Water Distillation Unit

I. Introduction

IN 2003, I built a water distillation unit out of large kitchen pot and parts from a plumbing supply store. The unit was designed to operate on a backyard charcoal grill. In the final design, the unit distilled water at the tested rate of one gallon per hour. This paper documents the design, construction and redesign of the water distillation unit.

II. Background

A LARGE comet/asteroid impact can produce a mass extinction event. One mechanism responsible for this mass killing is toxicity in the drinking water. Something that we take for granted, pure drinking water, will not exist after a large impact. Water is one of the keys to survival.

The impact debris will include heavy metals and a variety of acids including: nitric acid, hydrated sulfur dioxide, and hydrochloric acid. A deep impactor can penetrate through the earth's crust and produce massive volcanic flood basalt eruptions. Magma contains dissolved gases. These gases consist of predominantly water vapor (90%), carbon dioxide, sulfur dioxide, hydrogen sulfide, hydrogen, hydrogen chloride, carbon monoxide, hydrogen fluoride and helium. The release of these gases is the predominate cause of the global extinctions.

Hydrogen fluoride is released by the magma. Fluorine is a pale yellow gas that in relatively low concentrations is very toxic. Fluorine attached itself to fine volcanic ash particles and forms fluoride salts. This ash is flung high into the atmosphere and spread by the prevailing winds and will eventually fell back to Earth coating the surface of edible plants. Animals that eat these plants will die. Even in areas that received as little as a millimeter of this ash (a fluorine content exceeding 250 parts-per-million (ppm)), poisoning occurs. Some volcanic ash beds from the Permian extinction were 6 feet thick. Fluoride salts are very soluble. Rainfall will dissolve and flush these salts into rivers, streams and lakes, poisoning surface drinking water supplies.

One of the largest eruptions in modern time, the Lakagigar Eruption (Mount Skaptar) occurred on June 8, 1783 in Iceland lasting eight months. Most of the livestock in Iceland were killed because they ate grass contaminated with fluorine. One quarter of the island's human population perished. Some Eskimo tribes as far away as Alaska were mysteriously wiped out. Approximately 14.7 cubic kilometers of basalt was erupted. The Siberian Traps associated with the Permian extinction and the Deccan Traps associated with the Cretaceous extinction each produced basalt eruptions 300,000 times greater resulting in a global extinction threat.

After an extinction level impact, the infrastructure we rely upon every day will be gone. There will no longer be city water. There will no longer be electrical power. The world will be dark and quiet. This quiet will periodically be interrupted by a growl that comes just before the earth turns into a sea of waves. The earth will be hit by earthquake followed by earthquake, making it next to impossible to restore this lost infrastructure. Those that live outside the cities in many cases will find their water wells also destroyed. The only water available will be polluted rainwater and surface water with high levels of fluoride salt along with a variety of other toxic chemicals.

After pondering this hazard for some time, I set myself a goal to construct a water distillation unit out of common household materials that would function in this environment. After several attempts and redesigns, I was able to construct an operational prototype that could distill water at the rate of approximately 1-gallon per hour. By building and testing a prototype, I was able to identify problems and work out solutions that may be of interest to the reader.

III. Construction

THE concept of a water distiller is fairly simple. There is a heat source, a chamber in which you make steam and a condensing unit where you convert the steam back into water. I selected a backyard grill as the heat source, a cooking pot as the steam chamber, and a copper coil within a plastic bucket as the condensing unit.

Figure 1. Surgical Stainless Steel Cooking Pot

Three types of common household items that could be converted into a steam chamber are pressure cookers, cooking pots and tea kettles. I selected a cooking pot for the prototype because I considered it the most common of household items. In general, my wife tolerates most of my experiments. But to be on the safe side, I decided to purchase a new pot for the prototype rather than take one of our kitchen pots.

In selecting a cooking pot, I felt it is important **not** to select one made from aluminum. The acid content in the water can dissolve aluminum. I purchased a discontinued pot on the Internet at substantially reduced price. I selected a 24-quart pot for its capacity and contact surface area. The pot was made from one of the best of steels (surgical stainless steel). Refer to Figure 1. [After the experiments were completed, I was able to restore the pot to its original condition with just dish soap and water, and present it to my wife as a gift.] The top knob on the lid was easy to unscrew revealing a large hexagonal hole.

Figure 2. Cooking Pot Lid Connection

The first part of the process was to adapt the lid to the copper tubing. This took several trips to plumbing and hardware stores. (One important lesson that can be learned from this is that it is crucial to construct and test out a water distillation unit prior to an impact rather than after-the-fact.) I selected a series of copper pipes and fitting. Refer to Figure 2.

I soldered the pipe joints one at a time together using lead-free solder. I coated the pipe joints with a light coat of flux. Joined the pipe connections together. I held the pipe being soldered in place using a crescent wrench attached to a vise. I moved the bench with the vise outside to avoid starting a fire in the garage. I heated the joint using a propane torch. When the connection was hot, I melted the solder into the joint until the entire circumference had a solder seal.

The pipes were very hot after soldering so I let them cool down for several minutes and then inspected the joint using leather work gloves. This was the first time I ever torch soldered, so it was less than professional. But the joints were well sealed. The main problem that I had was that I used too much solder and it wicked into the inside of the pipe forming a solder bead on the inside. I chipped this solder from the inside using a screwdriver and a file. I was concerned this solder might break loose and plug up the smaller copper tubing. For that reason, it became important to join the large connections first and work my way down to the smaller connections.

When the entire copper assembly was complete, I blew air in the large end and held my finger on the end of the copper tubing to verify the absence of leaks.

Figure 3. Components of the Water Distillation Unit

I needed a watertight seal between the copper joint and the lid of the pot. The hexagon hole in the lid meant that it would be difficult to create a tight connection. I visited the hardware store and special ordered a box of 1 ¼ inch stainless steel flat washers. When I received the washers a couple weeks later, the inside diameter of the washer were too small to fit onto the pipe connections. I used a round file and a small grinder to enlarge the inside hole until I obtained a tight fit. The copper connection was slightly tapered; therefore the top two washers had slightly larger holes, so I labeled these T1 and T2. Refer to Figure 2.

Next I had to find a material that would seal the lid. I had some extra rubber roofing material. I took some of the material and tested it in boiling water for 15 minutes. There was no degradation so I decided this material was acceptable. I cut out a rubber washer from this material to fit between a stainless steel washer and the inside of the lid of the pot.

I tightly wrapped the copper tubing around an 8 inch diameter plastic pipe joint in order to produce a uniform copper coil.

I used a 5-gallon plastic bucket (several years ago, I purchased a number of these used pickle barrels from White Castle restaurant for $1 each.) During operation the bucket will be filled with untreated water. The bucket will serve two purposes. (1) The cold untreated water will cool off the steam in the copper tubing allowing it to quickly condense back into pure drinking water. (2) In this process, the untreated water will be preheated, which means that less energy will have to be expended before the next batch can produce steam. After all it takes longer to distill cold water than it does hot water.

In the plastic bucket, I drilled two holes 3 ½ inches from the bottom at 90-degree angles. One hole was for the distilled water line and the other hole was for the bucket drain.

An inexpensive ballcock assembly used in toilets is a good means for creating a water tight seal in plastic buckets. I selected an assembly that unscrewed between the shaft and the head. (In a pinch, it might be possible to salvage used ballcock assemblies from the home toilets in order to construct a water distillation unit.) I took each ballcock assembly and unscrewed the main shaft from the rest of the assembly. I retained only the ballcock shaft and the ballcock nut. The rest of the parts I discarded. Refer to Figure 4.

I used a round file to expand the drilled hole in the bucket until the ballcock shaft snuggly fit into each hole.

I fitted the ballcock shaft that would be attached to the copper tubing with the plastic coupling nut/cone washer/friction washer. This allowed a watertight connection between the copper tubing and the ballcock shaft. I also place one ¾ inch rubber washer between the inside and the outside of the bucket when I installed the ballcock shaft into the bucket. This gave me a near watertight seal. (I originally cut these washers out from the rubber roofing. But later I was able to find an exact fit ¾ inch oversized rubber washer.) A few drops leaked through this seal but the amount was so minor that I could live with this. To correct this problem in the future, I will use an automotive gasket sealant on both sides of the outer rubber washer.

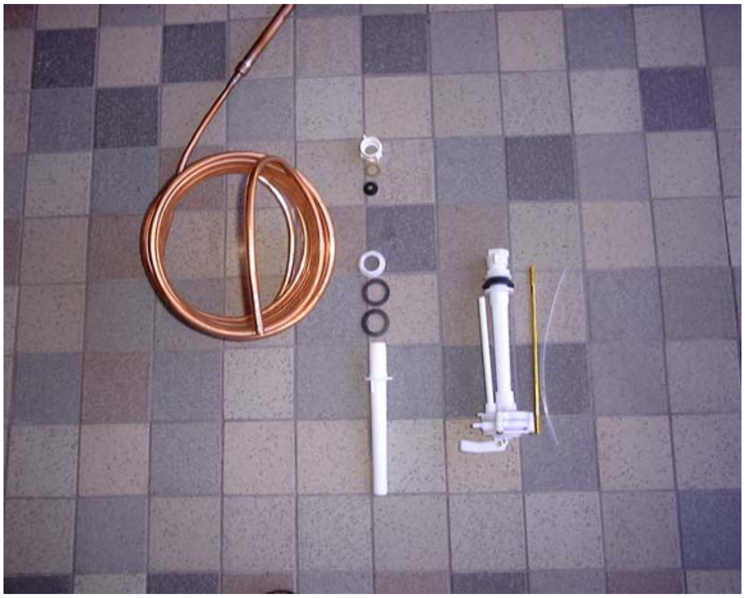

Figure 4. Toilet Ballcock Disassembled

On the second ballcock shaft, I used a flat file and sandpaper to grind away the outer threads of the ballcock shaft until I could fit the plastic Stop & Waste Valve onto the end of the shaft. I used all purpose (PVC, ABS, CPVC) cement to glue these two pieces together. Refer to Figure 5. I also used 2 rubber washers when I installed this ballcock shaft into the plastic barrel.

The first time I tested the distillation unit, it leaked steam between the lid and the pot. I fabricated a large rubber washer from the rubber roofing material to seal this seam. I used three vice grips to hold the lid to the pot. This worked extremely well. Almost too well! One of the problems I encountered was when I wanted to remove the lid, I released the vise grips but it was next to impossible to pull the lid from the pot because the rubber seal was too strong to break. The solution was to slowly pull out one side of the rubber seal until it allowed air to enter the pot. This broke the seal and the lid would pop off. This didn't appear to damage the large rubber washer.

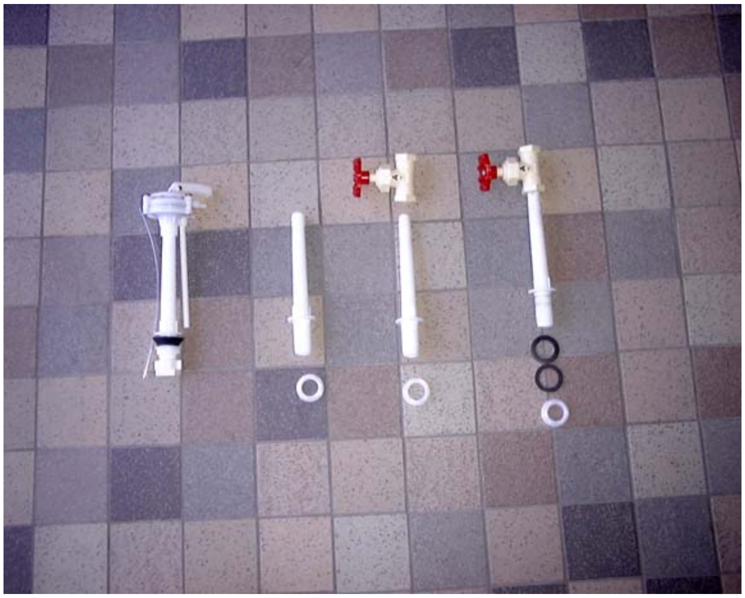

Figure 5. Bucket Drain Valve Assembly

The following is a parts list for the Water Distillation Unit:

PARTS LIST

Quantity	Manufacturer	Part Description
1	Precise Heat	24 quart Stock Pot (5-ply Surgical Stainless Steel)
1		5 gallon Plastic Bucket
30 feet	Reading	¼ inch copper soft temper tubing
1	NIBCO	1C x 1FIP copper sweat female adapter
1	NIBCO	1 inch copper male fitting adapter
1	NIBCO	1 inch, 90 degree copper elbow
1	NIBCO	1 inch to ½ inch copper reducing coupling
1	Cambridge Lee	½ inch by 12 inch straight copper tube
1	NIBCO	½ inch to ¼ inch copper reducing coupling
1.6 sq. ft.	Gen Flex EDPM	0.060 gauge Rubber Roofing (square piece)
4		1 ¼ inch stainless steel flat washers
2	LG Sourcing	Plastic Ballcock Assemblies (P/N 24419)
1	Plumb Pak Corp.	Plastic Coupling Nut for Ballcock w. Cone Washer & Friction Ring (P/N PP23549)
4		¾ inch oversized rubber washers
1	American Valve	½ inch CPVC Stop & Waste Valve (P/N P60SCPVC)

IV. Design Improvements

THE water distillation unit was able to distill water at the rate of one gallon per hour. The water in the plastic bucket was used to cool down the steam. In the process, this water absorbed much of the heat from the distillation process. When this water was drained and placed into the steel pot, very little additional heat was required in order to bring this hot water to the boiling point. This is a very efficient design.

As in any design there is still room for improvement. The primary weakness in the design was the use of a backyard charcoal grill. The grill prevented the reloading of fuel and the removal of ashes during the combustion process. A better approach is to construct an outdoor grill, one that is capable of being fueled with firewood or coal and one that makes it easy to load fuel and remove ashes.

Another weakness in the design is that the distilled water picked up the odor of melted plastic. I suspect that the plastic bucket was to blame. It came in contact with the hot copper tubing and melted some of this plastic. In a future design, I would replace the plastic bucket with a metal one. I have purchased an outdoor turkey fryer as its replacement. The fryer has a large metal bucket that contains a built in drain valve. This means fewer parts that need to be fabricated.

V. Water Purification Process

Hydrogen fluoride released during massive volcanic flood basalt eruptions will form a variety of fluoride salts. Some of these will be organic and others inorganic. The distillation process will only remove fluoride salts with a boiling point above the boiling point of water (100° C). Some of the organic fluoride salts will have boiling points below 100° C. Distillation must be coupled with other water purification process in order to bring the purity of water to safe drinking water levels.

The first step in the water purification process will be gross filtration. This will filter out large contaminants (such as leaves and twigs) from the surface water. Water can be filtered by running the water through bleached cotton cheese cloth, which can be obtained from a sewing supply store such as Jo Ann Fabrics. Other water filtering alternatives include coffee filters, paper towels or a cotton plug in a funnel. Another approach might be to use a sand filter.

The second step is to remove most of the inorganic salts by running the water through a carbon filter.

The third step is to neutralize the acid in the water. Pour the filtered water into the condensing unit (plastic bucket/metal turkey fryer bucket) and then add backing soda. This will allow some ionic exchange to occur between the residual organic salts and the sodium in the backing soda, the copper tubing and the aluminum turkey fryer bucket. In general, these ionic exchange formed inorganic fluoride salts will have higher boiling points than the organic salts. The boiling point of NaF is 1,700° C. The boiling point of CuF_2 is 1,676° C. The boiling point of AlF_3 is 1,290° C. All of these inorganic salts have boiling points well above that of water.

The final step in this process is to distill the water removing all the fluoride salts with boiling points above that of water. Any residue within the steam chamber after processing should be carefully discarded.

It is important to clean the distillation unit prior to its first use. Distill one gallon of water to start. The first gallon will clean the residue from the inside of the copper pipes. This first gallon should be discarded.

During distillation, it may be important to monitor the temperature within the bucket used as the condensing unit. During testing I clipped a Baking (Candy-Deep Fry) Thermometer on the side of the bucket to monitor temperature. The water temperature at the top of the bucket was up to 175° F. But at the same time the water at the bottom of the bucket was still cold. I decided to prevent the water from exceeding 175° F. I drained a pitcher of water from the bucket using the drain valve and poured it into the top of the bucket. After cycling a few pitchers of water, the temperature dropped to 125° F degrees. Circulating the water in this manner will also speed up the ionic exchange process.