Making Cheap Drinking Water from Air

Technical Report · May 2012

1 author:

Herman Vogel
Consultant

“Technology Makes Drinking Water From Air”

H.Vogel 5/2012

http://www.instructables.com/community/Technology-Makes-Drinking-Water-from-Air/

INTRODUCTION:

How can we best apply basic technology to assist the underprivileged and/or the recent disaster-hit countries like Haiti? Daily hygiene and nourishment are among the top needs for disaster ridden regions! Simply put, no water means no hygiene and death. The Romans understood that over two millennia ago … and created their complexly beautiful aqueduct networks for handling both fresh and wastewater! Other ingenious water systems like “air wells” have been found in the city of Theodosia (cf: discovered in 1900 by Zibold, see Zibold’s Collectors/Dehumidifiers) dating back to Greco-Roman times during the Byzantine Empire. These were strictly passive systems that naturally dehumidified air, collecting its potable water in underground basins.

All air, even in relatively dry desert regions, will precipitate or release its natural water content (initially in the form of vapor) through condensation when it hits its dew-point temperature and below. That means you “chill” it to an appropriate level that is anywhere from 5F to 50F below its current air temperature, depending upon how much water content (relative humidity) it has locally absorbed. The condensation of the water-vapor into water releases its internal latent heat (reheating the cooled air) which must be constantly dissipated (absorbed by something) in order for water formation to steadily continue. So how do we dissipate this resultant vapor-heat and chill our air without any infrastructure or electricity, in an underprivileged or disaster-ridden region? We simply bury a long cast-iron or any metallic drain-pipe sufficiently underground where the temperature of the earth is naturally held to a constant at around 45F to 65F. That’s our “free” chiller gift from nature. One end of the pipe, Figure-1, sticks out of the ground to suck-in local outside hot air, and the other end dumps cooled dry air and water into an underground cistern where it gets collected and is piped to the surface to both exhaust the cooled dry air and connect to a water pump. We need a hand operated water pump to lift up the water above ground, and we need an electric fan to constantly pump ambient air through the ground-chilled piping system. We can even force our dry, cooled piped air to exhaust into a tent-like structure to provide air conditioning as an added bonus, but this adds the penalty of both power and an increased fan size to drive our required airflow further into an enclosure!

While this concept is not “passive” (requiring electricity to work) like those clever Byzantine air-wells, it will produce much more potable water and within a smaller volume than those elegantly passive historic devices. The electricity for our fan power requirements can be produced by any one of four ways using either “active” or “passive-green” techniques: 1) An active playground or bike-pedaling-person or oxen-driven mechanism-generator, 2) A passive windmill generator, 3) A passive solar energy collection system that directly generates electricity, or 4) A passive thermo-electric system that directly generates electricity using the Peltier effect, operating solely on temperature differences between the cell’s top and bottom surface (we jury-rig the cool pipe and hot ambient air to contact separate sides of the cell).

Depending upon how much water is needed, the required air volume plus pipe length and diameter, together with the fan will be sized accordingly. We can also configure groups of parallel fan-driven air pipes that are radially fed into the cistern. The sizing of this underground network depends upon the ambient air’s local average temperature and relative humidity (how much water gets absorbed into the air) plus buried pipe depth and effective underground temperatures achieved.

The basic concept is one where we “wring” water from air at some given humidity content. The higher its relative humidity the more water is recovered from the air. The air-wringing process simply chills the air as it scrubs along the cooled internal pipe surface until it starts to rain inside the pipe from condensation onto its surface. The condensation is like the dew that forms on car windows, grass or any cooled surface in the early morning, before the sun comes out and evaporates the dew back into the heating air. A further bonus is that our dew-formed water is naturally distilled and very clean. It is potable water ready to drink without the need for additional sterilizing agents. Of course, we must make sure that the interior piping and cistern network is biologically cleansed before burying it underground. The hand pump with its 10 to 15 foot extended piping to reach the underground cistern must also be cleansed.

The beauty of this constantly replenishable water supply is its convenient underground installation anywhere! After the in-ground installation, we have a virtual, partially passive, no moving parts, non-breakdown system containing above ground total access to all moving parts that could breakdown, namely the water pump and electric fan. Also, it is easily maintained, with few moving parts (water hand-pump and electric fan) and basically lacking any technical complexity which makes it ideal for technologically backward regions.

The example below uses a relatively small industrial fan capable of moving air at 1500 CFM (Cubic Feet per Minute) with a DC motor rated at 1kW. This fan together with our underground piping system will conservatively generate 12 GPH (Gallons Per Hour) of potable drinking water without need for any purification chemistry. Based on an average electrical cost of 14-cents per kWh (kilo-watt hour), the typical commercial distillation of one gallon of drinking water costs roughly 35-cents as compared to our cost of only 1.2-cents plus the added bonus of comforting air conditioning. Furthermore, if we decide to go green and use solar energy for generating our water, it would effectively cost us nothing beyond the initial installation!

USING A PSYCHROMETRIC CHART TO SIZE OUR WATER SUPPLY:

The following gets a little technical and is only provided for those die-hards who are truly interested in how the science works. Those non-technically schooled may skip this part and not miss the basic concept.

Figure-2 shows a Psychrometric Chart for air. This chart summarizes some of the basic thermodynamic properties of air throughout its typical range of operating temperature. The chart uses six basic air properties that defines the physical chemistry of water evaporation into air: (1) the enthalpy or total energy contained within a unit of air which is a combination of its internal and external energy, expressed as the amount of BTU-energy per unit-mass (lbm) of reference dry-air, (2) the specific volume or the ratio of a unit-volume of local air to its unit-mass of reference dry-air, (3) the humidity ratio or the amount (mass) of moisture in a local unit of air divided by its reference mass of dry-air, (4) the percent relative humidity per unit of local air, or the mass ratio (expressed in percentage form) of the partial pressure of water vapor in the air-water mixture to the saturated vapor pressure of water at those conditions (the relative humidity depends not only on air temperature but also on the pressure of the system of interest), (5) the dry-bulb temperature or the locally measured air temperature, and (6) the wet-bulb temperature or saturation temperature which is the local air temperature experienced during constant water evaporation (a wet-bulb thermometer is typically used: a thermometer that measures resultant temperature while wrapped in a water wet-gauze and spun to generate local air movement and max-evaporation).

1.0 The Process and a Sample Calculation

Our Psychrometric Chart uses six thermodynamic properties that help to determine the amount of water available for extraction from the local ambient air as a function of its temperature, pressure and relative humidity. Let's assume the following local ambient conditions for the region we plan to construct our water system at: (1) Typical daily air temperature Td = 106F and one atmosphere pressure assumed at sea-level, (2) Relative Humidity, RH = 55%, and (3) Typical underground temperature down at six feet is measured at Tu=55F (at 12ft. it drops to ~45F).

This input yields the following calculated results for obtaining a steady-state supply (24/7) of water to fill the cistern (fill rates will change at night):

1) In our example, the "local" air (dry-bulb) temperature is Td=106F, at a relative humidity of RH= 55%. Fig-2 indicates that the resultant Humidity Ratio is HR= 0.0253 Lbs-water/Lb-Dry-Air (intersection of Td=106F line and RH=55% line, then horizontal to HR value). We then determine the "gulp" of air volume (mv) required that contains the HR Lbs-water which corresponds to the point of intersection of Td and RH. Interpolating on specific volume "mv" yields mv=14.7 ft3/Lb-Dry-Air (this value sets the optimum unit airflow for our given ambient conditions, and creates a ballpark pipe length to diameter ratio needed later). It represents the basic unit of air volume that will enter our underground pipe per given time, and ultimately defines the size of our fan and piping network. For increased water creation, multiples of this unit volume will scale up the additional amounts of water that can be collected.
2) As the inlet air cools down to a temperature of Tu=55F, from contact with the relatively cold underground pipe, we follow the constant enthalpy line (red upward left-diagonal) from the intersection of Td and RH to its saturated air temperature condition of Ts= ~88F, which is its dew-point temperature where the corresponding local RH=100%. At this temperature or under, the air precipitates and releases its moisture content, resulting in water condensation onto the pipe walls. Since our air will chill to a final pipe temperature of Tu=~55F, we follow the RH=100% saturated curve (green) down to yield an HR=~0.009 Lbs-water/Lb-Dry-Air. This is how much water is left in the air when it gets to 55F. Therefore for every pound of local outside air that enters the pipe, mw=0.0253 – 0.009 = 0.0163 pounds of absolute pure, distilled potable water precipitates onto the inside pipe wall (per pound of dry air that is cooled and dehydrated) to gravity-flow out the pipe exit and into the cistern.
3) We now convert pounds of air per unit time into a unitized volumetric airflow that yields gallons of hygienically pure potable water production per unit time. For every Va=100 ft3 of local volumetric air movement per minute (CFM) through the pipe, which translates into ma=Va/mv= 100/14.7 = 6.8 lbs. of dry air per minute or 6.8 * 60 = 408 lbs. per hour (PPH), to yield a water-flow of mwf=ma * mw = 408 * 0.0163 = 6.65 PPH or 6.65/8.345 = 0.8 GPH of water. An industrial fan rated at 1kW DC will typically move 1500 CFM at a pressure of 8-iwc, to continuously produce 15 * 0.8 = **12 GPH of pristine potable water**.
4) Not shown here are the design details of sizing our pipe, fan and solar collection system for electric power requirements using heat transfer principles coupled with a thermodynamic heat balance, and aerodynamic fan performance assessment. These details help to size the electric power generation requirements plus margin used to properly size a solar collector containing further margins for overcast days. With today's technology we could also smarten-up this system for optimum output (possibly increasing yield by ~30%) over any ambient condition, but this unduly complicates matters for "simple and reliable" 3rd world application. The detailed engineering involved in producing our water generator is straight forward but beyond the scope of the current article.

Figure-1: Buried Pipe to Make Distilled Drinking Water

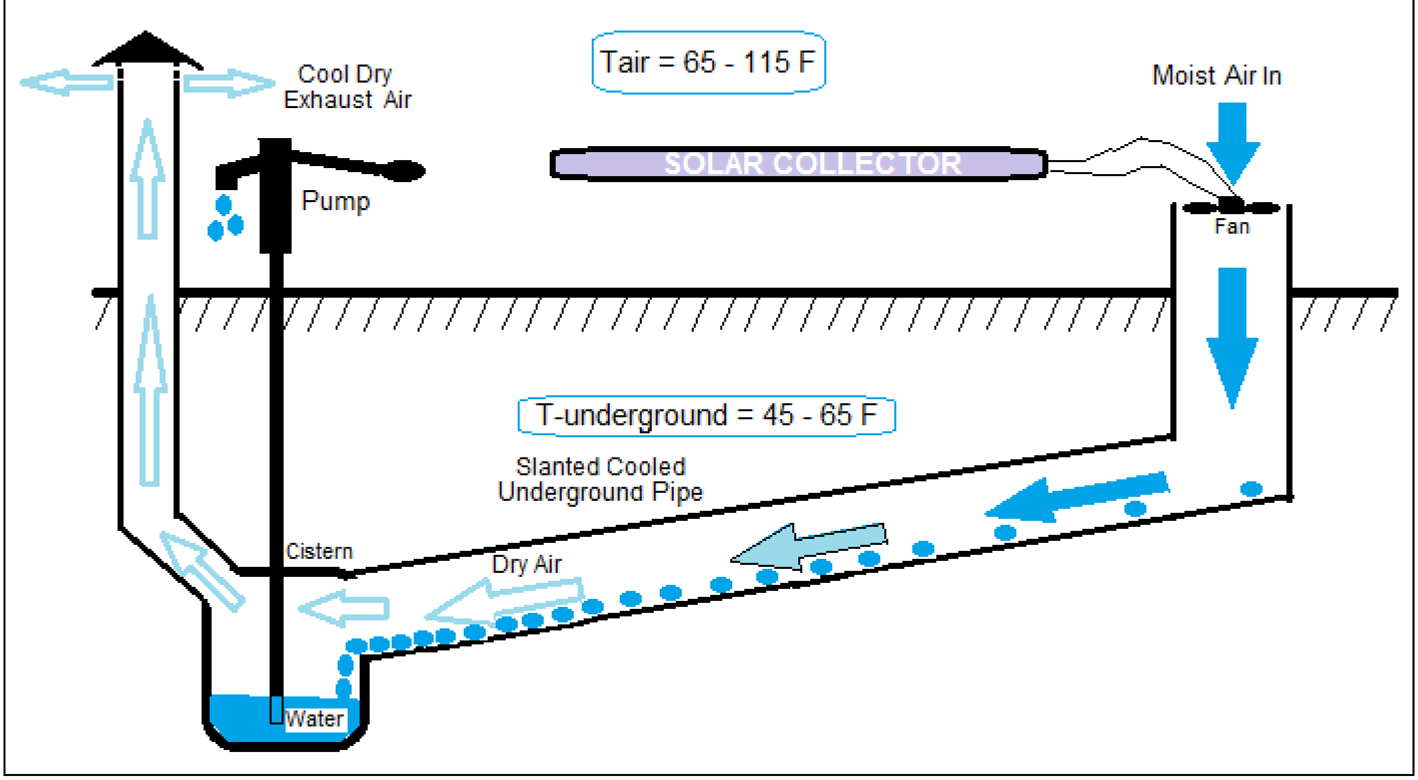

Figure 2: Psychrometric Chart for Air (at one atmosphere)