Passive Solar Home Design

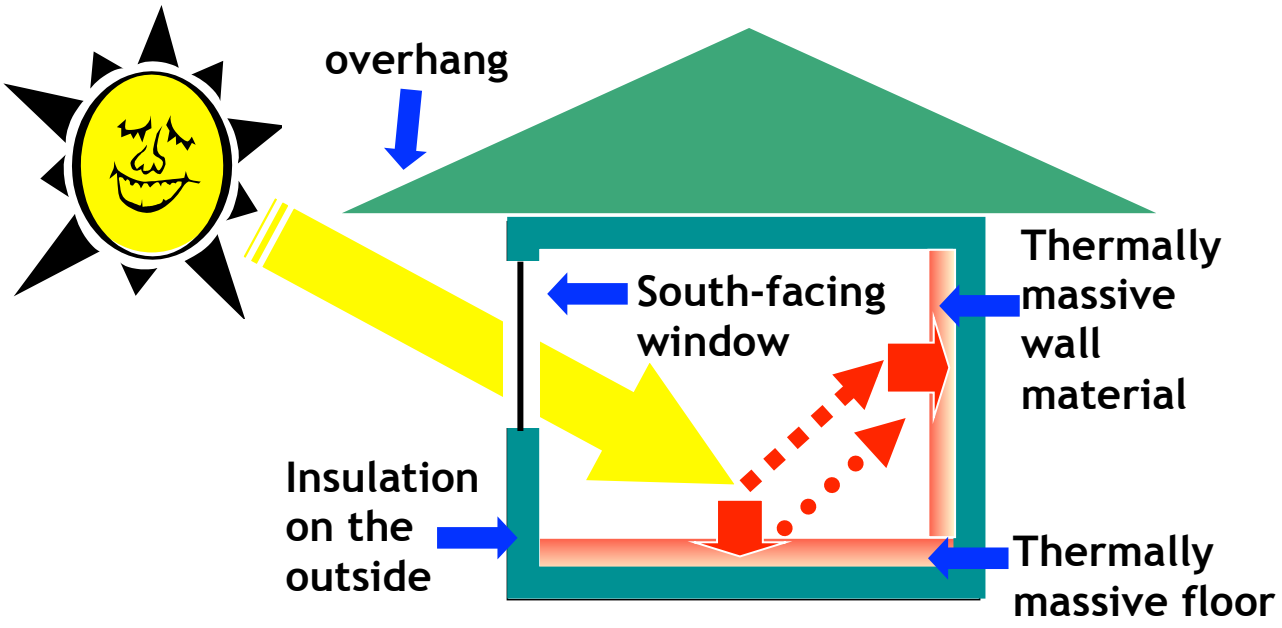
Northern New Mexico is sunny, but can be quite cold in the winter. Normally, we use natural gas, wood, oil, and electricity to heat homes. But we can also use the Sun, and we can do it in a very clever way!

Basic Ideas of Passive Solar Design:

The three basic ideas of passive solar design are:

1) **Solar Gain:** Let the sun shine in through *south-facing* windows in the winter, and *only* in the winter, to heat up the house;
2) **Thermal Mass:** Arrange for "thermally massive" materials in the floor and walls to absorb some of the solar energy to keep the house warm at night time or on cloudy days, and;
3) **Insulation:** Insulate the walls, roof, and floor, really well to keep the heat inside in winter, and to keep it cool in summer.

These ideas are illustrated in the following diagram:

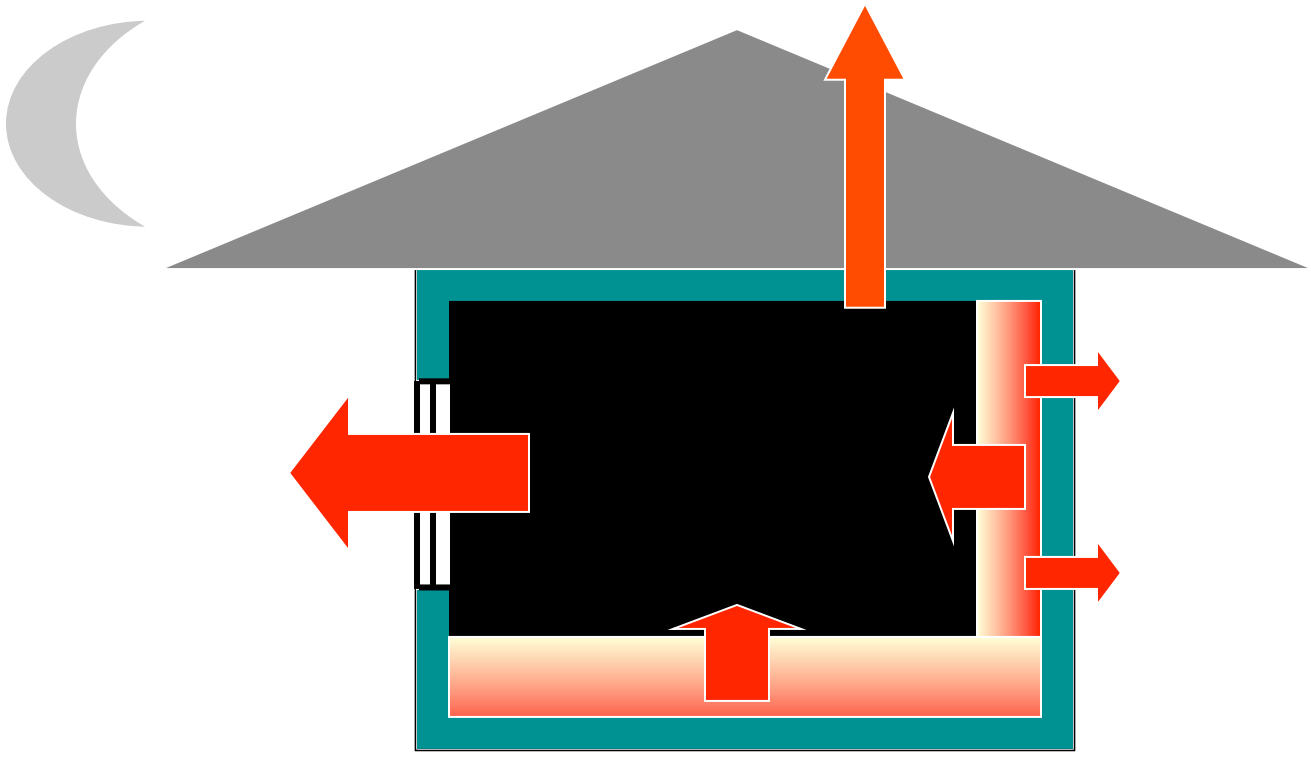


How it works: The south-facing window lets lots of sunshine in during winter months, and *only* in winter months because of the Sun's differing paths in different seasons (more on this below), and also because of the overhang. There are also very few, and only very small, windows on the other sides of the house, which keeps out the Sun during the summer.

Thermal Mass Effect: Notice how, in the diagram, that when the sunlight hits the floor, some of the light is absorbed into the material of the floor (shown by the arrows). This material has lots of "thermal mass": Thermal mass is any material like tiles, bricks, cement, or adobe, which can absorb and therefore store a lot of heat.

Note that some of the incoming energy is *reflected* away from the floor (as shown by the small "square dotted" arrow), or *radiated* away by the floor because the floor is warm (as shown by the "circle dotted" arrow). This energy can be re-absorbed into the thermally massive wall on the right hand side, as shown by the big red arrow on the right. So the thermal mass does not have to be only exactly where the sun shines. Additional thermal mass needs to be in *line-of-sight* of other sunlit thermal mass to work efficiently.

What happens at night?



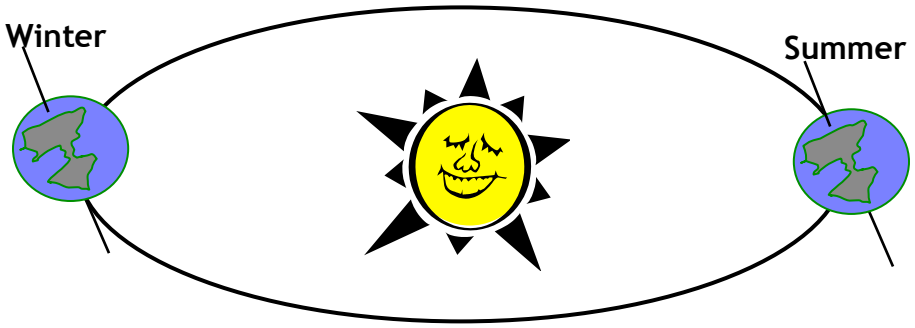
At night, the outside air gets colder, and the house starts to cool. The diagram above shows some of these heat flows. You can see why it's so important to have good insulation and good windows! Note that the heat flow out the windows is one of the biggest: Even windows that have two panes of glass (called "thermapane windows") let a lot of heat out, but they are still much better than single pane windows!

So why does the house stay fairly warm? At night the heat energy that is stored in the thermal mass materials comes back out as the house starts to cool, which helps keep the house warm. Can you find those heat flows in the diagram above?

Why the term "passive solar"? A passive solar house does not have any solar collectors on the roof, or pumps to move air and water. The *house itself* is the solar collector! Because it has no moving parts, it is a "passive" solar system.

Utilizing the Sun's path in passive solar design

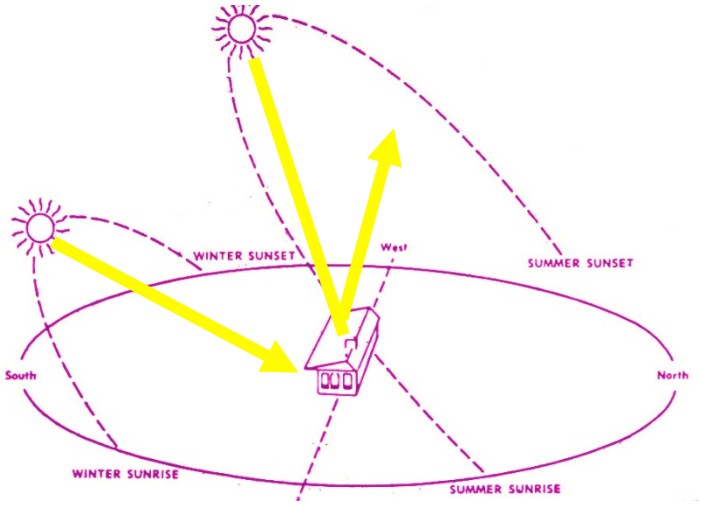
As mentioned above, an important idea is to let the Sun in *just* during the winter, and keep in out during the summer. We do this by placing most of the windows on the south side of the house. Why does this work? This works because of the different paths that the Sun takes through the sky in winter than in summer. The best way to understand this is to study how the Earth's axis is tilted with respect to the orbital plane of the Earth around the Sun, as the following diagram shows:



Note that the Earth's axis keeps pointing in the same direction as the Earth moves around the Sun. The Earth's tilt, besides causing the different seasons, causes the Sun, from *our* point of view here on the Earth, to take different "sun paths" through the sky in winter compared to summer, as the diagram below shows. In the summertime the Sun appears to pass almost straight overhead as it goes from east to west. In the winter, however, it rises in the southeast, and remains low in the southern part of the sky all day long.

Exercise: Use a globe and a yellow ball (for the Sun) to explore the concept of the Earth's tilt and the different sun paths in different seasons.

Therefore, as the diagram below shows, if we build a house with large south-facing windows, and only a few small windows facing the other directions, then the Sun will shine into the house only in winter, and not in the summer. The house, therefore, stays warm in winter and cool in summer.



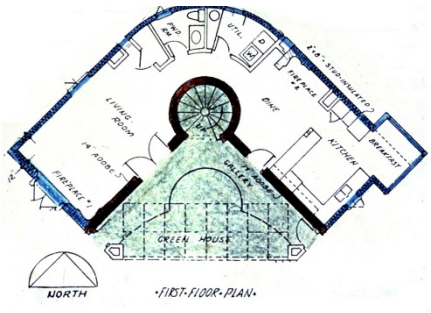
Passive solar homes in New Mexico

There are many passive solar homes in New Mexico today, with many different styles and shapes. Here are a few interesting and/or classic solar homes:

Classic New Mexico Style Passive Solar Home, in Eldorado, New Mexico. Note the overhangs over the windows.

Passive Solar Home in Los Alamos, New Mexico. The black looking areas on each side of the windows are "trombe walls".

The famous "Balcomb" passive solar home in Santa Fe, one of the most scientifically studied homes in the world (studied by Dr. Doug Balcomb, a Los Alamos scientist). The area behind the big windows is actually an "integrated greenhouse", not a living room. The living room, and all the other rooms, are actually located *behind* the greenhouse, in an "L" shaped arrangement, as shown below:



"Santa Fe Style" Passive Solar Home in Santa Fe, New Mexico.

The home above is an "Earthship", located in Taos, New Mexico, which gets *all* of its energy from the Sun and Wind.

Trombe Walls

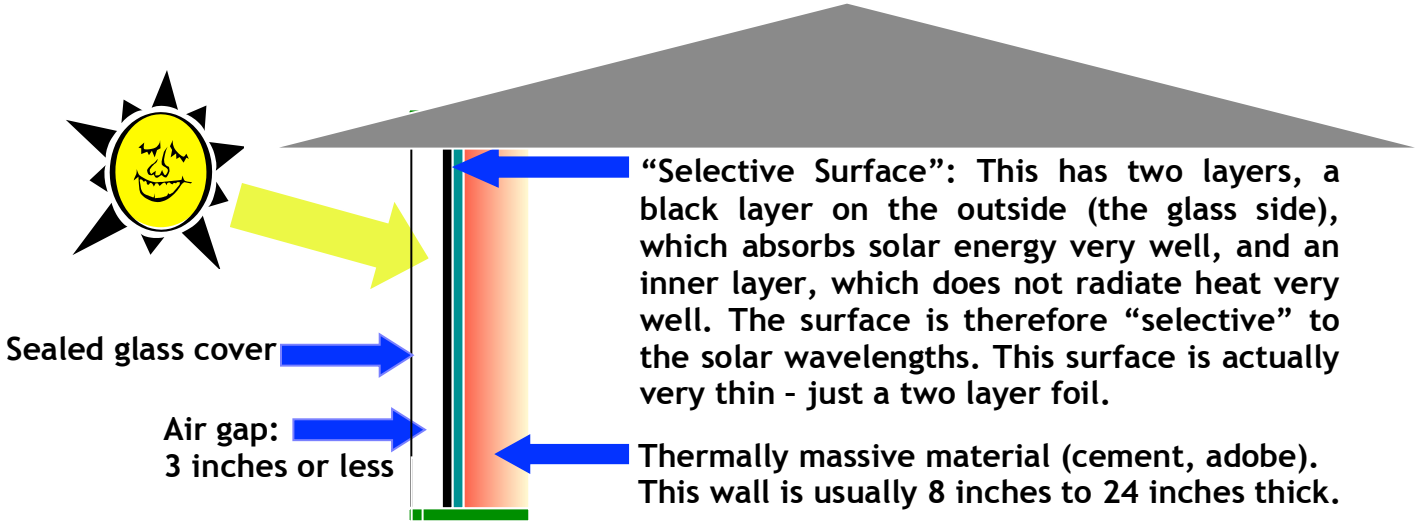
Trombe walls, pronounced “trom walls”, were invented by frenchman Felix Trombe to provide a convenient way to store solar energy for use at night. From the outside, a trombe wall just looks like a black window, as shown at right. From inside, it just looks like an ordinary wall. You can’t tell it’s there!

From the Outside: Two trombe walls, on either side of two windows. They just look like black windows.

From the Inside: The trombe walls look just like normal walls. If you touch them in the evening though, they feel very warm.

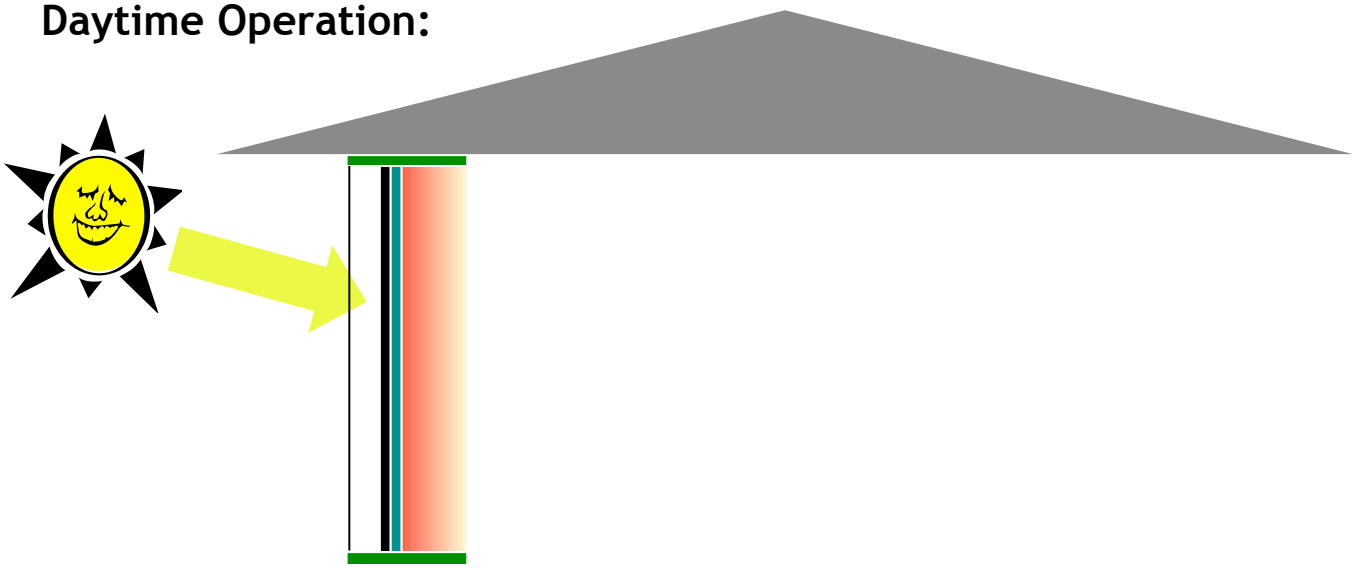
How trombe walls are constructed

A trombe wall is just an air tight sheet of window glass covering a black colored, solid wall made of some kind of thermally massive material, such as cement or adobe. There is no insulation, just an air space between the glass and the black surface. The construction is shown below. The black surface sometimes consists of a “selective surface”, which is especially good at absorbing sunlight (it absorbs the whole “solar spectrum” very well), but not radiating heat back out.

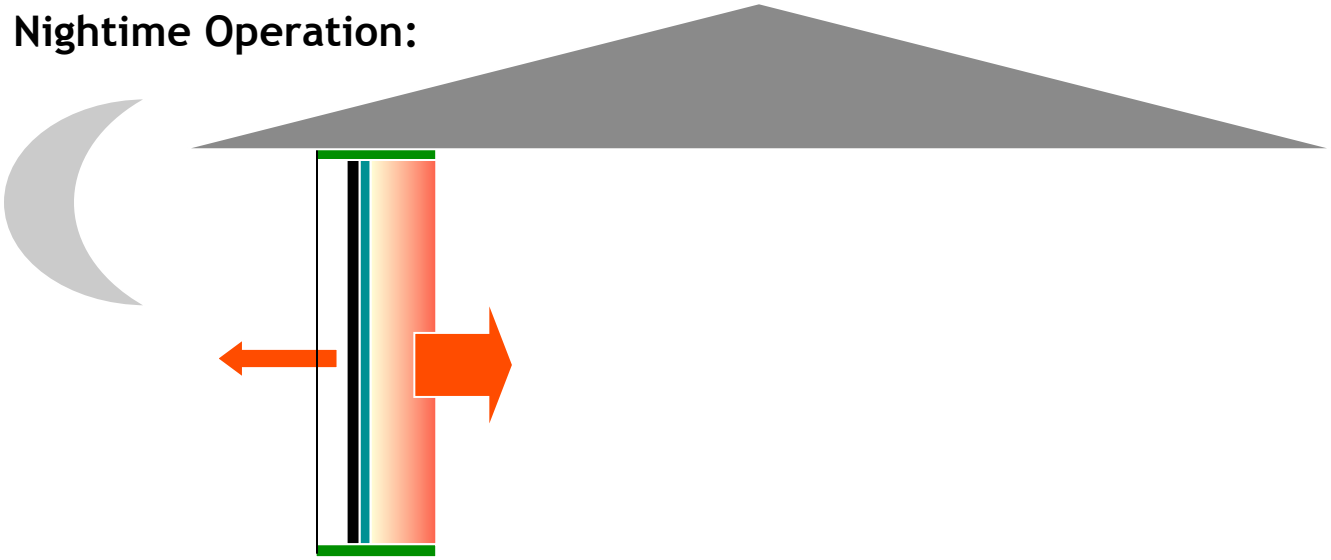


How it works: Sun shines on the trombe wall during the day, and is absorbed by the black surface. The surface and the air in the air gap get very hot (remember that the air gap is sealed), which helps drive the heat into the thermal mass of the trombe wall very efficiently. The heat gradually conducts through the wall, and then radiates into the house during the evening.

Daytime Operation:



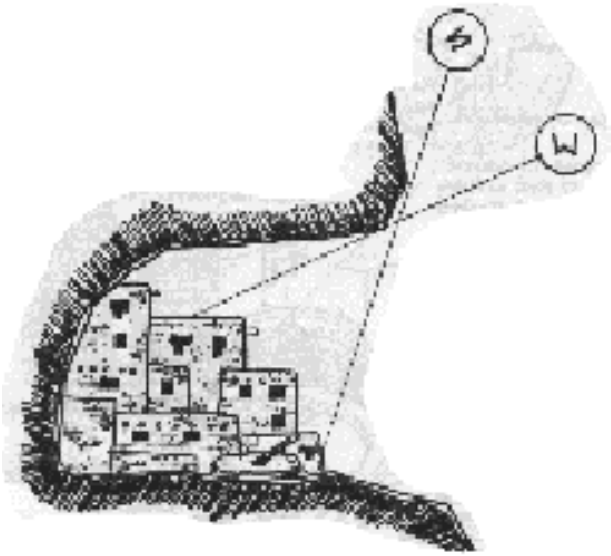
Nightime Operation:



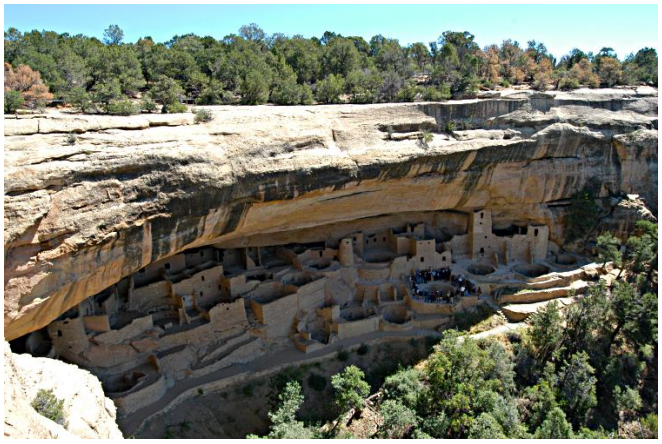
Combining a Trombe Wall with "Direct Gain": The south-facing windows in a passive solar house are called "direct gain" because they let the solar energy directly into the house, whereas a trombe wall is called "indirect gain" because the trombe wall first has to absorb the solar energy, and then re-radiate it into the house later. Combining direct and indirect gain (windows and trombe walls) works well, because the indirect gain only heats the home in the evening, after the Sun has gone down. It therefore doesn't make the home too warm during the day. The home in the photos above show how easily direct and indirect gain can be combined.

Special Topic: Native American use of passive solar

The idea of taking advantage of the Sun's differing paths in the sky during different seasons is not new: It was well known to the Native American Peoples of the Southwest. These peoples often built their cliff-dwellings in south-facing niches in the cliff walls where the Sun would naturally shine in during the winter, and not in the Summer. The massive adobe or rock walls would absorb the solar energy during the day, and radiate it back out at night, keeping their buildings relatively warm.



These photos show winter and summer views of "Cliff Palace" at Mesa Verde National Monument in Colorado:



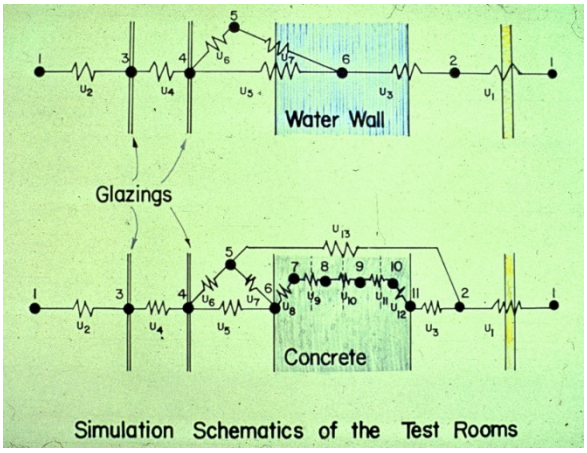
Summer

Winter

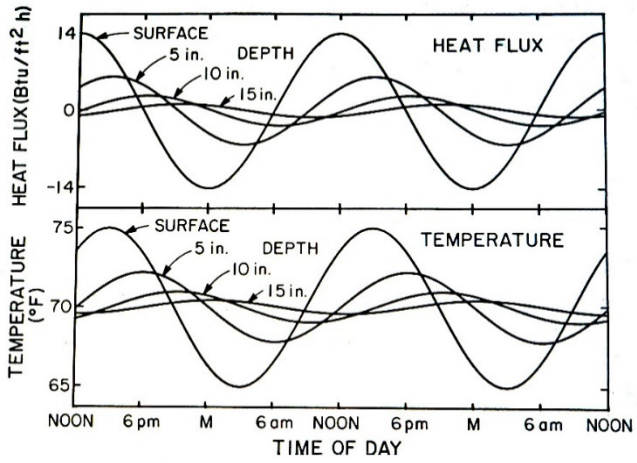
Other cultures that utilized passive solar design in such a clearly obvious way include the Greeks, who designed entire cities to face the south, and the Romans, who used passive solar to heat their bathes, especially when firewood supplies ran low in Rome.

Special Topic: Passive solar science at Los Alamos National Laboratory

Long after the Native Americans, in the 1970's and 1980's, scientists at Los Alamos National Laboratory in Los Alamos, New Mexico, studied passive solar design, and gave the World much of what we know *scientifically* today about passive solar design. Here are some pictures of the special test buildings they built, and some of their data:



Simulation Schematics of the Test Rooms



Guidelines for Passive Solar Design: Making the windows just the right size, and putting the thermal mass in the right place is very important. Special guidelines for this for Northern New Mexico can be studied in the section on Passive Solar Design Guidelines in Part III. These guidelines were developed by scientists and architects, such as those at Los Alamos National Laboratory, and especially by New Mexico architects, following the energy crises of the 1970's.