Living Web Farms

Earth Cooling Tubes for Ventilation and Climate Control

What this workshop is about

- Understanding how earth-coupled climate control works
- Recognizing the advantages and limitations of the technique
- Evaluating the appropriate materials
- Siting and applying the technology where possible

Structure and Insulation

- The building should be weather-tight with code-level R values and minimal air infiltration
- Open single-room floor plan works best
- Minimizing interior air distribution simplifies system and reduces cost
- Climate control in the soldier fly habitat has a different range than normal residential

Radiant Floor Heat

- Chosen because of the availability of hot water supply from the adjacent biochar facility
- Must be insulated from ambient temperatures for freeze protection and proper heat distribution
- Structures on slab must be insulated below grade and at perimeter
- Heat transfer fluid (water) is not glycol protected and operates at low circulation pump pressure
- Alternative heating options of solar thermal or conventional heat could be used

Earth-Coupled Cooling Tubes

- 6-inch diameter thinwall PVC bell-end tubes are very cost-effective and crush resistant
- Low friction surface supports laminar flow which lessens the need for aggressive fans
- Tubes should be laid consistently level with a slight pitch toward the outlet. Standard 0.25 inch per foot pitch is too great for long runs
- Some type of shading structure or housing or non-restrictive vegetation should be used at inlets

- A 6-inch diameter tube has an area of 28.26 square inches. At 198 cubic feet/min velocity is 1008 linear feet/min or 11.5 mph. Transit time approximately 12 seconds

Soil Properties

- Heat capacity (or specific heat) is the ability of a material to store heat energy
- The heat capacity of dry soils is only one-fifth that of water, or about 0.20 Btu per pound per degree F temperature change
- Moist soils have greater heat capacities--up to 25 percent greater. So they can better resist the seasonal temperature swings that occur at depths below the surface
- Dry soils are therefore less consistent in their ability to hold surface energy gained through the seasons
- Thermal conductivity determines the rate at which heat transfers between soil and earth tubes
- Heat transfer will increase with finer soil textures such as clay
- Coarser sandy soils benefit with more heat transfer in moist conditions because coarse soils are more porous and absorb more water when wet
- Fine soils contain less insulating air and have more soil-to-soil contact so conductivity is increased
- Soil volume or distance between tubes is critical as conductive heat travels laterally as well as vertically

Solar Chimney

- The solar chimney uses the sun to capture heat and initiate draw through a 10-inch vertical duct
- The duct is sealed in an insulated box faced with fiberglass-reinforced plastic glazing
- The cross-section area of the duct (78.5 square inches) should be close to the cross-section area of the inlet tubes
- The chimney functions when the building is closed up; solar draw pulls fresh cool air in from the inlet tubes

Controls

- Three muffin fans are used as contingency backup for cooling flow when doors are open
- Open flow design allows airflow when the fans are not powered
- Low-power fans are selected; 38 watts (0.4 amp) providing 198 cfm airflow
- When temperatures reach 86 degrees F the fans are activated
- The access door for the BSF insects can be set to close when ambient temperatures are below or above determined thresholds

Some Design Parameters

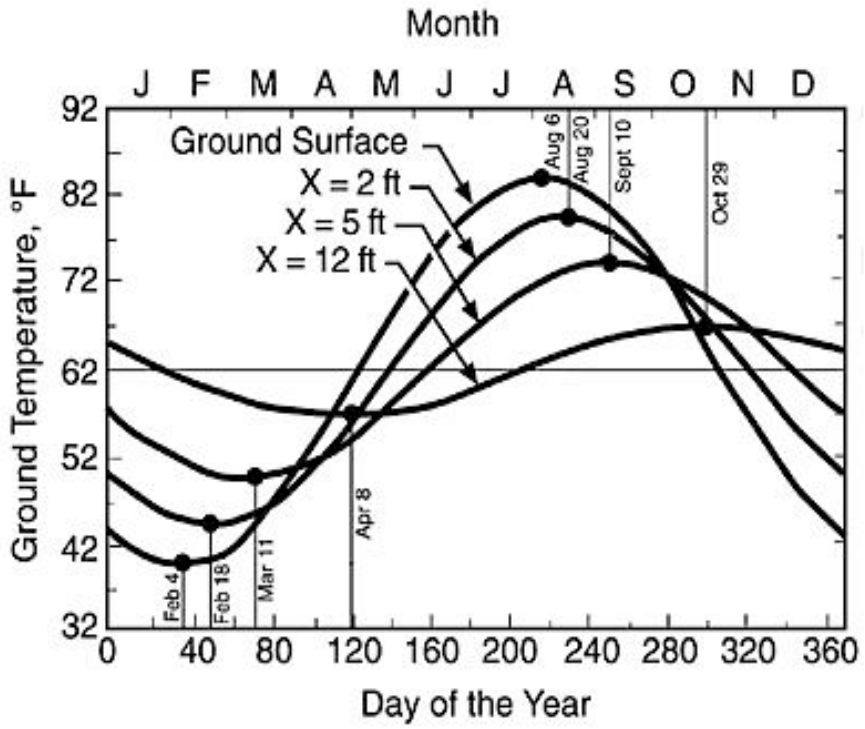
- Many types of piping material will work as long as its crush strength is adequate for the depth. Corrugated steel, plastic, concrete, ABS have all been used. Cost will likely be the major factor to consider
- Material conductivity may not be as important as other factors
- For small projects, piping between 4 inches and 12 inches diameter is most practical
- Multiple runs of smaller pipes can be calculated to replace the same capacity of a large diameter pipe if spacing between pipes is adequate; we used 5 foot spacing in this project
- Pipe depth can range between 5 and 10 feet for practical purposes. Return on investment for deeper trenches is minimal and increases equipment costs and risk
- The length of tube runs is a factor of diameter, site conditions, and soil properties. Our 192-foot length is greater than needed only because of site plan and because the PVC pipe is low-friction and hydraulically smooth
- In warm, humid climates steps must be taken to accommodate condensation removal from the Tubes through standpipes or some pump/drainage mechanism
- Powered fan systems should be considered, at least for a backup contingency and definitely if no solar chimney is used
- Higher fan airflows reduce air residency time in the tubes which will reduce conductivity and performance
- Rough cooling expectations can be determined by factoring flow, air density, specific heat of air, and the temperature change. The numbers here look like this:

  1008 ft/min x .196 cu.ft x .075 lb/cu.ft x 22.5 ^T x .24 Btu/ft = 80 Btu/min or 4800 Btu/hr

  Given three tubes that is 14,400 Btu/hr or approximately 1.2 Tons of air condition equivalency

(continued)

Seasonal Soil Temperatures as a Function of Depth



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Conductivity of Various Soil Types

Texture Class	Thermal Conductivity Btu/ft hr °F
Sand	0.44
Clay	0.64
Loam	0.52
Saturated sand	1.44
Saturated silt or clay	0.96

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Additional Reading and Resources

https://www.scribd.com/document/351766761/Ground-Temperatures-as-a-Function-of-Location-Season-And-Depth

https://www.thenaturalhome.com/earthtube.htm

Performance of Single Pass earth-Tube Heat Exchanger: An Experimental Study Girja Sharan Professor Coordinator Cummins-IIMA Lab Centre for Mgt in Agriculture Indian Institute of Management, Ahmedabad Ratan Jadhav Project Officer SEWA Ahmedabad

ISEC2004-65093 ANALYSIS, DESIGN, AND PRELIMINARY TESTING OF SOLAR CHIMNEY FOR RESIDENTIAL AIR-CONDITIONING APPLICATIONS Gang Wang Bing Chen Mingsheng Liu Joerg Henkel University of Nebraska - Lincoln 1110 South 67th Street Omaha, NE 68182 Stephan Raulin Berliner Energy Agency Holteistr.28 10245 Berlin, Germany

AIRFLOW CALCULATOR: https://www.engineering.com/calculators/airflow.htm

AIR DENSITY CALCULATIONS: https://www.ruppair.com/documents/white-papers/Actual%20Air%20Density%20BTU%20Calculation.pdf