A non-toxic zero-EMF radiant floor heating system

This house is heated with warm water that circulates in the concrete floor and by passive solar heat. It is designed for someone who is sensitive to chemicals, electricity and noise.

Keywords: heating system, radiant heat, floor heat, passive solar heat, healthy, non-toxic, EMF, noise, MCS, electrical sensitivity, hyperacusis

Here we describe the heating system of a house, that is located in the high desert of Arizona. At 5600 ft (1500 meter) elevation, the winters are cold, but sunny, with night-time temperatures routinely in the teens (around –10ºC) and occasionally lower.

The criteria for the heating system is that it must

- provide adequate, comfortable heat
- be non-toxic/pollution free inside the house
- be free of electromagnetic radiation inside the house
- be very quiet
- not require 110 or 220 volt electricity
- be energy efficient
- be reasonable in cost

The installed system has three components:

- super-insulated house
- passive solar heating
- radiant in-floor hydronic heating

This system costs much more than many common heating systems, such as forced-air heat, electric baseboards or wood stoves, but it is far superior to those in both comfort and cost to operate. A wood stove would be cheaper to operate, but not usable here due to indoor and outdoor air pollution. This system is worth the cost, the author has never been this comfortable during a cold winter, and after having to live in poorly heated houses for several years, due to environmental health issues, it was a real blessing.

It is difficult to say how much it all cost, as there are many components and some may not be of interest to all people. The extra insulation cost about $2,500, while the enhanced foundation added about $4,000 to the building cost. The passive solar system didn't cost much extra, as it is mainly good design that does it. The rest is difficult to price.

Insulation

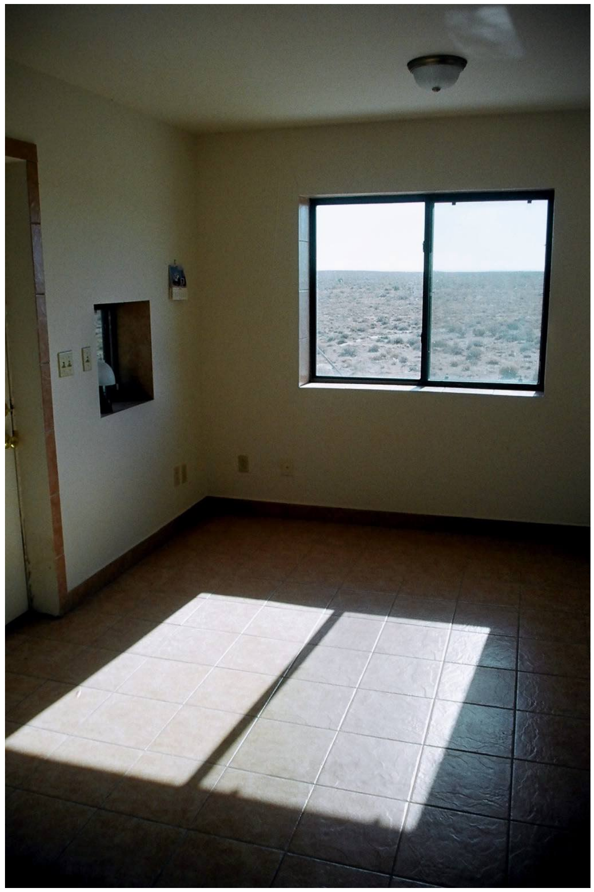
The house is insulated well in excess of the building code. The walls have 10 inches (25 cm) formaldehyde-free fiberglass insulation (Johns Manville brand) with an R-value of 32 (the building code requires R-19). The ceiling has R-60, double the requirement. The floor is a concrete slab, which is insulated around the perimeter and below to the ground with 2 inch (5 cm) foam boards. This has an R-value of 16. The insulated slab is essential when using in-floor heat, even in a warmer climate. Otherwise there will be too great a heat loss.

The roof overhang keeps the sun out during the summer and lets it in during the winter.

Passive solar heating

The Southwest USA is blessed with abundant sunshine year round, which is easy and cheap to use to help heat a house, if designed well.

This house uses passive solar heat. "Passive" means there are no moving parts: no pumps, no electronic controls, no valves. There are many books available on passive solar design, this author used *The Solar House: passive heating and* *cooling* by Daniel Chiras as a guide. People who seriously are considering a passive solar design should read a book about it. This article is only a brief introduction.

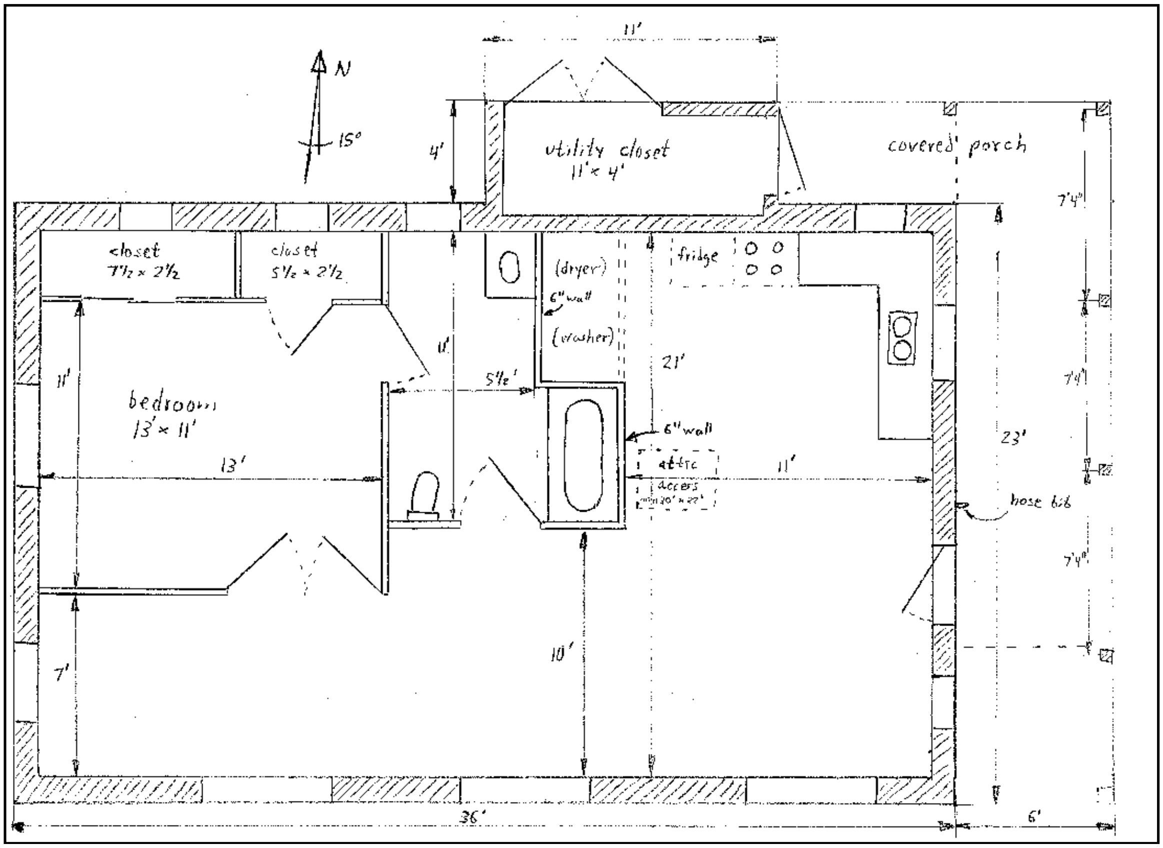


The sun enters the house in the winter to heat up the tiled floors.

The idea behind passive solar is that the sun's rays heat the house during winter days by shining through windows on the south façade. It does that very well since the sun is low on the horizon and shines directly through the glass. In the summer, the sun is much higher in the sky, and does not enter the house because the roof has a two-foot (60 cm) overhang that shades the windows. When the winter sun enters the house, it heats up the tiled floor, which sits on top of an extra-thick five-inch (12 cm) thick concrete slab that weighs about 23 tons. This heavy mass absorbs the heat and slowly releases it for many hours after sunset.

The most common mistake made in passive solar design is to simply fill the south wall with windows. Too many windows will make the house too hot on sunny winter days, and at night the many windows will lose too much heat. Chiras' book provides guidelines on how to calculate the size of the windows. This method worked very well.

For the other three sides of the house, only smaller windows were used, to reduce heat loss in the winter and solar heat in the summer. The north-facing windows are particularly few and small, for this reason. Low-E windows are used on all sides, except the south side where the solar heat is desired in the day, and simple shutters are used at night.



The house is oriented 15 degrees east from true south. This way, the sun hits the windows directly at 11 a.m. instead of noon. This gives a little more heat in the morning, when it is needed the most. Turning the house further east would reduce the overall heat gain.

The layout of the house is designed for the solar heat to be distributed throughout the house. The living room goes all along the south wall, while the rest of the house spreads out from it. This allows heated air to travel to the rest through the open doors.

There is a lot of glare from the sun during most of the day, which can be bothersome. This can be controlled by covering one or more windows with a piece of Reflectix insulation (aluminized "bubble wrap"), or simply by moving to an area of the house where there is no glare. A person who is willing to be a little flexible and work with nature can have a lower ecological footprint — and a lower heating bill.

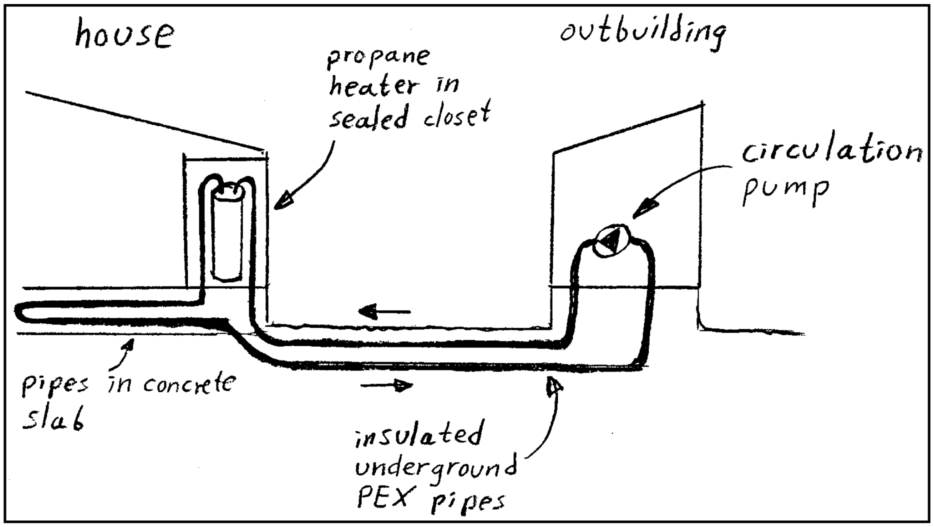
Pieces of Reflectix are used to cover the windows at night, to reduce heat loss. It only takes a minute to do every day. (Astro Foil is a little stiffer, but was not available locally.) This may scratch window sills made of drywall. In this house, the sills are covered with tile.

The passive solar system works very well in this house. As long as the sun shines, and for many hours after it goes down, the house stays very warm without using the furnace. And the house doesn't overheat, either.

During the first winter, the house was not yet finished. The walls were done and insulated, but the interior work was still ongoing. The heating system had not yet been installed. The author kept a recording thermometer in a north-facing window sill, probably the coldest spot in the house. During the winter, it recorded the coldest outside temperature as 1ºF (–17ºC), while the coldest inside temperature, in this coldest spot, to be 42ºF (+6ºC). Even without the furnace, this house would never freeze.

The radiant floor heating system

The concrete slab is ready to be poured. The PEX pipes and insulation can be seen.



The in-floor heating system consists of four loops of 1/2” (12 mm) PEX tubing that is embedded in the concrete slab. The four loops are fed warm water (about 90º–110ºF / 32º–44ºC) from a propane water heater that is located in a utility closet on the outside of the house. This closet is completely sealed off from the rest of the house by sealing the walls with aluminum foil used as wall paper and seal around all penetrations. The closet is only accessible through doors to the outside, and the propane pipes do not enter the living space. No fumes can enter the house.

The water heater is a standard propane water heater, but of a better quality that allows for full adjustment of the water temperature. The water is kept cooler than normal bath water, which saves a lot of propane. The water heater is also a high-elevation model, due to the lower air-pressure at the 5600 ft (1500 m) elevation. A low-elevation model would burn the propane less efficiently and thus consume more.

The water heater is completely mechanical and uses no electricity. It has a simple built-in thermostat that keeps the water in the tank within a temperature range.

The tank is 29 gallons (110 liters). Larger models have larger burners, but that was not needed here. The 30,000 BTU (about 29 kW) burner is fully capable of keeping up with the demand for this house of 830 sq ft (86 m^2).

A real boiler would be more energy efficient, but they are generally very expensive and designed for much larger houses. The company Buderus sells a small boiler that hangs on a wall, but it requires 110 volt electricity for the controls to function. This house has 12 volt DC electricity from solar panels and no 110 volt electricity.

The warm water runs in a loop from the water heater through the wall into the pantry. In the pantry wall sits the manifold: a plumbing device that distributes the water to the four PEX loops in the floor. The manifold has little valves so heat can be turned off in some parts of the house, or more heat directed to other parts.

The heat tunnel between the house and outbuilding.

The cooled water returns from the four PEX loops about 20 degrees (F) cooler and is received in another manifold that directs the water into a one-inch (2.5 cm) PEX pipe that goes down through an underground tunnel to the outbuilding 40 ft (13 meters) away. The underground tunnel is made of 6 inch (15 cm) polyisocyanurate insulation all around the outgoing and returning PEX pipes. This provides about R-24 insulation. The two PEX pipes carry water at nearly the same temperature and are only insulated from each other with thin strips of polyisocyanurate.

The sandwich of these boards is wrapped with two layers of 6 mil (about 0.15 mm) plastic, to keep moisture out. A layer of HardiBacker cement boards was placed on top, before the trench was filled in.

The outbuilding is well insulated (R–19 / R–30) and designed for passive solar heat through the large window in the south wall. It also has a large roof overhang to shield the window against the summer sun.

Inside the outbuilding sits a small 12 volt DC circulation pump, a Laing D5. The pump is specially designed for solar systems, and is very energy efficient, but sends out quite a bit of high frequency EMF, and some noise, so it had to be placed well away from the house.

An alternative 12 volt low-energy pump is the EL-SID, but it does not have speed control and sends out a lot more EMF than the Laing D5.

From the pump, the water either goes straight back to the house, or through a PEX coil in the concrete floor of the outbuilding. This is regulated manually with two ball valves, that are operated a few times a year. The outbuilding is just kept warm enough to be frost free in the winter.

From the outbuilding, the water returns to the water heater, through the underground tunnel.

In exposed areas, where PEX is not used, the water runs in 3/4 inch (2 cm) copper pipes. These diameters are used to reduce friction losses in the loop, so the pump does not need to work so hard and consume more electricity. In an off-grid solar house, energy consumption is much more important than in a regular house.

Air can be trapped in the system, and will tend to gather where the pipes turn downwards. In these places, a small vent ("coin valve") is installed to bleed off the air.

The gas water heater in its sealed-off closet, before the pipes were insulated.

Three temperature gauges measure the water temperature in the system: when exiting the water heater, when exiting the floor loops and when returning to the water heater.

The system is lightly pressurized, with about 5-10 psi, using a small expansion tank. The system is filled and pressurized by hooking up a garden hose to a hose bib mounted on a pipe.

Possible cheaper alternatives

The outbuilding was built anyway to house other things the author did not want in the house, such as a washing machine and the batteries for the solar electric system. It made sense to place the circulation pump here, which also allowed the building to be heated.

With a large house, it may have been possible to put the circulation pump in a closet in one end of the house. With a small house, one could dig a short tunnel (perhaps 20 ft / 7 m) out from the house. At the end of the tunnel, a small box could be placed to hold the pump and perhaps the batteries for it if running on solar. An ordinary large cooler could be used. It could be partially buried to protect against the cold.

Of course, people who are not bothered by EMF and noise could just put the circulation pump anywhere in the house.

Powering the circulation pump

The circulation pump is powered by a separate solar system that also powers the booster pump that pressurizes the tap water in the house. The pumps have their own electrical system for two reasons: First, the pumps send high frequency "dirty electricity" out on the wires, which the author did not want in the house. This does not seem to be such a large problem, as expected. The second reason is since these two pumps are very important to keep running, they should have their own system to ensure the batteries were not run down by lighting the house etc. during prolonged cloudy weather in the winter.

The solar system powering the two pumps consists of 120 watts of PV solar panels and two golf cart batteries. This has worked satisfactorily, even during three-day stretches of heavy clouds.

People who run their house on ordinary grid power and are not highly concerned about EMF need not pay attention to these issues. It is also possible to buy heavy line filters to remove any "dirty electricity" issues, though they are expensive.

Thermostat control

Since the system heats up the heavy floor, it provides a very even and comfortable temperature. With the radiant heat, it feels comfortable at a lower temperature than when using forced air heating. This saves energy.

It costs a lot of fuel to heat up the slab (imagine warming up a pot with 23 tons of water), but it takes little to maintain the temperature once it is warm. With this type of heating, it does not save anything to lower the temperature at night, it actually costs more to do so. It does not even save energy to lower the temperature if away for a weekend.

The temperature in this house is controlled by the flow of the warm water through the pipes in the slab. If the house is warm enough, the pump is stopped by the thermostat. When it needs to add heat, the pump is turned on again.

This can be controlled by an ordinary thermostat, located in the center of the house where the sun does not reach it. In this house, the thermostat is located on the kitchen wall, next to the pantry.

The thermostat must have a narrow range between on and off. Otherwise the temperature of the slab will vary too much, and that wastes fuel. A forced air furnace works best with a larger temperature range because it takes energy to get it started (start the motor and heat up the duct work), and a typical house sees more rapid changes in temperature than one with more thermal mass, like this one.

The thermostat used in this house is a very simple and cheap model (Honeywell CT31A1003). It works completely mechanically, with a metal spring that expands and contracts with changing temperature. No EMF-producing electronics. Two screws on the contacts inside the thermostat were adjusted to minimize the temperature range between on and off (about 1ºF, 0.5ºC). This was easy to do.

Remote thermostat communication

Since the pump is rather far away from the house, and no "dirty power" is wanted to travel on any wires, the pump is controlled by a home-built fiber optic system. It is very simple: the thermostat turns on an LED which shines into a plastic fiber that goes to the pump. Contact the author for the electronic diagram, but you must be able to put it together yourself.

An alternative is to let the thermostat drive a little relay, or use a thermostat with contacts that can handle about 1 ampere.

Using the heating system

The heating system has so far performed flawlessly for eight winters. The house has been comfortable under all winter conditions, in fact the author cannot tell whether it is 20ºF or 40ºF outside in the morning. There are no cold feet in this house.

The system is very quiet, the only noise is the faint sound of the water coming through the manifold and the low rumble of the boiler heard through the wall. The pump does make some noise, but it is not heard in the house. The pump would be very noticeable if it was inside the house and not in the outbuilding, though it is less noisy than forced-air systems.

The fumes from the propane heater in the outside closet have never been a problem.

The author experimented with the most energy efficient temperature setting of the water heater and the circulation pump. This was done with a variety of settings, and then watching the propane consumption over a two-week period for each setting. There are significant savings in optimizing these settings, it is well worth the small effort. The best combination was found to be with the water heater delivering at 100ºF (+/– 10º) (38ºC +/– 6º). The system does not have a flow meter (very expensive), but the Laing D5 pump was found to work most efficiently at the "3" setting (on a scale from 1 to 4). Every system is unique and must be tested. The heating system uses about 2 gallons (7.6 liters) of propane a day during the winter.

The passive solar system does produce a lot of glare on winter mornings. The author sometimes uses a desk in the bedroom during late mornings, to get away from it.

Resources

Laing (Laing D5 circulation pump for 12 volt, with plastic housing)
830 Bay Boulevard, Suite 101
Chula Vista, CA 91911
(619) 575-7466
www.lainginc.com
(search the web for the best deal)

The Solar House: Passive Heating and Cooling (book)
by Daniel Chiras
Chelsea Green Publishing, 2002

Other articles

Other articles about healthy houses can be found on
www.eiwellspring.org/saferhousing.html.

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