Senior Design Project
Spring 2007
Mechanical Engineering Design Competition –
Ann Arbor, Michigan

Participants:
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Executive Summary:

The 2007 ASME Mechanical Engineering Design Competition held in Ann Arbor, Michigan had a project statement that required participants to design and build a working model of a human powered water purification device. The team started their work in late December and worked through a battery of ideas, finally deciding on a heating system designed around rotating magnets and the process of induction. This idea and working model lead to a 1st place prize in the local competition and an invitation to compete on the national level.

Idea Process:

In order to take on the design challenge of only using human power in order to clean 200ml of water in 1 hour of time it was best in the initial phase to come up with as many feasible solutions and see which might work the best. An initial thermal dynamics calculation was made to determine how input energy was needed to heat 200ml of water from room temperature to a boiling temperature and vaporize all of the water to steam. Approximately 150 Watts of input power for 1 hour were needed to achieve this and thus it appeared that the most practical human powered solution would include using a bicycle driven system.

Three initial systems were considered to boil the water: a vacuum pump, a generator coil heater system, and a friction plate system. The vacuum pump would essential reduce the temperature that the water would have to boil, however its complexity, cost, and size ruled it out very early in the design process. The generator and the friction plate appeared to be both viable solutions and further research was necessary to make an appropriate choice. Oregon State University had posted an article discussing what their teams had used, and their best team had used a friction plate design. The overall efficiency of using a friction plate was unknown, and so the next step was to see what generators were readily available. Mendalson’s had a vast array of different generators, two of which were purchased at a reduced price along with 2 rare earth magnets. The problem of using a generator was that the efficiency of generators for this small wattage application is around 70% and this would result in large losses if this particular system was used.

When playing around with the two rare earth magnets, a new concept was proposed that showed great promise. The idea of attaching rare earth magnets in a circular fashion around a rotating disk, and heating up the boiler inductively was proposed. The idea uses the concept of eddy currents, and would potentially allow for a reduced weight and higher efficiency design. An additional 10 rare earth magnets were purchased, and a proof of concept test was conducted to see if the idea was feasible. A motor was used to rotate a wooden circular disk of 10 rare earth magnets placed within a small gap distance of an aluminum block. The test showed that after 10 minutes, the aluminum blocked became very hot (a temp of approximately 212 def F), but also that the magnets themselves were still very close to room temperature, indicating that virtually all of the usable energy was going in to heating the block. Once this test was concluded, the direction of all further detailed design and assembly was with the eddy current method of heating using the magnets.
Design Issues:

Once the final heating mechanism was selected, the device had to be sized for the required power input. A series of tests were performed to develop reasonable design criteria. First, a reasonable measurement of human power had to be obtained. Clearly, this varies from person to person, so rather than trying to find a reference values, the team members each participated in power testing. Taking advantage of the campus resources, the team headed to the recreational facility were exercise bikes could measure cadence, and power output of each rider. The team determined that 200 watt bursts with 2 minute rider rotation could be achieved. The average cadence was round 80 rpm. The cadence measurement later proved useful in determining an appropriate gear ratio.

The second part of power testing focused on determining the heating power of eddy current device. In this test, the goal was to determine how fast the magnetic disk needed to spin to generate 200 watts of heating power. Additionally, the air gap between the aluminum block was tested. An induction motor rated at 3600 rpm was used to spin the array of magnets and the aluminum eddy current block was allowed to pivot on bearings. The torque applied to the aluminum block was balanced using weights. From the torque and motor speed the power was calculated. The test apparatus is shown below:
The air gap and operating speed require to generate the require wattage were determined and the gear ratio was set using the data form the human power testing. The ratio was set to meet the optimal operator cadence and maintain 200 watts of heating power. A 50:1 speed multiplier was used to transmit torque from the rider to the magnet disk.

The condenser was also tested to make sure our design would dissipate the required 200 watts to condense the steam into distillate. The stovetop burner had to be adjusted to boil the equivalent of 200 watts worth of water. To determine the right amount of heat input, the team put a measured amount of water into the test apparatus and timed how long it took to boil off. The photograph below is a picture of that test.

The condenser test showed excessive flow restriction, but excellent heat extraction. The rev II design incorporated a larger diameter copper coiled eliminating this issue will maintain the proper heat transfer rate.

**Competition:**

On March 30th the group traveled to Ann Arbor, Michigan for the ASME Student Design Competition where the University of Cincinnati team would compete. We arrived at the competition and checked in with the judges to measure the girth and weigh the project. After weigh in, we were assigned an area where we could set-up our project for the
competition. We were given 30 minutes to set-up and test our water distillation machine. After set-up, we were given 30 minutes to check the other team’s machines to verify that the other teams were meeting the design rules for the competition. Next, we were given 200mL of red water to charge the distiller and 1L of green water for the condenser. When the competition began, we charged the distiller and begin heating the water via our apparatus. For the next 50 minutes we pedaled the bicycle at approximately 90 rpm until 190mL of water were distilled. We actually distilled the entire 200mL of water that we were given but some of it escaped or was lost in the condenser. At the end of the competition we weighed the distilled water and the condenser water with the judges to verify the results. We were the only team to distill all of the water given to us, and won the competition by a large margin.