Draft

Chapter 1—Solar orientation

The house is situated fewer than 5 degrees from true south with slight variation based on living space—the family room, kitchen and dining areas are a bit east of south the living area directly south and the master bedroom is a bit west of south to catch the most solar energy during the day. The two rear bedrooms face directly south.

South facing solar glazing is maximized at 32% of the south facing wall in the vestibule entry, 15% in the dining room, 70% in the living room, and 17% in the master bedroom. Additionally, the clerestory adds 46% of the upper wall in the living room and approximately 70% of the family room upper wall. The second bedroom has 12.5% south facing glass and the rear bedroom 23% of the south wall is glazing. The south facing windows all have overhangs that permit winter sun to enter and exclude summer sun.

In addition to the solar glazing, there are passive solar heat collectors in the form of a Trombé wall. This area is glazed on the exterior with solar glass over a black membrane that captures heat and radiates it into the home. The wall is most effective in the winter when the sun is low and shines directly on the glazing. In summer the glazing is shaded like the windows. The system is entirely passive and the south block walls are built with mass designed to hold the heat generated by the sun in the exterior hot box areas. This system requires no maintenance, except to replace the glass if broken and to be sure the area around the glass is sealed.

Chapter 2—Thermal envelope

The rear walls of the house to the north, west, and east sides are set into the hillside and buried with soil half way on the short rear west side, to the eaves on the northwest, to the windows on the northeast and about ¾ on the east. The earth berming protects the house from winter winds from the north and northwest. The garage is also on the west side of the house and is insulated. It protects the house from both the heat of the western sun and the force of winds on the western side of the house.

The buried walls are poured cement between caisson columns and covered on the outside with 4” of extruded polystyrene insulation. The stick walls of the house are wrapped with 1” foil faced polyiso insulation on the exterior walls that acts as a thermal break. The stick walls in the slab area also have the 1” foil faced polyiso sheathing as thermal break and were insulated with R23 of Roxul rock wool for about R30 total, and sealed with Siga air barrier membrane. The ceiling in this area was insulated with R46 Roxul rock wool and a thermal barrier of 1 ½ inch unfaced polyiso was added. The ceiling was also sealed with Siga air barrier membrane and a ¾” air space for about an R60 roof. The rear two bedrooms and bath have the original insulation with between 5 ½ to 8” inches of unfaced fiberglass (R19 to R23) in the walls and 11 ½ inches R38 in the cathedral ceiling of the second bedroom. The air barrier is 4 mil plastic and drywall. The back bedroom and bathroom have an attic above that has 6” of loose fiberglass covered with another 2 layers of 5 ½ inch unfaced fiberglass or about R57. The ceilings have a 4 mil plastic air barrier under the insulation above the drywall. The floor over the crawlspace is insulated with paper-faced fiberglass to R19.

The floor of the crawl space is covered in high density vinyl--recycled billboard material--and sealed to the exterior walls. The south crawlspace wall is not buried and is insulated at the floor joists with 1 ½" polyiso, the area has no outside venting. The interior wall of the crawl space in the master bedroom and partial hallway is insulated to R19 and sealed with drywall. There are vents to allow for conditioning the crawlspace.
The windows and doors have been replaced with high efficiency Alpen models (525S and 725 doors) that allow for solar radiation to maximize the south facing window area (41-48% Solar Heat Gain—the highest I could find in a well-insulated window.) The windows on the north, east and west sides of the building are glazed with low e insulated glass. All windows have been properly flashed and sealed. Product and maintenance instructions are in the home file.
The garage wall is insulated with rock wool and sealed with the air barrier and fire rated drywall has been installed. The door to the garage is weather-stripped and self-closing. The air lock entry area is designed to exclude the garage from the living space so the door to the dining area and the rest of the house should be kept closed except for entry and exit.
The slab floor is protected by a waterproof and radon proof membrane and is poured over Wafflemat™ recycled plastic boxes (a floating slab support product) that provide about 8" of air space between 12" deep concrete beams. The whole area around and on top of the boxes is insulated with 2" of sprayed foam for a total of about R23 in the floor. The exterior of the slab has 3" of xps insulation to 24" deep facing the outside foundation and 18" on the buried facing foundation. The three inches of insulation provides an R15 thermal break from the outside foundation and the slab is sealed at the wall edges with roofing tape and deck paint and caulk. More information about waffle boxes is in the home file.

Chapter 3—Water System

The water supply is drawn from a well located on the north side of the house. The well water enters at the utility room and is stored in a 120 gallon pressure tank. The tank is filled when the pressure in the tank drops below 20 psi and the well pump shuts off when it reaches 45 psi. If the system loses pressure, the pressure regulator must be reset by holding the lever in the up position until the water repressurizes the tank. This is to prevent the system from leaking water under low pressure.
The well water is filtered through a MangOx water conditioner to remove excessive manganese and reduce the concentration of iron. Then it is sent through a carbon filter to remove sediment and provide purification. There is also a electronic filter device to break up calcium deposits so they don't clog pipes and on the hot water there is an Aqua-Pure Scale Inhibition AP430SS Water Filter that requires an AP431 Replacement Cartridge about twice a year. The water filter instructions are located in the home file.
The large MangOx filter includes a smaller black tank that cleans the filter when it back flushes. About a cup of regular household bleach is added to the water periodically. The filter is currently set to back flush about every 600 gallons of usage. There are other settings for the filter that allow for a timed back flush instead.
The main supply trunk to the house is ¾" Uponor aquapex, a high quality pex that runs around the perimeter under the slab and then into the crawlspace in 4" PVC piping. The

supply is in a continuous loop from the pressure tank to the back bathroom and the hot water returns to a circulating pump that feeds the instantaneous water heater in the boiler. The hot water is all insulated to R9 inside the casing pipe. The cold is not insulated.
The hot water circulating pump is a stainless steel Taco 009 with an integrated thermostat. The pump is activated by remote control approximately 3-5 minutes before hot water is needed at the remote taps. The pump will run until the temperature hits 110 or the remote control system stops at 15 minutes. (The timer on the remote control can be customized to meet your needs.) Hot water runs continuously until the taps are shut off. The house heat is off when the hot water is being used, but will not reduce the heating capacity of the system.
The house is served by a septic system. The tanks are located under the asphalt parking area and the lids cover a double tank system. The primary tank is pumped out at least every 2-4 years depending on the number of people in the house. There is a valve located in the yard near the border landscaping in a white PVC pipe that will direct the overflow into one of two drainage fields. The valve is changed seasonally. However one of the fields seems to be used even with the valve in the opposite direction.

Chapter 4—Condensing Boiler

The condensing boiler is a Triangle Tube Challenger Combo 105 that was originally rated at 96% efficiency when it was ordered, however, upon retesting after the purchase the efficiency rating was lowered to 90%. It is capable of 85000 BTU's of heat, which is 100% of the Manual J calculations. The water heat portion of the Combo is a ½ copper coil that can produce up to 2.5 gallons per minute of hot water. The heating coil of the boiler is ¾" copper. The copper coils are fused to an aluminum casing that transfers heat to the water from the gas burner.
The PVC pipes at the top of the boiler deliver fresh air for combustion and provide exhaust. The boiler is modulated, so the amount of heat it produces is controlled by the outdoor reset sensor located at the roof eave on the east side of the utility room roof. As the temperature outside goes down, the boiler produces hotter water. The reset curve is set in the boiler control sequence. The instructions for the boiler are in the home file.
The water that returns to the boiler must be below 130 degrees for the boiler to condense. The condensation in the exhaust pipe releases extra heat that is recovered by the boiler to improve heating efficiency. Because the reset curve sends cooler water to the radiant heating coils and baseboards when the temperature is above zero, the return water is also cooler. This difference in temperature between the supplied water and the return is known as the delta T and should be between 10 and 40 degrees. Design delta T for this system is 20 degrees and the temperature of the water in the pipes should be about 120 degrees to heat at zero degrees design temperature—so the curve is set at 140 degrees for an outside temperature of zero. That allows for return water at or below120 degrees to condense in the boiler and extend the period of its most efficient running mode. The floor will be about 84 degrees at design temperature.
The boiler should be serviced after a long period of use—a year or so, to clean the burner plate and ensure continued successful operation. The condensate tube and holder should be checked for soot and cleaned and refilled two or three times a season. Condensate is

acidic so it is filtered with limestone and the waste is sent to the sump in the utility room floor.

Chapter 5—Radiant Heat and Cooling.
The concrete slab is heated by hot water passing through the ½" Uponor Oxygen barrier pex located approximately 2" below the surface of the slab. The warm water heats up the concrete and radiates into the room. This heating source can be slow to warm up but lasts longer than hot air heat.
The loops of pex are divided into zones based on the heat loss of the rooms and the length of the pipe. The zones are the dining area and the front entry, the family room, bathroom and kitchen, the living room, and two loops on the same thermostat feed the master bedroom and bath. The rest of the house has baseboard fin style radiators that are adequate to heat these rooms at 120 degrees water temperature. Baseboard heaters can take longer to recover from a nighttime setback so we don't typically set this zone lower at night. This run also helps to condition the crawl space under the house although all the heating pipes are insulated with R-9 pipe insulation. A layout of the radiant piping is located in the home file.
The radiant system can also obtain warm water from the fireplace boiler. The water is sent to the water heater storage tank and when hot enough will provide hot water for the radiant system instead of the gas boiler. A system of controls will turn on this function as explained in the Wood Boiler chapter.
Running cool water through the system in hot weather will also help cool the house. The water must just be warmer than the dew point to prevent condensation but dew point is generally quite low in Colorado. Since the system is designed to reuse the same water—the water must be artificially cooled which can be accomplished by using a split heat pump to circulate refrigerant through a brazed plate heat exchanger. Since we chose a boiler system cooling is not yet installed.
A Taco six zone controller receives a signal from the thermostat. Each thermostat is wired to its zone and the controller turns on both the boiler and the secondary system pump.
Honeywell thermostats control the zone temperatures and have the capacity to control multiple heat and cooling settings but are currently only set for heat. These are seven day programmable thermostats that allow for dialing in comfortable temperatures any time of day. Instructions for the thermostats are located in the home folder.
There is also a NEST learning thermostat in the living room area. This thermostat is designed to record the energy use of the home. It can be controlled by a smart phone. All account information is located in the home file.

Chapter 6—Fireplace Boiler
The fireplace is designed to supplement hot water for the radiant heat system. Piping under the slab connects the water heater tank in the utility room to the hot water pipes in the stove. The pumping system must switched on when the fire is started and when the water in the system reaches 90 degrees a zone valve opens and warmed water is sent to the storage tank. When the house calls for heat, the zone controls will check first to see if the water in the storage tank is warm enough to use. The stove water is run through a heat

exchanger so that the two sources do not mix (to avoid contamination of the radiant system from the steel in the fireplace pipes). If the storage water has used up its heat, then the boiler will fire to heat the house.
The fireplace has an external air source that flows through the cold water pipe chamber to the stove air supply. This will keep the combustion air from being drawn from the living space. The chimney is double insulated pipe up to the box that extends through the joists to the roof. It is safe to place combustibles within 12" of the pipe and within 12" of the stove because of the water jacket. A pressure relief valve is located on the left upper side of the stove. If the stove is over pressurized (too hot) then any steam and hot water will escape through the valve to the tank below the stove. The tank has an overflow that will seep under the floor. A small amount of water drainage will not affect the slab. Stove water temperature and pressure may be read from the gauge installed on the top of the stove. The door to the stove must be closed during use and the seal must be kept in good condition. The glass should self clean due to the draft, but extra cleaning should take place only when the stove is cool. The stove user manual is located in the home file.

Chapter 7—Ventilation and Cooling

The dry Colorado climate allows for use of an evaporative cooler to push cool air into the home. For this system to replace the warmer air in the house with cooler air, the windows need to be open to allow the warmer air to escape and pull the cooler air into the rooms. This cooling is effective to an outdoor humidity level of about 30% and loses effectiveness as the humidity level increases. The cooling is based on the difference between wet bulb and dry bulb temperatures. The lower the humidity, the greater this difference, and the higher the degree of cooling that can be pulled from adding humidity to cool the incoming air. The evaporative cooler works by having ¼ inch pipe deliver water to the pan below the fan and pumping that water through the cooling media that lines the sides of the cooler. Air is pulled through the wet media and is cooled to the wet bulb temperature and then pushed into the house with a large fan.
When the humidity rises above 50% or so, the difference between the wet bulb and dry bulb temperatures is lower so less cooling can be pulled from the wet air.
Ventilation is provided to the home through an ERV (Energy Recovery Ventilator) that is located above the kitchen pantry. The ducting for this system is run inside the house and delivers fresh air to the major living areas of the home. The temperature of the incoming outside air is modulated with the exhaust air leaving the house as well as the humidity levels. The returns are located above the kitchen pantry. The system has Merv 12 air purification filters that must be replaced periodically according to the maintenance instructions in the home file.
In addition the two bathrooms located away from the ERV have energy efficient exhaust fans that run automatically when the humidity level in the rooms reaches 60%. These fans are vented to the outside.
The garage is also vented with a fan that pushes contaminated air outside. The vent is located in the ceiling and is controlled by a timer that is activated by a switch when the garage door is opened or closed.

Chapter 8—Radon Mitigation

The home is treated to reduce radon gas infiltration from the ground under the house. There are two under slab vents based on the square footage of the house and the crawlspace is sealed with a vinyl layer and vented with a Fantech radon vent fan located on the outside vent pipe. There is an outlet in the loft over the living room walk in closet for one radon vent. The kitchen panty radon vent exhausts radon through a second Fantech fan. The sump pit in the utility room has a radon cover that is sealed at the openings for the piping. The slab is sealed around the perimeter and has a 10 mil plastic vapor barrier installed underneath the slab and the waffle boxes that is sealed around all penetrations with good quality vinyl tape. The layer of spray foam over the waffle boxes is an additional deterrent to radon. The edges of the slab are also sealed against radon penetration with caulk, painted roofing tape, and tile. Design and radon fan information are located in the home file.

Chapter 9—Air Lock Entry

The reception area of the house between the garage and the living space is designed as an airlock entry. The interior door should remain closed when the front door or garage door are opened. This airlock will reduce pollutants introduced to the house and will temper the outside air to reduce heat loss or gain. The entry also allows for shoe, boot and coat storage that will help the interior of the home stay cleaner.

Chapter 10--Wiring and utility chase

The main wiring trunk for the home is located in a separately insulated cavity in the roof that runs along the south side of the main beams. The wires enter from the garage and continue across the living area to a branch that crosses to the north end of the back bedroom hallway roof. The wires enter the attic to be distributed to the rear bedrooms and bathroom.

This exterior wiring is run outside the air barrier and openings are sealed with tape or caulk. Any outlets on exterior walls are either below grade, sealed to the air barrier, or are located inside the air barrier. There are no outlets and switches located inside exterior walls except on the garage wall.

The home is protected by direct-wired fire and carbon monoxide alarms in the airlock entry, dining area, living area, and master bedroom and back bedroom areas.

Chapter 11—Plumbing Fixtures

All plumbing fixtures are water sense certified. The toilets are either Stealth very low water use dual flush (.5/1.0) or regular dual flush (.8/1.1). The faucets are Delta and Kohler brands and are all water sense certified. Showerheads reduce water flow to an average of less than 1.75 gallons per minute. Fixture and faucet user manuals are located in the home file.

Chapter 12—Appliances

The refrigerator, dishwasher, and clothes washer are all Energy Star Certified. The dryer is gas, a more energy efficient alternative to electric. The stove is gas with a downdraft

filtered exhaust system. The ventilation system is sized to boost kitchen ventilation to 100 cfm when needed. Manuals for these appliances are located in the home file.

Chapter 13—Central Vacuum System

The home has a central vacuum system that has HEPA filtration and outdoor venting to provide the most clean air method of vacuuming the house. The unit is located in the garage where there is a utility outlet for cleaning car interiors. The unit's piping is located in the ventilation duct chase under the clerestory windows. The outlets are either powered for use of the carpet head, vacuum only, or dustpan function. The outlet in the entry room is dual purpose, vacuum only or dustpan. There are two sets of hoses, one powered and the other plain that are stored in the closets near the outlets. The unit is an Aspria, capable of cleaning a much larger home. It is either bagged or bagless but we have chosen to use bags for ease of cleanup. The bag needs to be changed two or three times a year depending on use. Maintenance information and user manual can be found in the home file.

Chapter 14—Lighting and Light Shelves

All light fixtures have LED bulbs installed. These bulbs are Feit warm light and they are among the highest for color rendering among LED bulbs. The bulbs use less than half the energy of CFL bulbs and produce a more natural light.

The ventilation ductwork chase serves two purposes. Where the chase runs under the clerestory windows the white surface of the Corian shelf helps distribute light throughout the rooms by distributing light waves up onto the ceiling as reflective light instead of direct. To fulfill this function it is helpful if the shelf is kept dusted to allow for the reflective quality of the white Corian and ceiling to effectively distribute light.

Chapter 15—Landscape

The natural soil on the 1.8 acre lot is a bentonite clay. This soil is characterized by deep cracks in dry seasons and swelling in wet. To mitigate water runoff, several berms have been created across the downslope. These are designed to capture the water and let it seep into the soil. The turf has been seeded with drought tolerant buffalo grass and other drought tolerant species. Colorado grass does not grow quickly and the turf areas only need mowing about once a month.

The pergola in the front yard defines the home's outdoor living space. The patio is both flagstone and recycled rubber tile with a small wood deck for a table and chairs.

Outdoor electricity is one 20 amp circuit that is GFCI protected from the outlet inside the garage next to the door. A separate 50 amp circuit is run to the hot tub located on a concrete slab and a separate 15 amp circuit is in the same service box. The side yard includes a dedicated 20 amp circuit for a small removable pool's equipment or other uses.

The back garden area is enclosed by a recycled concrete wall that extends down 3 ft into the earth to help rid the garden area of voles and other pests and to avoid frost heaving of the wall. The garden soil has been improved for years with manure and supplements so that it is organic, very healthy and productive.

The fruit tree area is also bermed to catch water from the adjacent canal elevated walkway. Fruit trees are very needy of water so water is captured from the roof to help

keep them alive in the hot season. Currently this water is hand carried to the trees or fed from a barrel. Colorado limits the amount of captured rainwater to two 55 gallon barrels, however these can be emptied as often as needed.
A railroad tie border surrounds the playground area. This area is covered with fine gravel and there is a sandbox under the fort. Climbing structure, swings and slides are used at your own risk. Be sure to have adult supervision especially for small children.

Chapter 16—Durability Issues

The preliminary meeting identified durability issues for the continued trouble free maintenance of the home.

Exterior Moisture

In addition to the required exterior moisture control measures, a waffle box system was installed under the slab floor to allow for the expansion of the soil under the slab. The slab is fully floating inside the foundation and the walls are constructed to float with the slab.
The siding incorporates both a SIGA moisture barrier and a rain screen layer to allow for complete drying behind the siding. Fiberglass edging is installed over the exterior insulation past the concrete walk to protect the insulation from moisture penetration.

Interior Moisture

In addition to LEED required protections, a special SIGA air barrier that allows for drying through the air proof membrane protects against moisture in the roof and wall areas. The exterior retaining wall around the rear window area has been rebuilt to improve drainage. High R-Value well sealed windows help keep moisture from penetrating into the home.

Air Infiltration

The home uses several layers of air barrier to minimize air infiltration. The reconstructed area uses the special air barrier, with all the joints caulked underneath the barrier and the film sealed with caulk or tape to the exterior walls. The ceiling uses a sealed polyiso layer and this layer is also applied to exterior walls where multiple 2 x 4’s come together.

Interstitial Condensation

The use of the SIGA “breathable” air barrier also prevents warm moist air from inside the building from meeting any cold dry air and condensing inside the walls and ceiling. The high R value windows and doors keep condensation on the outside of the house.

Pests

Fine stainless steel Xcluder mesh is used around exterior piping and at the top and bottom of the siding to avoid mouse and insect penetration. The windows and doors are caulked and sprayed with foam to eliminate openings that would allow for pests to enter. Also when the airlock entry is used to enter and leave the home, another barrier is in place to avoid pests in the home.

Heat Loss

In addition to the high R values of the walls, roof, and floor, the concrete slab edges are insulated both inside and outside the foundation walls.

Natural Disasters

Features that protect this passive solar home from natural disasters are that the earth berming protects from high winds and tornados, the post and beam construction protects

against earthquakes, and the non-vegetative barrier around the house protects from wildfires.

Appendix

i. The completed checklist of LEED for Homes features
ii. A copy of each signed Accountability Form
iii. A copy of the durability inspection checklist
iv. The product manufacturers' manuals for all installed equipment, fixtures, and appliances (home file)
    a. Windows
    b. Waffle boxes
    c. Water filters
    d. Challenger boiler
    e. Radiant layout
    f. Thermostats
    g. Wood boiler
    h. ERV
    i. Radon design and fans
    j. Faucets and fixtures
    k. Appliances
    l. Central vacuum