

Ground Loop Performance Tests in Quincy, CA

This is a message from Bill Martin, your geothermal heat pump user/advocate explaining some of the mysteries of my home's interaction with the renewable thermal resource beneath the earth. This message is an illustration of the thermal exchange between the inside of our house, the outside air temperature, and the dirt on our property at a seven foot depth. This arrangement, coupled with our solar photovoltaic array on the south-facing roof is what got us to *carbonless* ZeroNetEnergy *positive* performance for the year ending 11/16/15. We exported 1,500 Kilowatt-hours more electricity to our utility than we consumed in this house. Wanna know what's going on here? Keep reading.

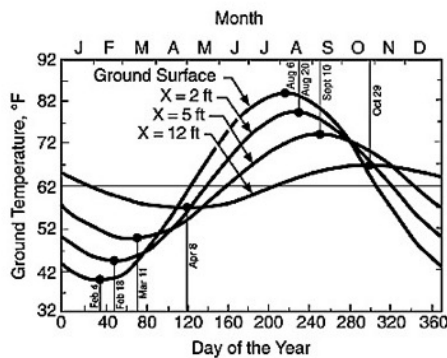
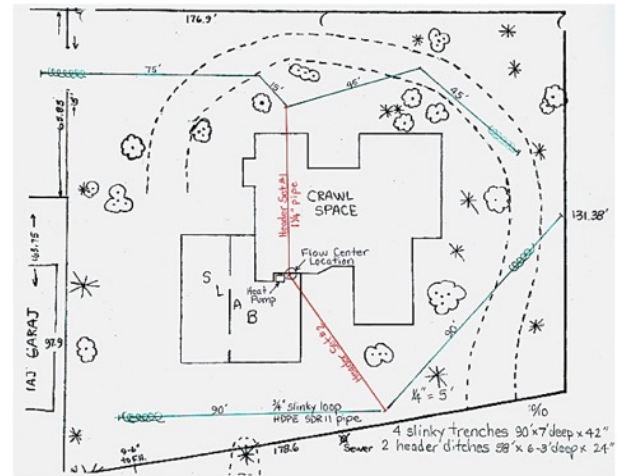


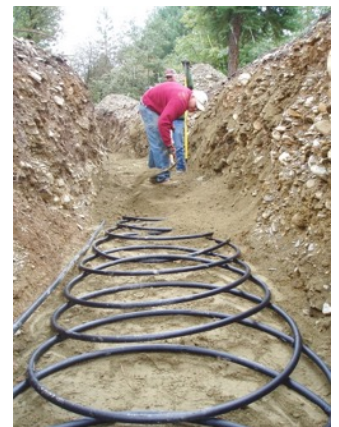
Figure 4. Seasonal soil temperature change as a function of depth below ground surface for an average moist soil.

Performance testing for my heat pump installation began 10/31/15 and will continue 11 more Saturdays until early April, 2016. It is normal for a horizontal ground loop like mine to experience lowered (and then recovering) temperatures as we move into winter and then out to spring. As you've heard, California has completed four years of drought and the soil moisture levels have been at 100-year lows. This increases the difficulty in pulling energy from or rejecting energy to the underground, shallow earth.

In Figure 4, notice that the deeper the ground loop, the greater the delay in underground temperatures' response to above ground temperatures. This represents the normal underground seasonal variation, absent heat exchange loops or any other influences. The deeper you go, the lesser are the temperature swings, and they come later in the year from the peak and minimum solar radiation inputs (solstices).

The yellow boxes with a red number (page 2) display the average of five tests on each morning for entering water temperature from my ground loop. Some of the thermal energy represented in the early heating season's EWT average undoubtedly comes from the previous summer's cooling. Unwanted summer heat rejected underground provides a bit of a "flywheel effect" as we move toward winter. For heating, anything above 41° guarantees that I am getting *better than* nameplate performance efficiency from my heat pump. In January of 2015, our EWT average touched 40.9° during tests, but climbed back to 46.4° by April 4th. Decent soil moisture would improve this performance and thus far, the winter of '15-'16 looks likely to improve conductivity because of better rainfall.

With the exception of those \diamond t readings displayed in pumpkin-colored cells, I always try to test at 67% of compressor capacity (known as Stage One). When this GHP runs at 67%, the entire system is consuming under 1,800 watts—an amount that's less than wife Susie's hair dryer.



A thermal cause-and-effect to watch for in the testing spreadsheet below includes the ducted air circuit (loop) between the inside of the house and the heat pump unit placed adjacent in the garage. This is abbreviated as EAT and LAT. Also, check the displays of temperature of the incoming ground loop water and the outgoing water, which will circulate underground for 11 minutes before returning (3-3.5° warmer in Stage 1 and 4.2-5° warmer in Stage 2 operation) to the main heat exchanger. Other measurements track the hot water pre-heat loop, and its effect on the refrigerant circuit. A full set of abbreviations and definitions are found on page three.

Regarding the LAT product that is discharged for heating, let me remind that heat pumps (whether air-sourced or ground-sourced) are designed for maximum efficiency. This requires that they discharge into occupied spaces at much lower temperatures than fossil-furnaces do. For this reason, all heat pump ducting is designed for lower temperature distribution of high *volumes* of air at much lower *velocity* than typical furnaces. This also prevents the sensation of cold drafts and the visual of waving curtains on your walls. Heat pumps are also designed for longer cycles of run time. Many people prefer this delivery because the consistency of summertime humidity removal is improved, while the sensation of circulating air is maintained. The spreadsheet below is all about winter heating, where the same run-time characteristics are helpful for the same reasons.

The Δt readings you see represent the thermal energy removed from underground that was used to evaporate liquid refrigerant in the heat exchanger into a gas. The compressor can raise the temperature of this gas by over 100°, something helpful to distribute energy where needed.

Performance records for the Martin heat pump at 220 Miller Ct Quincy, CA											
<12> Winter Loop Tests 10-31-15 to 4-2-16											
Date	Time	OAT	EWT	LWT	Δt	EAT	LAT	HWIN	HWOUT	R1< dsh	R2> dsh
10/31/15	8:35	37.1	58.6	53.6	5.0	65.7	88.5	89.0	91.8	125.1	105.2
	8:40	37.0	58.0	54.1	3.9	67.9	91.7	91.9	95.5	137.2	109.7
avg. EWT=	8:45	37.0	57.0	53.3	3.7	68.3	91.4	92.5	96.0	137.5	110.0
57.4	8:50	37.5	56.8	53.2	3.6	68.5	91.5	93.1	96.5	138.5	110.6
base	8:55	37.8	56.6	53.0	3.6	68.7	91.9	93.6	97.1	140.0	111.4
11/14/15	7:50	30.4	52.8	49.3	3.5	64.9	84.3	88.6	90.1	114.8	97.7
	7:55	30.6	52.4	48.9	3.5	66.3	87.6	90.9	93.6	129.9	105.3
avg. EWT=	8:00	30.7	51.9	48.4	3.5	67	88.4	91.2	94.3	134.5	107
52.0	8:05	30.8	51.6	48.1	3.5	67.3	88.6	91.6	94.9	137.2	108
-5.4	8:10	31.1	51.4	47.9	3.5	67.5	88.7	92	95.4	138.7	108.8
11/28/15	7:35	17.1	46.1	41.8	4.3	66.6	94.3	115.1	117.8	147.8	127.9
	7:40	16.7	45.7	41.5	4.2	67	94.6	115.7	118.5	150.4	129.2
avg. EWT=	7:45	16.4	45.5	41.2	4.3	67.2	94.7	116	119	151.9	129.9
45.6	7:50	16.8	45.3	41.1	4.2	67.3	94.7	116.2	119.3	152.8	130.4
-6.5	7:55	17.6	45.2	41.0	4.2	67.4	94.8	116.6	119.6	153.4	130.8
12/12/15	7:15	33.5	43.8	40.7	3.1	68.3	87.7	103.3	106.1	146.2	116.3
	7:20	33.3	43.5	40.4	3.1	68.2	87.6	104	106.7	145.3	116.5
avg. EWT=	7:25	33.5	43.6	40.5	3.1	68.2	87.7	104.3	107	145.4	116.8
43.6	7:30	33.6	43.5	40.4	3.1	68.2	87.6	104.6	107.4	145.6	117
-2.0	7:35	33.3	43.5	40.4	3.1	68.2	87.6	104.9	107.6	145.7	117.3
Date	Time	OAT	EWT	LWT	Δt	EAT	LAT	HWIN	HWOUT	R1< dsh	R2> dsh

Last Post		Web Energy Logger Sample Image	
Time: 10:18:08 EST		CRWL	54.4°F
Date: 11/29/2015		GAR	50.1°F
R1	154.8°F	HWIN	117.4°F
R2	131.6°F	HWOUT	120.4°F
		Zone1	74.7°F
		Zone2	68.7°F
		Zone3	66.5°F
R4	37.2°F		
R5	41.3°F		
EWT	44.8°F		
LWT	40.7°F		
OAT	14.6°F		
EAT	67.8°F		
LAT	95.5°F		
ATT	14.3°F		

Last Post		Web Energy Logger Sample Image	
Time: 03:06:58 EST		CRWL	54.8°F
Date: 12/16/2015		GAR	50.4°F
R1	147.0°F	HWIN	109.1°F
R2	119.9°F	HWOUT	111.6°F
		Zone1	74.8°F
		Zone2	69.2°F
		Zone3	66.0°F
		UG Temp@3ft	42.6°F
		UG Temp@7ft	47.7°F
R4	36.1°F		
R5	41.9°F		
EWT	42.3°F		
LWT	39.3°F		
OAT	23.1°F		
EAT	67.9°F		
LAT	87.2°F		
ATT	24.2°F		

In the two red boxes above, we see “snapshot” displays that report actual temperatures at the time. On the left, the difference in EWT-LWT temp of 4.1° and the LAT temp of 95.5° reflect both Stage 2 operation and a higher entering water temperature. On the right, the heat pump is running in Stage 1, about 1,800 watts of consumption. Two more sensors for underground temperature show the thermal improvement of loop pipe at seven foot depth. 24-hr access to this information is at the following link: <http://www.welserver.com/WEL0675/>

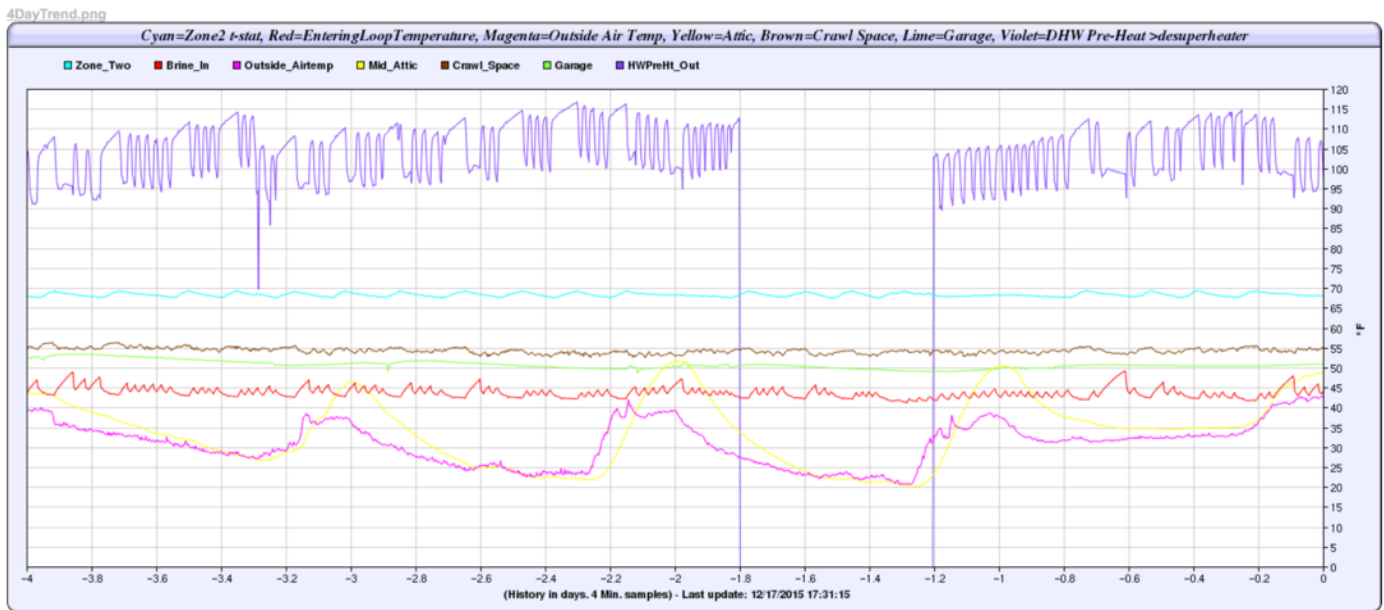
Temperature Sensors strapped to pipes, hanging inside or outside, or suspended in ducts

Left side of reporting display

R-1	Refrigerant (gas) after leaving the compressor, headed for the de-superheater
R-2	Refrigerant (gas) after leaving the de-superheater (a device that pre-heats hot water)
R-3	A Refrigerant (gas) sensor that does not report and is in a near-impossible location to access
R-4	Refrigerant (liquid) after passing (Htng) or before entering (CIng) the thermo expansion valve
R-5	Refrigerant (gas) just before entering the compressor
EWT	Entering water (“ brine ”) temp to ground loop heat exchanger inside heat pump
LWT	Leaving water (“ brine ”) temp from ground loop heat exchanger, headed back underground
OAT	Outdoor air temp, in a sun-protected enclosure, NE corner of house @4 feet above ground
EAT	Entering air temp in return air duct (from 4 ceiling intakes) just before entering heat pump
LAT	Leaving air temperature in supply air duct (under-floor) on the way to perimeter floor registers
ATT	Temperature in mid-point in tallest portion of attic

Right side of reporting display

CRWL	Air temperature in approximate center of crawl space, 30” above pea gravel and vapor barrier
GAR	Air temperature in attached 1,950 sf garage at 5’ above slab
HWIN	Water from the 50-gallon pre-heat tank just before entering de-superheater
HWOUT	Water from de-superheater, pumped back to the 50-gallon pre-heat tank
Zone1	Thermostat in public (largest) area of house. It reads 5° high due to placement near electronics
Zone2	Thermostat in master suite including office (where we spend the most time)
Zone3	Guest bedrooms and bath. Turned off when no entertaining or without stay over company
UG Temp@3ft	Underground temperature near ground loop trench at 3 foot depth
UG Temp@7ft	(same) at 7 foot depth



Above, we see a 4-day continuous display that comes from plotted data generated by the sensors shown in red boxes on page three. Starting with its instrumentation, this is not the typical residential geo heat pump system. But, the most telling point may be that for 3,265 sf of conventionally-built conditioned space, there would normally be a heat pump unit *twice* as large. The difference is the quality of the house's envelope. Maximum heat loss at the ASHRAE 10°F winter design temperature is under 20,000 Btu/hr, and this 3-ton unit nearly always runs at 67% of its capacity (2-tons). Extraordinary measures during ground loop construction were taken to counteract what has to be the worst possible soil for extracting or rejecting heat (it's coarse sand with cobbles and boulders with large pore space that hinders thermal conduction).

This Geothermal Heat Pump System includes the following:

GeoComfort 3-ton, dual speed, water-to-air heat pump w/3 zones of conventional ducting

- down flow unit w/supply ducts in crawl space and four branched ceiling returns in the attic
- supply/return ducting is R-8 flex w/metallic joint fittings (also insulated)
- supply hung from floor truss joists is discharged upward thru standard registers into living space
- return ducting rests on roof truss bottom chord members, covered in 17.3" of blown fiberglass
- de-superheater circuit travels to/from 50-gallon pre-heat tank, upstream of an 80-gallon water heater
- a timed, 25-watt circulator pump pushes hot water around two insulated loops near all fixtures
- a steam humidifier is driven by a humidistat and enters the system's return air duct
- an electronic air filter in the system's ducted air circuit
- an HRV (Heat Recovery Ventilator) draws from 3 baths and laundry, puts fresh air into return duct

Horizontal ground loop at 7-foot depth in poor, "coarse sandy soil with boulders & cobbles"

- 4 branched loops in separate areas of yard, connected by two header sets to interior garage
- each trench is 87' long by 42" wide, with one slinky® deployment pipe circuit
- each circuit carries 800 feet of 3/4" HDPE SDR-11 pipe slinky® @40" diameter/15" pitch
- each circuit compacted inside 12" of extra fine silt (mine stampings) for moisture retention
- each ditch re-trenched @24" carrying 18"wide x 12"deep drain rock w/4" pvc leach pipe
- leach pipe/rock assy. laser-leveled, covered by fabric, and fed by gutter + surface drainage
- 3,200 feet of ground loop conducting pipe serves a 3-ton heat pump = 1067 feet per ton
- entering water temperature from the loop never dropped below AHRI temps for Stages 1 & 2