Energy Basics

Concrete Masonry Association
of California and Nevada

SECTION 1 INTRODUCTION

1.1 Why is Energy An Issue With Masonry Walls?

Designers and builders have understood masonry as a building material for thousands of years, but many have become confused about its role in building energy performance. The purpose of this booklet is to clear away any confusion, to provide solid information on how masonry can contribute to energy efficient building design and, at the same time, help to meet the energy standards.

The reason buildings use energy is to maintain comfortable living and working conditions. The temperature outdoors swings above and below comfortable temperatures, and the building envelope provides a thermal barrier between them. The amount of energy that flows across this barrier determines how much energy must be expended in heating or cooling the building to maintain comfort.

Lightweight walls and heavy walls moderate the temperature consequences of these energy flows differently. With light frame walls, the heat and temperatures that cross the building's thermal barrier arrive on the interior soon after they enter the wall exterior. With heavy, masonry walls, the heat and temperatures are reduced and delayed. In many cases, this means that less energy expenditure is needed to maintain inside comfort. While this energy saving characteristic of masonry is not new, it is receiving new recognition.

There are two primary energy issues with buildings:

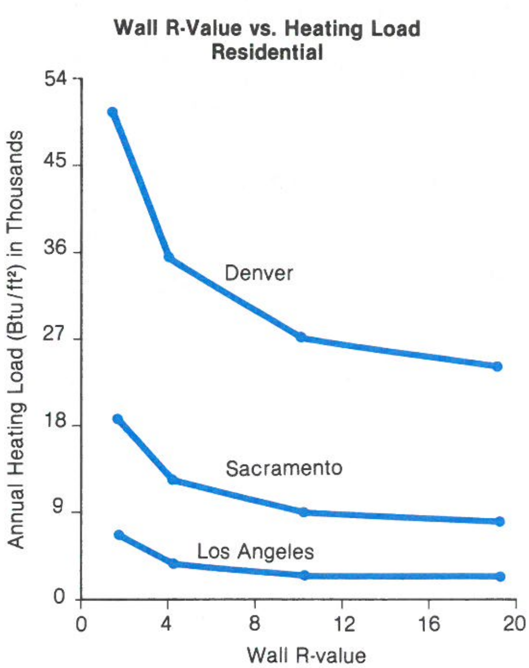
Energy performance: How efficiently the building uses energy over the long run (seasonally, annually). This can be evaluated in such terms as annual loads on the heating and cooling equipment, system energy consumption, or operating costs. (For simplicity,this booklet focuses on loads.)

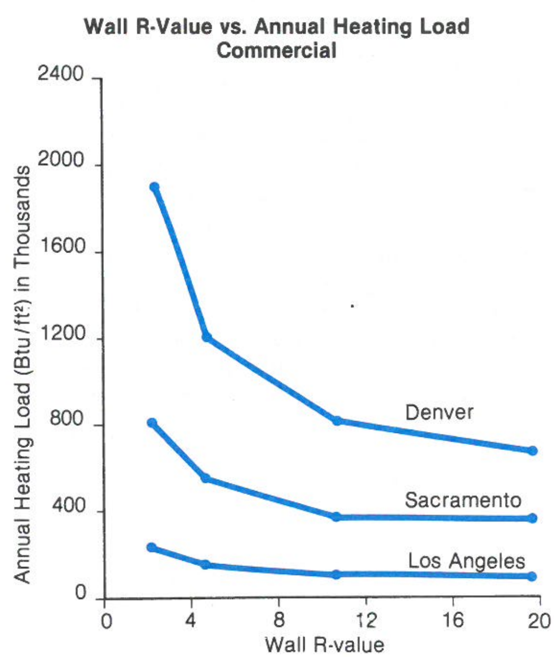
Energy codes: Requirements designed to ensure at least a minimum level of energy performance in buildings.

This *Energy Basics Booklet,* along with the other booklets in the Masonry Energy Information Series, explains the use of masonry to achieve good energy performance and to comply with the energy codes. See Section 5 for more information on the other booklets.

1.2 Walls in the Overall Energy Picture

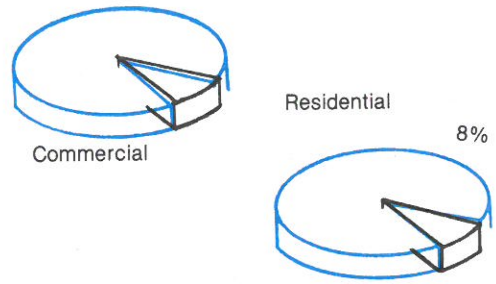
Increased emphasis on energy use in buildings has led many to believe that highly insulated walls are necessary for energy efficiency. It is true that well designed walls save energy costs and improve occupant comfort, but energy performance concerns should not dominate the design and selection of wall systems. Other concerns, such as durability, maintainability and long term value, should be given their due in the selection process.





DIMINISHING RETURNS OF WALL INSULATION. As wall insulation (R-value) increases, the energy savings benefits level out. They are indicated here in terms of annual heating load. Beyond a certain point, heating energy savings are outweighed by the extra costs of the insulation. This point varies depending on building type and location, and on insulation cost.

One way to understand the role of insulation in walls is to look at what would happen if the insulating value of the wall were increased dramatically. The graphs on the previous page show what happens to overall building energy performance as wall insulation (R-value) is increased in two prototype buildings; all other details of the buildings, such as lighting, glazing and roof construction, stay the same. The graphs show results for three climate types. In mild climate locations (Los Angeles, CA), the energy savings from increased wall insulation level out quite rapidly, and the benefits of adding more insulation quickly diminish. In colder climates (Denver, CO), more insulation is beneficial, but the same kind of "diminishing returns" phenomenon occurs.



Walls in the Overall Building Load. These pie charts indicate the portion of the overall building annual energy load due to heat flows through opaque wall surfaces. While wall energy performance should not be ignored, other factors, such as durability, fire resistance and beauty need not be over-shadowed by energy concerns, especially in commercial buildings.

[Pie chart analysis performed on prototype commercial and residential buildings, using the DOE-2.1B computer program (See Section 4.1). Base cases used R-2.5 in commercial walls and R-11 in residential walls. These were compared to runs using R-100 in walls, with all other parameters held constant.]

Walls play a significant, but not commanding, role in the overall energy performance of a building. In cold climates, walls are one of the more important components in reducing heating loads in commercial buildings, usually following the mechanical, glazing and roof systems. In heating residential buildings, the walls are somewhat less important for saving energy. In warmer climates, the roof, windows, internal heat gains, and other components of the building contribute to the cooling energy requirements, but it's the windows that usually let in the most heat.

The accompanying pie charts show the role of walls in the total energy consumption of two prototype buildings. In the commercial building, the opaque wall accounts for about 10% of the total building energy consumption in a moderate climate like Sacramento, CA. Most of this wall-related energy consumption is due to heating loads. Changing wall insulation produces very little change in the cooling load. In colder climates, the wall takes on a larger role because of the increasing significance of heating loads. In a climate like Denver, CO, for example, the wall accounts for about 20% of the total energy consumption. In milder climates, such as Los Angeles, CA, the wall effect drops to a few percent.

For the residential building, the opaque wall accounts for about 8% of the total building energy consumption in Sacramento. This increases to nearly 13% in a Denver-like climate, and decreases to about 3% in mild climates. Again, this is mostly due to the impact of the wall on heating loads.

These findings can help to keep walls in their proper perspective as one element in a building's overall energy performance.

The remainder of this book focuses on the details of how masonry walls contribute to energy efficiency. The information will help in:

- Taking maximum advantage of the energy savings that can be achieved through good masonry wall design, and
- Dealing with energy code requirements for wall construction.

SECTION 2 DEFINITIONS AND CONCEPTS

In order to analyse and understand how masonry walls affect building energy performance, it is necessary to master some basic concepts about heat transfer and masonry materials. These are elementary concepts that may be familiar. This section begins with concepts that together describe the "thermal mass," or heat storing properties of walls. Next is a discussion of the insulating qualities of walls, concluding with a comparison of the annual energy performance of light frame and heavy masonry wall systems.

2.1 Properties of Thermal Mass

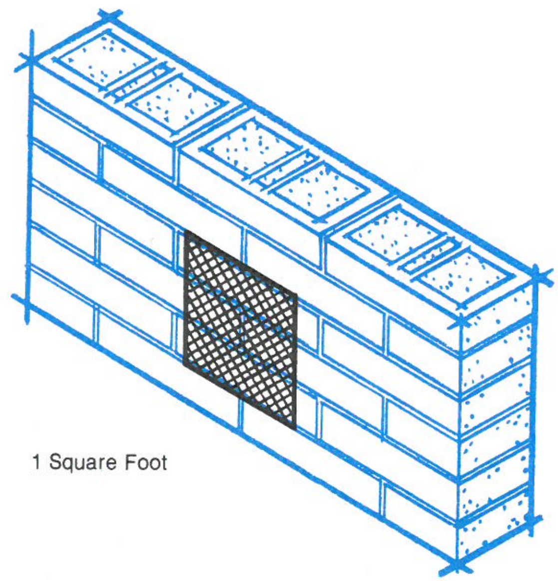
Wall Weight and Density

The *thermal mass* of a wall is directly related to its unit weight. For energy analysis purposes, *wall weight* is expressed in terms of wall surface area; the units are "pounds per square foot" of wall. The weight of a masonry wall is determined by the density of its materials, its physical configuration and its thickness.

Density is a property of the raw material. For example, the clay material used to make typical bricks has a density of about 135 pounds per cubic foot. The density of concrete used to make hollow concrete masonry units varies from 80 to 150 pounds per cubic food. As the material is fabricated into masonry units, the density of the basic material is unchanged, but the density of the finished product can be lower. A cubic foot of concrete block would include the hollow cores as well as the solid material, and so its weight would be lower than that of a cubic foot of solid concrete. The density would therefore be lower as well.

The *thickness* of a masonry wall also affects the wall weight. An 8″ wall is heavier than a comparable 4″ wall. Likewise, the construction of the wall affects its weight, because it can include a combination of materials and layers. Masonry walls are frequently filled with grout and/or insulation, and they are also laid in double wythe assemblies. All of these variations lead to different wall weights and different energy behavior.

A short list of typical wall assemblies in the Wall Properties Table gives some example wall weights. Tables in *Energy Calculations and Data* give the wall weight for many common masonry wall constructions. (See Section 5 for more information.)



WALL WEIGHT. For energy analysis purposes, is measured in pounds per square foot of wall surface area, or lb/ft^2. In practice, the total wall weight is divided by the wall area to obtain the average wall weight. This weight is influenced by the wall construction and by the density of the materials in the wall.

Specific Heat

Specific heat is a property of materials that describes their ability to store heat energy. As a material absorbs energy, its temperature rises. A material with a high specific heat, such as water, can absorb a great deal of heat energy per pound of material, with little rise in temperature. The same weight of a material with low specific heat, such as copper, rises to higher temperatures with only a small quantity of heat absorbed.

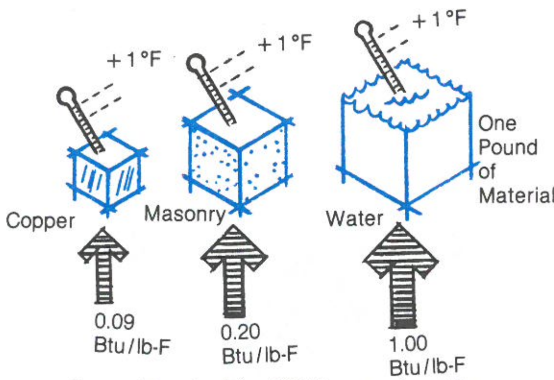
Specific heat is defined as the quantity of heat energy (in Btu) required to raise the temperature of one pound of a material by one degree Fahrenheit. The specific heat of water is 1 Btu/lb-F, or one Btu per pound per degree Fahrenheit. The specific heat of copper is 0.092 Btu/lb-F, less than one-tenth that of water. The specific heat of most masonry materials is around 0.2 Btu/lb-F.

Because specific heat defines the relationship between heat energy and temperature for a given weight of material, it can also be used to determine the change in temperature for a material as it absorbs or releases energy. For example, if a pound of water absorbed 20 Btu, its temperature would rise 20 degrees F. If a pound of copper absorbed the same 20 Btu its temperature would rise 217 degrees F (20 Btu / 0.092 Btu/lb = 217 F).

THERMAL MASS is a non-technical term that refers to heavy materials used in buildings to store heat energy. Interior and exterior masonry walls are a common form of thermal mass. Related technical terms include specific heat and heat capacity.

DENSITY is the weight per unit volume of a material, measured in units of pounds per cubic foot, or lb/ft^3. For two material samples of equal weight, the denser material will occupy a smaller volume. For two samples of the same volume, the denser will weigh more.

THICKNESS of a masonry wall, for energy analysis purposes, should be the actual thickness of the material rather than the nominal thickness. For example, a nominal 6″ hollow concrete masonry unit is actually 5-5/8″ thick.

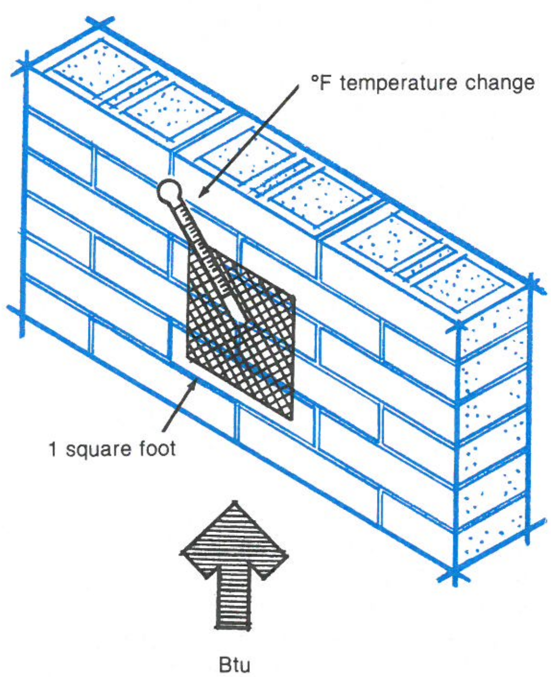


Energy Required for 1 °F Temperature Rise

SPECIFIC HEAT. Different materials have different abilities to store heat. Specific heat is the amount of heat required to raise the temperature of one pound of a material by one degree Fahrenheit, in units of Btu/lb-F.

Heat Capacity (HC)

The heat capacity of a wall is like the specific heat, in that it defines the energy required to raise the wall temperature one degree, but it is expressed in terms of wall surface area rather than pound of material. HC, then, is the amount of energy required to raise the temperature of one *square foot* of wall by one degree Fahrenheit, or Btu/ft²-F. It is found by multiplying the wall weight by the specific heat.



HC (HEAT CAPACITY) is the amount of energy that is stored in a square foot of wall area for each degree of temperature change, or Btu/ft²-F.

STEADY STATE HEAT FLOW is the rate of heat flow across a wall or other building assembly, under constant or long term average temperature conditions. It is comparable to the average heat flow over time.

HC is sometimes called "areal" heat capacity, in reference to area measurement, to distinguish it from "volumetric" heat capacity, which is the heat capacity per cubic foot, or Btu/ft³-F. In this sense, HC is a special term, but it is widely used in energy codes, as discussed in the other booklets in this series (see Section 5 for more information).

Wall Properties Examples

TABLE 1: WALL PROPERTIES

Wall construction	Weight (lb/ft²)	Heat Capacity (HC)	U-value (Btu/h-ft²-F)
4″ studs, plywood, gyp. board, R-11	6.42	1.76	0.093
Brick veneer over 4″ stud wall, R-11	41.0	8.54	0.104
8″ hollow clay, reinf. @ 48″ o.c.	49.7	9.94	0.43
8″ hollow conc. solid grouted	81.0	15.3	0.69
12″ hollow conc. ungrouted	57.0	11.6	0.45

This table shows how some common wall constructions compare in terms of wall weight, HC and U-value (see Section 2.2 for a complete discussion of U-value).

2.2 Steady State Heat Flow: U-values and R-values

One way to describe the energy characteristics of a building is in terms of the *steady state heat flow* into or out of the building. It is called *steady state* because it assumes that all the temperatures are held constant, and the heat flows at a steady rate. It is characterized by U-values and R-values.

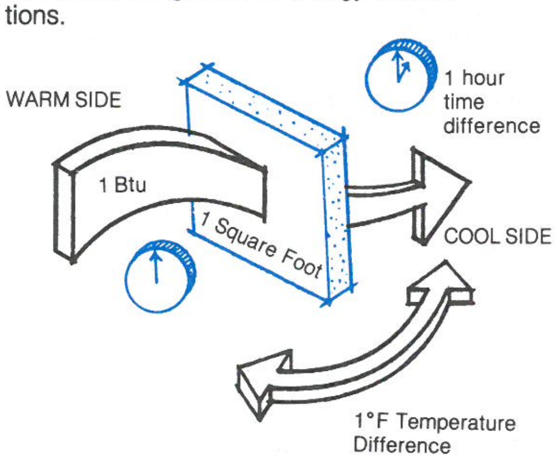
Steady state heat flow is a simplification, because in the real world temperatures change constantly, but it is reasonably accurate for describing average heat flow rates over time, and is useful for many purposes. For example, heating equipment is commonly sized using the steady state heat flow out of a building during peak heating conditions. Many energy codes specify minimum building insulation levels in terms of steady state heat flow. Because they are so useful, the terms for steady state heat flow are part of the basic vocabulary of building energy performance.

U-value

The *U-value* describes the rate of steady state heat flow through a single building assembly, such as a wall or a roof. It is the amount of heat flowing per hour through one square foot of the assembly, for every degree of temperature difference between the inside air and outside air, in units of Btu/h-ft^2-F. The heat flow can be in either direction; it can be heat loss from the building or it can be heat gains.

Each of the elements of the building assembly, such as sheathing and insulation, has its own *conductance,* or rate of heat transfer. The conductance is like the U-value, and it has the same units, but it is only for a single element.

The U-value includes the conductance of every element of the building assembly, including the surface conductances (air films) on the interior and exterior faces of the assembly. These surface conductances quantify the rate at which heat is transferred between the surface of the assembly and the surrounding environment. They contribute to the overall insulating qualities of a wall or roof in a significant way, and so cannot be ignored in energy calculations.



U-VALUE is the "thermal transmittance" of a building assembly. It is the number of Btu of heat energy transmitted through a square foot of building assembly per hour, for every degree of temperature difference between interior and exterior. It applies to the entire wall assembly, including surface conductances. *Smaller U-values mean less heat flow.*

The U-value expression tells a good deal about the building assembly. It says that the heat flow rate is proportional, and directly related, to the area, time and temperature differences experienced by the assembly. For example, if the U-value is cut in half, only half as much heat will flow through the building assembly (assuming a constant temperature difference). We can also use the U-value to calculate the total heat flow through a large wall or over a period of time.

For light frame walls, the steady-state U-values provide an adequate description of heat transfer between interior and exterior. For heavy masonry walls, however, this is only true under constant or average temperature conditions. The dynamic heat storage properties of the masonry alter the thermal behavior of the wall, and the U-value alone is insufficient to predict the heat flow rate over short time periods. (See Sections 2.3 and 2.4.)

***CONDUCTANCE** is the conductivity for a given thickness of material, in Btu/h-ft^2-F.*

***CONDUCTIVITY** is the rate at which heat is conducted through a one inch thick layer of the material, in terms of Btu per hour per square foot of material per degree F temperature difference, or Btu-inch/h-ft^2-F.*

It is sometimes useful to go beyond the U-value of a single building assembly and to calcuate the *overall U-value,* U_o, of a building component. This is the heat flow rate for an average square foot of the entire component. For example, a building wall component may include windows, doors and different opaque wall areas. Each has its own U-value, and they can be averaged into an *overall U-value* for the building wall. This is done with an area weighted averaging technique.

***OVERALL U-VALUE,** U_o is the average rate of heat flow through a building component having more than one type of assembly. It is the area weighted average of the individual assembly U-values.*

It is also useful to know the heat flow rate through the entire area of the building component, rather than just through a unit area. To find this rate, the area of the component is multiplied by its U_o, to arrive at the *UA-product.* The UA-products for all building components can be added together to get the building UA, which is the overall heat loss (or heat gain) rate from conduction through the envelope, in units of Btu/h-F. This is frequently done to determine design heat loads in buildings. The building UA multiplied by the design temperature difference is the design heat load for conducted heat losses.

***UA-PRODUCT,** or simply UA, is the U-value times the area for a building component. The sum of all component UA's is the building UA.*

R-value

R-values are also used to describe steady-state heat flow, but in a slightly different way. Rather than the rate of heat flow, R-value is the thermal resistance to heat flow of a building assembly. Thus, a larger R-value has a greater resistance, or more insulating capacity than a smaller R-value.

***R-VALUE,** or thermal resistance, is the resistance to heat flow of a building element, such as sheathing or insulation. Units are: ft^2-h-F/Btu.*

The primary advantage of R-values is that they can be added together for layers of materials. This cannot be done for U-values.

To obtain the *total R-value,* R_t, for a building assembly, the R-values of the individual layers are simply added together. These include the R-values of the sheathing and

***TOTAL R-VALUE,** or R_t is the sum of R-values for each element (layer) of a building assembly, including the surface conductances. Total R-value is therefore the inverse of U-value: $R_t = 1/U$. Same units as R-value.*

finishes, the insulation and weatherproofing elements, and the surface resistances. R_t is the inverse of the U-value because it includes all of these elements. The U-value is derived from R_t by taking the inverse: $U = 1/R_t$. In practice, it is not quite so simple, but the principle still applies. Refer to the *Energy Calculations and Data* for full details (see Section 5 for more information).

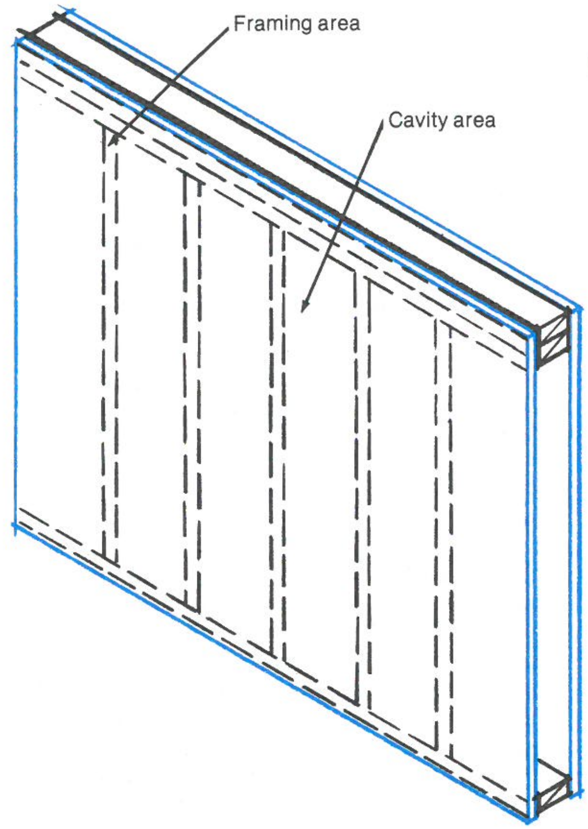
The R-value expression has become widely recognized in the building industry because it is also used to describe simple insulation effectiveness. For example, insulation with an R-value of 11 (R-11) is commonly used in walls. This is not the total R-value (R_t) of the wall, however. It only describes the thermal resistance of the insulation material. The R_t for the entire wall assembly can be significantly lower because of framing effects.

Framing Effects

Many building assemblies are composite constructions. For example, a wood stud wall includes cavity areas where there is insulation between the interior and exterior sheathing elements, and some areas where there are solid wood studs. The wood areas have a higher thermal transmittance, and conduct heat more readily, than the insulated areas. It is misleading to neglect the wood studs when calculating the U_o for the wall assembly, and to use only the insulated cavity area U-value. The correct U_o lies somewhere between the individual U-values for the insulated portions and the solid stud portions of the wall.

In calculating the U_o for a wall assembly, then, we use the *framing fraction,* which tells what fraction of the total wall surface area is taken by solid studs. The framing fraction can become quite important when there is a large area of framing in a building assembly, or when the framing is highly heat conductive. In these cases, the U_o and the wall heat loss are significantly higher than those of the insulated wall areas alone.

The negative effects of framing can be reduced by placing a continuous layer of insulation on the assembly. Insulating wall sheathing for example, covers both cavity and stud areas. It is more effective in reducing overall heat transfer through a wall than a comparable amount of insulation placed in the cavities alone. This same principle applies to masonry cavity walls and hollow masonry units.



FRAMING FRACTION is the fraction of the assembly surface area occupied by framing. The remainder of the area is occupied by wall cavity.

TABLE 2: FRAMING EFFECTS

Type of framing	R-11 cavity insul.	R-19 cavity insul.
No framing (cavity)	13.16	21.28
Wood @ 24″ o.c.	8.68	12.14
Wood @ 16″ o.c.	8.36	11.39
Steel @ 24″ o.c.	6.61	8.64
Steel @ 16″ o.c.	5.50	7.68

This table shows the effects on R-values of different types of framing in reducing the effectiveness of wall insulation in framed walls. The more framing there is in the wall, the lower the R-value and the greater the heat loss. Highly conductive steel studs reduce the R-value even further. A steel stud @ 16″ o.c. wall has only one-third the thermal resistance as the R-19 insulated wall cavity.

[Source: California Energy Commission Energy Efficiency Manual for the 1985 Office Standards.]

Masonry Wall U-values

Masonry walls present some of the same problems as frame walls when it comes to calculating R-values and U-values. Many masonry walls are hollow, with *cores and webs* connecting the inside and outside surfaces. Furthermore, some of the cores are usually filled with reinforcing and solid grout. Over the face of the wall, there are significant areas that are solid and hollow, and each has a different thermal transmittance.

The U-value of a masonry wall can be calculated in much the same way as a framed wall, using a "framing fraction" approach, but this introduces some inaccuracies because masonry materials are more thermally conductive than wood studs. In the real world, heat flows sideways as well as through the wall, and the approach needs to account for that. The *Energy Calculations and Data* (see Section 5) presents ways to deal with these problems, and also provides extensive data tables of rigorously calculated U-values and R-values for masonry walls.

2.3 Temperature Damping and Thermal Lag

Masonry exterior walls act as thermal dividers between conditioned interior space and the outdoor environment, in addition to performing the other functions of walls, such as holding up the roof and keeping out rain. Their thermal function is complex, because heat is:

- absorbed from solar radiation and hot air,
- radiated to cold skies and transferred to cool air,
- conducted to the interior,
- stored within the walls, and
- absorbed from and released to the interior.

The directions and magnitudes of these heat flows are constantly changing in the environment, and the amount of heat stored and released within the masonry wall changes accordingly.

Temperature damping is a characteristic of masonry walls that describes the way exterior temperatures and heat flows affect the interior of a building. For example, in the summertime, the temperature on the outside surface of a wall fluctuates widely, from a high temperature during the sunny midday to a low temperature in the middle of the night. This can be thought of as a temperature "wave." The inside surface of the wall, however, will experience a much smaller temperature fluctuation or wave. One says that the wall "damps," or reduces the amplitude of the temperature wave. The narrower temperature fluctuation on the interior means that the cooling loads are lower, and the inside of the building is more comfortable.

Heat capacity plays an important role in temperature damping. If a wall has very little heat capacity, the degree of damping depends only on the amount of insulation in the wall. If, however, the wall is massive, the damping depends on both the insulation and the heat capacity. For two walls with the same insulation value, the more massive wall will display greater temperature damping characteristics.

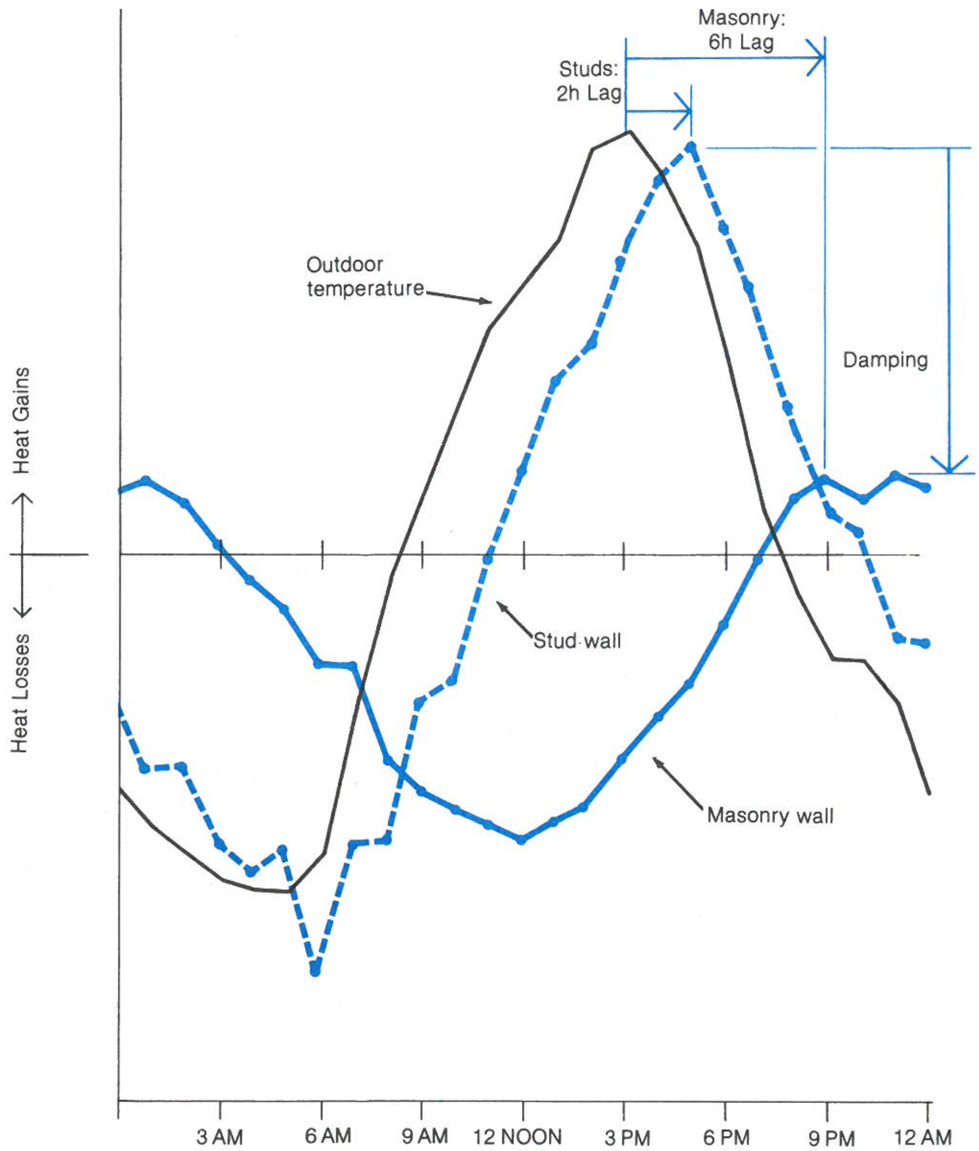
Another result of heat capacity in walls is that the time of peak temperatures and heat gains on the interior is delayed, compared to the peak times on the exterior. This phenomenon is called *thermal lag.* With masonry walls the time of highest interior temperature will be three to eight or more hours later than the time of highest exterior temperatures. As a result, peak cooling loads can be delayed to cooler times of the day when the air conditioning equipment operates more efficiently, or when the building is unoccupied and not air conditioned at all.

Taken in combination, temperature damping and thermal lag can produce a significant change in the cooling (or heating) loads in a building. In the example, the *average* heat flow into the building is nearly the same for the two walls. However, the peak heat gains (and losses) are very much lower for the masonry wall, and the time of peak heat gain is delayed to the cooler evening hours. As a result, the masonry wall can be more energy efficient, despite the fact that it has a somewhat higher thermal transmittance than the stud wall. These savings depend on climate, and do not occur in all locations, but the broad conclusion is valid for most of the less extreme climate conditions in the U.S.

***CORES AND WEBS** in hollow masonry units conduct heat at very different rates. Because concrete and clay are relatively good conductors of heat compared to air, the continuous webs carry a disproportionate amount of heat between the two faces of the masonry unit. A proper analysis of heat flow through masonry walls must account for this complex phenomenon.*

***THERMAL LAG** refers to the difference between the time of peak heat flow on one side of a wall and the time of peak heat flow on the other side.*

***TEMPERATURE DAMPING** refers to the reduction in amplitude of the temperature wave. As the wave passes through a wall, the difference between the maximum and minimum temperatures is reduced.*



TEMPERATURE DAMPING AND THERMAL LAG. This graph compares an insulated stud wall to a masonry wall of comparable insulation value. It shows, for a typical sunny day, when the heat gains and losses for the interior space are highest. The stud wall has a peak gain at 5 p.m. This is lagged two hours behind the outdoor temperature peak. The masonry wall has a time lag of six hours, with the peak occuring at 9 p.m. There is also considerable temperature damping with the masonry wall, as shown by the fact that peak energy flows are only about half those of the stud wall.

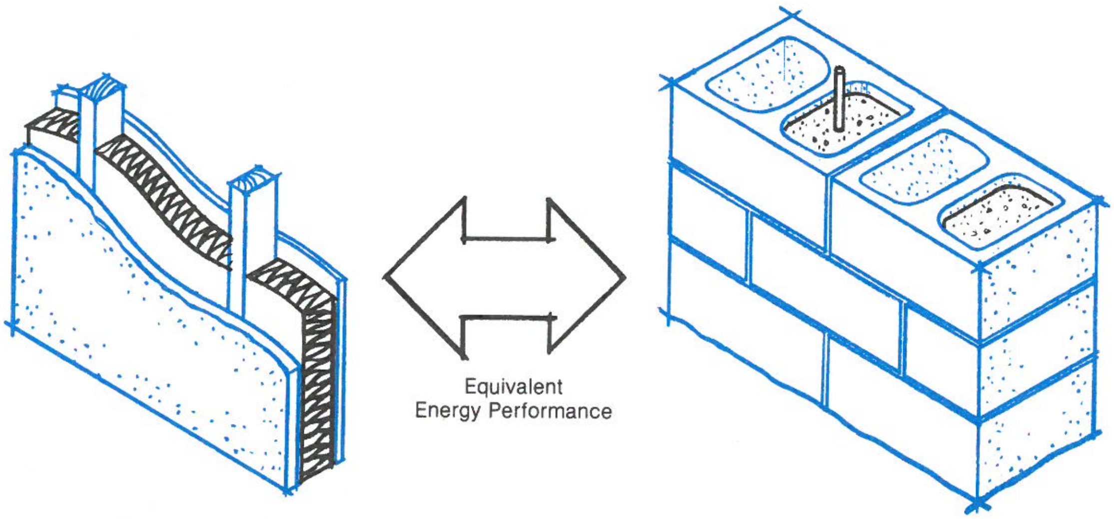
[Stud wall is 2 × 4's @ 16″ o.c. with R-11 insulation and U = 0.09. Masonry wall is insulated cavity wall with brick exterior wythe, 6″ concrete block interior wythe, and 2″ of loose fill cavity insulation with U = 0.11. Data based on calibrated hot box measurements (Reference 10)].

2.4 Comparison of Light Frame and Heavy Masonry Walls

A complete comparison of the thermal performance of light frame and heavy masonry walls must take into account the temperature damping and thermal lag behavior of the heavy wall material. Because temperatures fluctuate widely, this is a dynamic phenomenon, and a simple, steady state comparison of the U-values of light and heavy walls is misleading. A better comparison would calculate the annual heating and cooling loads on a building with light walls, and then again with heavy walls.

Such a series of detailed computer studies of building energy performance, using an analysis program that accounts for the variables of weather, building occupancy and thermal mass behavior, has been performed by the California Energy Commission (CEC) in the development of its new energy code for nonresidential buildings.

The basic conclusion from these CEC studies is that thermal mass reduces the need for thermal resistance (R-value) in walls. In other words, a masonry wall does not require as much insulation as a light frame wall to develop the same level of performance. This is primarily because the temperature damping and lag effects of thermal mass reduce the cooling loads in the building. The two different wall assemblies shown in the figure below would result in the same total loads in a building. This is despite the fact that the masonry wall has a higher U-value (heat loss), and less insulation, than the comparable frame wall.



LIGHT FRAME WALL VERSUS HEAVY MASONRY WALL. These two wall assemblies have very different insulation levels, yet they produce equivalent annual energy use in a typical commercial building in Los Angeles. This is because of the heat capacity of the heavier wall, which damps the temperatures and lags the heat gains to the interior.

[Source: California Second Generation Non-Residential Energy Code, Alterative Component Package for Low-Rise Office Buildings, climate zone #9, Package A. Frame wall is plywood siding, 2 × 4 studs @ 24″ o.c., R-11 insulation, gypsum wallboard; U = 0.087, R_t = 11.53, HC = 1.67. Masonry wall is 12″ hollow concrete masonry, 135 pcf, grouted vertically @ 16″ o.c., horizontally @ 48″ o.c.; U = 0.44, R_t = 2.25, HC = 20.6]

SECTION 3 INSULATING MASONRY WALLS

The temperature damping and thermal lag effects in masonry walls come from maximizing thermal mass. Solid grouted walls are the most common way to do this. The thermal behavior of exterior masonry walls can also be modified and controlled by adding insulation to the wall assembly. This may be desirable because of certain energy code requirements, or to fine-tune building energy performance in a specific situation.

There are a variety of techniques for insulating masonry walls, and each has advantages and disadvantages. There is no "best" technique. The choice will depend on many factors, including the wall system, building design and installation cost of the insulation.

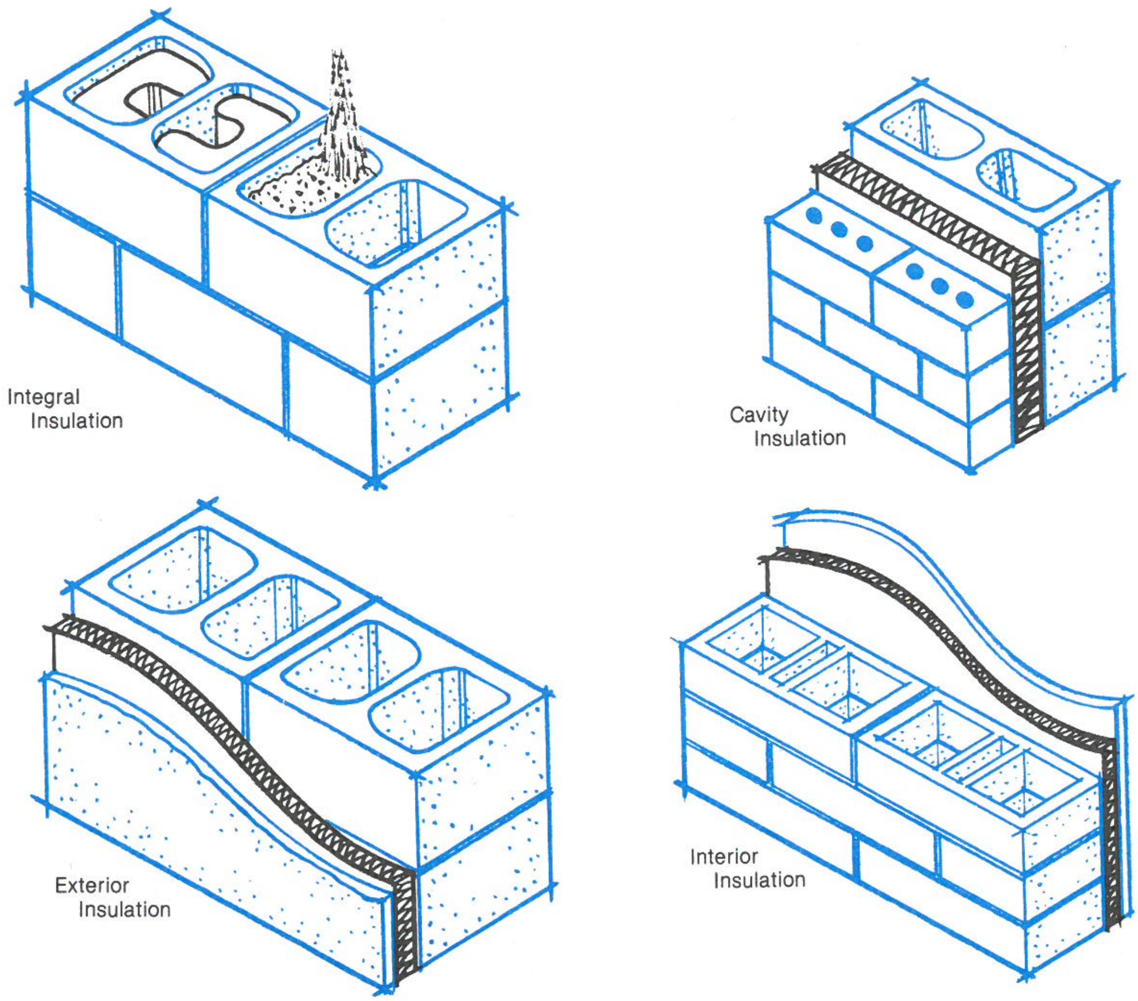
3.1 Integral Insulation

Hollow masonry units have dead air spaces built-in, and these provide some insulating capacity to the wall. This can be enhanced by adding insulating material to the cores.

Advantages:
- Masonry wall surfaces unaffected
- Least expensive insulating technique

Disadvantages:
- Not a continuous insulation layer
- Amount of insulation limited by open core area

There are a number of integral insulation products available. Perhaps the most common are the loose-fill types, which are poured into the cores. A variation of this is foamed-in-place core insulation. Other products are in the form of inserts which are placed into the cores of the masonry unit. There are also special masonry units on the market which permit high levels of integral insulation.



BASIC MASONRY WALL INSULATION TECHNIQUES. Masonry wall insulation can be made integral to the wall, either by filling the hollow cores or by using cavity wall construction. It can also be applied to the exterior or interior surfaces of the wall, followed by a finish surface to protect the insulation.

3.2 Cavity Insulation

In masonry cavity wall construction, an insulation layer can be built into the wall between the wythes of masonry. Insulation thickness can be as much as desired.

Advantages:
- Masonry wall surfaces unaffected
- Continuous insulation layer

Disadvantages:
- Cavity wall construction is expensive
- Complicated by structural wall tie details

This technique typically uses board insulation placed during wall lay-up, but loose fill and foamed-in-place insulation products are also used.

3.3 Interior Insulation

In many masonry wall applications, it is desirable to add an interior finish surface other than the masonry. This provides an opportunity to incorporate an insulation layer between the masonry wall and the finish surface. Depending on the thickness of the furring, any amount of insulation can be added in this manner.

Advantages:
- Wide variety of insulation and finish choices
- Can provide space to run wires and other utilities

Disadvantages:
- Isolates thermal mass from interior spaces
- Covers the durable masonry wall surface

Typically, the systems employ wood or metal furring strips attached to the masonry wall, with batt or board insulation placed between the strips, and a finish surface (drywall, paneling, plaster, etc.) fastened on top of the strips. Many manufacturers offer insulation and furring systems for this application, with a wide variation in features and costs.

3.4 Exterior Insulation

Exterior insulation systems generally employ a layer of insulation applied to the masonry wall surface, and protected from the elements by a weather skin.

Advantages:
- Possibility of a different appearance to the wall
- Thermal mass is located inside the insulation layer

Disadvantages:
- Durable masonry weather surface is covered
- Generally the most expensive insulation technique

There are several exterior insulation systems on the market. Insulation is fastened to the masonry either mechanically or with adhesive. Weather surface is typically a modified cement stucco material, but can also be a panel material. As with all elements of the weather skin, proper detailing is important to keep water from penetrating the building.

SECTION 4 ENERGY DESIGN INFORMATION

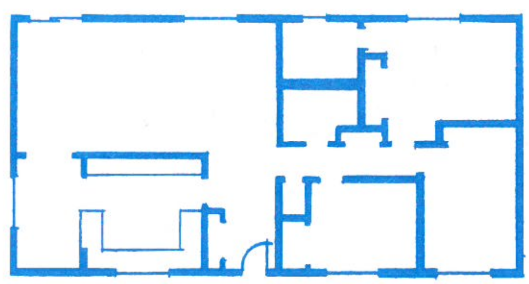
The following sections provide some specific information on how masonry materials and thermal mass affect the energy performance of buildings. They are intended to provide both general knowledge and specific guidelines about how to use masonry in buildings to achieve energy efficiency.

4.1 Background Information

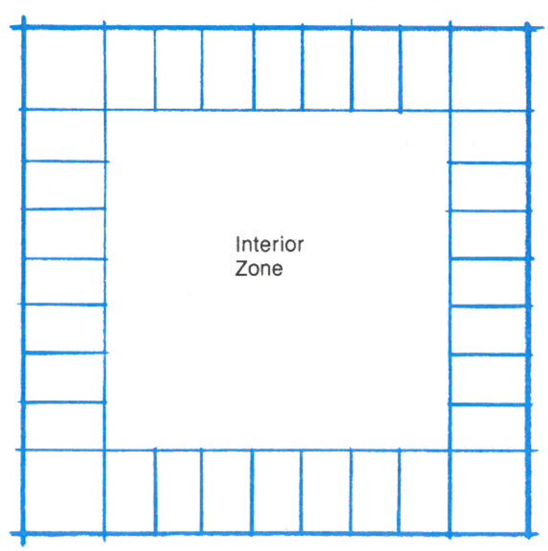
The information in this section is based on a series of studies of building energy behavior, performed by a sophisticated computer program (DOE-2.1B) which simulates the hourly energy use of buildings over the course of a typical year, under changing weather and operating conditions. Each of the studies was performed for two buildings, a prototype residential and a prototype commercial building, and for three different climate types.

The two prototype buildings represent typical examples of their construction type. They have been used widely in energy studies because they are similar to many buildings across the country.

In the commercial building, only one floor was modeled. It was assumed that this floor was a mid-floor in a multi-story office building, with no thermal transfer between floors, which is a realistic assumption for multi-story buildings. This modeling simplification allowed extensive parametric analysis and produces useable results. The vertical windows were modeled as a continuous strip in the exterior wall of each perimeter zone.



The prototype residence is a one-story, 1540 ft², ranch house. It has double pane glass area equal to 15% of the floor area. The house was modeled as a single thermal zone, with wood frame walls and a slab-on-grade floor.



The prototype commercial building is a single story, generic office building module, with an internal core area of 100 feet by 100 feet surrounded by a perimeter zone 15 feet deep on each orientation. The total area of this typical floor is 16,000 square feet.

ANNUAL HEATING AND COOLING LOADS describe the amount of energy that must be added or removed from a space during a year of operation in order to maintain desired temperature conditions. These loads include the effects of heat gain and loss, stored heat, internal heat gains, solar gains, etc. They do not consider mechanical system performance, energy costs or other measures of building energy performance.

The three different climate types used in the analysis were chosen to represent a range of severity. The mildest climate is that of Los Angeles, CA. Sacramento, CA is a moderate climate. Denver, CO is the coldest of the three climates, yet requires summer cooling.

4.2 Exterior Walls

In the following sections, the results of the analysis are presented. They compare the behavior of masonry walls under different combinations of climate, occupancy, insulation and heat capacity. The information is intended to help designers use masonry more efficiently in exterior walls.

Heat Capacity and U-value

Section 2 presented the concepts of heat capacity and thermal transmittance (U-values). It also pointed out that U-values alone are poor indicators of masonry wall energy performance.

The "Heat Capacity and U-value" graphs on pages 18 and 19 compare energy performance, as measured by the annual heating and cooling loads of typical residential and commercial buildings. The graphs show how these loads are affected by wall heat capacity and U-value.

The first set of graphs is for the prototype residential building, with cooling loads on the left and heating on the right. The second set is for the prototype commercial building. Three representative cities, Los Angeles, Sacramento and Denver were used. All graphs assume integral insulation position.

There are several general conclusions to be drawn from the graphs:

- If you hold the wall U-value constant and increase heat capacity, the annual loads will diminish.
- This effect depends on climate and type of load. In the Sacramento climate, for example, the cooling load drops more with increasing heat capacity, than in the more severe Denver climate.
- For both building types, heat capacity has a greater effect reducing cooling loads than heating loads.
- The Sacramento cooling graphs show a substantial load reduction with increasing heat capacity. This can be accounted for by the large day/night temperature variation in that climate type, which works well with thermally massive exterior masonry walls. For the other climate types, the same effect is apparent, but is more obvious in the commercial buildings, which are unoccupied in the evening and nighttime hours.

The graphs express the benefits of heat capacity in terms of heating and cooling loads. In order to translate these into energy costs, it would be necessary to account for heating and cooling system efficiencies, and costs of fuel and electricity.

The following graphs can be used to study alternatives in wall design, although the results will be approximate. Suppose one wanted to compare some alternative wall constructions in terms of annual performance. Assume the project is a commercial building located in Sacramento.

The U-value and heat capacity for some different wall assembly options is first determined. The graphs are then used to estimate annual heating and cooling loads. The sum of these loads is the total annual load, and provides a basis for comparing the alternative wall assemblies.

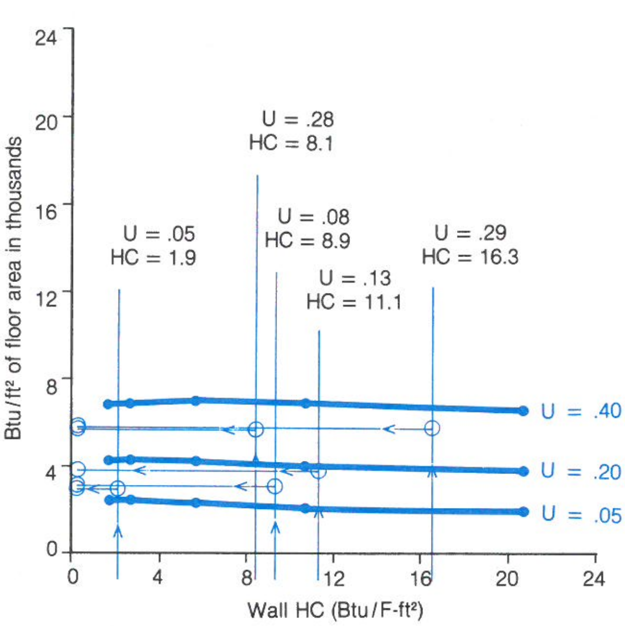
TABLE 3: EXAMPLE RESULTS

Wall Assembly	HC	U	Cooling Load	Heating Load	Total* Load
6″ wood studs, R-19	1.9	.05	22	4	26
Brick veneer, R-11 wd. studs	8.9	.08	21	4	25
8″ hollow con. w/perlite	8.1	.28	21	7	28
6″ solid grout hollow clay + R-6 interior	11.1	.13	21	5	26
8″ solid grout hollow conc. + R-2 exterior	16.3	.29	20	7	27

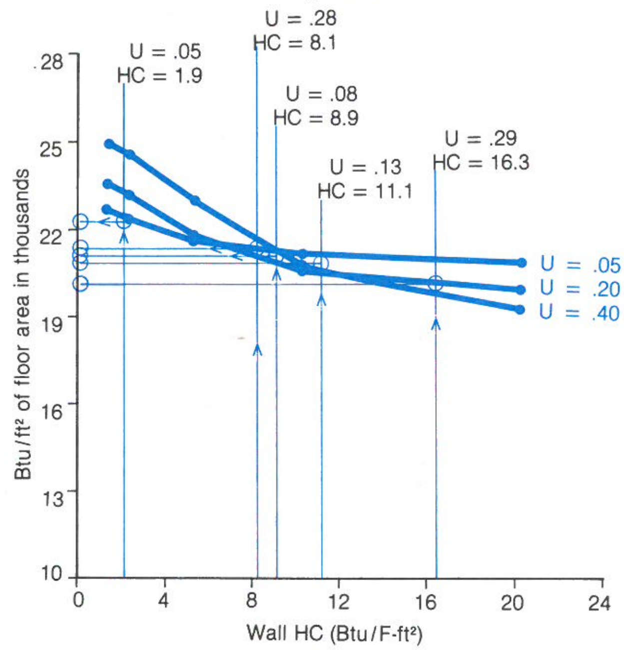
* All loads are in thousands of Btu/year, per square foot of building floor area

The HC and U-values for the alternative wall constructions in this table were plotted on the graphs below to find the annual heating and cooling loads. These graphs are for the commercial prototype in the Sacramento climate. They were excerpted from the following set of graphs.

Annual Heating Load vs. Wall HC



Annual Cooling Load vs. Wall HC



In the example, all the alternative walls have similar total loads, despite the fact that they differ greatly in HC, U-value and physical characteristics. The 6″ wood stud wall contains R-19 insulation and is quite lightweight, yet its performance is comparable to the 6″ solid grouted hollow clay masonry wall with R-6 insulation. The two walls will be very different in terms of fire ratings, STC sound ratings and structural capabilities, surface finishes, cost and durability.

Similar comparisons can be made for other wall types, for other occupancies, in other locations. This is useful for preliminary design decisions. More rigorous analysis can be used to more completely study construction alternatives.

Insulation Position

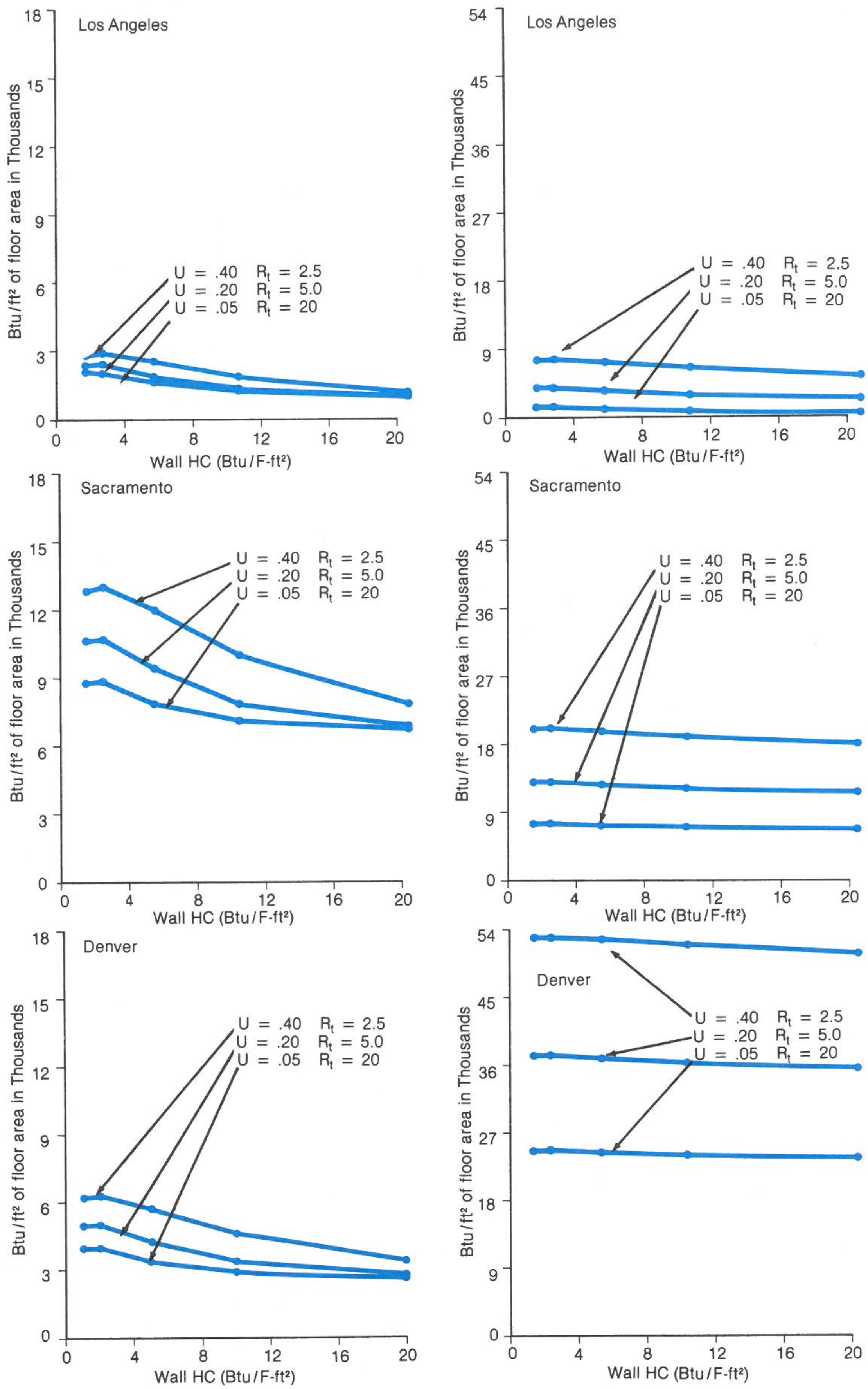
The basic techniques for insulating masonry walls, if that is desired, were discussed in Section 3. From an energy point-of-view, there are three basic choices of insulation position: interior, exterior or integral (cavity insulation is a variation of integral). In some climates, there are energy performance differences between these alternatives, as well as the advantages and disadvantages discussed earlier.

Within each of the three alternatives, the performance of insulation systems may vary. For example, a furring system with wood furring strips would have a greater thermal bridging effect than a non-furred system. These differences may be analyzed in detail using the methods found in the *Energy Calculations and Data Booklet* (see Section 5).

For the present purpose, the insulation systems have been generalized to compare the energy performance differences between the three basic insulation positions.

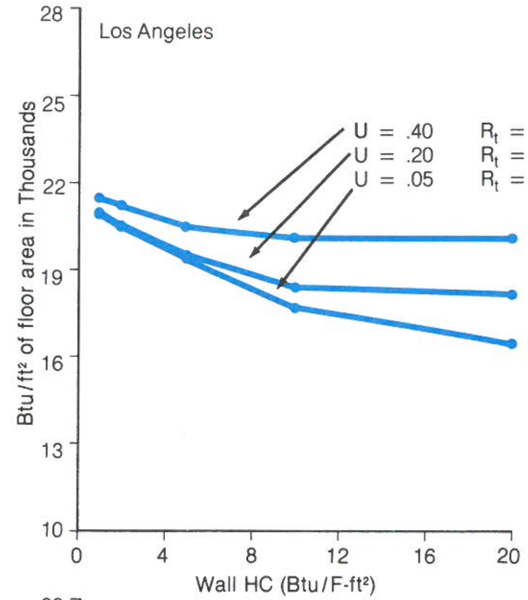
Heat Capacity and U-Value
Residential

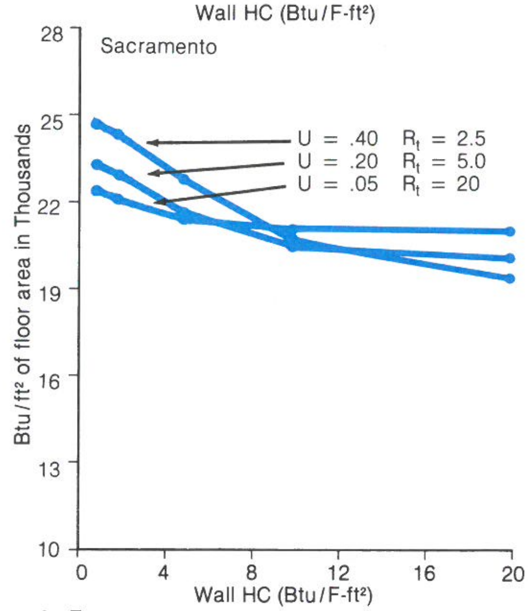
Annual Cooling Load vs. Wall HC | **Annual Heating Load vs. Wall HC**

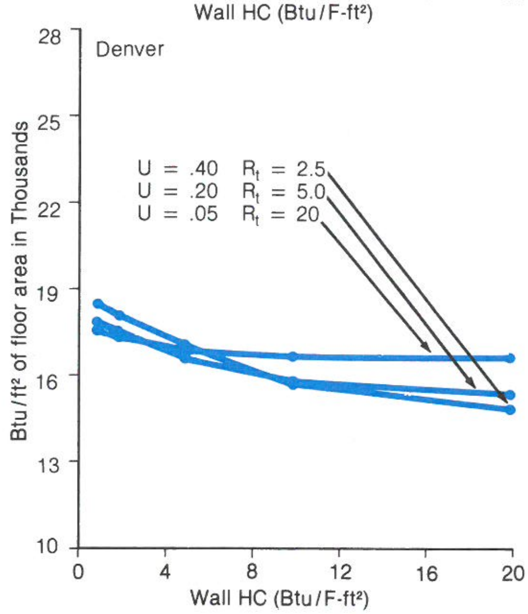


Heat Capacity and U-Value
Commercial

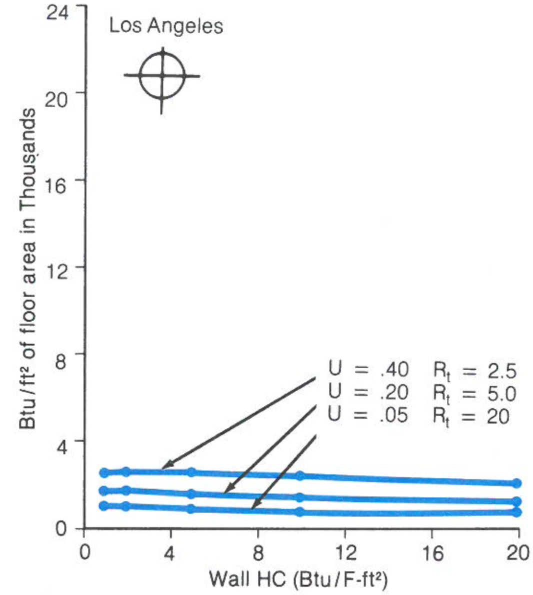
Annual Cooling vs. Wall HC

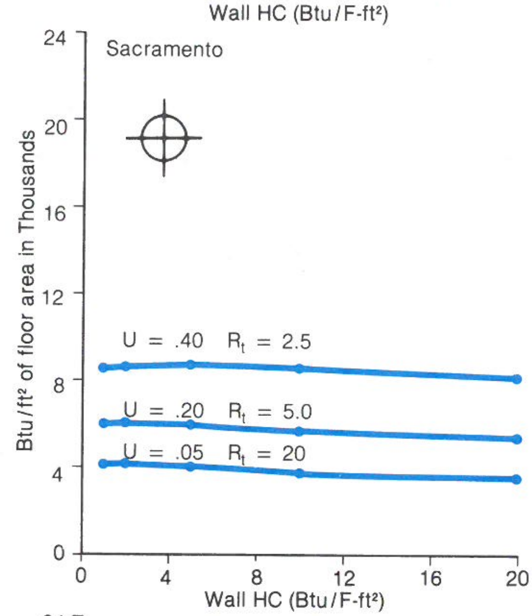


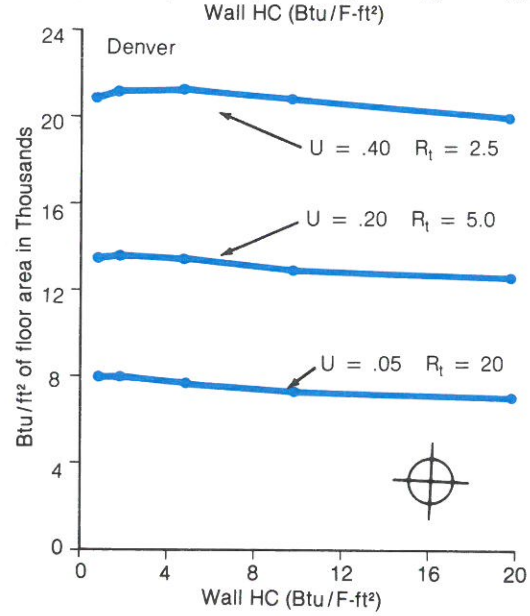




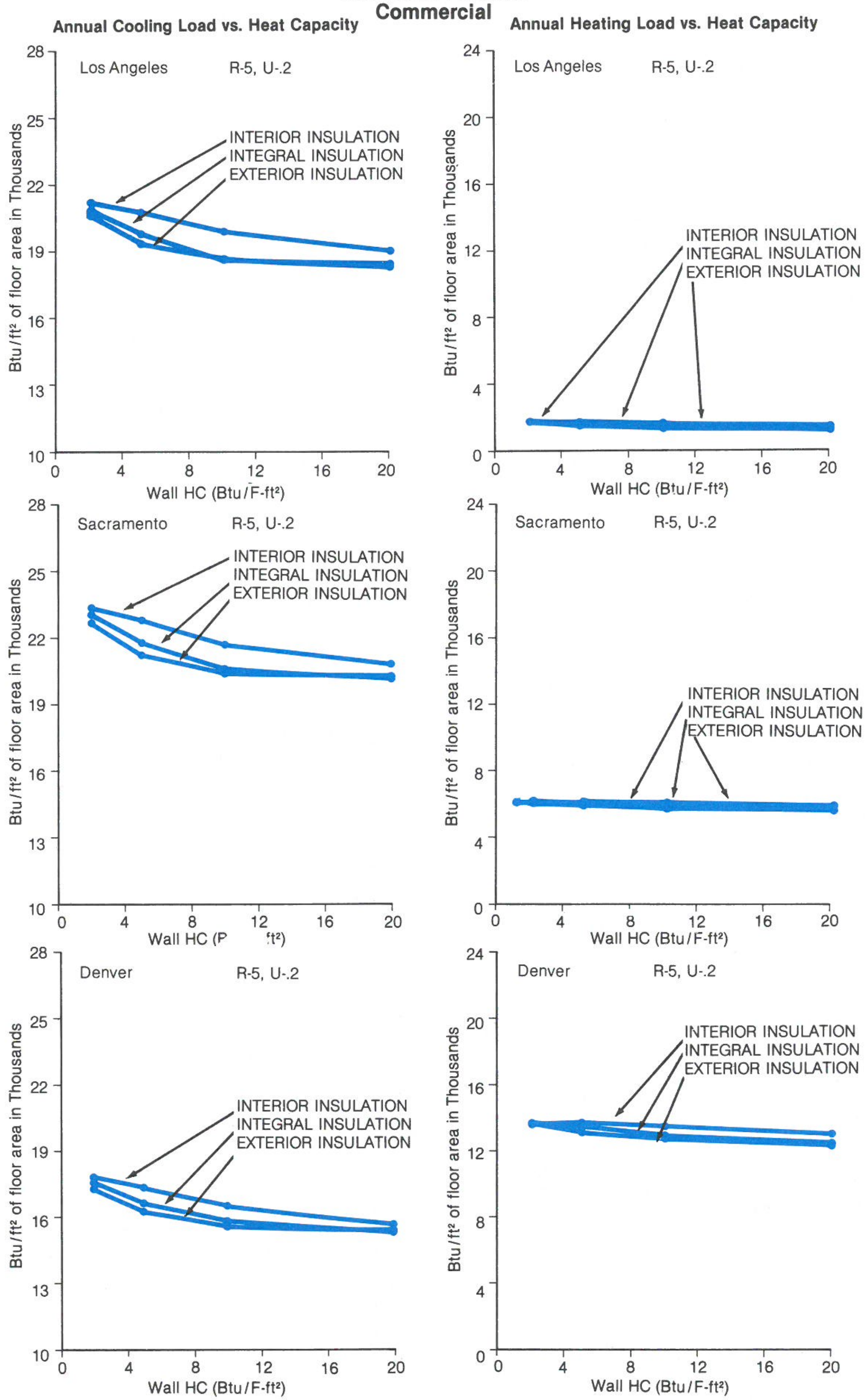
Annual Heating Load vs. Wall HC







Insulation Position
Commercial



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