BUILDING

Keeping Cool Without Air Conditioning, Part I: The Cool Pool

David Bainbridge • May 16, 2014

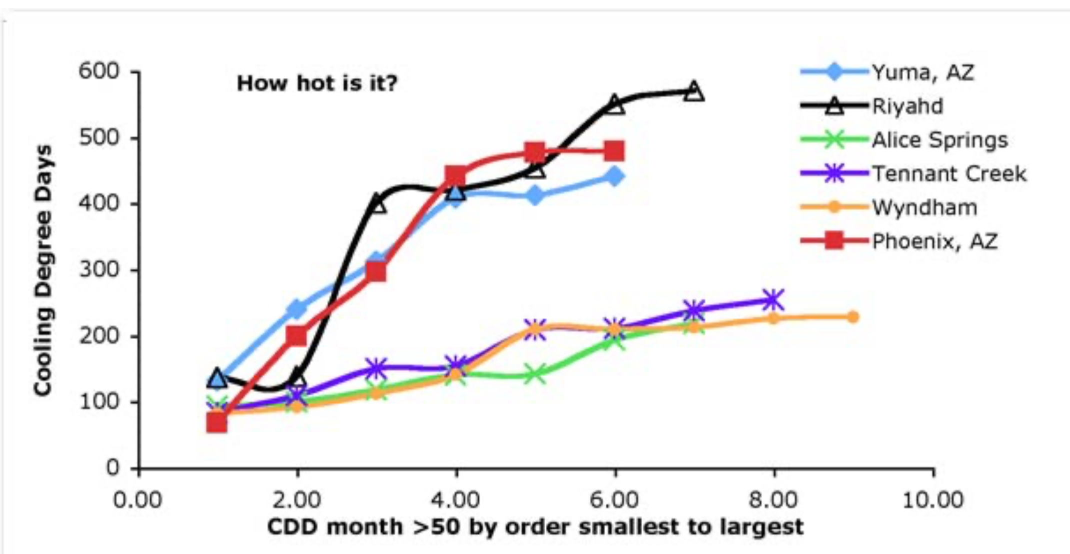
3 8 minutes read

Staying cool without an air conditioner is possible. It is easier in hot, dry areas. A building that gets too cool in winter is a problem, but occupants can add a vest or jacket and be comfortable even with temperatures as low as 10-15°C. A building that overheats in summer is more problematic — even with minimal clothing it is hard to stay comfortable as the temperature rises above 27-30°C.

Passive cooling strategies for new and existing buildings will become increasingly important as global warming causes many more heat waves and increases the need for cooling for comfort in buildings that were historically comfortable in summer, but are no longer. It will also be important for net-zero energy buildings.

Cooling demands vary widely with the orientation of the building's windows, the metabolism of the building and occupant behavior. Cooling loads are strongly influenced by unwanted solar heat gain in summer and by internal loads. The opportunities for passive cooling are influenced by building type, but good design can bring passive cooling to small-scale skin-dominated buildings and large buildings with low skin-to-volume ratios.

Cooling loads are usually described in cooling degree days — the difference between the average daily temperature and the base temperature. These may be base 23°C (65°F) or 26.7°C (80°F). In hot areas where people are adapted to higher temperatures base 26.7°C (80°F) is often used because people are acclimated. The following chart shows the cooling degree days for Alice Springs, Tennant Creek, Wyndham, Phoenix and Yuma (Arizona) and Riyadh, Saudi Arabia. These places all get hot in summer, (Figure 1), but although the Australian summers are longer the temperatures are hotter in Phoenix, Yuma and Riyadh. These are shown as months over 50 Cooling Degree Days (CDD), ordered by severity.

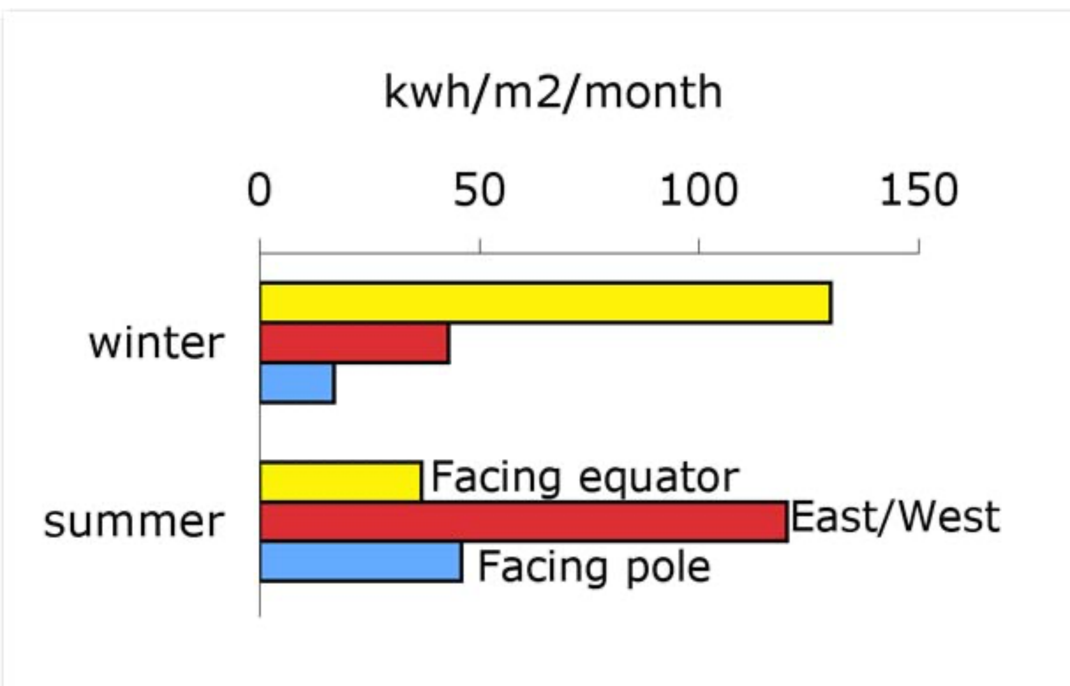


Hot hot climate (Figure 1)

Cooling degree days are not enough to base design on. Humidity and wind speed are very important for passive cooling and comfort.

Relative humidity (hour by hour) and average wind speed and direction are often reported and helpful to know. Low humidity will make it easier to use a downdraft cooling system (Part 2 in the series) or a direct (where it is dry) or indirect (where it is more humid) evaporative cooler (Part 3).

In smaller skin-dominated buildings the external loads commonly dominate the cooling load. Building and window orientation are critical to reduce unwanted heat gain in summer. Fortunately, the best orientation for cooling is also best for passive heating in winter (Figure 2). By adding an overhang the equator facing window gain in summer can be reduced further. This can be canvas or vegetation so that it can be extended in fall when it is hotter and minimized in spring when you still may need the heat. East and West facing windows cause overheating in summer and fall. They should be small and will benefit from lower solar heat gain factor glazing, but equator-facing windows should generally have high solar heat gain glazing for winter heating. In really hot places a summer insulated wall may be rolled into place on barn door tracks to cover windows that are used for heating in winter.



Window orientation (Figure 2)

Solar control with light colored walls and roofs, wide porches, double roofs, window overhangs, shutters, screens and shade is inexpensive and very effective. Landscaping can also be used to reduce external loads. Shade trees, green screens and even living roofs can reduce heat gain. Neighborhoods with extensive landscaping and trees can be 5-10°C cooler than those without.

Internal heat loads must also be managed carefully to reduce cooling demand. Lights, refrigerators, etc. all add heat. In larger buildings these internal loads often dominate the cooling demand. A super-insulated efficient refrigerator like a Sunfrost provides a double bonus for homeowners by reducing both energy use and cooling cost. In home, office and commercial buildings the use of daylight can reduce unwanted heat gain from lights. Careful placement of large heat producers such as refrigerators, freezers, and computer servers can help reduce heat gain in conditioned spaces.

Cooling opportunities

Passive cooling can rely on a wide range of cooling strategies, including solar control, ventilation, evaporation and radiant cooling. The goal is to modify the microclimate to provide comfort for occupants. Comfort may come from evaporative cooling, conductive cooling or radiant cooling.

Ventilation by opening windows and capturing cooling breezes is often sufficient to provide comfort in temperate areas. Ventilation can also be used to cool off thermal mass when outside temperatures drop at night to store coolness for use during the following day. Evaporation of water in a fountain, cool pool or roof pond can be used to provide powerful cooling. Radiant cooling to the cool night sky during the day can add additional cooling – and was used to make ice in ancient Iran. These strategies can provide sufficient cooling for full comfort in virtually any climate. Passive cooling can eliminate or minimize use of electricity while providing comfortable and healthy conditions.

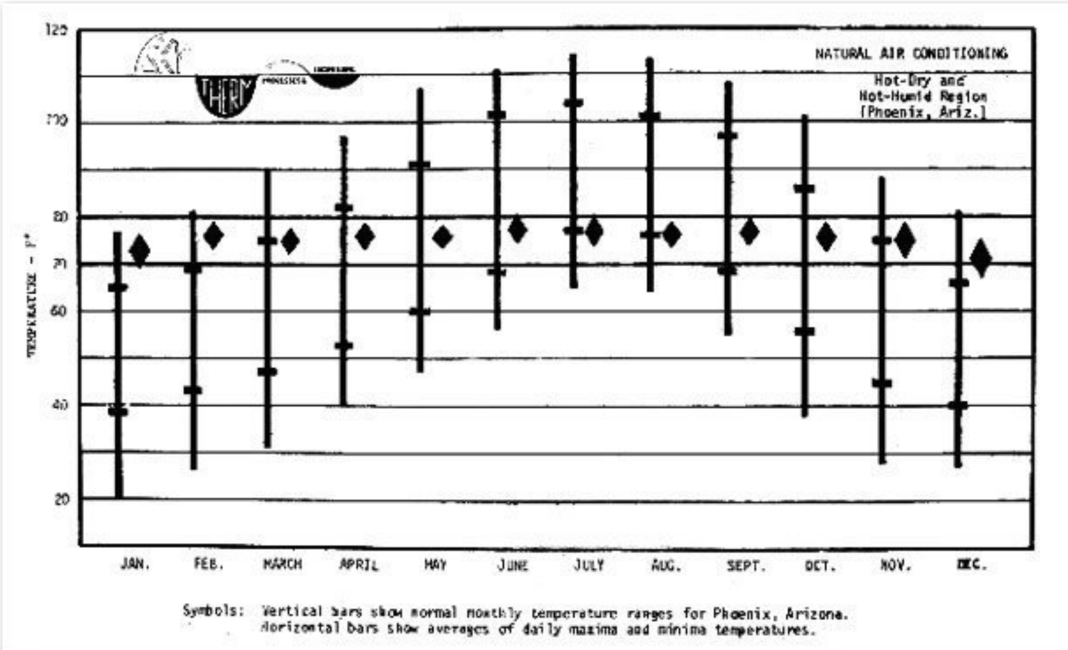
The most powerful cooling system is a ‘cool pool’. The cool pool is a pool of water over the room that is in thermal contact with the room below but is fully shaded from the sun during the day and throughout the cooling season. The pool stays cool primarily by radiating heat to the cool night sky and evaporation.

Living Systems conducted a series of experiments in Indio, California to test its potential for natural cooling in hot areas. The cool pool experiments were designed by Living Systems after a careful review of previous efforts. The research by professor Loren W. Neubauer included radiant exchange with the sky (day and night), cooling of low cost farm homes (including one with metal trays in the ceiling with open evaporating water for radiant cooling inside, and optimizing shapes for shading livestock. This demonstrated the cooling potential of a shade that provides full shading yet allows north sky cooling and ventilation. Harold Hay invented and studied the use of roof ponds for natural heating and cooling, beginning with a test cell in Phoenix, AZ (Figure 3), and then a full-scale house in Atascadero, California (Figure 4). These flat roof ponds were in water bags on a thermally conductive metal support. Sliding movable insulation above them could be opened at night and closed in the day in summer and vice versa in winter. These were operated by hand.

Phoenix test cell (Figure 3)

Atascadero house (Figure 4)

Test cell performance is shown in Figure 5. In the hottest time a fan coil added a bit more cooling to the room with cool water circulated from the roof pond. Insulation in the walls was poor as Hay wanted to show a system usable for the rest of the world. Super-insulation would be much better – and straw bales can do it. The principle stumbling block has been the lack of research in developing an inexpensive insulation system with automatic controls and tracks. Jon Hammond's ag based solution using hydraulic rams was a good one (Figure 6). Hay was not easy to get along with, like many pioneers, and this discouraged use of his patented system by others.



Phoenix test cell data (mid-summer fan coil using cool water from roof pond or evaporation
needed to maintain mid 70s. But still comfortable without) (Figure 5)

Jonathan Hammond and Marshall Hunt and the Living Systems team conducted several experiments on the cool pool concept that combines radiant cooling (Neubauer and Hay) with evaporation without sliding or lifting insulation panels.

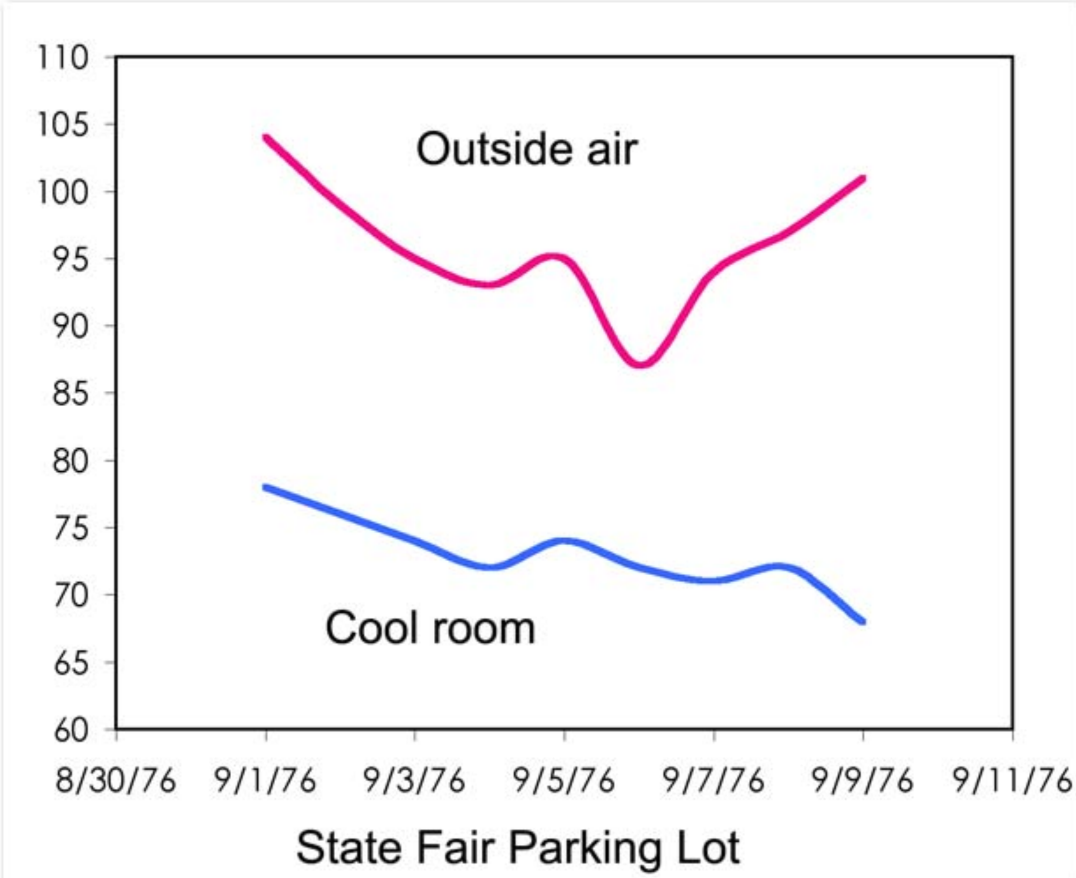
Jon Hammond's roof pond — lid up (Figure 6)

Three experiments were conducted in Indio to evaluate cool pool performance. The first test used two open cool pools in an effort to establish a baseline. In the second test, one pool was covered with clear plastic in an effort to establish the importance of evaporation in cooling. And the final test evaluated the cooling ability of the cool pool when a constant heat load was added.

The first experiment established a good performance baseline. The temperature of the water from the hose was 29° and the "cool pool" responded quite well, bringing the temperature down in two days to 21°. The second test showed the importance of evaporative cooling. In the final test a heat source was added to one cool pool to evaluate the cool pool's response to added heat input. The heat source at the bottom of the pool stimulates the operation of a cool pool building where internal heat gain from the room below would be transferred to the pool.

The results of this test series were very encouraging — as might be expected, the hotter the water the greater the evaporation. The results are summarized below with performance of the full size “cool pool” room in an asphalt parking lot at the California State Fair in Sacramento — see also Figure 7.

Initial cool pool tests:
Average Air Temperature
Average Cool Pool Temperature
Average Temperature with Plastic Cover on Cool Pool
Average Temperature with Heat Source
For full scale experiment: Sacramento State Fair Room in pa door
Average Cool Pool Temperature
Average Air Temperature
Average High Air Temperature
Average Low Air Temperature



Sacramento cool pool (Figure 7)

Cool pools can work for permaculturists, back-to-the-landers and folks 'beyond the black stump' who are off-grid. The roof tanks for a test cell could be made from some shallow galvanized sheep water tanks or feed trays or similar to hold the water. Full shading is a challenge and takes some calculations but sun angles can be found online now. Fins and/or sails for shading that maintain a clear view from the water surface to the polar sky are also needed. A clever person should be able to build a cool pool house but a good first step might be trying a cool pool room for sleeping comfort. This should be well insulated (straw bales perhaps), with excellent shading, good window orientation, and an insulated footing to reduce heat gain from soils around the building. A thermally conductive ceiling (the easiest being metal) is needed to conduct cool into the room below. Like the Sacramento test room, the cool pool can be connected to a water wall or central culvert for added cooling. Putting a metal cistern inside the house can also add cooling. In extreme events a PV powered fan can be set to blow across the pool for added evaporative cooling, or a small fountain pump can be activated.

As an aside, a pioneering below ground home and garden network in California ‘s hot central valley was dug by hand by Baldassare Forestiere (1879-1946), much like Coober-Pedy. Acres of tunnels, courtyards and pits had fruit trees, grapes and more. His hottest day retreat was at the deepest point in his cave network, underneath a glass-bottomed pool with fish. See: www.undergroundgardens.com/summary.html

Underground garden

More info:

- Passive Solar Architecture: Heating, Cooling, Ventilation, Daylighting and More Using Natural Flows by David Bainbridge and Ken Haggard (Chelsea Green, 2011). Some metric.
- Passive Solar Architecture Pocket Reference (Energy Pocket Reference) by David Bainbridge, Ken Haggard and Rachel Aljilani. (Int'l Solar Energy Society/Routledge 2010). All metric.
- Neubauer, L. W. and R. D. Cramer. 1965. Diurnal radiant exchange with the sky dome. *Solar Energy* 9(2):95-103.
- Neubauer, L. W. and R. D. Cramer. 1965. Shading devices to limit solar heat gain but increase cold sky radiation. *Transactions ASAE.* 8(4):470-472, 475.
- Cramer, R. D. and L. W. Neubauer. 1959. Summer heat control for small homes. *Transactions ASAE* 2(1):102, 103, 105.
- Haggard, K., P. Cooper and J. Renwick. 2005. Chapter 3, "Natural Conditioning of Buildings" in Alternative Construction: Contemporary Natural Buildings. Elizabeth & Adams. Wiley.
- Haggard, K., P. Niles and H. Hay. 1976. Nocturnal Cooling and Solar Heating with Water Ponds and Movable Insulation, ASHRAE Transactions 82:part 1, 793-807.
- www.degreedays.net will generate degree days to the base temperature you set almost anywhere in the world.
- https://www.susdesign.com/windowheatgain/ for more on windows
- Loren W. Neubauer was an agricultural engineer who preferred to be called "Tod". Co-author of Farm Building Design, 1961 – still useful. The motto in his office was *"It is better to be crudely right, than precisely wrong"*. Still good words to live by.

3 Comments

Gerald Katz

May 16, 2014 at 4:13 pm

Saw Hays cool roof system decades ago does work, but concentrated about leaks, a nd durability of moving insulation especially in high wind conditions and during occasional heavy rain. Choose perlite cement roof with imbeded Styrofoam and heat reflecting emitting elastomeric coating. 18 Inch Thick Rammed Earth walls thermal mass stabilizes temperature. Solar powered evaporative cooler with 8 inch honeycomb pads give 15 to 20 temperature drop using 100 Watts 12 volt DC. Radiant floor heating hybrid propane and solar. Solar water heating and we’ll pump.

Reply

Neal Spackman

May 17, 2014 at 3:06 am

Unfortunately for us in places like Riyadh (or Makkah), water is largely unavailable for letting it evaporate off our roofs. It makes more sense to me to use waste water off the house to grow plants shading the most solar-gain intensive sides of the home. Water is far too valuable in arid deserts to give it only one use, especially if that use is evaporation off the roof. This would be a difficult application for waste water as it would smell bad, quickly. Perhaps the brine off of desalinating R/O systems could be used for this, as a salty roof isn't nearly the problem that salty soil is.

Reply

Adil Maniar

May 24, 2014 at 6:36 pm

Neal, what about waste water on the roof to grow algae, the algae would be used to feed animals and the water would evaporate and cool the place. Isn't there any way to mask the smell?

Reply