TECHNICAL NOTES on Brick Construction
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Technical Notes 43C - Passive Solar Cooling with Brick Masonry - Part 1 - Introduction
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Abstract: Brick masonry passive solar energy systems can be used to significantly reduce the use of fossil fuels for heating and cooling buildings. The concepts of passive solar cooling systems discussed here are simple modifications to passive solar heating systems. For locations where humidity is high, or there is little exterior temperature fluctuation, or applications where low interior design temperatures are required, passive solar cooling may not be viable. Several methods of pre-cooling and the concept of dehumidifying air with these systems are introduced.

Key Words: attached sunspace, **bricks**, buildings, cavity wall systems, climatology, conservation, direct gain systems, **effective temperature**, energy, masonry, **passive solar cooling systems**, passive solar heating systems, solar radiation, system operation, temperature, thermal storage wall systems.

INTRODUCTION

The application of passive solar energy systems using brick masonry can help to significantly reduce the amounts of fossil fuels and electric energy currently being used for heating and cooling buildings. Other *Technical Notes* in this Series address passive solar heating systems with brick masonry. They discuss the general concepts, the procedures for sizing the systems, and the performance calculations. This *Technical Notes* introduces the concept of passive solar cooling systems using brick masonry.

PASSIVE SOLAR COOLING

The terminology "passive solar cooling" does not necessarily refer to the actual reduction of the interior air temperature of the building. "Passive solar cooling" is a means of providing comfortable interior conditions by properly using the natural flow of thermal energy to create air movement. These "cooling" systems provide comfort by controlling the *effective temperature* of the interior of a building.

The *effective temperature* is a measure of the comfortable air conditions in a building dependent upon the actual temperature of the air, the level of relative humidity, and the amount of air movement. By properly varying any one, or any combination of these factors, more comfortable interior conditions can be achieved. The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) provides methods which may be used to determine the amount of change or fluctuation necessary to achieve comfortable interior conditions. These methods are described in ASHRAE 1997 *Handbook of Fundamentals,* and ASHRAE Standard 55-92, *Thermal and Environmental Conditions for Human Occupancy.*

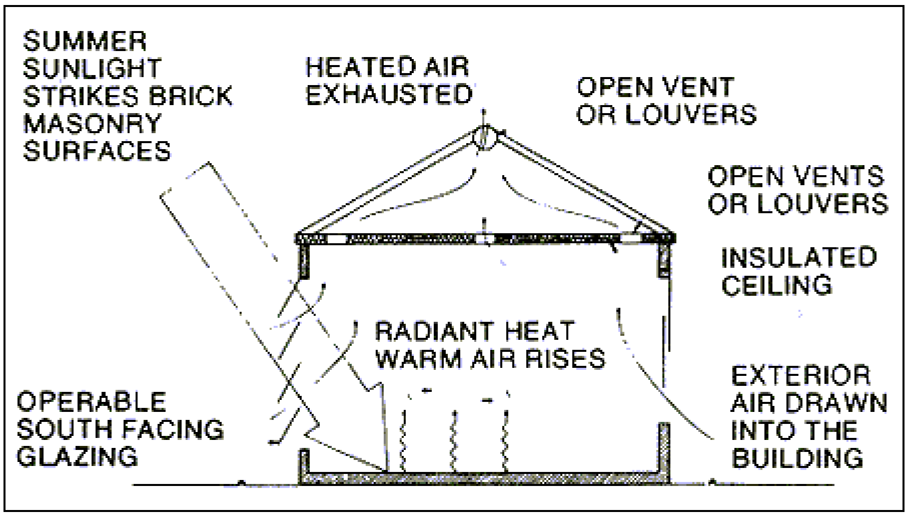
The actual determination of the effectiveness of passive solar cooling is complex and its performance is not yet satisfactorily predicted with calculation procedures alone. The type of passive solar cooling system selected, and its performance can be greatly affected by the site and the climatological conditions.

SYSTEMS AND OPERATION

The basic passive solar heating systems, utilizing brick masonry, are discussed in *Technical Notes* 43, These systems are: thermal storage wall systems, direct gain systems, attached sunspaces and combinations of these. These passive solar heating systems can be easily modified to provide interior comfort during the cooling season. *Obtaining all the necessary cooling with passive solar cooling systems usually is neither economically nor thermally feasible for the entire cooling season.* These simple modifications to passive solar heating systems *can* be used to create more comfortable interior conditions for at least part of the cooling season in most climates.

The necessary modifications to passive solar heating systems to provide passive solar cooling are provisions for 1) exhausting air from the interior, and 2) intaking exterior air. Schematics are shown in Figs. 1, 2, and 3 for the direct gain system, attached sunspace, and thermal storage wall system, respectively. The principal modification is to provide controlled openings for exhausting the internal heat gained by the passive solar heating system. The controlled openings should be at the highest points of the structure, preferably in the roof/ceiling, or gable. Control of the openings may be provided with operable vents, or registers. Similar openings can be placed at the low points of the structure for intaking exterior air. The openings for intaking exterior air may be the windows or doors of the structure.

The operation of each of these systems is very similar in the cooling mode: (1) sunlight strikes the south-facing glazing, (2) solar energy is transmitted through the south-facing glazing to the brick masonry thermal storage media, (3) the brick masonry absorbs and stores the heat, (4) radiant heat from the surface of the brick masonry rises, (5) the heated air is exhausted through the controlled openings at the top of the structure, (6) as the heat is exhausted, exterior air is drawn into the structure, and (7) the air movement created by exhausting and intaking air through the structure creates the effect of cooling and provides more comfortable interior conditions.



Cooling With the Direct Gain System

FIG.1

Direct Gain System

The direct gain system, when applied as passive solar cooling, is the most economical, but probably the least effective. The minimum 4-in. (100 mm) thick brick masonry floors and walls on the interior are exposed to direct sunlight to absorb and store heat.

The interior brick masonry should be dark to absorb most of the heat and radiate and reflect only a small portion during the day. The gradual release of radiant heat through the night draws the cool night air into the structure and cools the structure.

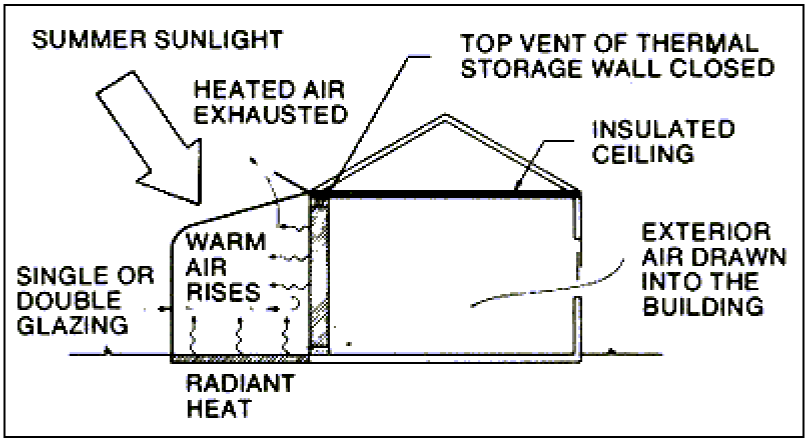
The system is only advantageous when the nighttime temperatures consistently fall below the interior design temperature and when internal solar heat gain can be adequately controlled to prevent overheating in the daytime.

A major problem with using a direct gain system is that the interior space used to store heat is also an integral part of the habitable space of the building.

Attached Sunspace

Using the attached sunspace for passive solar cooling is probably more effective but less economical than direct gain cooling. In the attached sunspace, the heat storage element is not usually part of the space that is to be cooled. The system schematic is shown in Fig. 2.

Although the intent in many applications is to use the attached sunspace as a greenhouse, this is not advantageous in most applications because the greenhouse will be vented to the interior and the humidity from watering plants may result in uncomfortable interior conditions and condensation problems. The major disadvantage of this system is the cost of the additional floor area which has limited use.



Cooling With the Attached Sunspace

FIG. 2

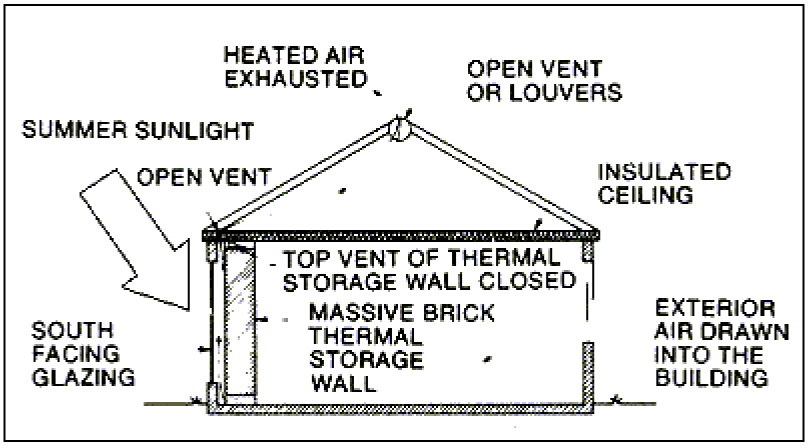
The system consists of minimum 4-in. (100 mm) thick brick masonry floors, south-facing glazing and preferably a 10 to 18-in. (250 to 450 mm) thick vented brick masonry thermal storage wall between the sunspace and the habitable portion of the building.

In the cooling mode, the top vents of the brick masonry storage wall are closed and the bottom vents are open. The air in the sunspace is heated by radiant heat from the brick masonry. The heated air rises through operable openings in the roof of the sunspace, drawing air from the habitable spaces through the bottom vents of the brick masonry thermal storage wall. The air drawn from the habitable space is replaced by exterior air drawn in through operable windows or doors.

Thermal Storage Wall System

One of the most economical and effective passive solar cooling systems is the vented thermal storage wall, shown schematically in Fig. 3. The greatest advantage of the thermal storage wall is that the heat used for the passive solar cooling does not directly enter the interior spaces of the habitable portion of the building.

The system consists of exterior glazing 2 to 4 in. (50 to 100 mm) in front of a 10 to 18-in. (250 to 450 mm) thick vented brick masonry wall used for storing heat. Operation is similar to that of the attached sunspace. The operable openings for exhausting the heated air may be located at the top of the exterior glazing. The exhaust system may also be operable vents at the top of the airspace from which the air may be exhausted through additional vents in the roof. When using the latter exhaust system, additional vents from the habitable space through the roof/ceiling component may be used to increase the heat flow from the interior, thereby drawing additional air into the building.



Cooling With the Vented Thermal Storage Wall System

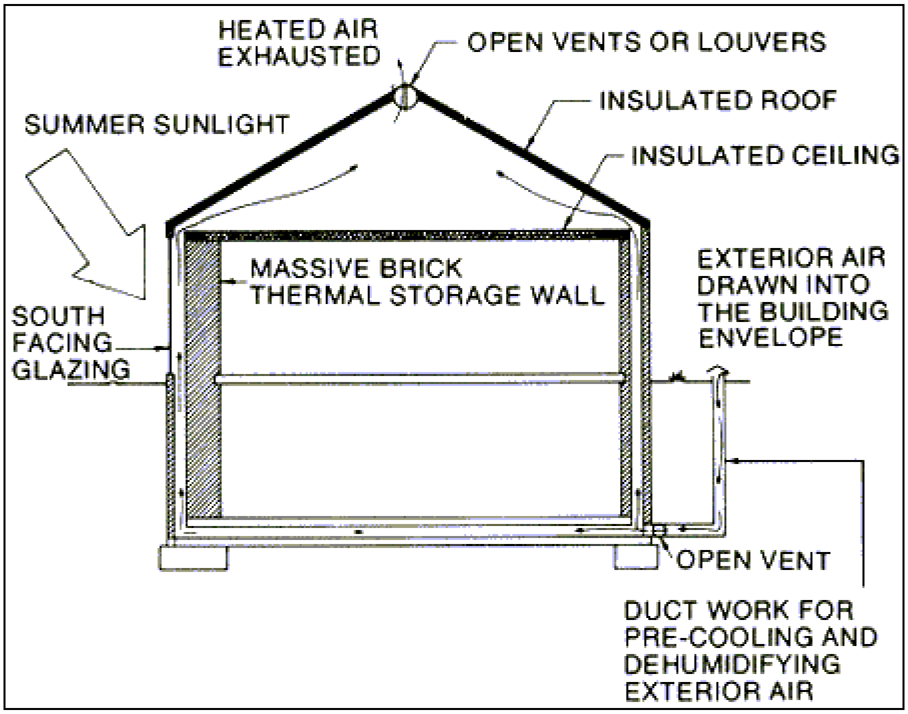
FIG. 3

CONTROLS

These three basic passive solar heating systems, as modified for passive solar cooling, require controls to regulate internal heat gain and the level of comfort, "cooling", achieved. These controls may be automatically or manually operated vents, or registers. The controls should be such that the system can be totally "shut down" when it is not being effective, i.e., when exterior conditions are such that a comfortable effective temperature cannot be maintained inside the building. Shading devices are required as a means of controlling the amount of sunlight permitted to enter the structure for operation of the passive solar cooling system. These may be automatic or manual devices, but are necessary to prevent overheating that can occur during the cooling season when the interior temperature, i.e., effective temperature, will no longer be within the comfort range. The entire system must be completely shut down before mechanical/refrigeration cooling systems are put into operation. Shading the south-facing glazing and closing openings are required for efficient use of any conventional cooling system. Obviously, operation is a critical factor in the performance of "passive solar cooling systems".

CAVITY WALL SYSTEM

A system which may be effectively used for cooling, with less consideration of the climatic conditions, is the cavity wall system, schematically represented in Fig. 4. The north and south walls of the structure are uninsulated cavity walls (see *Technical Notes* 21 Series). The south-facing wall, above grade, is an unvented thermal storage wall. The airspace in the thermal storage wall system is open at the bottom to the cavity of the basement or foundation wall, and at the top to the roof/ceiling. The cavity of the wall is open to ductwork extended in the north-south direction through the basement floor, or crawl space. As shown in Fig. 4, this provides an air passageway within the building envelope components. A ductwork system is provided from the base of the cavity to vents on the exterior. Exhaust vents are provided in the roof or gable ends.



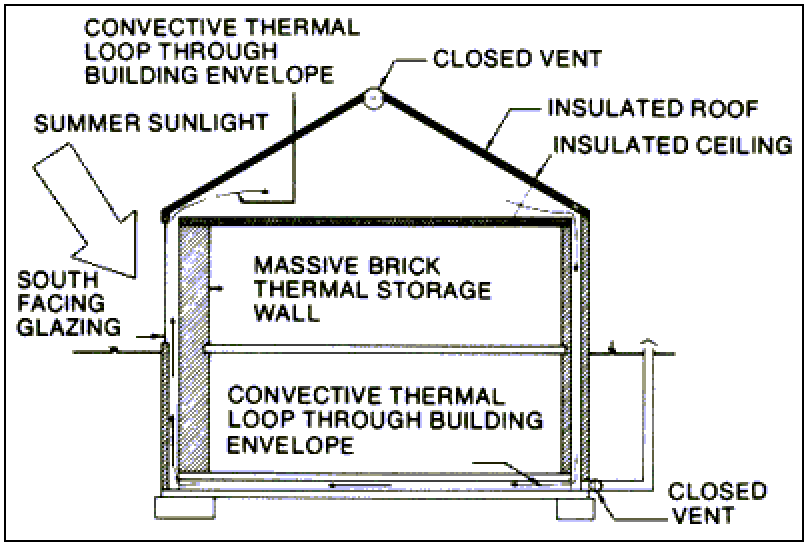
Cavity Wall System Cooling Mode

FIG. 4

With the cavity wall system, the south-facing glazing exposes the brick thermal storage wall to sunlight, which heats up and causes air to rise through the cavity. As the air rises, it is vented to the exterior from the top of the cavity, and exterior air is drawn into the cavity via the ductwork system and exterior vents. This provides a means of keeping the entire building envelope cooled. Since the surfaces warmed during the daytime hours retain heat, this continues through the evening hours, further cooling the building envelope. The cooled building envelope and interior require a longer time period to be heated up to uncomfortable temperatures during the daytime hours of the next day. The advantages of passive solar cooling with the cavity wall system are: (1) shutdown is not essential for conventional cooling to work effectively (the cooling systems are isolated from each other), and (2) since the exterior air for cooling is not brought into the habitable space, the effects of humidity (a major drawback in most passive solar cooling systems, depending on climate), may be reduced.

The east and west walls do not have to be uninsulated cavity walls. By keeping all walls cavity walls, the east and west walls may perform as a buffer zone between the north and south walls. This may increase the overall performance of the system.

A schematic of the system in the heating mode is shown in Fig. 5. The vents are closed, which creates a convective loop around the entire shell of the building; through the floor, wall and roof/ceiling components. This thermal convective loop warms both the interior and exterior wythes of the building envelope. Since this operation warms the interior wythe, there is little or no heat loss through those portions of the building envelope. This system, properly designed and operated, may provide the most effective passive solar heating and cooling.



Cavity Wall System Heating Mode

FIG. 5

FACTORS AFFECTING PERFORMANCE

The effects of the environmental conditions and building use on passive solar heating systems are discussed in *Technical Notes* 43. These must also be considered for passive solar cooling systems, however, the necessary considerations of these factors vary for passive solar cooling systems. The major variations and additional effects which must be addressed specifically are: temperature, humidity and shading.

Exterior Design Temperature

The exterior design temperature may be such that the effective temperature range cannot be achieved or maintained within the structure. Since the effects of cooling are principally achieved by air movement, this may make the cooling system ineffective. One option is to take maximum advantage of the daily temperature swing. When the nighttime temperatures drop below the interior design temperature, the structure may be cooled during the night, delaying the time to heat up the next day. Caution must be used when considering the daily temperature swing to guard against overcooling in moderate climates.

Humidity

Humidity is an additional environmental factor not generally addressed in passive solar heating systems. In areas where the effects of high humidity cannot be eliminated by air movement, these simple versions of passive solar cooling systems may not be effective. Additional complex modifications to the basic passive solar cooling systems may be necessary to dehumidify the air.

Shading Devices

Operable shading devices are usually required in passive solar cooling systems. The shading devices are used to control the amount of solar radiation permitted to strike the system. This is necessary to prevent overheating, especially when the system is marginal because the effective temperature cannot be attained by natural air flow. In this case, the system should be completely shaded from the summer sunlight.

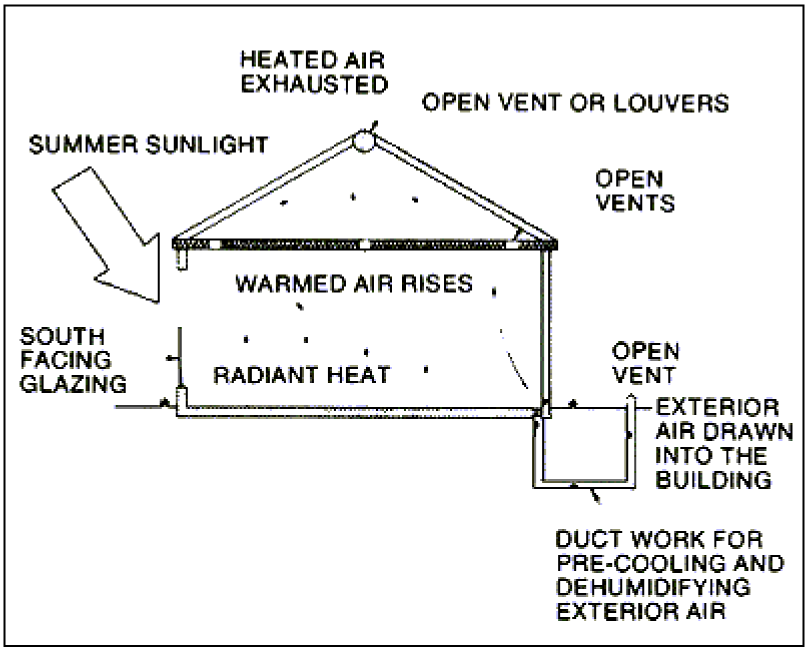
In instances where the system is providing cooling by night air intake, it may be advantageous to have the system shaded from the morning and possibly early afternoon sunlight. Exposure to only the late afternoon sunlight may result in sufficient performance to draw cool night air through the structure.

SPECIAL CONSIDERATIONS

The performance of the passive solar cooling system may be greatly increased by pre-cooling, or dehumidifying the air before introducing it into the structure. Pre-cooling and dehumidifying the air are both fairly straightforward concepts. Adapting the system for pre-cooling air is usually simple, but dehumidifying the air is much more complicated.

Pre-Cooling Air

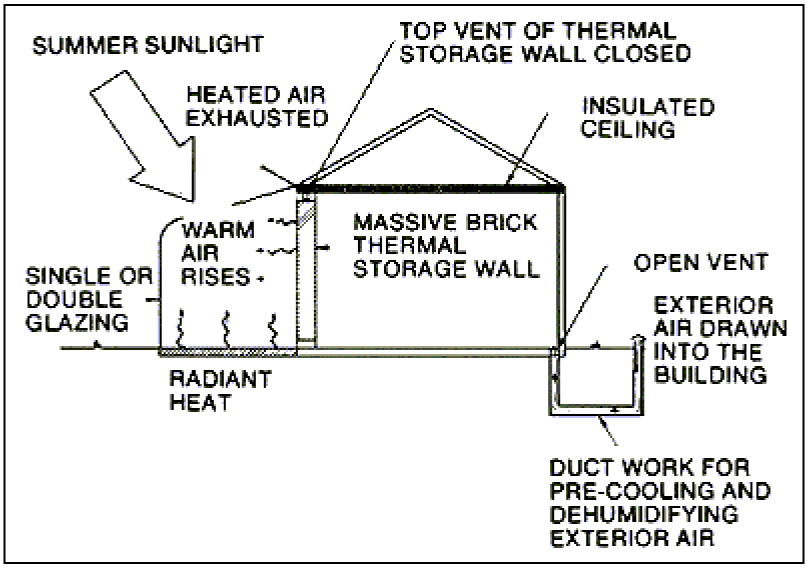
Air may be cooled before it is introduced into the structure by providing underground ductwork or piping, and venting it to the surface as shown schematically in Figs. 6, 7 and 8. This is easily adaptable for direct gain, attached sunspace and thermal storage wall cooling systems. The ductwork should be corrosion-resistant and installed for a sufficient length and at the appropriate depth to pre-cool the air. The number of ducts and their length and depth requirements are beyond the scope of this *Technical Notes* because they are a function of climate, soil type, elevation of ground water and other related factors, all of which affect the amount of pre-cooling, both required and attainable. General design information and calculation procedures may be obtained from the References 1, 2, 6 and 7 of this *Technical Notes.*



Pre-Cooling and Dehumidification of Exterior Air

for Cooling With the Direct Gain System

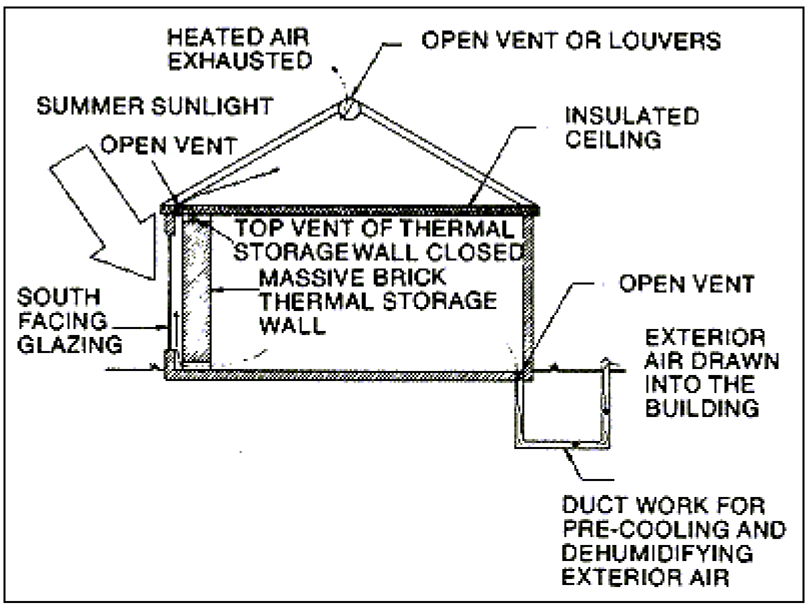
FIG. 6



Pre-Cooling and Dehumidification

of Exterior Air With Attached Sunspace

FIG. 7



Pre-Cooling and Dehumidification

of Exterior Air With Vented Thermal Storage Wall System

FIG. 8

DEHUMIDIFICATION

Air may be dehumidified by using the concept shown in Figs. 6 through 8, for pre-cooling. Dehumidifying the air with the passive solar system alone can be very difficult. Again, it is a function of climate, soil type, level of ground water and other related factors. The procedure for determining the amount of dehumidification involves fairly complex calculations. These calculation procedures are similar to those in the ASHRAE 1997 *Handbook of Fundamentals* and ASHRAE Standard 55-92. The temperature fluctuations necessary to saturate air and condensate water by the natural flow of air further complicates the use of passive solar cooling systems for providing dehumidification.

SUMMARY

This *Technical Notes* provides general information concerning passive solar cooling systems. In addition to describing modifications of the passive solar heating systems which may be used to supply successful passive solar cooling, it introduces an innovative system - the cavity wall system - which may be quite effectively used for heating and cooling buildings. The basic concepts of the passive solar cooling systems and the principles of their operation are also discussed. The purpose of this *Technical Notes* is to provide general information on passive solar cooling systems with brick masonry. It discusses type, operation, advantages and disadvantages of these systems. This *Technical Notes* does *not* and is *not* intended to provide information for specific designs or applications, but rather offers general information to assist in the consideration of the use of passive solar cooling systems of brick masonry. The information and suggestions contained in this *Technical Notes* are based on the available data and the experience of the engineering staff of the Brick Industry Association. The information contained herein must be used in conjunction with good technical judgement and a basic understanding of the properties of brick masonry. Final decisions on the use of information contained in this *Technical Notes* are not within the purview of the Brick Industry Association and must rest with the project architect, engineer and owner.

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