



TECHNICAL NOTES on Brick Construction

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Technical Notes 43D - Brick Passive Solar Heating Systems - Part 4 - Material Properties Reissued September 1988

Abstract: The inherent properties of brick masonry make it one of the most advantageous storage media materials for passive solar energy systems. Brick masonry may be used to provide an aesthetic effect, structural capacity and other design considerations in addition to thermal storage. Most of these inherent properties of brick masonry are already well understood for conventional applications. However, in order to properly use brick masonry as a thermal storage media for passive solar energy systems additional information may be needed by the designer. This additional information has to do with the effective thermal storage of brick masonry.

Keywords: absorptivity, brick, density, emissivity, energy heat transfer, masonry, material properties, passive solar energy systems, reflectance, solar radiation, specific heat, temperature, effective thermal storage, thermal conductivity, thermal diffusivity.

INTRODUCTION

Brick masonry can be used most advantageously as the thermal storage media in direct gain systems, thermal storage wall systems and attached sunspaces. The general concepts, empirical procedures for sizing systems and performance calculations are discussed in Parts I through III of this *Technical Notes Series*. This *Technical Notes* provides information and references regarding the material properties of the basic components of passive solar energy systems. This information includes the properties of brick masonry when used for thermal storage, with major emphasis on the effective thermal storage of brick masonry and a general discussion of the properties of glazing materials when used as collectors.

BRICK MASONRY

General

Most of the design requirements and performance of brick masonry as a general building material are discussed in other *Technical Notes*. The inherent properties of brick masonry offer many design advantages in addition to those required for use as a thermal storage material.

Structural

Brick masonry has many applications as a structural element in buildings. Brick masonry is commonly used as loadbearing elements in commercial and residential structures. Brick masonry when considered as a thermal storage media for passive solar energy systems may also be considered as a structural element. Information on loadbearing brick masonry is provided in *Technical Notes 24 Series*.

One of the reasons brick masonry is less frequently considered as a structural element in one and two-family construction is because of the difficulties in insulating solid masonry walls to meet prescriptive energy code requirements for the reduction of heat loss. This can be overcome by using loadbearing insulated cavity walls which provide a durable facade, sufficient space for insulation and interior brick masonry which may be used as thermal storage in direct gain systems. Cavity wall construction is addressed in *Technical Notes 21 Series*.

The structural design may require reinforced brick masonry. Reinforcement in brick masonry usually has little if any effect on the thermal performance of the wall. This is because the reinforcement is usually horizontal and/or vertical in the plane of the wall, and occurs at or near the center of the wall section resulting in very little increase of thermal transmission through the wall. Information regarding reinforced brick masonry is provided in *Technical Notes 17 Series*.

Durability

Brick masonry is an extremely durable building material requiring little or no maintenance. It does *not* require coatings or coverings which could reduce its thermal performance as a storage media. Coatings and coverings may decrease the emissivity and thermal conductivity of the brick masonry. This is not desired when trying to optimize on the available thermal storage and thermal energy retrieval. Since coatings and coverings are not required, brick masonry may be exposed to enhance the aesthetics of the building. The use of coating applied to exterior brick masonry is discussed in *Technical Notes 6A*.

Aesthetics

Brick masonry is normally used as an exterior facade, not only because of its durability but also because it provides architectural freedom. Brick masonry offers many bond patterns, colors and textures. As elements of the building, brick masonry provides options for architectural freedom that no other building material can offer. For instance, not only the texture of the brick itself is available in many varieties, but brick allows variation in wall texture, also. The texture of the wall may be varied by using projected or recessed brick or even sculptured brickwork. The typical modular sizes of brick masonry are given in *Technical Notes 10B* and common bond patterns are given in *Technical Notes 30*. Brick masonry used as paving is discussed in *Technical Notes 14 Series*. Information on the use of brick masonry sills and soffits is provided in *Technical Notes 36 Series*. The use of brick masonry arches and reinforced brick masonry lintels are discussed in *Technical Notes 31 Series* and *17H*, respectively.

Fire Resistance

Depending upon the specific application of brick masonry in passive solar energy systems, brick masonry may be designed and placed to offer fire protection. The fire resistance of brick masonry is discussed in *Technical Notes 16 Series*.

Sound Transmission Resistance

Brick masonry, because of its inherent properties offers considerable reduction in sound transmission. Thus, depending on specific design applications, strategically placed thermal storage elements may be used to reduce sound transmission from one area of the building to another or from the exterior to the interior of the building. Information on the sound transmission classification of brick masonry is provided in *Technical Notes 5A*.

Effective Thermal Storage

The overall performance of the brick masonry as a passive solar energy system thermal storage component is dependent on its absorptivity, emissivity, and ability to store heat. The ability of a material to store heat is usually referred to as heat capacity which is a function of the specific heat and density of a material. In addition to the heat capacity, the way the wave of thermal energy penetrates the material being used to store heat should also be considered. The performance as a thermal storage media may be estimated using the value of the thermal

diffusivity of the material. Thermal diffusivity is not only a good value for assisting in the selection of materials but is also useful in simplified heat flow calculations to determine the amount of heat penetrating a material and the number of hours it takes for the heat transmission to occur. This information is useful for selecting the thickness of thermal storage. The thermal diffusivity is a function of the specific heat, density and thermal conductance of a material.

Specific Heat. The specific heat, c , of material is the amount of heat required to increase the temperature of a unit weight of material one degree. The specific heat, c , in Btu per pound per degree Fahrenheit, for brick may vary from 0.20 to 0.26. Typically this variation is due to the impurities in the clay used to manufacture the brick. The greater the percentage of metallic oxides in the clay, usually the greater the specific heat. Building brick which usually have a low percentage of metallic oxides by weight have low specific heats usually between 0.20 to 0.22 Btu/lb/°F, whereas face brick which contain larger amounts of metallic oxides, typically up to 35%, have specific heats ranging between 0.22 to 0.26 Btu/lb/°F. A value of specific heat of face brick which may be used when the actual specific heat is not known is 0.24 Btu/lb/°F.

For building brick or brick containing a low percentage of metallic oxides, a value of 0.22 Btu/lb/°F may be used. Generally red, brown and blue brick contain high amounts of metallic compounds.

The value of the specific heat for brick may be assumed for brick masonry. The specific heat of grouted hollow brick may be approximated by determining the percent of the brick masonry which is to be grouted, and averaging the specific heat, accordingly. This may be done by adding the product of the specific heat of face brick times the fraction of the brick which is solid, at least 0.60, and the specific heat of grout times the fraction of the brick which is cored, less than or equal to 0.40. For grouted hollow walls, the specific heat for the masonry wall may be modified for the grout by using Equation 1:

$$c_w = [(t_{b1} \times c_{b1}) + (t_{b2} \times c_{b2}) + (t_g \times c_g)] / (t_{b1} + t_{b2} + t_g) \quad (1)$$

where: c_w = Average specific heat of a grouted brick masonry wall, in Btu/lb/°F.

t_{b1} = Nominal thickness of the exterior wythe of brick masonry, in inches.

c_{b1} = Specific heat of the brick in the exterior brick masonry wythe, in Btu/lb/°F.

t_{b2} = Nominal thickness of the interior wythe of brick masonry, in inches.

c_{b2} = Specific heat of the brick in the interior brick masonry wythe, in Btu/lb/°F.

t_g = Nominal thickness of the grout, in inches.

c_g = Specific heat of the grout, in Btu/lb/°F.

Consider a 14-in. thick brick thermal storage wall constructed of 4-in. face brick, a 4-in. grouted space and a 6-in. grouted hollow brick wythe. Although this example is *not* representative of typical brick masonry thermal storage components, it is offered to include the available combinations of brick masonry construction. The specific heat of the wall assembly components may be determined by using Table 1 where:

$$t_{b1} = 4 \text{ in.}, c_{b1} = 0.24 \text{ Btu/lb/°F}$$

$$t_{b2} = 6 \text{ in.}, c_{b2} = 0.22 \text{ Btu/lb/°F}$$

$$t_g = 4 \text{ in.}, c_g = 0.20 \text{ Btu/lb/°F}$$

TABLE 1
Typical Material Properties of Brick^a

Material	Face Brick, ASTM C 216	Building Brick ASTM C 62	Paving Brick, ASTM C 902	Hollow Brick, ASTM C 652^b	Mortar or Grout
Specific Heat ^c c Btu/lb/°F	0.24	0.22	0.24	0.22	0.20
Density ρ lb/cu ft	130	120	135	126	120
Thermal Conductivity ^d k Btu/hr/°F/ft ² per inch	9.00	5.00	9.00	10.00	12.00
Thermal Resistivity r (hr °F ft ²)/Btu per inch	0.11	0.20	0.11	0.10	0.08
Thermal Conductance (Btu/hr/°F/ft ²)/ft C_a	0.758	0.417	0.758	0.833	1.042
Heat Capacity β Btu/cu ft/°F	31.2	26.4	32.4	27.7	24.0
Thermal Diffusivity δ ft ² /hr	0.024	0.016	0.023	0.030	0.043
Emissivity ε	0.93	0.93	0.93	0.93	-----

^aThese values are representative of the information available to the Brick Institute of America, and are typical for brick being manufactured today. These values may vary by plus or minus 10 % depending on the specific brick being considered.

^bHollow brick are assumed to be 60 % solid and the core space fully grouted.

^cSource is Reference 3.

^dThe thermal conductivity of grouted hollow brick should be determined by dual path analysis. Typically grouted hollow brick, 60 % solid, fully grouted will have a thermal conductivity of approximately 10 Btu/hr/°F/ft², per inch.

The approximate average specific heat of the wall assembly is found by substituting these values into Equation 1:

$$c_w = [(4 \times 0.24) + (6 \times 0.22) + (4 \times 0.20)] / (4 + 6 + 4)$$

$$c_w = 0.22 \text{ Btu/lb/°F}$$

Density. The density, ρ , of brick varies with the type of clay, the additives used in manufacturing and with the extent of firing. Generally the longer the firing and the higher the temperature, the more dense the brick. Typical densities for various brick are provided in Table 1. These values are average densities. The density for grouted

hollow brick assumes 130 lb per cu ft density brick and 120 lb per cu ft density grout. Hollow brick may range from 75% to 60% solid. This may significantly change the density, however the values provided in Table 1 are for grouted hollow brick assuming 60% solid.

The density, as the specific heat, of brick masonry is slightly less than that of brick, however for simplified effective thermal storage calculations these differences are usually insignificant. Typically, the maximum amount of mortar in solid brick or grouted hollow brick walls constructed with full collar joints would be about 30% of the wall volume; however, considering that mortar has a density of about 120 lb per cu ft. this results in a less than 3% reduction in the density of the wall as compared to the density of the brick.

when considering the use of a grouted hollow wall, two wythes of masonry constructed with a grouted space in between, the density of the wall should be approximated by calculation using Equation 2:

$$\rho_w = [(t_{b1} \times \rho_{b1}) + (t_{b2} \times \rho_{b2}) + (t_g \times \rho_g)] / (t_{b1} + t_{b2} + t_g) \quad (2)$$

where: ρ_w = Average density of the wall, in lb/cu ft.

ρ_{b1} = Density of exterior brick, in lb/cu ft.

ρ_{b2} = Density of interior brick, in lb/cu ft.

ρ_g = Density of grout, in lb/cu ft.

For a 14-in. thick brick thermal storage wall, constructed of a wythe of 4-in. face brick, a 4-in. grouted space and a 6-in. grouted hollow brick wythe, the densities may be selected from Table 1 where:

$$t_{b1} = 4 \text{ in.}, \rho_{b1} = 130 \text{ lb/cu ft}$$

$$t_{b2} = 6 \text{ in.}, \rho_{b2} = 26 \text{ lb/cu ft}$$

$$t_g = 4 \text{ in.}, \rho_g = 120 \text{ lb/cu ft}$$

By substituting these values into Equation 2, the average density of the wall, ρ_w , is found to be:

$$\rho_w = [(4 \times 130) + (6 \times 126) + (4 \times 120)] / (4 + 6 + 4)$$

$$\rho_w = 125 \text{ lb/cu ft}$$

Thermal Conductivity. The thermal conductivity, k , of brick is discussed in *Technical Notes 4 Revised*. Typical values of the thermal conductivity of brick are provided in Table 1. The thermal conductivity of brick varies with

density. The denser the brick, generally the greater the thermal conductivity. The thermal conductivity of grouted brick should be determined by the dual path procedure described in *Technical Notes 4 Revised*.

For hollow brick which is grouted, there are two paths for heat flow, one path is through the webs of the hollow brick and the other path is through the face shells and grout. The average thermal resistivity of grouted hollow brick may be determined by using Equation 3:

$$r_h = [(r_b \times t_w) / l] + [(r_b \times 2t_f) + r_g \times (t - 2t_f)] \times [(l - t_w) / (l \times t)] \quad (3)$$

where: r_h = Average thermal resistivity of grouted hollow brick, in ($^{\circ}\text{F ft}^2 \text{ hr}$)/Btu. in.

r_b = Thermal resistivity of brick, in ($^{\circ}\text{F ft}^2 \text{ hr}$)/Btu. in.

r_g = Thermal resistivity of grout, in ($^{\circ}\text{F ft}^2 \text{ hr}$)/Btu. in.

t = Thickness of the brick, in inches.

t_f = Thickness of the face shell, in inches.

t_w = Total thickness of the webs, in inches.

l = Length of the brick, in inches.

Considering the thermal resistivities and thickness of a 6 X 4 X 12 grouted hollow brick:

$r_b = 0.11$ ($^{\circ}\text{F ft}^2 \text{ hr}$)/Btu. in. $t = 6$ in.

$r_g = 0.08$ ($^{\circ}\text{F ft}^2 \text{ hr}$)/Btu in. $t_f = 1.25$ in.

$l = 12$ in. $t_w = 4$ in.

and substituting these values into Equation 3, the average thermal resistivity of a 6 X 4 X 12 grouted hollow brick would be:

$$r_h = [(0.11 \times 4) / 12] + [(0.11 \times 2.50) + 0.08 \times (6 - 2.50)] \times [(12 - 4) / (12 \times 6)]$$

$$r_h = 0.037 + [0.275 + 0.280] \times 0.11$$

$r_h = 0.098$ ($^{\circ}\text{F ft}^2 \text{ hr}$)/Btu in. or approximately 0.10 ($^{\circ}\text{F ft}^2 \text{ hr}$)/Btu. in.

The average thermal conductivity is the inverse of the average thermal resistivity. The average thermal conductivity, k_h , for a 6 X 4 X 12 grouted hollow brick would be:

$$k_h = 1/r_h \quad (4)$$

$$k_h = 1/0.10 \text{ ($^{\circ}\text{F ft}^2 \text{ hr}$)/Btu in.}$$

$$k_h = 10.00 \text{ Btu/hr}^\circ\text{F/ft}^2 \text{ per inch of thickness}$$

The average thermal resistivity of a storage media is the summation of the thermal resistivity times the thickness of the materials divided by the total thickness. This is expressed in Equation 5:

$$r_w = [(r_1 \times t_1) + (r_2 \times t_2) + \dots] / (t_1 + t_2 + \dots) \quad (5)$$

where: r_w = The average thermal resistivity of the storage media, in ($^\circ\text{F ft}^2 \text{ hr}$)/Btu. in.

r = The thermal resistivity of each component, in ($^\circ\text{F ft}^2 \text{ hr}$)/Btu. in.

t = The thickness of each component, in inches.

Thus consider again the 14-in. grouted hollow wall constructed of a 4-in. wythe of face brick, a 4-in. grouted space, and a 6-in. wythe of grouted hollow brick. The nominal thickness and respective average thermal resistivities of each component would be:

$$t_1 = 4 \text{ in.}, r_1 = 0.11 \text{ (}^\circ\text{F ft}^2 \text{ hr)/Btu in.}$$

$$t_2 = 4 \text{ in.}, r_2 = 0.08 \text{ (}^\circ\text{F ft}^2 \text{ hr)/Btu. in.}$$

$$t_3 = 6 \text{ in.}, r_3 = 0.10 \text{ (}^\circ\text{F ft}^2 \text{ hr)/Btu in.}$$

Substituting these values into Equation 5, the average thermal resistivity of the wall, r_w , is determined to be:

$$r_w = [(0.11 \times 4) + (0.08 \times 4) + (0.10 \times 6)] / (4 + 4 + 6)$$

$$r_w = [1.36 \text{ (}^\circ\text{F ft}^2 \text{ hr)/Btu in.}] / 14 \text{ in.}$$

$$r_w = 0.097 \text{ (}^\circ\text{F ft}^2 \text{ hr)/Btu per inch of thickness}$$

Thermal Conductance. Thermal conductivity and thermal resistivity refer to the value of heat loss for one inch of thickness. The thermal conductance is the value of heat loss for a specified thickness. The average thermal conductance for a one foot thickness of the storage media is used in the simplified equations of heat transfer for determining effective thermal storage. The average thermal conductance for a one foot thickness of the brick storage media may be determined using Equation 6:

$$C_a = 1 / (r_w \times 12 \text{ in./ft}) \quad (6)$$

where: C_a = The average thermal conductance of the storage media for one foot of thickness. in (Btu/hr $^\circ\text{F/ft}^2$) / ft.

The 4-in wythe of face brick, 4-in. grouted space and 6-in. wythe of grouted hollow brick is calculated to have a thermal conductance per foot of thickness of:

$$C_a = 1 / [0.097 \text{ (}^\circ\text{F ft}^2 \text{ hr) / Btu in.} \times 12 \text{ in./ft}]$$

$$C_a = 0.859 \text{ (Btu/hr/}^\circ\text{F/ft}^2) / \text{ft}$$

Thermal Diffusivity. Typically the storage capacity of a material is represented by the amount of heat which can be stored in the material, the heat capacity of the material. The heat capacity may be determined by using Equation 7:

$$\beta = c \times \rho \quad (7)$$

where: β = Heat capacity, in Btu/cu ft/ $^\circ$ F.

Typical values for the heat capacity of various brick are provided in Table 1. Thermal diffusivity is a function of the heat capacity and thermal conductance per foot of material thickness. The thermal diffusivity of a material may be determined by using Equation 8:

$$\delta = C_a / \beta \text{ or } \delta = C_a / (c \times \rho) \quad (8)$$

where: δ = Thermal diffusivity, in ft²/hr.

The values of thermal diffusivity for typical brick masonry are provided in Table 1. The value of thermal diffusivity may be used to provide the designer with a better concept of heat storage in the passive solar energy system thermal storage component. The use of the thermal diffusivity in simplified heat transfer equations may provide a more rational approach for selecting the thickness of thermal storage walls.

The average value of thermal diffusivity may be determined by using Equation 9:

$$\delta_a = C_a / (c_w \times \rho_w) \quad (9)$$

where: δ_a = Average thermal diffusivity, in ft²/hr.

Thus for the 14-in. thick wall assembly constructed of 4-in. solid brick wythe, a 4-in. grouted space, and a 6-in. wythe of grouted hollow brick the average thermal diffusivity may be determined using Equation 9. C_a for this wall was determined to be 0.859 (Btu/hr/ $^\circ$ F/ft²)/ft, ρ_w was determined to be 125 lb/cu ft and $c_w = 0.22$ Btu/lb/ $^\circ$ F. Thus, the average thermal diffusivity would be:

$$\delta_a = 0.859 \text{ (Btu/hr/}^\circ\text{F/ft}^2) / \text{ft} / (0.22 \text{ Btu/lb/}^\circ\text{F} \times 125 \text{ lb/cu ft)}$$

$$\delta_a = 0.031 \text{ ft}^2/\text{hr}$$

The value of the average thermal diffusivity is useful in simplified heat transfer equations, however if precise values are desired, each component in section should be analyzed individually.

Emissivity. The emissivity of a surface is its ability to radiate heat to the surroundings. This is the basis of heat retrieval in passive solar energy systems as discussed here. The radiant heat from the surface of the brick masonry is what causes the useable natural flows of thermal energy; i.e., surface to air conduction, convection between surfaces and radiation to surfaces and the air, which heat the interior spaces of the building. Typical values of emissivity for brick are provided in Table 1.

Exposed brick masonry allows the use of various bond patterns, projections and even sculptured brick work to increase the aesthetic value of the thermal storage media. Although at first the idea of leaving the brick exposed seems merely aesthetic, it does serve a function important to the thermal performance of the thermal storage media. Brick masonry does not require nor should it have any coverings; i.e., gypsum wall board, paints, wall papers, or carpeting which could decrease the emissivity of the surface. The addition of coatings and coverings not only may reduce the emissivity of the thermal storage element but will usually decrease the thermal conductivity thus decreasing the surface temperatures and the amount of surface radiant heat available.

If the value of emissivity, the surface temperature of the thermal storage element, and the surface temperature of the interior materials being radiated to are known, the amount of radiant thermal energy emitted may be approximated. The approximate amount of thermal radiation emitted per square foot of thermal storage surface area may be calculated using Equation 10:

$$q_r = [0.174 \times \epsilon \times [T_r^4 - T_c^4]] / 10^8 \quad (10)$$

where: q_r = Radiation, in Btu/hr/ft²

ϵ = Emissivity.

T_r = Temperature of the radiant surface measured from absolute zero, degrees Fahrenheit plus 459.6.

T_c = Temperature of the receiving surface measured from absolute zero, degrees Fahrenheit plus 459.6. For most applications in passive solar energy systems, the value of T_c is usually interior design temperature in °F plus 459.6, typically 72°F + 459.6 or 531.6.

Consider an average surface temperature of a radiating surface at 83°F and an interior design temperature of 72°F. Measuring these temperatures from absolute zero would result in $T_r = 83 + 459.6$ or 542.6 and $T_c = 72 + 459.6$ or 531.6. The radiation from a dark brown brick wall, with $\epsilon = 0.93$, may be determined using Equation 10 to be:

$$q_r = [0.174 \times 0.93 \times [(542.6)^4 - (531.6)^4]] / 10^8$$

$$q_r = [0.168 \times (8.668 \times 10^{10})] / 10^8$$

$$q_r = (1.103 \times 10^9) / 10^8$$

$$q_r = 11.03 \text{ Btu/hr/ft}^2$$

Absorptivity. The solar absorptivity of a material is mostly dependent on color. The solar absorptivity is the ratio between how much solar radiation is absorbed by a material to that absorbed by a standard black surface. Typically, passive solar thermal storage components (or any finish applied to such components) should be as dark a color as possible to provide sufficient energy absorption. However, trade-offs do exist between color, wall

thickness and the amount of surface area exposed to sunlight. Trade-offs also exist between darkness of color and how much heat is desired and when the available heat is wanted. These trade-offs can only be adequately determined by rigorous analysis and are not recommended for use with rule-of-thumb approaches. Surfaces (such as frame walls) not being used for storage should be painted light colors in order to reflect as much energy as possible to the darker storage material. Although black is the most desirable storage material color from a thermal point of view, it has been determined that the darker natural brick colors (browns, blues and reds) will perform almost as effectively, without deterioration problems which may result when using paint or other coverings. Typical values for solar absorptivity of brick are given in Table 2. Brick with glossy glazed ceramic coatings should be avoided as they will reflect too great a percentage of the solar radiation striking them. Several brick manufacturers can supply brick with dull black ceramic glazed faces, which may increase the solar radiation absorbed.

Although it would seem at first glance that rough-textured brick, by providing more surface area for the collection of energy, would be more effective than smooth brick as an energy storage media, but it has been determined that this is not the case. It appears that brick texture does not have a major impact on the performance of passive solar installations and that any desired texture can be used without significant loss or gain in effectiveness.

GLAZING MATERIALS

General

Information regarding the transmittance, reflectance, absorptance, thermal performance and durability of glazing materials for passive solar energy systems should be obtained from the glazing manufacturer. Some general suggestions to assist in the design and selection of glazing materials for passive solar energy systems applications are discussed.

Transmittance

The glazing material used should have a high transmittance, low absorptance and low reflectance of solar radiation. The high transmittance is important so that the maximum amount of solar energy may be transmitted to the interior of the passive solar building where it can be absorbed and stored in the interior brick masonry. Generally, the higher the transmittance the lower the absorptance and reflectance. When the glazing is desired to provide specific daylighting requirements, it may be preferred to use a glazing material which diffuses the direct solar radiation.

Absorptance

Depending on the glazing material and the frame assembly, absorptance should be a factor in selecting the glazing material or a proper framing assembly. The higher the absorptance, the lower the amount of energy transmitted to the interior. Typically, the absorptance of most glazing materials is low. The amount of solar absorptance may be important because of thermal stress that may occur within the glazing material itself or between the glazing material and framing assembly. The framing assembly should be such that it allows for thermal expansion of the glazing material being used to avoid structural failure of the collector component.

Reflectance

The reflectance of the glazing material should be kept to a minimum, so that the maximum amount of solar radiation may be transmitted to the interior. In addition to the consideration of reflectance, as related to transmittance and maximum solar performance, reflectance might also require consideration of exterior glare which may be annoying or even hazardous because of impairing vision.

Thermal Conductivity

Typical values for overall coefficient of heat transmission of glass are given in Table 3. Table 3 also provides solar transmittance correction factors for glass. The solar transmittance correction factors are based on double glass having a solar transmittance value of 1. Information regarding plastics or other glazing materials must be obtained from the material manufacturer.

The basic material properties for single, double and triple glass given in Table 3 may be used as a means of selecting the appropriate glazing material by considering the trade-offs between the transmittance and U value. Single glass has about a 21% increase in transmittance and 124% increase in heat loss, over double glass, and thus should only be used in lieu of double glass when night insulation is used. However, triple glass has approximately an 18% reduction in transmittance and a 37% reduction in heat loss over double glass and may be used in lieu of double glass with night insulation, to increase economic feasibility at only a slight reduction in overall performance. When considering such trade-offs it is extremely important to consider the specific environmental factors at the site. Triple glass in lieu of double glass may be excellent in areas of high solar radiation and cold exterior temperatures, but not effective in areas of low solar radiation and moderate exterior temperatures. The effectiveness should be determined by steady-state heat loss calculations and passive solar performance analysis.

^aValues may vary with material, see manufacturers recommendations.

Durability

The durability of the glazing material must be such that it resists failure due to thermal stresses and that it does not degrade or discolor when exposed to solar radiation for extended periods of time. Of course these considerations will vary with economics. If a material degrades frequently but is inexpensive to replace, it may be more economical than a more expensive, more durable glazing material. Additional considerations in selection of a glazing material may be resistance to impact, and ease of replacement due to breakage.

No matter what glazing material is selected, the designer should be assured it will maintain an expected condition that is not detrimental to the performance of the passive solar energy system for its intended period of use. Materials that discolor or degrade rapidly and have significant reduction of solar radiation transmittance should not be used.

METRIC CONVERSION

Because of the possible confusion inherent in showing dual unit systems in the calculations, the metric (SI) units are not given in the examples. Table 13 in *Technical Notes 4* provides metric (SI) conversion factors for the more commonly used heat transmission units.

SUMMARY

This *Technical Notes* provides information on the component materials for passive solar energy system applications. This offers a designer or owner sufficient information regarding the material properties of brick to assist in the design and use of brick masonry in passive solar applications. Consideration of the properties of brick masonry could result in a thermal storage media that is an aesthetic, durable, maintenance free, fire resistant structural component of a building that provides sound transmission reduction. In addition, sufficient values of the material properties of brick masonry are provided for passive solar energy system analysis techniques, manual or computer calculations. The decision to use the information and concepts presented in this *Technical Notes* is not within the purview of the Brick Industry Association, and must rest with the designer or owner of any specific project.

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