P11462 Mechanical Engineering (ME) Documentation for Next Iteration of TEG and Fan System for Cook Stove

The following recommendations are intended to aid the next group to work on the Thermoelectric System for the Haitian Cook Stove. This hand-off will hopefully reduce the time required to come up to speed on the project. It will be broken into two sections – one to guide you in how best to learn about the current system and one to provide you with recommendations based on our experience.

Guide

1. If you have not actually seen the current system, ask someone and go find it. Look at both the 1st generation stove (P10461) and our system that mates to it (P11462). Pick at it. Take it apart. Put it back together. Do a demo. The system is now yours so do what you need to do to make it help you.
2. Become as familiar with the 2nd generation stove. This is the stove you will need to adapt to. Become as familiar with this stove as your own system.
3. Look at the system energy flow diagram
4. Brush up on fin or extended surface heat transfer equations (adiabatic tip condition, convection, conduction, etc.) – this will aid in the rod and heat sink math. The main equations we used are

   $$q = Mtanh(mL_c)$$

   where $M^2 = \frac{hP}{kA_c}$ and $m = \sqrt{hPkA_c} * \theta_b$

   All parameters are defined in greater detail in the Beam Sizing Memo and partially in the Heat Sink Sizing Memo.

5. Understand how the flow rate of air through the stove is determined. For the stove as the flow rate increases the pressure drop through the stove should also increase. Meanwhile, for the fan as the flow rate increases the pressure drop it provides decreases. The intersection of these two curves should be the operational point of the system. This also means that any changes in the system (for example, the “bypass” being opened any amount) will changed the stove curve and thus affect the flow rate. If you are having trouble with these concepts ask for help!
6. Once you feel comfortable with the previously mentioned technical concepts look at the P11462 Detailed Design Review (DDR) presentation document and its related documentation. Afterwards look through the MSD II documentation on our testing and recommendations. Most of the math and ideas would not have made sense until you understood the system and concept well enough.
7. Get a lecture on the theory behind thermoelectrics (TE) from Dr. Stevens as early as possible. Supplement this lecture with demonstrations of the Thermoelectric Test Bed and through use of

a stove demo (use instructions provided with rheostat) to actually see TE output power move up and down the power curve.

8. Look for documentation on the heat transfer coefficient of fire. We performed a test to try to back out this value (see U-value determination document) however actual technical equations or research would be very helpful.
9. Don't feel constricted by any perceived lack of equipment. Ask around because someone usually has the equipment you need. For example, Professor Wellin is a good resource for pressure taps and measurement equipment.
10. This is a small item but when you begin writing engineering specifications specify separate specs for the target hot side temperature and the target cold side temperature.
11. Test every idea as much as possible in MSD I. Come up with a way to test if it is not immediately apparent. If you have ideas to change the heat conduction rod test those ideas. Lots of scrap metal is available in the machine shop if you ask. Try to test ideas before a large amount of money is procuring supplies.

Recommendations

Short falls of 2011 system

While the system developed during the 2010-2011 section of senior design did work, not all of the specs set for the project were met. Below is a list of the issues with the system and below that some suggestions on how to avoid making the same mistakes.

1. Not enough thermal energy conducted out to TE
2. Heat sink cooling capacity to low
3. Method of resistance matching to obtain peak power ineffective
4. Better measurement of temp gradient along the rod needed
5. Efficiency of circuit too low (chips consuming too much power just to operate)
6. Active model of thermoelectric not developed
7. Fully coupled model of the thermal and electrical system not developed (change in one area can be propagated to see effects on other components)
8. Method used to maintain pressure on TE failed under heat load (springs became annealed, but pressure is necessary due to fasteners becoming loose due to thermal expansion)
9. Heat sink thermally coupled to heat sink through fasteners (heat conducted through springs and screws)

Suggestions

1. Preform early testing to get a "feel" for the system
2. Take advantage of fair weather days, they will be in short supply
3. More robust model of heat conduction rod, accounting for losses on external section (if rod type design)

4. Actual model of thermoelectric
5. Dynamic model of whole thermal electrical system to see effects of power draw on temperature differences
6. Testing to determine the effects of the temperature gradient across the face of the thermoelectric
7. Priority of electrical system to be peak power tracking and maintaining power budget
8. Order components before the transition from MSD1 to MSD2
9. Try to order components from one supplier (shipping charges)
10. Keep accurate list of components as they come in
11. Verify components are not surface mount style (unable to breadboard or solder)
12. Fix any issues with wrong components as soon as possible
13. Components that need machining should be done as soon as possible (machine shop gets busy)