Description and Use of Equipment

Read the article below. It has been adapted from an article published in the *Scientific American* in April 2000. Write complete instructions in your own words for making the furnace and using it to measure the organic content of soil.

A Furnace in a Thermos

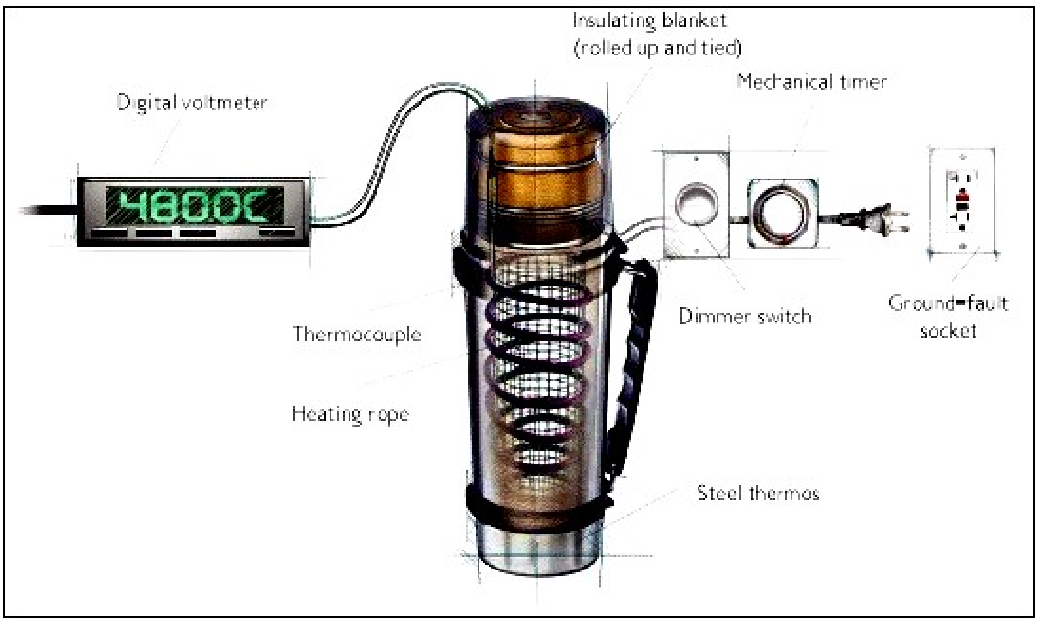
Original by Shawn Carlson

When set at its maximum temperature of about 260 degrees Celsius a kitchen oven is quite capable of burning an expensive steak. This I know from sorry experience. But ordinary ovens are still not hot enough for many research needs. Measuring the organic content of soil is one example. Fertile soil contains all sorts of biochemical and microbial nutrients that higher plants cannot live without. To discover how organically rich a soil is, you have to weigh a sample, remove the organics and then weigh it again. The only way I know to eliminate all the organic material is to bake the soil at a high temperature. At around 450 degrees C, organics break down into their constituent elements, and the carbon bonds to atmospheric oxygen to create carbon monoxide and carbon dioxide gases. The charred residue evaporates, leaving the soil devoid of all the constiuents of life.

Because the same process that cooks organic material out of soil will also remove it from the surface of glass, a furnace that approaches 500 degrees C can be used to clean the most intricate laboratory glassware. Likewise, baking sorbents at this temperature drives away chemical contaminants and recharges them for reuse in, say, pumps for producing ultraclean vacuums. Such a furnace would have other uses as well, including melting enamels, activating glass beads for use in chemical separators, annealing glass and metals, and making chemical feed-throughs for laboratory glassware.

So you can see why I was thrilled to learn that Roger Daschle a friend of mine, had developed a small furnace that is safe to operate at these high temperatures. It consumes only 80 watts, heats up in less than an hour and can be built for as little as $60.

Roger and I are part of an informal group of friends who hike every Friday in the San Diego County foothills to get away from our offices and talk about technical subjects. Roger's ingenious innovation came to him while he was pouring a cup of hot chocolate during a lull in our discussions. Roger wanted to build a stout furnace to service a small chemical separator he was developing. When he poured a cup of cocoa from his thermos and saw the rising steam in the cold afternoon air, he realised that he had found the perfect container. A thermos is inexpensive and has neglegible thermal mass. He knew that if he could secure a high-temperature electric heater inside a suitable thermos and plug the top with an insulator, he would have a fully functional and highly efficient desktop furnace.



Roger showed off his invention at our next hike. He had purchased a Stanley-brand wide-mouthed thermos (the kind typically used to hold soup) for $25 from a local discount store. But the brand doesn't matter. Just make sure the vacuum bottle is made of steel and not glass, which might break, or aluminum, which might soften and implode. Roger used a rope heater: a prefabricated bundle of Nichrome wire wrapped around an insulating core and covered with an insulating sheath. These chords run on wall current and are much safer than bare wire. Omega Engineering sells them in three-foot lengths for $22 (www.omega.com, part no, FGR-030). The rope is rated for operation at 480 degrees C. This sets the safe operating temperature of the furnace. The device will get much hotter if you run too much currrent through it. You can keep the current at a safe level by wiring in a household dimmer switch and monitoring the temperature. As a precaution, Roger wisely wired in a one-hour mechanical timer to make sure that his unit could not accidentally be left on.

To install the heater in the furnace, Roger fashioned a cylinder out of a wide-mesh steel screen, available at a well-stocked hardware store. He loosely coiled the heating rope around the cylinder and covered the entire assembly with a centimeter-thick blanket of Fiberfrax, a clothlike material made of spun alumina fibers. Muffler packing, available at a motorcycle parts store, would also do. The whole thing fits into the thermos through its wide mouth. Finally, Roger tightly rolled a strip of Fiberfrax into a plug that just fit into the thermos mouth. A single twist of steel wire wrapped around the plug prevents it from unraveling.

The most economical way to measure the temperature is to use a K-type thermocouple, which produces a voltage in proportion to the temperature. The voltage can be read with a high-end digital voltmeter that has internal circuitry to interpret this sensor. Otherwise you can estimate the temperature by measuring the voltage developed between the leads using a digital voltmeter. The temperature in Celsius is given approximately by multiplying the voltage in millivolts by 27.7. I tested Roger's furnace using a bare-wire therocouple from Omega Engineering (part no. CHAL-015). I insulated it using a short length of Nextel sleeving (Omega part no. XC4-116) and installed the sensor near the top of the furnace. At 480 degrees C inside, the exterior was uncomfortably warm but not too hot to touch. When, as a safety test, I pushed the device to 600 degrees C using an ultra-high-temperature heating tape, the outer casing got far too hot to handle.

So make sure to monitor the temperature at all times and keep it at or below 480 degrees C. Keep it well away from curious children and pets. Wire in a timer switch. And connect the heating unit through a ground-fault switch, such as those often seen in bathroom wall outlets these days. These switches contain an internal circuit breaker that blows when a short circuit occurs. That way, if the furnace should overheat and short out, the power will be cut off.

Using the furnace, you can easily measure the organic content of soil. First, carefully weigh out about 100 grams of soil from your garden and dry it in your kitchen oven for one hour at 120 degrees C. Then weigh it again. The soil in my garden turned out to contain 33.2 percent water by weight. Tightly wrap the dry soil in aluminum foil and bake it in your thermos furnace for two hours at 480 degrees C. The charring organics liberate a ghastly cloud of smelly smoke, so use a fume hood or keep the device outdoors. A final weigh-in revealed that my garden soil is 8.6 percent (dry weight) organic material. Sand from a nearby children's playground weighed in at just 3.2 percent water and contained only 0.7 percent organics (dry weight).

It would also be interesting to monitor the weight continuously, in order to look for physical processes that occur at different temperatures.

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