

2007 ASME Student Design Challenge

Human-Powered Potable Water Still

Initial Posting Version HPPW3.0

This version of the problem is posted for the benefit of those student teams who may have early decision times regarding their Senior Design Projects (or who want to get an early start on the next contest). Please note that there are a few things which are still under discussion, particularly in the details of scoring or in the test procedures. A final version of these contest rules will be posted shortly after the Summer Annual Meeting of ASME in June 2006.

DESIGN PROBLEM

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DESIGN PROBLEM

*"Water, water everywhere
And not a drop to drink."
Coleridge, "The Ryme of the Ancient Mariner"*

Coleridge's ancient mariner had much in common with many people marooned on rooftops during the recent hurricanes-surrounded by water, they were dying of dehydration and desperate for at least a minimum of clean potable water. But in New Orleans the city water system was down and the water people were surrounded by was either brackish or filled with both biological and chemical pollutants. One of the ways of purifying some of it would have been to distill it. However, electrical power was not available, solar energy was limited or not available, and filter systems, which could have been available, might not have removed all of the pollutants present.

One possible solution to this problem would be to make use of a human-powered still. This could provide at least limited amounts of purified water, enough at least for drinking purposes in an emergency situation. A major question to be answered, however, is whether or not using human work input to heat the water is a feasible approach. Handbook values for the work output by a human are varied, but calculations based on this limited information, as well as thermodynamic properties and heat transfer considerations, seem to indicate that there is some reason for optimism on this point. The purpose for this competition is to see if students can design and build a device which will heat water significantly, particularly heating it enough to reach boiling temperatures, and if so to condense the steam generated to get potable water.

Such a "human-powered boiler" would have the following characteristics:

1. All significant energy input would come from a linkage or mechanism driven by human effort.
2. It should be small enough to be easily stored or transported for emergency use.
3. It should be easily assembled from its stored configuration.

DESIGN REQUIREMENTS

For this contest, the specific device requirements and procedures will be as follows:

1. Each team must arrive with their device and its support equipment, if any, packed into

the smallest rectangular parallelepiped box it can fit into. Immediately after check-in each team must report to the judging team to have the outside dimensions of their storage box determined. This volume will be used in the scoring of this contest. (Smaller is better!)

2. In any event, the storage box must be small enough to meet shipping requirements, which are determined as follows:
 - a. Measure the longest dimension of the storage box. That is the "Length".
 - b. Measure the circumference around the box in the plane normal to the length measurement. This is the "Girth".
 - c. When added, Length plus Girth must be less than or equal to 4.2 m
3. Once the storage dimensions have been determined the teams may assemble their devices and take them to the judges for weighing in the "dry" state. All system components must be included in the weight. This includes auxiliary equipment needed to operate the still. For example, any separate charging aids such as funnels must be included. This weight will also be used in the scoring. (Light is better!)
4. Energy input can be by any convenient mechanical means driven by human effort. Examples would be pedal systems, linkages, lever systems, cranks, etc.
5. The human mechanical energy input can be changed to any other kind of energy desired in the process of heating the water.
6. The use of a vacuum in any part of the system is permitted, but the vacuum must be generated and maintained by the human operator.
7. Two bottles of "polluted" water will be given to each team prior to the start of the timed period. One of these bottles will contain 200 ml of "polluted" water. The second bottle will contain a weighed and recorded quantity (approximately one liter) of "polluted" water. All of the water will be at room temperature, as verified by measuring with a thermometer.
8. The water for all teams will come from the same mixed batch of "polluted" water. The "polluted" water will be formed by adding 3.5 grams of table salt for each liter of water mixed. This should produce a solution with a specific gravity (SG) of 1.035, as measured by a standard hydrometer. In addition, a colored food dye will be added to the "polluted" water so that contestants and spectators can distinguish the polluted water from any which is purified by the team's device. {Need to determine the extent to which the coloring will influence the specific gravity (SG) of the "polluted water", and may need to specify this in the final version of the problem.}
9. Each team will be required to charge their still with a minimum of 200 ml of "polluted" water from the first bottle they are given. Teams wishing to charge greater amounts of water will need to make arrangements with the judging team for proper measurement of the quantity prior to the start of the testing period, or to bring all of the water not used in charging for weighing after the test period.
10. Any time the judges observe spilled "polluted" water they will require that the team clean up the spill, and the team will incur a 5% automatic decrease in the water weight value used in computing their score.
11. Each team must arrange to have the "outside temperature" bulb of a digital indoor/outdoor temperature gage (or its equivalent) in the water inside the still at all times during operation so that water temperature can be continuously monitored. The digital readout must be easily readable by judges and nearby spectators.
12. Teams must attempt to condense any steam escaping from the human-powered still. The weight of recovered condensate will be included in the scoring.
13. The final quantity of distilled water, if any, will be determined by weight. Thus the collecting vessel in which any condensate will be collected must be weighed prior to the test in a dry state to determine its tare weight. All such vessels must be clearly marked with the team name and tare weight.
14. Any waste water (e.g., concentrated "polluted water" left in the still at the end of the run) must be collected by the team in a second vessel of some sort either during or after the run.
15. The still must be empty and dry at the beginning of the test run, and as empty and dry as possible at the end of the run.

TESTING PROCEDURES

1. All contestants will be distilling at the same time. The timed test period for all teams will be 30 minutes. When the start signal is given teams may charge their devices with the "polluted" water and begin operating their device.
2. Teams may split work input times among themselves in any way they see fit. It is not required that all team members participate in this. Any person providing the work input must be a bone-fide member of the design team, not someone recruited only for the work input part of the contest. {This may come under additional discussion and refinement when the rules are reviewed at SAM 2006.}
3. As the test period proceeds roving judges will continuously record the current water temperatures each team is reaching. Temperatures reached in each device will also be reported on a timely basis to a central scorer for entry on a spreadsheet by volunteer (student) runners. A student "runner" may not report values for a team from his or her own school. Also on the spreadsheet will be the weight of water charged into the still at the start of the heating process. The total thermal gain of each team thus will be projected in bar-graph format in as close to real-time as possible on a large screen for everyone to see as the contest progresses.
4. Any condensate from the still must be collected in a clean, preferably clear vessel calibrated in milliliters and supplied by the team. If and when the team begins to distill water across into the receiving vessel (and the temperature of the still thus reaches a stable point) the runners will begin to report the volume of the condensate to the nearest 0.5 ml as well as the current temperature.
5. At the end of the 30 minutes and at a signal from the time-keeper the receiving containers for any distilled water will be removed and may be covered. The containers will then be moved to the measuring location, where the quantity of any distillate will be determined by weighing.
6. In order to be counted in the scoring, distilled water should have a hydrometer reading (specific gravity) between 1.00 and 1.01. If the quantity of distillate is too small for the use of a hydrometer the salinity may be determined by boiling away the water with a small heat source and weighing any recovered crystal distillate. {The upper limit may need adjustment before becoming the final ruling}
7. Also determined will be the weight of the water in each still at the end of the test period. Teams are responsible for recovering this from their still and taking it to the measuring station along with any of the water they were given that they have not used. The judges will check the total weight of returned water. If less than 90% of the water given to a team is present at the end of the run the score the team receives will be reduced by the percentage of water returned.

SCORING

At the end of the half-hour test period, the winner will be the team which maximizes the score according to:

$$\begin{aligned} \text{SCORE} &= (\text{Weight of distilled water, gm}) * 100,000 \\ &+ (\text{Wt of water in boiler, gm, at start}) * (\text{Tend} - \text{Tstart, C}) \\ &- (\text{Dry weight of the device, gm.}) / 1000 \\ &- (\text{Volume of box in which device can be packed,} \\ &\quad \text{cm}^3) / 10000 \end{aligned}$$

Note: all scoring values and calculations will be rounded to the nearest integer value.