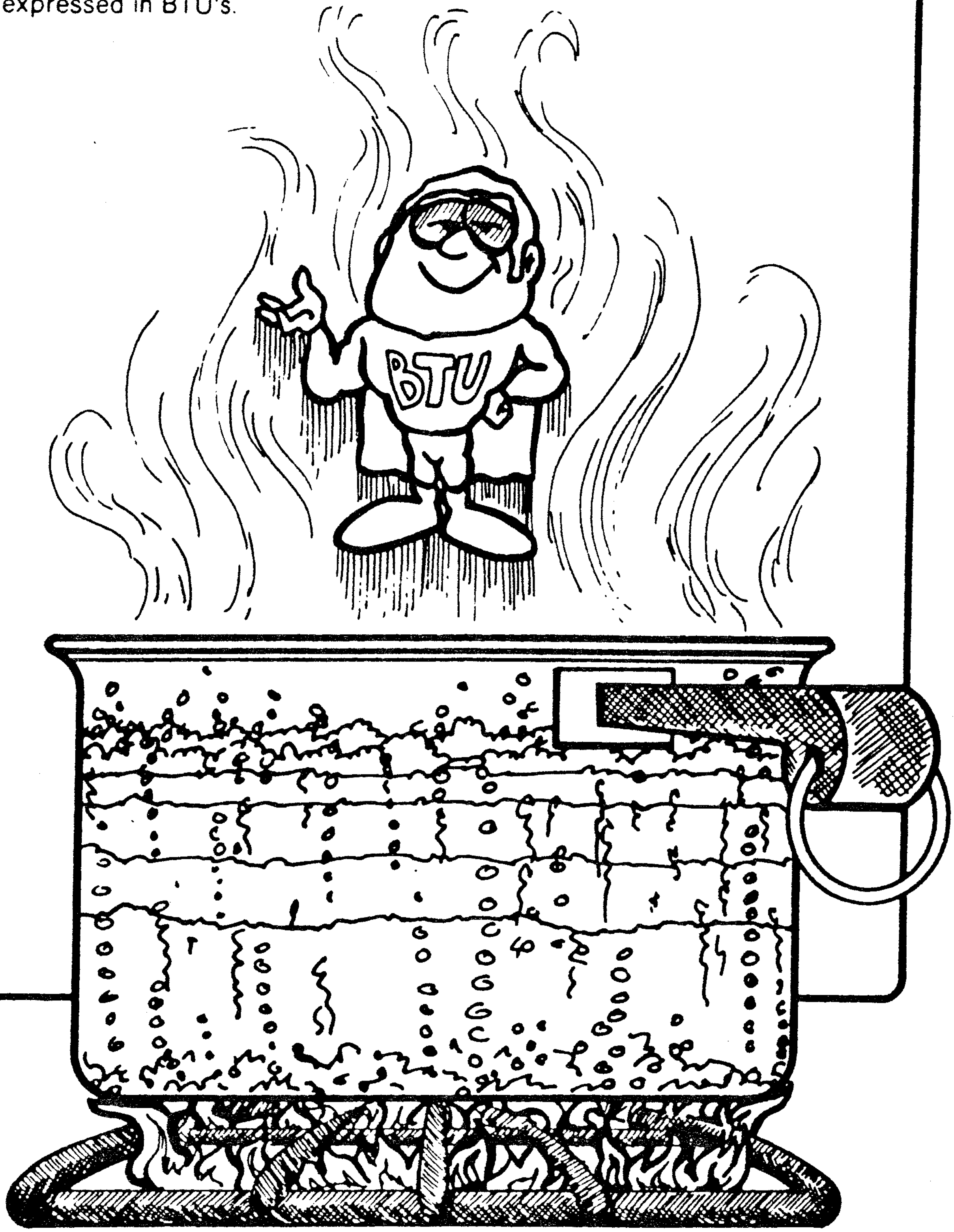
WHAT'S A U?
by
Korfil®

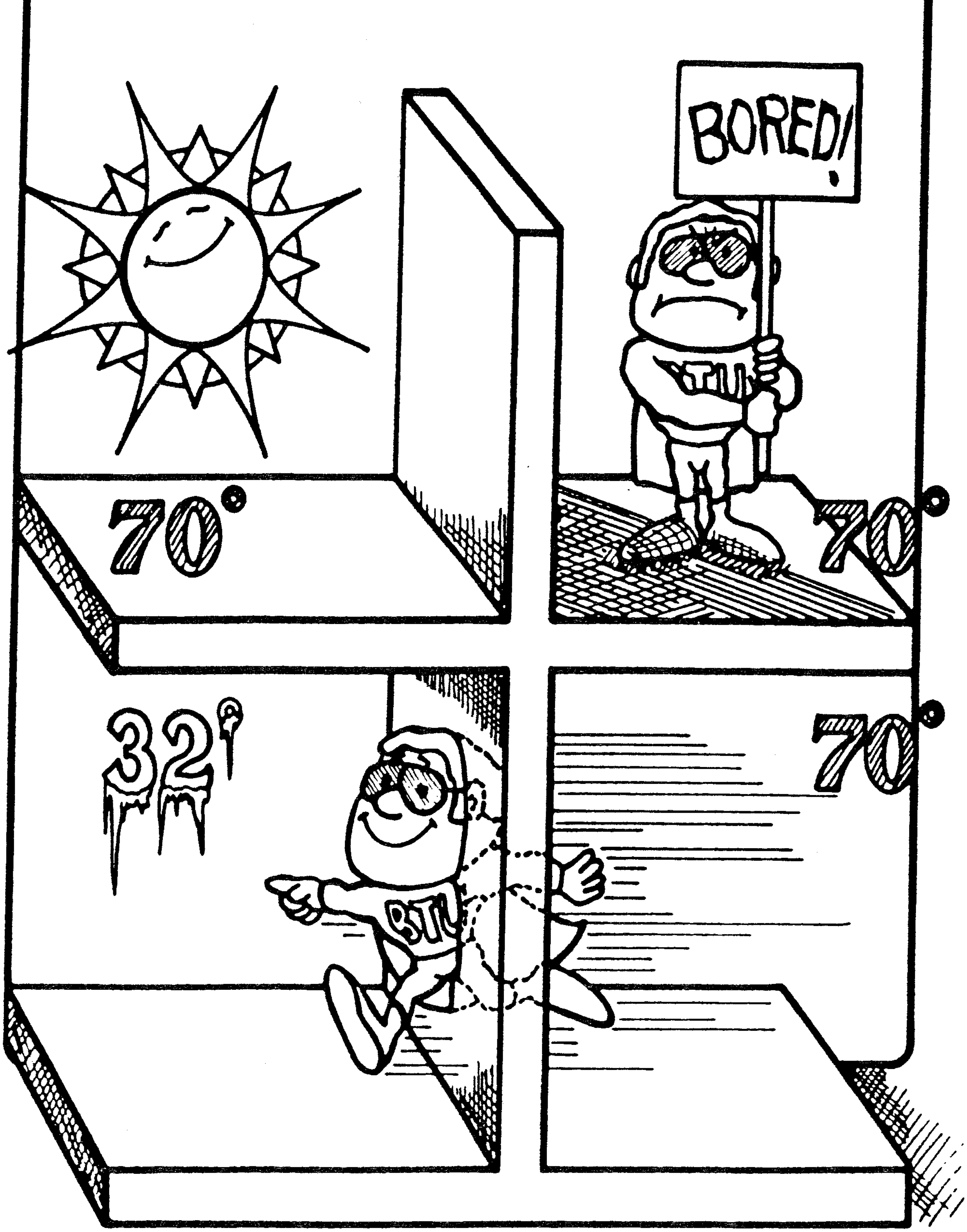


Mr. BTU is born

Many years ago, a scholarly gentleman in England measured the amount of heat it took to raise the temperature of 1# of water 1°F. He named this amount of heat a British Thermal Unit, or BTU. Today, the heat value of fuels is expressed in BTU's.

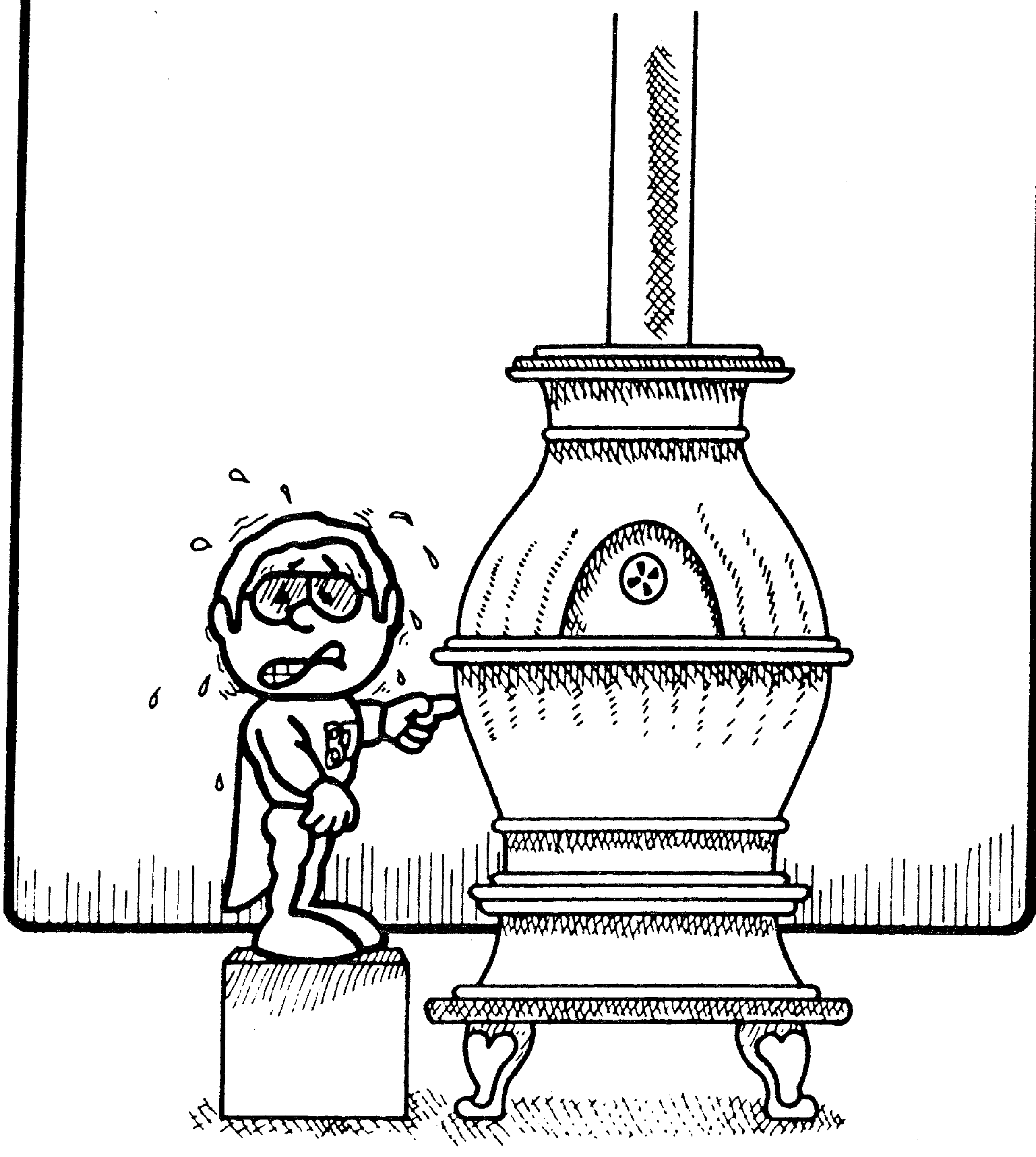


Heat flow is always from the hot side to the cold side.

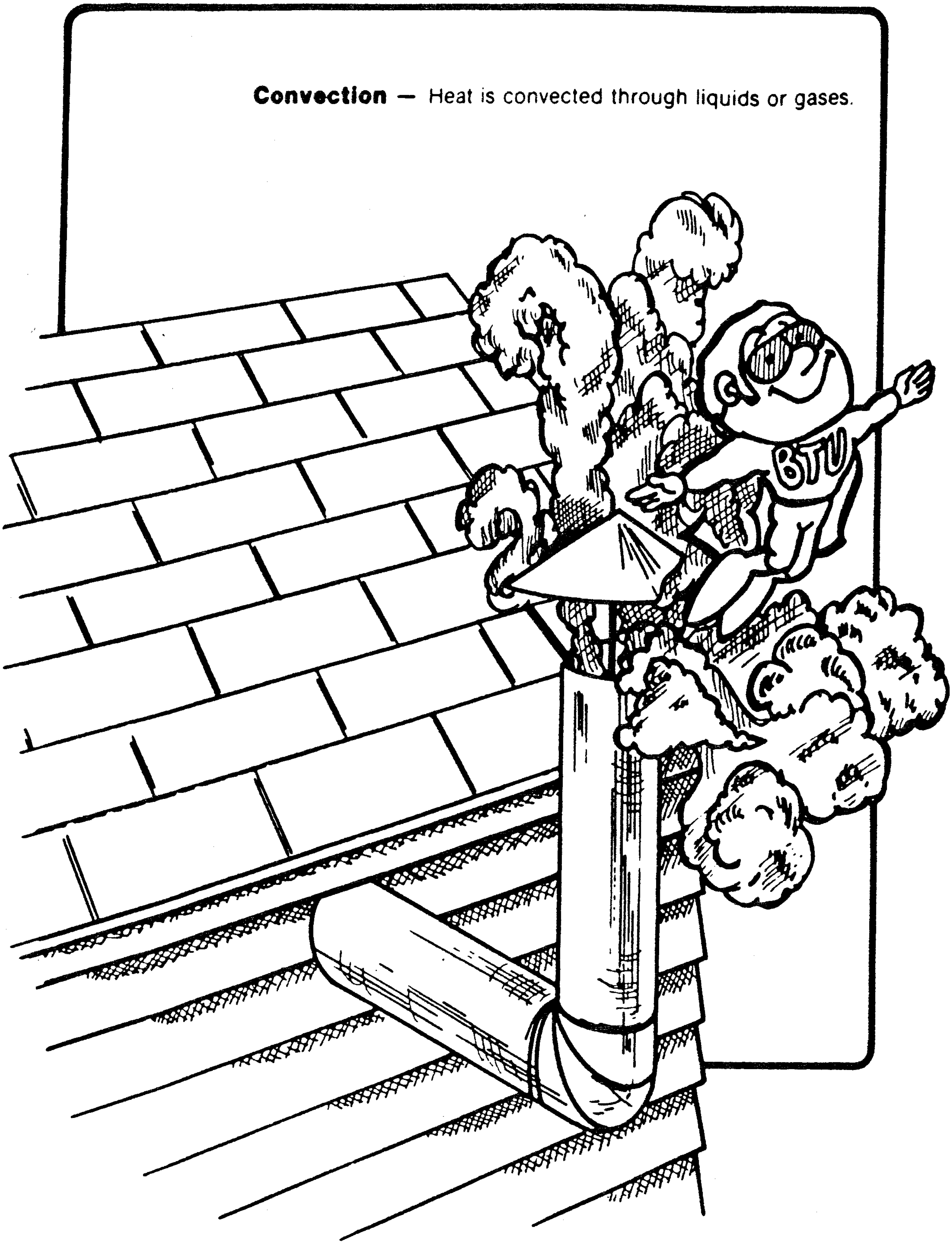


Heat flows in 3 ways:

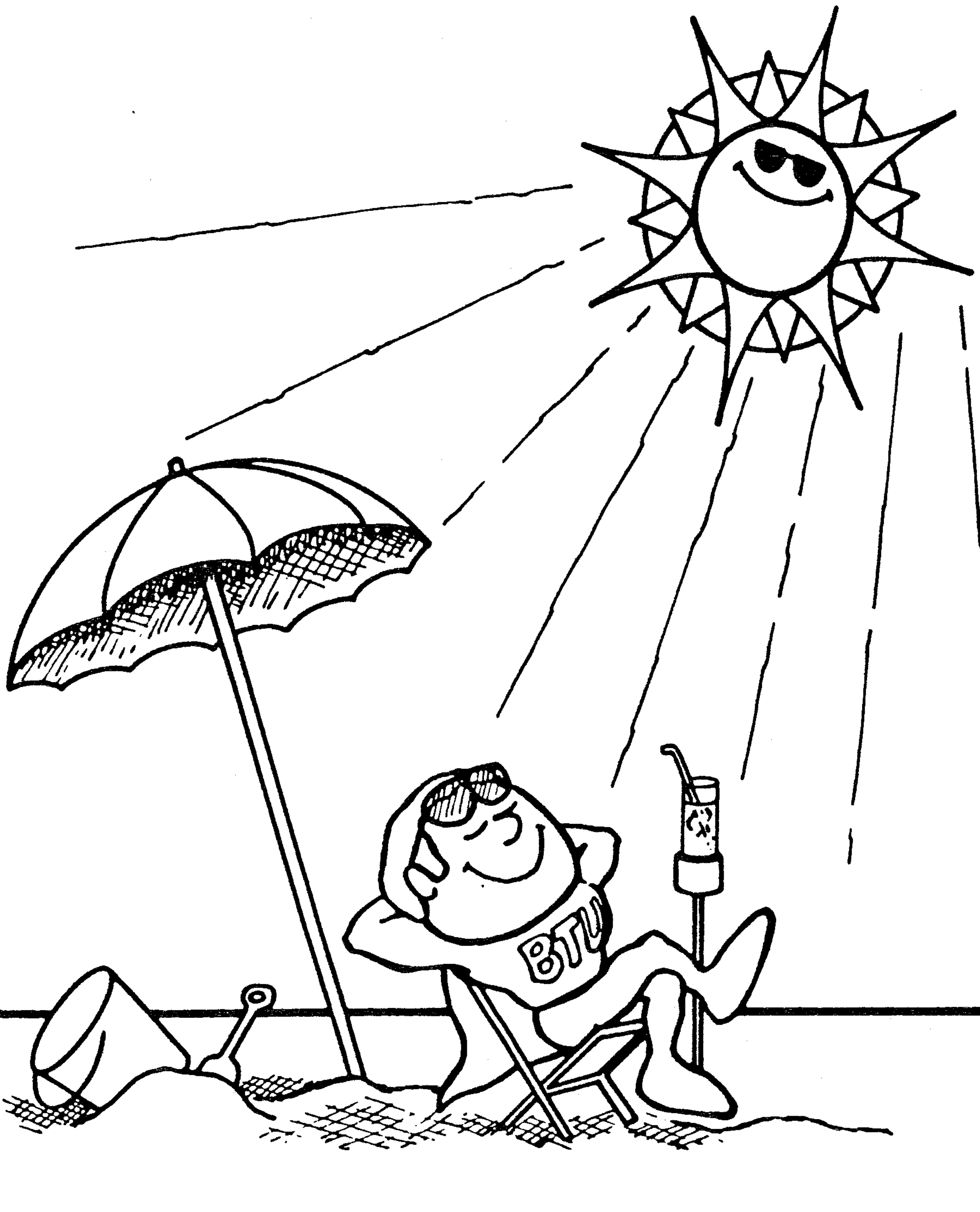
Conduction — As examples, heat is conducted through metals and concrete.



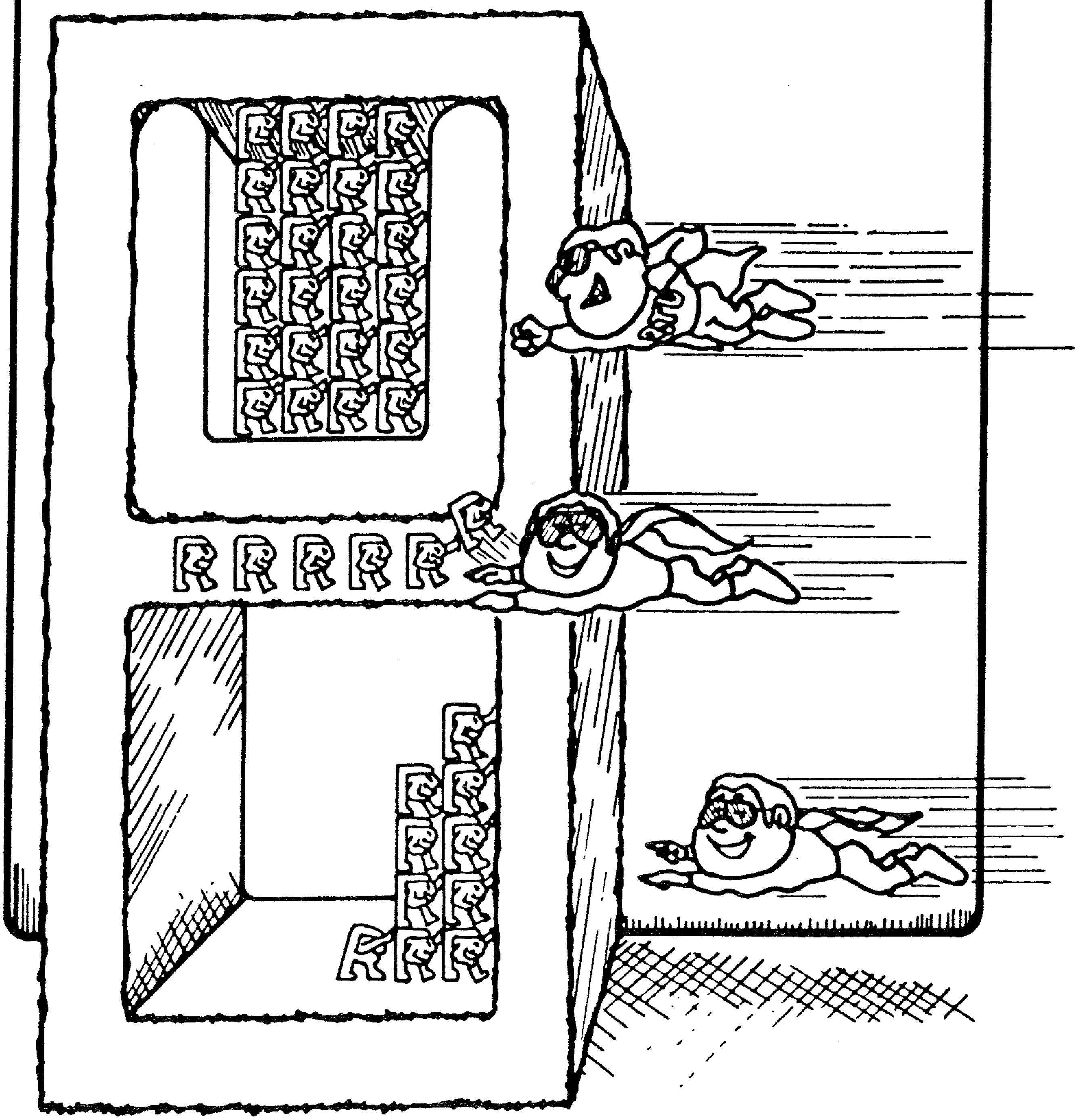
Convection — Heat is convected through liquids or gases.



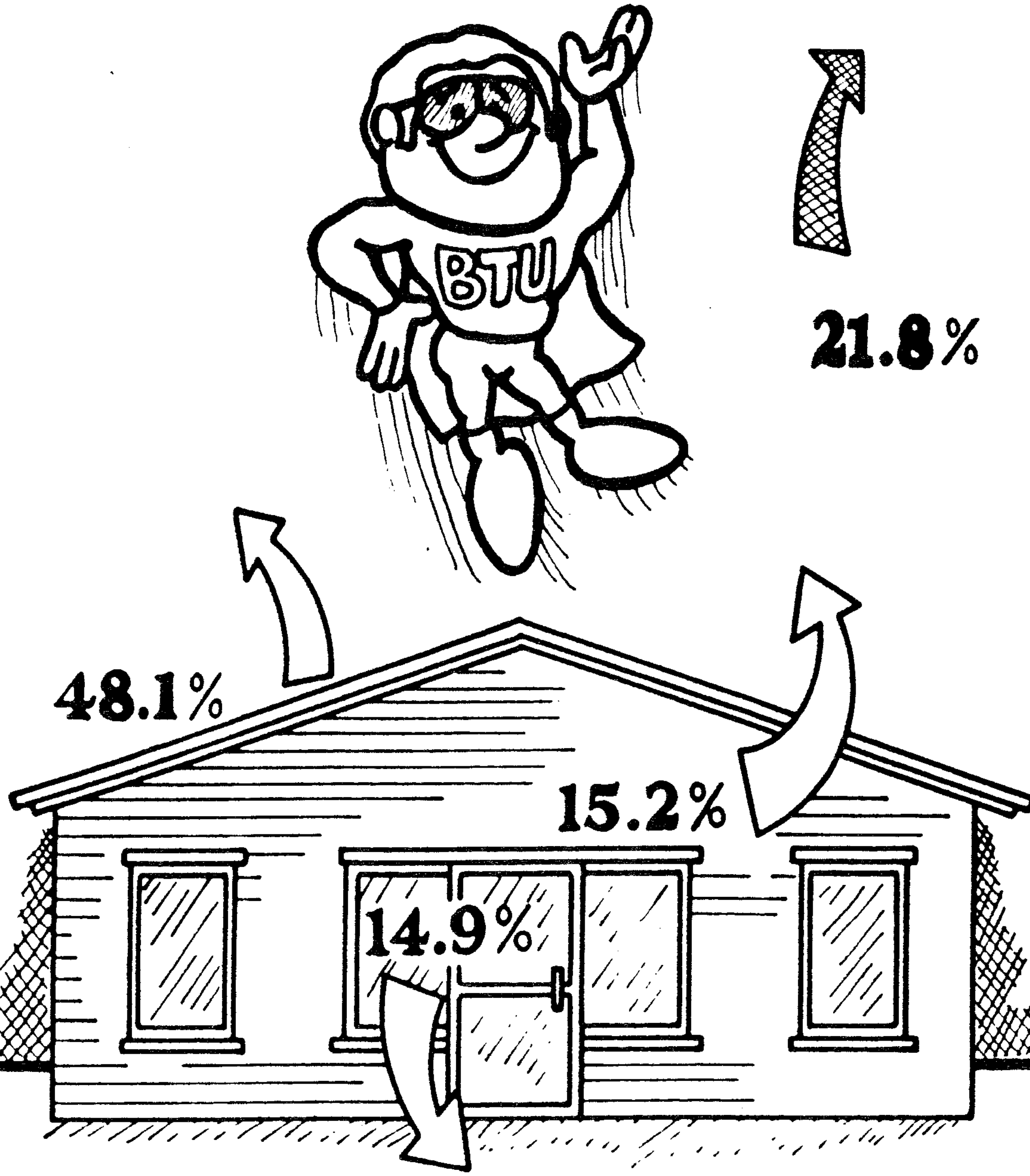
Radiation — Heat is radiated through space by electromagnetic waves.



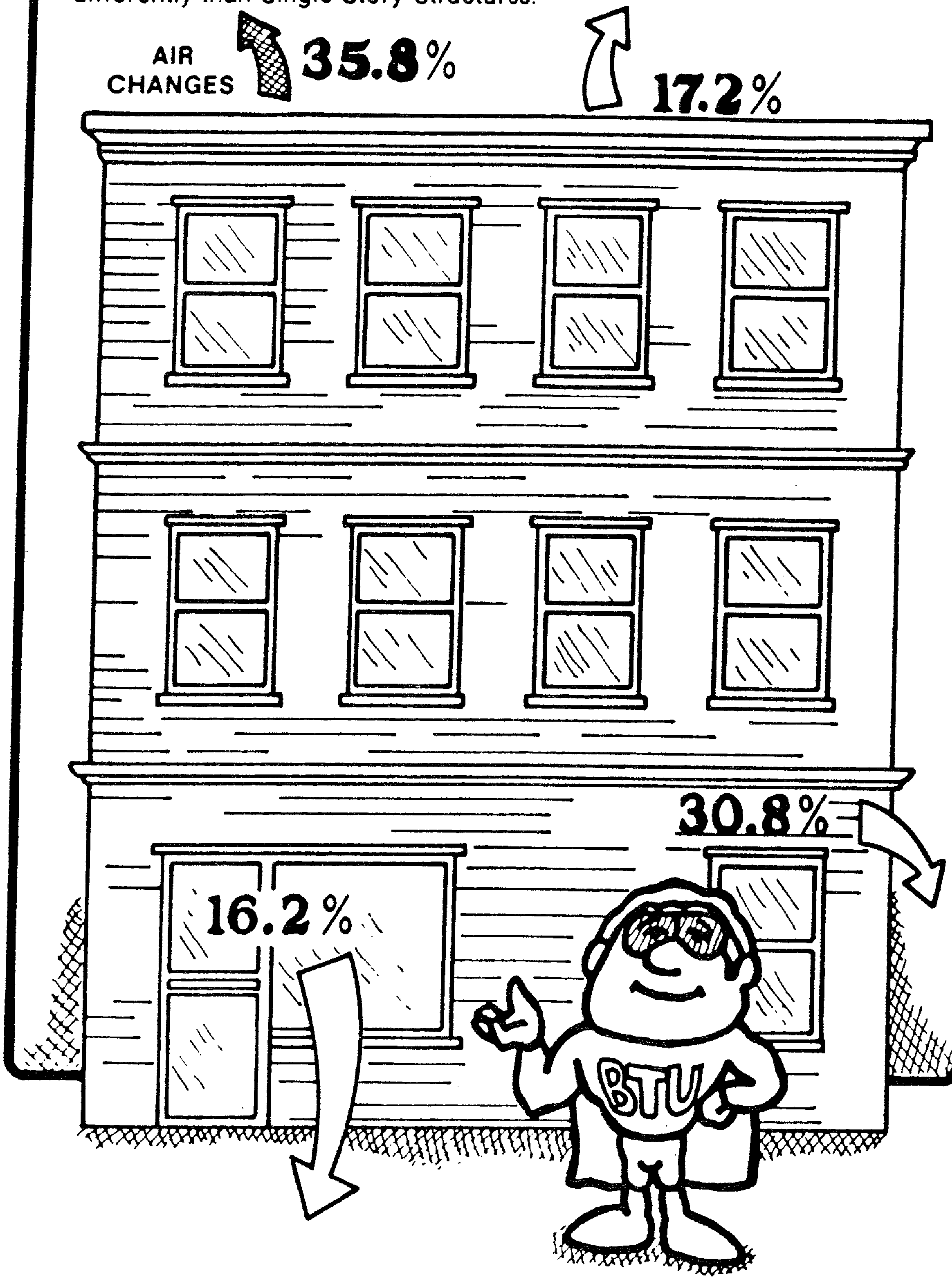
Concrete Masonry Units provide several paths for heat flow. As the weight of the mix design for the concrete becomes heavier, heat flows through blocks more rapidly.



Uninsulated Single Story Structures lose heat in many ways.

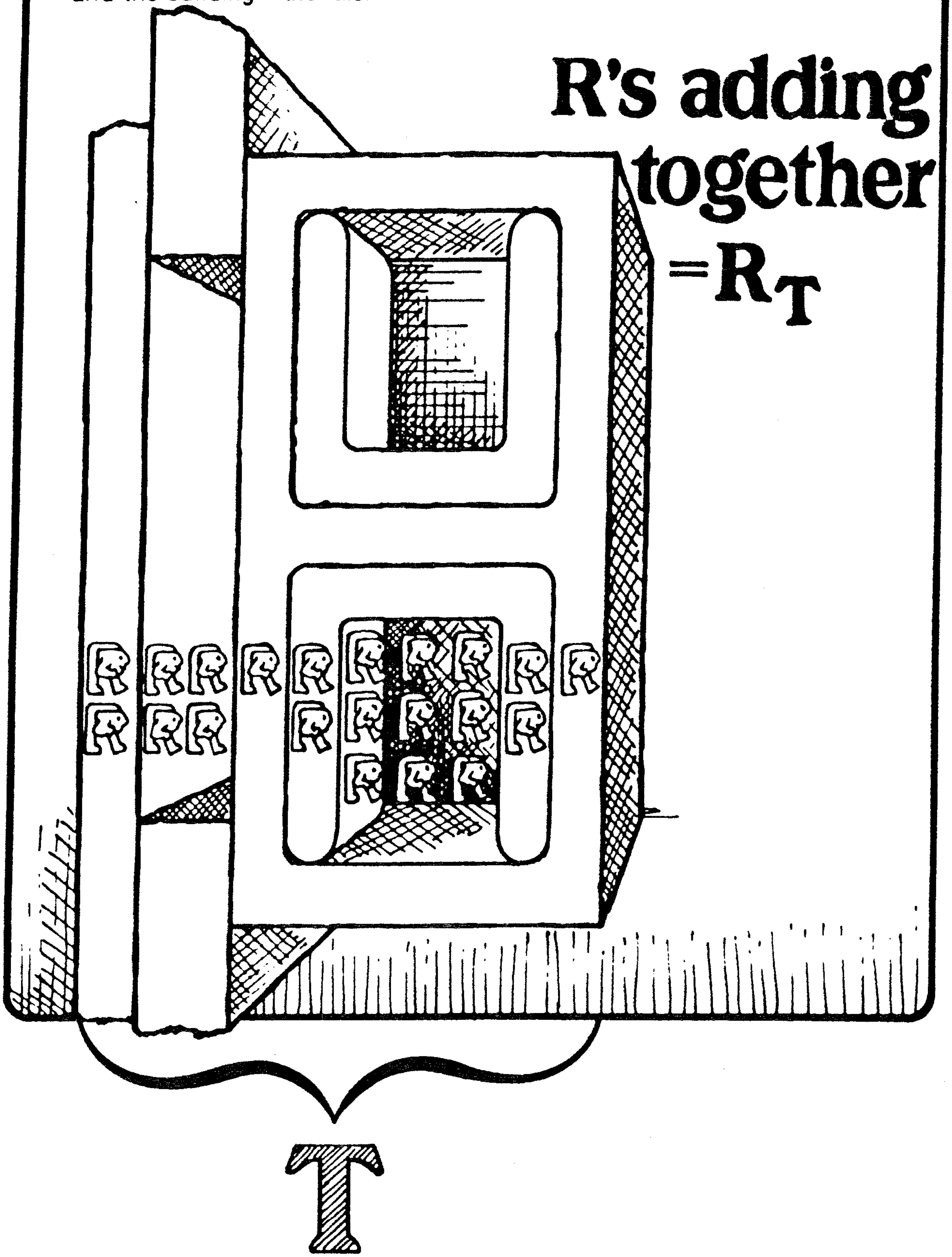


Uninsulated Multi-Story Structures lose heat a little differently than Single Story Structures.

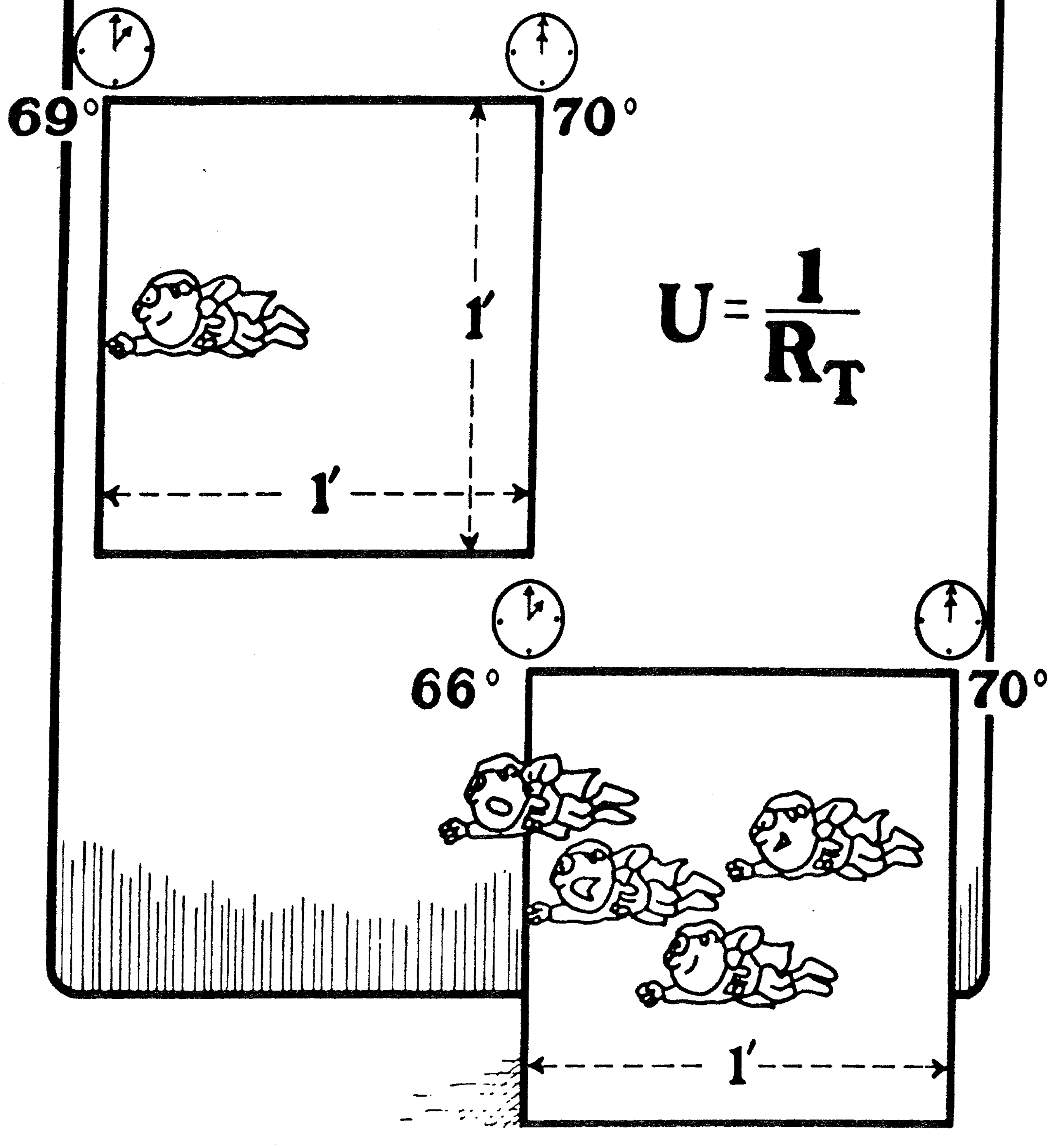


Wall constructions have a Total Thermal Resistance known as R_T. It is made up of the R values of surface resistances, air spaces and the building materials.

R's adding together $=R_T$



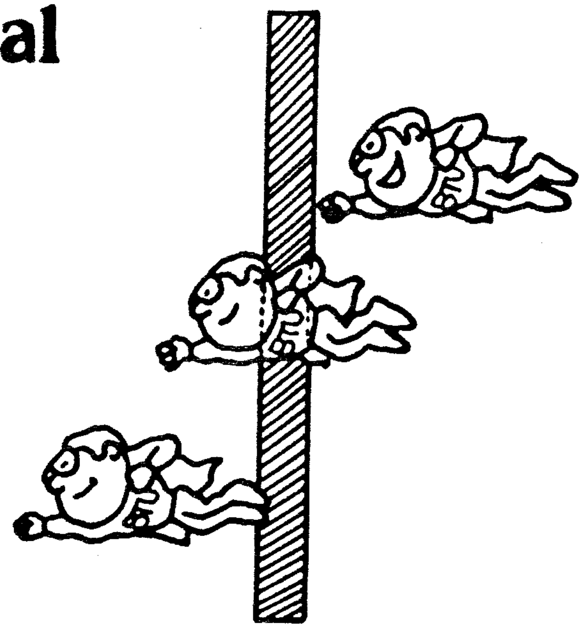
The U value of a building section is a measure of the ability of that wall section to permit the flow of heat. Masonry walls, roofs, windows and doors are building sections that can be expressed in U value.



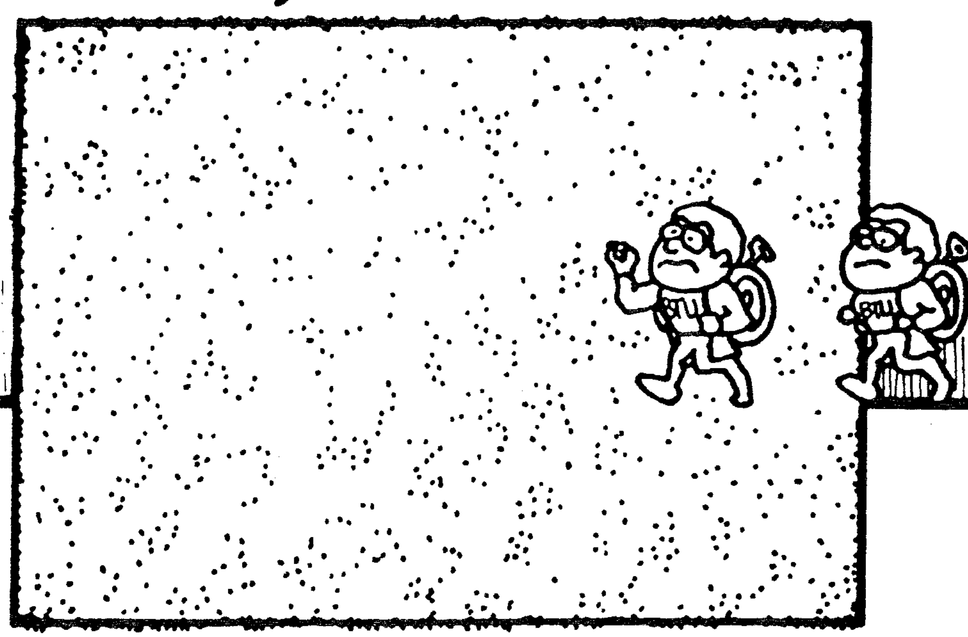
$$U = \frac{1}{R_T}$$

The physical weight or mass of wall sections may have lower R values than insulation materials but they can compensate for this lower R with a heat storage capability.

Metal



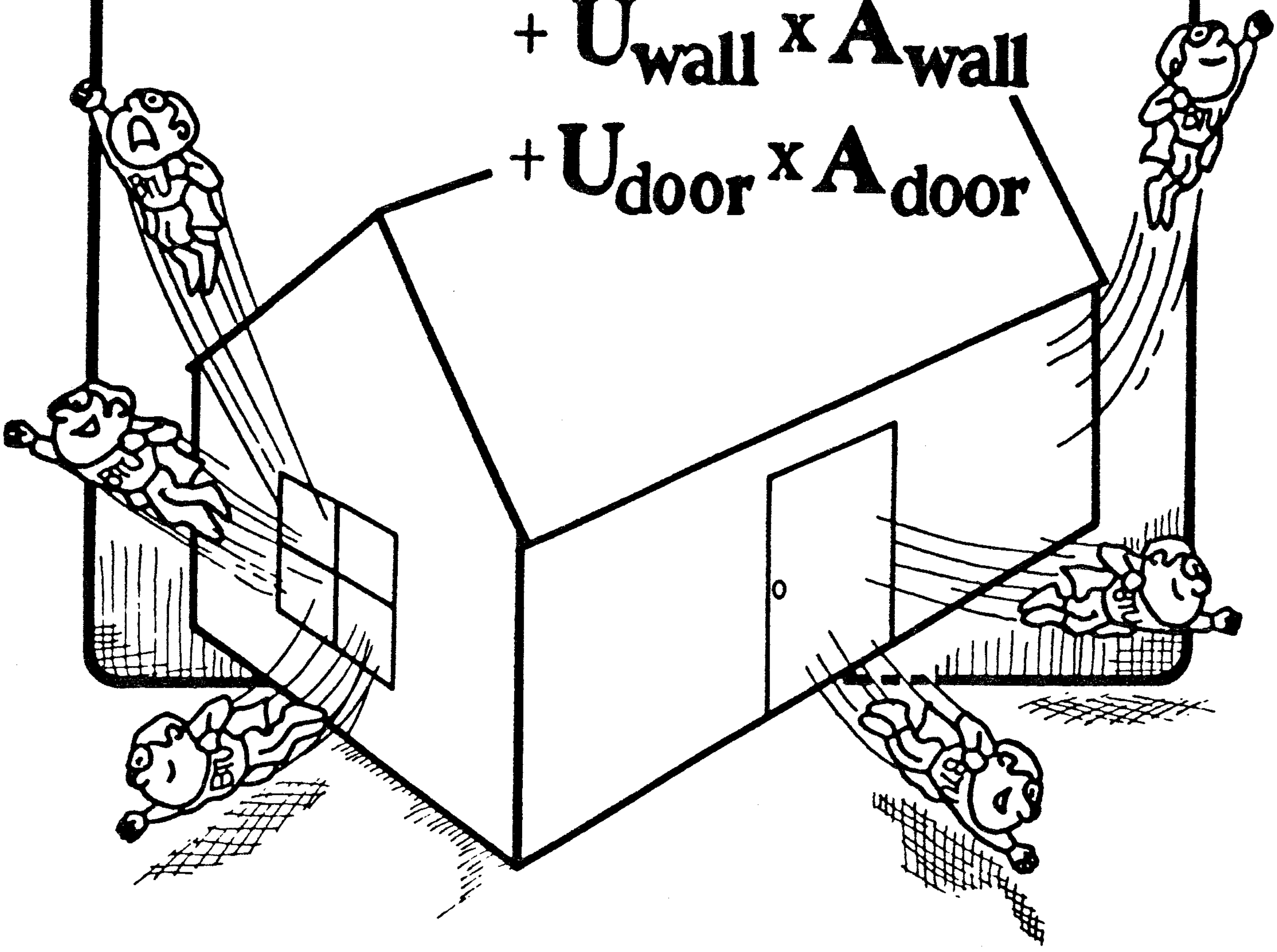
Masonry



U_o, or average U Factor, is an expression used in Federally Mandated Building Energy Codes.

U_0 or Average U Factor

$$U_0 A_T = U_{windows} \times A_W + U_{wall} \times A_{wall} + U_{door} \times A_{door}$$



An Information series from National Concrete Masonry Association

Estimating U-Factors for Concrete Masonry Construction

Excellent thermal insulation along with the ability to carry building loads is rather a unique feature of concrete masonry construction. Generally, materials which are good heat insulators cannot support loads, and most load-carrying materials are poor insulators and require added insulation to increase thermal resistance to an acceptable level. Load-bearing concrete masonry is the exception in that it possesses both high thermal resistance and high strength for load-bearing walls. In most instances, walls of concrete masonry have sufficient thermal insulation to meet the requirements imposed by climate and modern construction without the addition of "nonload-bearing" insulating material. And, when insulation must be added, the amount required is minimized due to the excellent inherent thermal characteristics of the concrete masonry wall.

Heat Transfer Symbols

U = U-FACTOR
Overall heat transmission coefficient; the amount of heat, expressed in BTU transmitted in one hour through one square foot of a building section (wall, floor or ceiling) for each degree F of temperature difference between air on the warm side and air on the cold side of the building section.

R = 1/C = RESISTANCE
Overall resistance; the amount of resistance to heat flow between air on the warm side and air on the cold side of the building section.

k = CONDUCTIVITY
Thermal conductivity; the amount of heat, expressed in BTU transmitted in one hour through one square foot of a homogenous material one inch thick for each degree F of temperature difference between the two surfaces of the material.

C = CONDUCTANCE
Thermal conductance; the amount of heat expressed in BTU transmitted in one hour from surface to surface of one square foot of material or combination of materials for each degree temperature difference between the two surfaces. It should be noted that this value is not expressed in terms of per inch of thickness but from surface to surface.

f = FILM CONDUCTANCE
Film or surface conductance; the amount of heat, expressed in BTU transmitted in one hour from one square foot of a surface to the air surrounding the surface for each degree F temperature difference. The symbols f_i and f_o are used to designate the inside and outside surface conductances, respectively.

a = CONDUCTANCE OF AIR SPACE
Thermal conductance of an air space; the amount of heat, expressed in BTU transmitted in one hour across an air space of one square foot area for each degree F temperature difference.

National Concrete Masonry Assn.
January, 1969
4
UNIT MASONRY
Concrete Units

Estimating Thermal Coefficients (U-Factors)

The measure of the quantity of heat transmitted through a building wall is the BTU (British Thermal Unit). In figuring heat loss, it is always accompanied by a definite time factor, generally one hour, and a unit of area, generally one square foot. Heat loss is stated as the number of BTU's lost per degree difference in temperature, the temperature on the warmer side of the building wall being at least one degree higher than on the cooler side. Thus, the coefficient of heat transmission is based on the number of BTU's lost per hour, per square foot, per degree difference in temperature (BTU/Hr/Sq.Ft/°F).

There is a thin film of air at the surface of all walls, floors, or roofs, which in itself acts as insulation. For this reason, the heat loss from the air on one side of the wall to the air on the other side will be less than that due solely to the resistance of the material. Also, the temperature of the air and the temperature of the surface will always be different due to the resistance of these surface films of air. The insulating value of the air film (f) will be greater in still air than in moving air such as caused by wind or forced circulation.

Air spaces are insulators against heat loss. Thus, the air spaces within concrete masonry walls are insulators, their value depending upon their location, width, air flow in them, and other factors.

The resistance of a homogeneous material to heat transmission is directly proportionate to its thickness. With the same temperature differences, half as much heat is lost from surface to surface through a 2-inch thickness of a given material as lost through one-inch in thickness.

The most common source of information on the U-factor of various wall construction is the ASHRAE Guide published by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers. In addition to values of conductivity, conductance, and resistance, the ASHRAE Guide also gives a procedure for calculating overall coefficients (U-factors) for composite constructions. Using the procedure outlined in the Guide, building designers and engineers can estimate U-factors for various types of construction, such as, cavity walls, veneer walls, and masonry walls with added insulation.

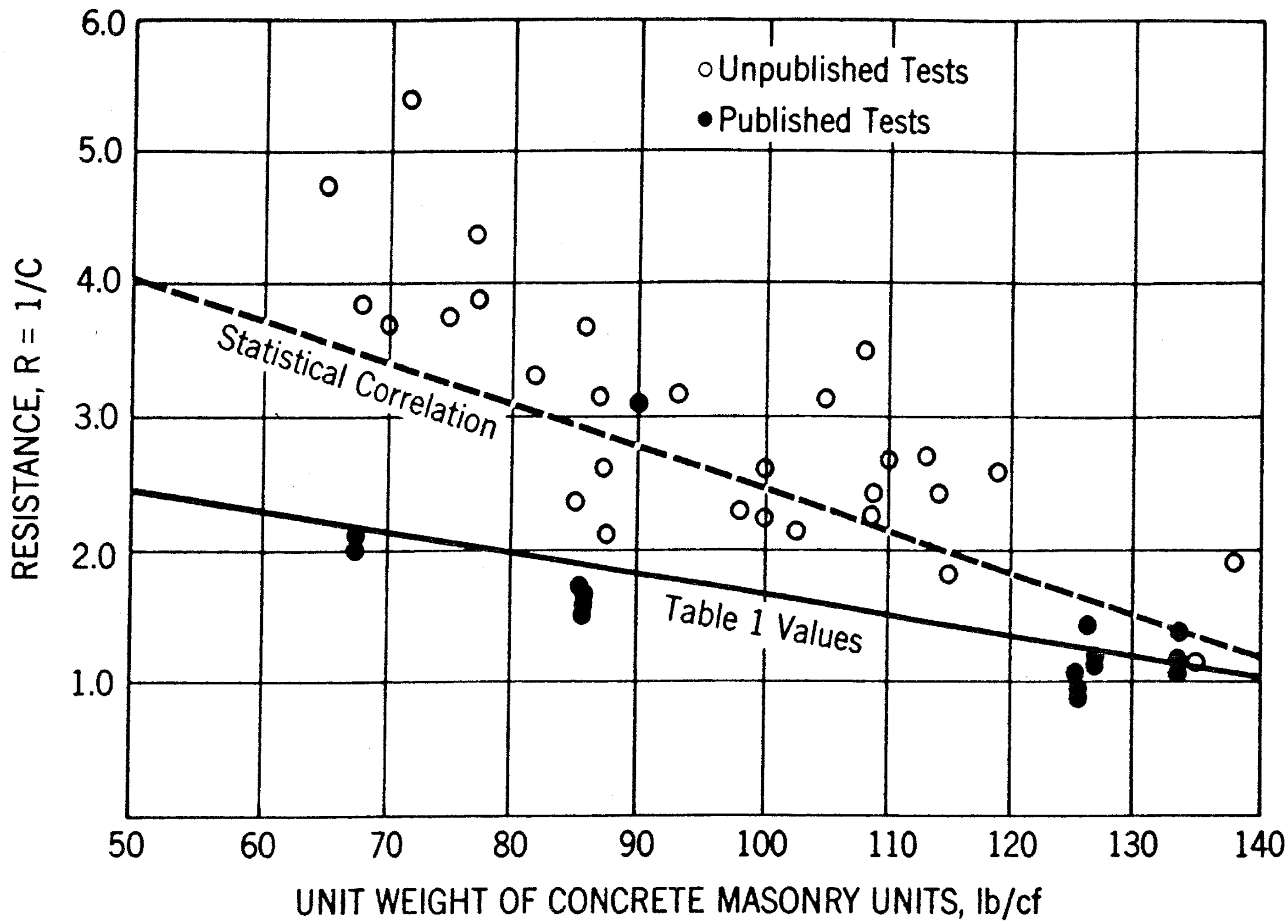
A limitation to the ASHRAE Guide is that it contains few data on concrete masonry units of different unit weight (density). Conductance values are listed for: (1) sand and gravel, (2) cinder, and (3) lightweight aggregate concrete block of different thicknesses ranging between 3 and 12 inches, but no relationship is established between conductance and unit weight beyond that implied by aggregate name. Since the unit weight of lightweight aggregate concrete can vary over a wide range, 60 to 115 lb/cf, values of conductance for concrete masonry of lightweight aggregate could differ considerably from the Guide values. Thermal conductance varies with the unit weight—directly and significantly. Conductance values shown in the ASHRAE Guide for lightweight concrete indicate an increase in conductivity greater than twofold between 60 and 100 lb/cf density and threefold between 60 and 120 lb/cf.

The total resistance (1/U) to heat flow through a building section numerically equals the sum of the thermal resistances of the various components of the building section. These components consist of air films, materials of construction, and air

TABLE 1—Resistance Values (R = 1/C) of Single-Wythe Concrete Masonry Walls with Hollow Cells Empty and Filled with Bulk Insulation.

CM Units	Insulation in Cells	Unit Weight, lb/CF				
		60	80	100	120	140
4":	Filled	3.36	2.79	2.33	1.92	1.14
	Empty	2.07	1.68	1.40	1.17	0.77
6":	Filled	5.59	4.59	3.72	2.95	1.59
	Empty	2.25	1.83	1.53	1.29	0.86
8":	Filled	7.46	6.06	4.85	3.79	1.98
	Empty	2.30	2.12	1.75	1.46	0.98
10":	Filled	9.35	7.46	5.92	4.59	2.35
	Empty	3.0	2.40	1.97	1.63	1.08
12":	Filled	10.98	8.70	6.80	5.18	2.59
	Empty	3.29	2.62	2.14	1.81	1.16

FIGURE 1. Resistance Values Shown in Table 1 are Compared with Published and Unpublished Test Results on 8-inch Hollow Concrete Block Walls.



spaces. The reciprocal of the total resistance is the overall heat transmission coefficient, or U-factor.

Thermal resistance values, 1/C, that can be used to predict the conductance of concrete masonry of various nominal thicknesses and unit weights, are contained in Table 1. Values are shown for both uninsulated concrete masonry walls and walls in which the hollow cells of the concrete masonry unit are filled with loose-fill insulation such as Perlite, Vermiculite, and others. Table 1 values do not include individual resistance to heat flow due to surface conductance (air film and treatment of masonry wall surface such as paint). For example, the total resistance of an 8-inch hollow concrete masonry wall composed of units weighing 80 lbs/cf would be compared to one constructed of units weighing 140 lbs/cf as shown in table at right.

Resistance Value	Unit Weight of Masonry Units	
	80 lbs/cf	140 lbs/cf
Outside Surface* ($1/f_o$)	0.17	0.17
Concrete Unit** ($1/C$)	1.94	1.00
Inside Surface* ($1/f_i$)	0.68	0.68
Total Resistance, $R_t = 1/U$	2.79	1.85
U-Factor = $1/R_t$ =	0.36	0.54

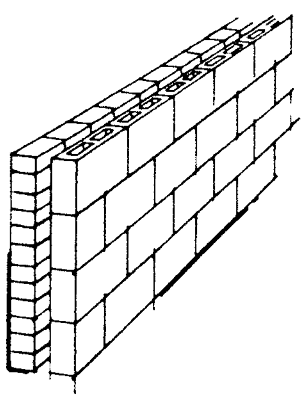
**15 MPH wind for outside surface and still air inside surface (see Table 2).*
***Resistance value from Table 1.*

In general, total resistance values calculated from the data in Tables 1 and 2 will be similar to results from the ASHRAE Guide. However, it should be kept in mind that estimating thermal resistance of building components which contain air spaces of unconventional shape, such as concrete masonry units, is not as accurate as would be obtained by a laboratory test. Where laboratory test values of thermal conductance are available, they should be employed.

Values shown in Table 1 are based upon published test data only, and are generally conservative. Figure 1 compares test data from a large number of unpublished thermal conductance tests made on 8-inch concrete block walls with published data, and suggests that considering all known test data, the values listed herein are quite conservative. Note in Figure 1 that the statistical correlation based upon all data (published and unpublished tests) would yield resistance values considerably greater than those contained in Table 1.

TABLE 2 CONDUCTANCE (C OR k) AND RESISTANCE (R) OF
VARIOUS BUILDING MATERIALS OTHER THAN HOLLOW CONCRETE MASONRY

Material	Density p.c.f.	Conductivity or Conductance		Resistance	
		(k)	(C)	(1/k)	(1/C)
Poured Concrete, Mortar, and 100% Solid Concrete Masonry Units	60	1.7		0.59	
	80	2.5		0.40	
	100	3.6		0.28	
	120	5.2		0.19	
	140	9.0		0.11	
Surface Conductance					
f_o—for outside wall, 15 mile/hr. wind (winter)			6.00		0.17
f_o—for outside wall, 7½ mile/hr. wind (summer)			4.00		0.25
f_i—for inside wall			1.46		0.68
Air Space Conductance					
Vertical air space ¾"-4'					
Winter			1.03		0.97
Summer			1.16		0.86
Reflective lining one side			0.33		3.00
Plaster					
Cement, sand aggregate		5.00		0.20	
Gypsum, perlite aggregate		1.50		0.67	
Gypsum, vermiculite aggregate		1.70		0.59	
Gypsum, sand aggregate		5.60		0.18	
Lath and Plaster					
Metal lath, ¾-in. plaster					
Sand aggregate			7.69		0.13
Lightweight aggregate			2.12		0.47
⅜-in. gypsum lath, ½-in. plaster					
Sand aggregate			2.43		0.41
Lightweight aggregate			1.56		0.64
½-in. insulation board lath and ½-in. sand aggregate plaster			0.66		1.52
Wood lath and ½-in. sand aggregate plaster			2.50		0.40
Insulating Materials					
Mineral wool, fibrous form		0.27		3.70	
Loose fill		0.50		2.00	
Rigid fiber boards, typical		0.33		3.03	
Wood					
Maple, oak, similar hard woods		1.10		0.91	
Fir, pine, similar soft woods		0.80		1.25	



Sample Calculation

10" Cavity Wall

4" Concrete Brick
Unit Weight = 140 lb/cf

2" Air Space

4" Hollow Concrete Block
Unit Weight = 60 lb/cf

Referring to Tables 1 and 2

$1/f_o$	Outside Surface	0.17
1/C	Concrete Brick $4 \times 0.11 =$	0.44
1/a	Air Space	0.97
1/C	Concrete Block	2.07
$1/f_i$	Inside Surface	0.68
R_t	Total Resistance =	4.33

$U = 1/R_t = 1/4.33 = 0.23$

"U" VALUES FOR CONCRETE MASONRY WALLS WITH LOOSE FILL and/or GROUT

TEK 6-2
Energy & IAQ (1988)

Introduction

Often concrete masonry walls are constructed of hollow block having the cores filled with loose fill and/or grout. Determining the thermal insulation values of such walls may be time consuming, especially where the wall is composed of several materials with different thermal conductivity properties. This TEK is intended to facilitate the calculation of the thermal resistance (R) or thermal transmittance (U) properties of such concrete masonry walls.

Included are tables of calculated "R" and "U" values for hollow block of 6", 8", 10" and 12" in thickness made with concrete having densities ranging from 80 to 135 lbs. per cubic foot. The concrete block used in the tables represent typical 2-core block used in masonry construction. Also included is a table which shows the approximate percentage of grouted and ungrouted wall volume for different spacings of vertical and horizontal grouted elements. R values of the different insulating materials used in compiling the tables are shown in Table 6.

When using these tables the first step in determining the R or U-value of the wall is to calculate the percentages of the grouted and ungrouted areas of the wall. Table 1 provides a rapid method for doing this. The U-value of the wall is equal to the decimal percentage of the grouted area times its U-value plus the decimal percentage of the ungrouted area times its U-value. This can be demonstrated by the following example:

Assume an 8" wall composed of hollow concrete masonry having a density of 105 lb. per cu. ft. grouted at 48" o. c. both vertically and horizontally with grout fill having a density of 130 lb. per cu. ft. Ungrouted cores contain perlite loose fill insulation.

From Table 1, 31% of the wall is grouted and 69% contains loose fill insulation. From Table 3, the U-value for a fully grouted concrete masonry wall (block density is 105 lb. per cu. ft. and grout density is 130 lb. per cu. ft.) is 0.44. From the same table, a wall containing perlite loose fill insulation has a U-value of 0.15. The U-value of the wall may then be calculated as follows:

$$U = (0.31 \times 0.44) + (0.69 \times 0.15)$$

$$U = 0.24 \text{ Btu/(hr}\cdot\text{ft}^2\cdot{}^\circ\text{F)}$$

Table 1. Percent Ungrouted Area/Percent grouted Area

Horizontal Grout Spacing, Inches \ Vertical Grout Spacing, Inches	48"	40"	32"	24"	16"
48"	69/31	67/33	63/37	56/44	42/58
40"	67/33	64/36	60/40	53/47	40/60
32"	63/37	60/40	56/44	50/50	37/63
24"	56/44	53/47	50/50	44/56	33/67
16"	42/58	40/60	37/63	33/67	25/75

The ASHRAE Series-Parallel Method was used in calculating the base case values (i. e., Exposed Block, Both Sides - Cores Empty or containing Loose Fill Insulation or Grout) which appear in the following Tables.

In calculating the values for the remainder of the Tables, the assumption was made that the gypsum board was mounted on 1" furring strips in all cases, resulting in a framing factor of 19% (rounded to 20%)

For example, if 1" of polyisocyanurate plus 1/2" gypsum board was installed on the surface of the wall, the added value of the insulation would be:

$$R = \frac{1}{\frac{.20}{1.45} + \frac{.80}{7.65}} = 4.12 \qquad U = 1/R = 0.24$$

Where:

$$1.45 = R_{wood} + R_{gyp}$$

$$7.65 = R_{poly} + R_{gyp}$$

The total R-value for the wall system in the first example with 1" of polyisocyanurate plus 1/2" gypsum board added to the surface would be 4.12 + 4.12 = 8.24.

Table 4. "R" and "U" Values of typical 10-Inch Hollow Concrete Masonry Walls

Construction	Cores Empty		Loose-Fill Insulation				Grout Fill 100 lb/ft³		Grout Fill 130 lb/ft³		Density of Block lb/ft³
			Perlite		Vermiculite						
	R	U	R	U	R	U	R	U	R	U	
Exposed Block, Both Sides	3.00	.33	11.02	.09	10.22	.10	3.88	.26	3.06	.33	80
	2.73	.37	9.06	.11	8.52	.12	3.54	.28	2.78	.36	95
	2.57	.39	7.90	.13	7.50	.13	3.34	.30	2.63	.38	105
	2.43	.41	6.88	.15	6.58	.15	3.14	.32	2.48	.40	115
	2.31	.43	5.95	.17	5.73	.17	2.95	.34	2.35	.43	125
	2.19	.46	5.14	.19	4.99	.20	2.77	.36	2.22	.45	135
1/2" Gypsum Board on Furring Strips	4.45	.22	12.47	.08	11.67	.09	5.33	.19	4.51	.22	80
	4.18	.24	10.51	.10	9.97	.10	4.99	.20	4.23	.24	95
	4.02	.25	9.35	.11	8.95	.11	4.79	.21	4.08	.25	105
	3.88	.26	8.33	.12	8.03	.12	4.59	.22	3.93	.25	115
	3.76	.27	7.40	.14	7.18	.14	4.40	.23	3.80	.26	125
	3.64	.27	6.59	.15	6.44	.16	4.22	.24	3.67	.27	135
1/2" Foil-backed Gypsum Board on Furring Strips	5.70	.18	13.72	.07	12.92	.08	6.58	.15	5.76	.17	80
	5.43	.18	11.76	.09	11.22	.09	6.24	.16	5.48	.18	95
	5.27	.19	10.60	.09	10.20	.10	6.04	.17	5.33	.19	105
	5.13	.19	9.58	.10	9.28	.11	5.84	.17	5.18	.19	115
	5.01	.20	8.65	.12	8.43	.12	5.65	.18	5.05	.20	125
	4.89	.20	7.84	.13	7.69	.13	5.47	.18	4.92	.20	135
1" Rigid Glass Fiber or 1" Expanded Polystyrene Plus 1/2" Gypsum Board	6.15	.16	14.17	.07	13.37	.07	7.03	.14	6.21	.16	80
	5.88	.17	12.21	.08	11.67	.09	6.69	.15	5.93	.17	95
	5.72	.17	11.05	.09	10.65	.09	6.49	.15	5.78	.17	105
	5.58	.18	10.03	.10	9.73	.10	6.29	.16	5.63	.18	115
	5.46	.18	9.10	.11	8.88	.11	6.10	.16	5.50	.18	125
	5.34	.19	8.29	.12	8.14	.12	5.92	.17	5.37	.19	135
1" Extruded Polystyrene plus 1/2" Gypsum Board	6.51	.15	14.53	.07	13.73	.07	7.39	.14	6.57	.15	80
	6.24	.15	12.57	.08	12.03	.08	7.05	.14	6.29	.16	95
	6.08	.16	11.41	.09	11.01	.09	6.85	.15	6.14	.16	105
	5.94	.16	10.39	.10	10.09	.10	6.65	.15	5.99	.17	115
	5.82	.16	9.46	.11	9.24	.11	6.46	.15	5.86	.17	125
	5.70	.16	8.65	.12	8.50	.12	6.28	.16	5.73	.17	135
1" Expanded Polyurethane plus 1/2" Gypsum Board	6.88	.15	14.90	.07	14.10	.07	7.76	.13	6.94	.14	80
	6.61	.15	12.94	.08	12.40	.08	7.42	.13	6.66	.15	95
	6.45	.16	11.78	.08	11.38	.09	7.22	.14	6.51	.15	105
	6.31	.16	10.76	.09	10.46	.10	7.02	.14	6.36	.16	115
	6.19	.16	9.83	.10	9.61	.10	6.83	.15	6.23	.16	125
	6.07	.16	9.02	.11	8.87	.11	6.65	.15	6.10	.16	135
1" Polyisocyanurate plus 1/2" Gypsum Board	7.12	.14	15.14	.07	14.34	.07	8.00	.13	7.18	.14	80
	6.85	.15	13.18	.08	12.64	.08	7.66	.13	6.90	.14	95
	6.69	.15	12.02	.08	11.62	.09	7.46	.13	6.75	.15	105
	6.55	.15	11.00	.09	10.70	.09	7.26	.14	6.60	.15	115
	6.43	.16	10.07	.10	9.85	.10	7.07	.14	6.47	.15	125
	6.31	.16	9.26	.11	9.11	.11	6.89	.15	6.34	.16	135

Table 5. "R" and "U" Values of typical 12-Inch Hollow Concrete Masonry Walls

Construction	Cores Empty		Loose-Fill Insulation				Grout Fill 100 lb/ft³		Grout Fill 130 lb/ft³		Density of Block lb/ft³
			Perlite		Vermiculite						
	R	U	R	U	R	U	R	U	R	U	
Exposed Block, Both Sides	3.12	.32	13.44	.07	12.44	.08	4.49	.22	3.45	.29	80
	2.83	.35	11.02	.09	10.34	.10	4.10	.24	3.15	.32	95
	2.66	.38	9.59	.10	9.09	.11	3.86	.26	2.97	.34	105
	2.52	.40	8.32	.12	7.95	.13	3.63	.28	2.81	.36	115
	2.38	.42	7.17	.14	6.90	.14	3.42	.29	2.86	.38	125
	2.26	.44	6.18	.16	5.98	.17	3.20	.31	2.52	.40	135
1/2" Gypsum Board on Furring Strips	4.57	.22	14.89	.07	13.89	.07	5.94	.17	4.90	.20	80
	4.28	.23	12.47	.08	11.79	.08	5.55	.18	4.60	.22	95
	4.11	.24	11.04	.09	10.54	.09	5.31	.19	4.42	.23	105
	3.97	.25	9.77	.10	9.40	.11	5.08	.20	4.26	.23	115
	3.83	.26	8.62	.12	8.35	.12	4.87	.21	4.11	.24	125
	3.71	.27	7.63	.13	7.43	.13	4.65	.22	3.97	.25	135
1/2" Foil-backed Gypsum Board on Furring Strips	5.82	.17	16.14	.06	15.14	.07	7.19	.14	6.15	.16	80
	5.53	.18	13.72	.07	13.04	.08	6.80	.15	5.85	.17	95
	5.36	.19	12.29	.08	11.79	.08	6.56	.15	5.67	.18	105
	5.22	.19	11.02	.09	10.65	.09	6.33	.16	5.51	.18	115
	5.08	.20	9.87	.10	9.60	.10	6.12	.16	5.36	.19	125
	4.96	.20	8.88	.11	8.68	.12	5.90	.17	5.22	.19	135
1" Rigid Glass Fiber or 1" Expanded Polystyrene Plus 1/2" Gypsum Board	6.27	.16	16.59	.06	15.59	.06	7.64	.13	6.60	.15	80
	5.98	.17	14.17	.07	13.49	.07	7.25	.14	6.30	.16	95
	5.81	.17	12.74	.08	12.24	.08	7.01	.14	6.12	.16	105
	5.67	.18	11.47	.09	11.10	.09	6.78	.15	5.96	17	115
	5.53	.18	10.32	.10	10.05	.10	6.57	.15	5.81	.17	125
	5.41	.18	9.33	.11	9.13	.11	6.35	.16	5.67	.18	135
1" Extruded Polystyrene plus 1/2" Gypsum Board	6.63	.15	16.95	.06	15.95	.06	8.00	.13	6.96	.14	80
	6.34	.16	14.53	.07	13.85	.07	7.61	.13	6.66	.15	95
	6.17	.16	13.10	.08	12.60	.08	7.37	.14	6.48	.15	105
	6.03	.17	11.83	.08	11.46	.09	7.14	.14	6.32	.16	115
	5.89	.17	10.68	.09	10.41	.10	6.93	.14	6.17	.16	125
	5.77	.17	9.69	.10	9.49	.11	6.71	.15	6.03	.17	135
1" Expanded Polyurethane plus 1/2" Gypsum Board	7.00	.14	17.32	.06	16.32	.06	8.37	.12	7.33	.14	80
	6.71	.15	14.90	.07	14.22	.07	7.98	.13	7.03	.14	95
	6.54	.15	13.47	.07	12.97	.08	7.74	.13	6.85	.15	105
	6.40	.16	12.20	.08	11.83	.08	7.51	.13	6.69	.15	115
	6.26	.16	11.05	.09	10.78	.09	7.30	.14	6.54	.15	125
	6.14	.16	10.06	.10	9.86	.10	7.08	.14	6.40	.16	135
1" Polyisocyanurate plus 1/2" Gypsum Board	7.24	.14	17.56	.06	16.56	.06	8.61	.12	7.57	.13	80
	6.95	.14	15.14	.07	14.46	.07	8.22	.12	7.27	.14	95
	6.78	.15	13.71	.07	13.21	.08	7.98	.13	7.09	.14	105
	6.64	.15	12.44	.08	12.07	.08	7.75	.13	6.93	.14	115
	6.50	.15	11.29	.09	11.02	.09	7.54	.13	6.78	.15	125
	6.38	.16	10.30	.10	10.10	.10	7.32	.14	6.64	.15	135

Table 2. "R" and "U" Values of typical 6-Inch Hollow Concrete Masonry Walls

Construction	Cores Empty		Loose-Fill Insulation				Grout Fill 100 lb/ft³		Grout Fill 130 lb/ft³		Density of Block lb/ft³
			Perlite		Vermiculite						
	R	U	R	U	R	U	R	U	R	U	
Exposed Block, Both Sides	2.64	.38	6.75	.15	6.26	.16	2.65	.38	2.21	.45	80
	2.42	.41	5.64	.18	5.31	.19	2.43	.41	2.02	.50	95
	2.29	.44	4.99	.20	4.73	.21	2.30	.43	1.91	.52	105
	2.17	.46	4.40	.23	4.21	.24	2.18	.46	1.82	.55	115
	2.05	.49	3.86	.26	3.72	.27	2.06	.49	1.73	.58	125
	1.95	.51	3.40	.29	3.30	.30	1.96	.51	1.65	.61	135
1/2" Gypsum Board on Furring Strips	4.09	.24	8.20	.12	7.71	.13	4.10	.24	3.66	.27	80
	3.87	.26	7.09	.14	6.76	.15	3.88	.26	3.47	.29	95
	3.74	.27	6.44	.16	6.18	.16	3.75	.27	3.36	.30	105
	3.62	.28	5.85	.17	5.66	.18	3.63	.28	3.27	.31	115
	3.50	.29	5.31	.19	5.17	.19	3.51	.28	3.18	.31	125
	3.40	.29	4.85	.21	4.75	.21	3.41	.29	3.10	.32	135
1/2" Foil-backed Gypsum Board on Furring Strips	5.34	.19	9.45	.11	8.96	.11	5.35	.19	4.91	.20	80
	5.12	.20	8.34	.12	8.01	.12	5.13	.19	4.72	.21	95
	4.99	.20	7.69	.13	7.43	.13	5.00	.20	4.61	.22	105
	4.87	.21	7.10	.14	6.91	.14	4.88	.20	4.52	.22	115
	4.75	.21	6.56	.15	6.42	.16	4.76	.21	4.43	.23	125
	4.65	.22	6.10	.16	6.00	.17	4.66	.21	4.35	.23	135
1" Rigid Glass Fiber or 1" Polystyrene Plus 1/2" Gypsum Board	5.79	.17	9.90	.10	9.41	.11	5.80	.17	5.36	.19	80
	5.57	.18	8.79	.11	8.46	.12	5.58	.18	5.17	.19	95
	5.44	.18	8.14	.12	7.88	.13	5.45	.18	5.06	.20	105
	5.32	.19	7.55	.13	7.36	.14	5.33	.19	4.97	.20	115
	5.20	.19	7.01	.14	6.87	.15	5.21	.19	4.88	.20	125
	5.10	.20	6.55	.15	6.45	.16	5.11	.20	4.80	.21	135
1" Extruded Polystyrene plus 1/2" Gypsum Board	6.15	.16	10.26	.10	9.77	.10	6.16	.16	5.72	.17	80
	5.93	.17	9.15	.11	8.82	.11	5.94	.17	5.53	.18	95
	5.80	.17	8.50	.12	8.24	.12	5.81	.17	5.42	.18	105
	5.68	.18	7.91	.13	7.72	.13	5.69	.18	5.33	.19	115
	5.56	.18	7.73	.13	7.23	.14	5.57	.18	5.24	.19	125
	5.46	.18	6.91	.14	6.81	.15	5.47	.18	5.13	.19	135
1" Expanded Polyurethane plus 1/2" Gypsum Board	6.52	.15	10.63	.09	10.14	.10	6.53	.15	6.09	.16	80
	6.30	.16	9.52	.11	9.19	.11	6.31	.16	5.90	.17	95
	6.17	.16	8.87	.11	8.61	.12	6.18	.16	5.79	.17	105
	6.05	.17	8.28	.12	8.09	.12	6.06	.17	5.70	.18	115
	5.93	.17	7.74	.13	7.60	.13	5.94	.17	5.61	.18	125
	5.83	.17	7.28	.14	7.18	.14	5.84	.17	5.53	.18	135
1" Polyisocyanurate plus 1/2" Gypsum Board	6.76	.15	10.87	.09	10.38	.10	6.77	.15	6.33	.16	80
	6.54	.15	9.76	.10	9.43	.11	6.55	.15	6.14	.16	95
	6.41	.16	9.11	.11	8.85	.11	6.42	.16	6.03	.17	105
	6.29	.16	8.52	.12	8.33	.12	6.30	.16	5.94	.17	115
	6.17	.16	7.98	.13	7.84	.13	6.18	.16	5.85	.17	125
	6.07	.16	7.52	.13	7.42	.13	6.08	.16	5.77	.17	135

Table 3. "R" and "U" Values of typical 8-Inch Hollow Concrete Masonry Walls

Construction	Cores Empty		Loose-Fill Insulation				Grout Fill 100 lb/ft³		Grout Fill 130 lb/ft³		Density of Block lb/ft³
			Perlite		Vermiculite						
	R	U	R	U	R	U	R	U	R	U	
Exposed Block, Both Sides	2.86	.35	9.07	.11	8.37	.12	3.27	.31	2.65	.38	80
	2.61	.38	7.53	.13	7.06	.14	2.99	.33	2.41	.41	95
	2.46	.41	6.62	.15	6.26	.16	2.82	.35	2.27	.44	105
	2.33	.43	5.80	.17	5.53	.18	2.66	.38	2.15	.47	115
	2.21	.45	5.06	.20	4.86	.21	2.51	.40	2.04	.49	125
	2.10	.48	4.40	.23	4.26	.23	2.37	.42	1.94	.52	135
1/2" Gypsum Board on Furring Strips	4.31	.23	10.52	.10	9.82	.10	4.72	.21	4.10	.24	80
	4.06	.25	8.98	.11	8.51	.12	4.44	.23	3.86	.26	95
	3.91	.26	8.07	.12	7.71	.13	4.27	.23	3.72	.27	105
	3.78	.26	7.25	.14	6.98	.14	4.11	.24	3.60	.28	115
	3.66	.27	6.51	.15	6.31	.16	3.96	.25	3.49	.29	125
	3.55	.28	5.85	.17	5.71	.18	3.82	.26	3.39	.29	135
1/2" Foil-backed Gypsum Board on Furring Strips	5.56	.18	11.77	.08	11.07	.09	5.97	.17	5.35	.19	80
	5.31	.19	10.23	.10	9.76	.10	5.69	.18	5.11	.20	95
	5.16	.19	9.32	.11	8.96	.11	5.52	.18	4.97	.20	105
	5.03	.20	8.50	.12	8.23	.12	5.36	.19	4.85	.21	115
	4.91	.20	7.76	.13	7.56	.13	5.21	.19	4.74	.21	125
	4.80	.21	7.10	.14	6.96	.14	5.07	.20	4.64	.22	135
1" Rigid Glass Fiber or 1" Expanded Polystyrene Plus 1/2" Gypsum Board	6.01	.17	12.22	.08	11.52	.09	6.42	.16	5.80	.17	80
	5.76	.17	10.68	.09	10.21	.10	6.14	.16	5.56	.18	95
	5.61	.18	9.77	.10	9.41	.11	5.97	.17	5.42	.18	105
	5.48	.18	8.95	.11	8.68	.12	5.81	.17	5.30	.19	115
	5.36	.19	8.21	.12	8.01	.12	5.66	.18	5.19	.19	125
	5.25	.19	7.55	.13	7.41	.13	5.52	.18	5.09	.20	135
1" Extruded Polystyrene plus 1/2" Gypsum Board	6.37	.16	12.58	.08	11.88	.08	6.78	.15	6.16	.16	80
	6.12	.16	11.04	.09	10.57	.09	6.50	.15	5.92	.17	95
	5.97	.17	10.13	.10	9.77	.10	6.33	.16	5.78	.17	105
	5.84	.17	9.31	.11	9.04	.11	6.17	.16	5.66	.18	115
	5.72	.17	8.57	.12	8.37	.12	6.02	.17	5.55	.18	125
	5.61	.18	7.91	.13	7.77	.13	5.88	.17	5.45	.18	135
1" Expanded Polyurethane plus 1/2" Gypsum Board	6.74	.15	12.95	.08	12.25	.08	7.15	.14	6.53	.15	80
	6.49	.15	11.41	.09	10.94	.09	6.87	.15	6.29	.16	95
	6.34	.16	10.50	.10	10.14	.10	6.70	.15	6.15	.16	105
	6.21	.16	9.68	.10	9.41	.11	6.54	.15	6.03	.17	115
	6.09	.16	8.94	.11	8.74	.11	6.39	.16	5.92	.17	125
	5.98	.17	8.28	.12	8.14	.12	6.25	.16	5.82	.17	135
1" Polyisocyanurate plus 1/2" Gypsum Board	6.98	.14	13.19	.08	12.49	.08	7.39	.14	6.77	.15	80
	6.73	.15	11.65	.09	11.18	.09	7.11	.14	6.53	.15	95
	6.58	.15	10.74	.09	10.38	.10	6.94	.14	6.39	.16	105
	6.45	.16	9.92	.10	9.65	.10	6.78	.15	6.27	.16	115
	6.33	.16	9.18	.11	8.98	.11	6.63	.15	6.16		125
	6.22	.16	8.52	.12	8.38	.12	6.49	.15	6.0		135

Table 6. Values Used For Compiling Tables

Material	R-Value Per Inch
Mortar	0.200
Grout 100 pcf	0.271
Grout 130 pcf	0.149
Concrete 80 pcf	0.404
Concrete 95 pcf	0.299
Concrete 105 pcf	0.245
Concrete 115 pcf	0.201
Concrete 125 pcf	0.164
Concrete 135 pcf	0.134
Insulation:	
Gypsum Board	0.90
Wood Furring	1.00
Vermiculite	2.44
Perlite	3.13
Rigid Glass Fiber	4.00
Expanded Polystyrene	4.00
Extruded Polystyrene	5.00
Polyisocyanurate	7.20
Surface Conductance:	
Outside (15 mph wind)	0.17
Inside	0.68
Air Space Conductance:	
3/4" - 4"	0.97
3/4" - 4" w/bright foil lining	3.00

NCMA-TEK

An Information series from National Concrete Masonry Association

COMPLIANCE WITH ASHRAE/IES STANDARD 90.1-1989 REQUIREMENTS

TEK 6-4
Energy & IAQ (1990)

Key Words: ASHRAE, ENVSTD program, ACP Tables, System Performance Criteria, Prescriptive Criteria, fenestration, Building Energy Cost Budget, internal load density, opaque wall, shading coefficient, specific heat, heat capacity, projection factor, energy, energy efficient design, energy standard, thermal mass

INTRODUCTION

ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.) and IES (Illuminating Engineers Society of North America) have published ASHRAE/IES 90.1-1989, "Energy Efficient Design of New Buildings Except New Low-Rise Residential Buildings," representing the state-of-the art in building energy conservation.

This TEK will discuss the background of ASHRAE Standard 90 and its impact on concrete masonry, as well as introduce the ENVSTD computer program. Examples are provided illustrating how the ENVSTD computer program may be used to achieve compliance with the exterior building envelope requirements of Standard 90.1.

Background

ASHRAE's first energy conservation standard, Standard 90-75, "Energy Conservation in New Building Design," was published in August 1975 and was based on "Design and Evaluation Criteria for Energy Conservation in New Buildings" (NBSIR 74-452), which was developed by the National Bureau of Standards (NBS, known today as NIST).

"In January 1977 the National Conference of States on Building Codes and Standards (NCS/BCS), Building Officials and Code Administrators International, Inc. (BOCA), International Conference of Building Officials (ICBO), and Southern Building Code Congress, Inc. (SBCCI) published a preliminary draft of a 'Code for Energy Conservation in New Building Construction.' Essentially based on Standard 90-75, the document was submitted to public review and hearings, and in December, the final version was published. Over the ensuing ten years, all 50 states enacted regulations based on Standard 90, the model energy conservation code, or one of several regional codes which also use the standard as a technical base."[1]

Several revisions have been made to Standard 90. The latest revisions have split the original standard into two separate standards for two distinct building types. Standard 90.1 applies to all new buildings except low-rise residential buildings. The second standard, ASHRAE 90.2P, "Energy Efficient Design of New Low-Rise Buildings," is in the public review phase of its development and will apply, once published, to all residential buildings three stories or less above grade.

Purpose

"The purpose of this standard is to:
(a) set minimum requirements for the energy efficient design of new buildings so that they may be constructed, operated, and maintained in a manner that minimizes the use of energy without constraining the building function nor the comfort or productivity of the occupants.
(b) provide criteria for energy efficient design and methods for determining compliance with these criteria.
(c) provide sound guidance for energy efficient design."[2]

Impact on Concrete Masonry

As Standard 90 and related codes have been revised, the overall coefficient of heat transfer for exterior walls, U_{ow}, requirements have generally been decreasing; increasing R-value requirements. Standard 90.1 is no exception to this trend; however, there are several aspects of the standard which are particularly beneficial to concrete masonry:
(1) Thermal mass credits are available for massive wall assemblies such as concrete and masonry.
(2) The ENVSTD computer program allows for massive wall assemblies to meet compliance with higher U_{ow}, lower R-values, than those values mandated in the prescriptive section (see Examples 1 and 2) and,
(3) The ENVSTD computer program allows design flexibility, so that U_{ow} values will no longer dominate compliance to the standard (see Example 2). In fact, wall heat capacity, HC, in conjunction with wall U_{ow}, glazing area and type, internal loads and other parameters will determine compliance.

How to Comply with Standard 90.1

Although there are many requirements in the standard, such as those for electric power, lighting, envelope, HVAC system and equipment, service water heating, and energy management, concrete masonry manufacturers and those designing concrete masonry buildings will be concerned with the U_{ow} requirements for exterior walls. These can be found in Chapter 8, Building Envelope, sections 8.5 and 8.6.

There are three methods, or compliance paths, available to comply to Standard 90.1:

(1) Prescriptive Criteria are listed in section 8.5 and include exterior wall U_{ow}, listed in a series of 38 Alternate Component Package (ACP) Tables, one for each of 38 climate ranges within the United States.

(2) System Performance Criteria, listed in section 8.6, employ a pc-based procedure, the ENVSTD program, to determine, for a particular building design in a specific location, the exterior wall U_{ow} requirement based on other building design parameters.

(3) Building Energy Cost Budget, listed in section 13, requires the use of sophisticated computer programs that model the energy consumption of a building on an annual basis.

It is anticipated that the majority of architects and engineers will use either the ACP tables or the ENVSTD program to determine exterior wall U_{ow} requirements. The Prescriptive Criteria provide a simple compliance procedure with limited flexibility, whereas the System Performance Criteria provide a lengthier compliance procedure with greater flexibility.[3]

Prescriptive Criteria Requirements

The ACP tables contain requirements for maximum allowable percent fenestration, maximum U_{ow} for opaque walls, minimum R-value for below-grade walls, maximum roof U_o and other criteria, based on information regarding internal load density, projection factor, shading coefficient and perimteter daylighting.

For instance, Table 8A-31 for LaCrosse, Wisconsin, lists the base case, frame wall (no mass wall credit), maximum U_{ow} = 0.076 (R = 13.2). Depending on internal load density, percent fenestration, heat capacity (HC), and insulation position, the U_{ow} requirement for this table ranges from U_{ow} = 0.079 to 0.12 (R = 12.7 to 8.33) for mass walls. This ACP table allows the mass wall U_{ow} to be increased by up to 58%.

Mass walls are separated into three levels of credit, HC ≥ 5, HC ≥ 10, and HC ≥ 15. Heat capacity is formally defined as the amount of energy needed to raise the temperature of a given mass one degree; numerically, the product of a mass multiplied by its specific heat. In this standard HC is equal to wall weight (lb/ft^2) multiplied by wall specific heat (Btu/lb•°F) and has the units of (Btu/ft^2•°F). HC values can be obtained from NCMA-TEK 164, "Heat Capacity (HC) Values For Concrete Masonry Walls."

How to Use the ACPs

The first step in using the ACPs is to determine which table's climate most closely matches the climate of the building site. Tables 8A-0 and 8A-39 list climate variables for most cities across the country. Choose the ACP table (8A-1 through 8A-38) that corresponds with the building site's city, or if that city is not listed, choose the city that is climatologically closest to the building site.

For a quick check of opaque wall requirements (Max. U_{ow}) look at the rightmost column of three boxes listed under OPAQUE WALL. For instance, table 8A-31 lists a base case, or light weight wall (HC < 5), maximum U_{ow} = 0.076. For mass walls (HC ≥ 5), this same table lists a maximum U_{ow} = 0.12. Hence, one must design a wall with an R-value between R = 13.2 to R = 8.33 (U_{ow} = 0.076 to U_{ow} = 0.12) to meet the requirements of this ACP Table.

Even though this range of U_{ow} requirements represents compliance for this table, 8A-31, actual use of ACPs requires that several more variables be considered. The combination of these variables determine the exact U_{ow} requirement, which is somewhere within the range listed above. After the correct ACP Table has been selected, the maximum allowable percent fenestration must be determined; these requirements are listed in the middle two columns of boxes under FENESTRATION. Start by determining which of the three internal load density (ILD) ranges applies to your building. ILD is equal to the sum of the lighting power density, the equipment power density and the occupant load adjustment (values for these variables are tabularized in the standard, see 8.5.5.2). Next, determine the external shading projection factor (PF). PF is equal to the depth of an overhang divided by its height above the top of the fenestration, or window. Buildings without overhangs will have PF = 0.00. Next, determine the shading coefficient (SCx) of the fenestration; choose values from the ASHRAE Handbook, Fundamentals Volume, Chapter 27. Finally, choose the type of fenestration which corresponds to three ranges of fenestration thermal transmittance (U_{of}). These three ranges generally represent single glazing, double glazing, and triple, or high performance glazing. The FENESTRATION requirements (Max. Pct. Fenestr.) provide two options, a base case and a perimeter daylighting option. The range of maximum percent fenestration is 18% to 60%. Combinations of actual values for the variables listed above will dictate exact values for both the FENESTRATION and OPAQUE WALL requirements somewhere within the ranges mentioned above, which are taken directly from Table 8A-31.

System Performance Criteria Requirements

This method is more flexible than the ACP table approach because the ACP tables lump several cities together in one table and determine compliance based on ranges of design factors. The ENVSTD program, on the other hand, accounts for exact climate and building design variables to determine compliance for a specific project. Using ENVSTD the U_{ow} requirements are not controlled by the stringent ACP table requirements when wall HC exceeds 7; i. e., the U_{ow} can be increased above the value listed in the corresponding ACP table. In addition, larger glazing areas are permitted when using ENVSTD than are allowed in the ACP Tables.

The ENVSTD program is in a spreadsheet format which facilitates design input changes. Example 1 shows the input screen with design parameters filled in for a high-rise

EXAMPLE 1

CITY: 112 La Crosse, Wisconsin — BUILDING: Sample 1 Apt. Bldg.
CODE: <B,C,H>: Both Heated and Cooled — DATE: Metal Frame Wall

	WALL ORIENTATION								WEIGHTED	
	N	NE	E	SE	S	SW	W	NW	AVG.	CRITERIA
WL AREA	17158		59646		20896		58800		0.230	0.300
GL AREA	3410		14130		4720		13800		WWR	WWR
SCX	0.83		0.83		0.83		0.83		0.830	0.606
PF	0		0		0		0		0.000	0.0
VLT	0.79		0.79		0.79		0.79		0.790	N/A
U_{of}	0.520		0.520		0.520		0.520		0.520	0.471
WALL U_o	0.08		0.08		0.08		0.08		0.08	0.076
HC	10		10		10		10		10	1
INS POS	3		3		3		3		3	N/A
EQUIP	0.38		0.38		0.38		0.38		0.380	0.380
LIGHTS	0.67		0.67		0.67		0.67		0.670	0.670
DLCF	00		0		0		0		0.000	0.0

LOADS	N	NE	E	SE	S	SW	W	NW	TOTAL
HEATING	3.229		8.819		2.324		8.930		23.302 < 25.269
COOLING	2.076		11.150		3.897		11.373		28.497 > 27.532
TOTAL	5.305		19.969		6.221		20.303		51.798 < 52.801

F1 Load F2 Save	F3 Clear Input F4 Directory	F5 Other Screen F6 List Cities	F7 Help F9 Calculate	F10 Copy Across Esc Exit to Dos

********* PASSES *********

EXAMPLE 2

CITY: 112 La Crosse, Wisconsin — BUILDING: Sample 2 Apt. Bldg.
CODE: <B,C,H>: Both Heated and Cooled — DATE: Masonry Cavity Wall

	WALL ORIENTATION								WEIGHTED	
	N	NE	E	SE	S	SW	W	NW	AVG.	CRITERIA
WL AREA	17158		59646		20896		58800		0.209	0.300
GL AREA	3410		12800		4720		11800		WWR	WWR
SCX	0.83		0.83		0.83		0.83		0.830	0.606
PF	0		0		0		0		0.000	0.0
VLT	0.79		0.79		0.79		0.79		0.790	N/A
U_{of}	0.520		0.520		0.520		0.520		0.520	0.471
WALL U_o	0.14		0.14		0.14		0.14		0.14	0.076
HC	15.6		15.6		15.6		15.6		15.600	1
INS POS	2		2		2		2		2	N/A
EQUIP	0.38		0.38		0.38		0.38		0.380	0.380
LIGHTS	0.67		0.67		0.67		0.67		0.670	0.670
DLCF	00		0		0		0		0.000	0.0

LOADS	N	NE	E	SE	S	SW	W	NW	TOTAL
HEATING	3.817		10.728		2.762		10.867		28.174 > 25.269
COOLING	1.931		9.709		3.571		9.263		24.474 < 27.532
TOTAL	5.748		20.437		6.333		20.130		52.649 < 52.801

F1 Load F2 Save	F3 Clear Input F4 Directory	F5 Other Screen F6 List Cities	F7 Help F9 Calculate	F10 Copy Across Esc Exit to Dos

********* PASSES *********

apartment building. The two right hand columns show how each envelope component compares to the 90.1 criteria. The bottom row shows annual heating and cooling figures of merit for the building. These are compared to the criteria to determine compliance.

ENVSTD requires data on wall area, WL AREA; glass area, GL AREA; glass shading coefficient, SCx; glass projection factor, PF; glass visible light transmittance, VLT; glass (fenestration) U_o, U_{of}; wall U_o, WALL U_o; wall heat capacity, HC; insulation position, INS POS; equipment power density, EQUIP; electric lighting power density, LIGHTS; and daylighting features (if used), DLCF. Some sources of data on these design variables include the 1989 ASHRAE Handbook of Fundamentals (Chapter 22), manufacturers literature for glazing data, and the standard itself for equipment power density and electric lighting power density.

The data is entered separately for each wall, in a column corresponding to the walls orientation (north, northeast, etc.). Using this input, the program calculates the loads, which must be lower than the stated criteria in order to comply. If the building loads are too high, ENVSTD will print **FAILS** at the bottom of the screen. At this point it is very simple to adjust one of the building components and determine if this new design passes. Because of the flexibility of ENVSTD, there are several ways that the calculated loads can be lowered to bring a building into compliance. Some of these are: by increasing the opaque wall heat capacity, by decreasing the glazing or opaque wall U-factor, by decreasing the glazing area, or, on a mass wall, by using exterior or integral rather than interior insulation.

lation on a high-rise apartment building (9 story, 496,976 ft^2) in La Crosse, Wisconsin, is shown in Example 1. This apartment building passes the requirements, or attains compliance with the standard.

Example 2, essentially the same building as described in Example 1, also passes. Several small differences exist between Examples 1 and 2:

Glass area was decreased from 23% to 21% of the wall area, wall U_o was increased by 75% from Uo = 0.08 to 0.14 (R-12.5 to R-7.1), HC has been increased from HC = 10 to 15.6, and insulation position, INS POS, within the wall has changed from 3 (interior) to 2 (integral). These changes, with the exception of glass area, reflect an insulated (3/4 in. rigid EPS) brick veneer-block backup cavity wall finished on the interior with gypsum board. Example 1 reflects an insulated metal frame wall with 4" masonry veneer. Comparing these two samples to one another and to ACP Table 8A-31 for La Crosse illustrates:

(1) the flexibility that is afforded when using ENVSTD,
(2) U_{ow} values greater than those listed in the ACP table can meet the requirements, and
(3) that similar buildings with vastly different U_{ow} values, one representative of a frame wall, low U_{ow}, the other of a concrete masonry cavity wall, high U_{ow}, can meet the requirements of Standard 90.1.

References

[1] ASHRAE/IES Standard 90.1-1989, Foreword
[2] ASHRAE/IES Standard 90.1-1989, Page 1
[3] ASHRAE/IES Standard 90.1-1989, section 8.3.1

Section 5: Summary of the Thermal Capabilities of Concrete Masonry

Ever since the ancient Greeks and Romans developed the art of masonry construction, the unique ability of a material to support a load has been further enhanced by its capability to provide good thermal insulating capabilities. Generally, materials which are good heating insulators are poor structural members.

The measure of the quantity of heat transmitted through a wall is the BTU (British Thermal Unit). In figuring heat loss, it is always accompanied by a definite time factor, generally one hour, and a unit of area, generally one square foot. Heat loss is stated as the number of BTU's lost per degree difference in temperature, the temperature on the warmer side of the building wall being at least one degree higher than on the cooler side. Thus, the coefficient of heat transmission or U-Value is based on the number of BTU's lost per hour, per square foot, per degree difference in temperature (BTU/Hr/Sq. Ft./°F).

There is a thin film of air at the surface of all walls, floors or roofs, which in itself acts as insulation. For this reason, the heat loss from the air on one side of a masonry wall to the air on the other side will be less than that due solely to the resistance of the masonry material. Also, the temperature of the air and the temperature of the surface will always be different due to the resistance of these surface films of air. The insulating value of the air film (f) will be greater in still air than in moving air such as caused by wind or forced circulation.

Air spaces are insulators against heat loss. Thus, the air spaces within concrete masonry walls are insulators. The thermal resistance (R) of these air spaces or cores depends on several factors such as location, width and air flow within the cores.

The resistance of a homogeneous material to heat transmission is directly proportionate to its thickness. With the same temperature differences, half as much heat is lost from surface to surface through a 2-inch thickness of a given material as lost through 1-inch in thickness.

The most common source of information on the U-Value of various wall construction is the ASHRAE Handbook of Fundamentals published by the American Society of Heating, Refrigeration, and Air-Conditioning Engineers. In addition to values of Conductivity (k), Conductance (C), and Resistance (R), the ASHRAE Guide also gives a procedure of calculating overall coefficients (U-Value) for composite construction. Using the procedure outlined in the Guide, building designers and engineers can estimate U-Values for various types of construction, such as, cavity walls, veneer walls, and masonry walls with added insulation.

Concrete masonry, because of the variety of unit weights available, can vary widely in thermal capabilities. It is possible to have a range of densities from 60 to 140 lbs./cu. ft. Since thermal Conductance (C) varies with the unit weight-directly and significantly, an increase in conductivity greater than twofold can occur between 60 and 100 lb/cf density and threefold between 60 an 120 lb/cf.

The total resistance (1/U) to heat flow through a building section numerically equals the sum of the thermal resistance of the various components of the building section. These components consist of air films, materials of construction, and air spaces. The reciprocal of the total resistance is the overall heat transmission coefficient, or U-Value.

In the past, walls of concrete masonry provided sufficient thermal insulation to meet the requirements imposed by climatic conditions without the need of additional thermal insulation. Since the seventies and the heightened concern over energy conservation a major change has taken place in the design of all types of buildings. The American Society of Heating, Refrigeration and Air-Conditioning Engineers developed ASHRAE Standard 90 which has essentially become the National basis for energy conservation in new building construction. Part of this Standard requires a more careful study of the heat loss or gain through exterior walls. In the case of masonry walls this has led to the developed numerous commercial methods to further improve thermal efficiency.

The cores of concrete masonry units generally make up nearly 80% of the surface area of walls with the remaining percentage made up of the web and mortar joint area. The cores themselves form a natural thermal insulator primarily due to the dead air space they enclose. Other materials have been developed to fill the core areas either before the wall is constructed or after. Examples of these materials are:

Granular: Perlite-Glassy volcanic rock expanded by heating. May be treated with silicone to increase resistance to water penetration.

Vermiculite-Hydrated magnesium aluminum iron silicate with foliated structure. Exfoliated or expanded by heating. May be treated for water repellency.

Foamed: Plastic substances expanded into foam by mixing with air, carbon dioxide, fluorocarbons or other gaseous media and molded into rigid shapes.

The above techniques are used primarily in single wall or single wythe construction. When an exterior veneer of masonry such as brick or specialty masonry units are added to the block, thermal insulation may also be placed in the cavity formed between the block and the outside masonry exterior. In other construction requirements, the cores of masonry units are steel reinforced and grouted to improve the structural integrity. Certain expandable polystyrene inserts have been tested and are allowed by Building Codes to be left in the cores of reinforced and grouted construction.

In summary, concrete masonry is one of the most cost efficient building products known both from a structural and energy efficient standpoint. Thermal tests namely ASTM C236 (Guarded Hot Box Test) have shown concrete block, particularly those with modified web designs, can provide the necessary U-Values to meet today's energy code requirements.