Waste Heat Recovery

of Electronic Equipment

With the rapid increase of power dissipation in electronics' components, the energy needs for cooling are also increasing at a rapid pace. During the process of activating and cooling components, heat is generated and dumped in the atmosphere. This wasted energy in a global scale is huge and, if only a percentage of this wasted heat can be converted, it would account for a significant amount worthy of consideration. Ishizuka et al [1] conducted an interesting experiment to harness some of the wasted heat and it is described below.

The schematic of their experiment is shown in figure 1.

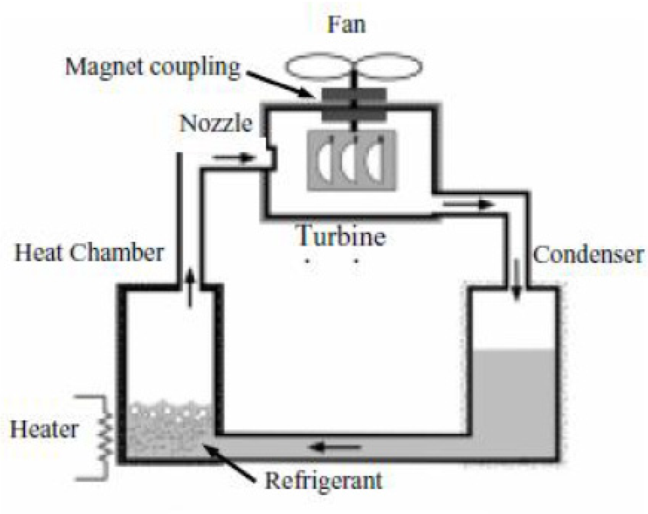

Figure 1. Experimental Setup , [1]

In this experiment, the heat generated by a heater raises the temperature of the refrigerant inside the heat chamber. The refrigerant, FC-72, evaporates inside the heat chamber. The evaporated gas increases its pressure due to its heating and passes through a nozzle to increase its speed. The exhaust of the nozzle then impinges on the rotor blades, which are magnetically coupled to an external fan. The exhaust gasses then go through the condenser and its heat is extracted to change the gas into liquid. The liquid then returns to the heat chamber, due to gravity. The increased pressure in the heat chamber also works as a back pressure to force the liquid through the heat condenser. The experiment was done with two types of turbine blades: an aluminum blade and a plastic blade as shown in figure 2.

Figure 2. Left(Aluminum Blade), Right(Plastic Blade), [1]

FC-72 was pumped into the system under low pressure with a vacuum pump. Three different nozzles with outlet bore diameters of 2, 2.5 and 3 mm were tested. After applying power to the heat chamber, it took almost 240 minutes for the temperature in the heat chamber, turbine chamber and the condenser to reach steady state, as shown in figure 3.

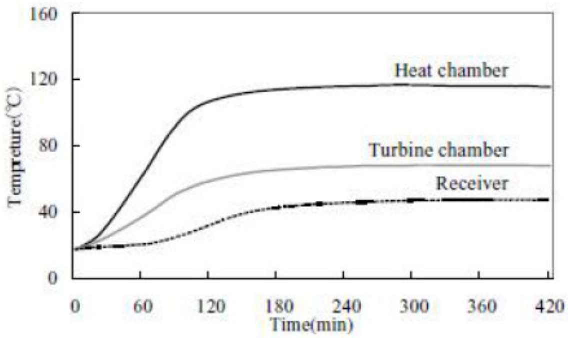

Figure 3. Temperature Change In Different Sections Of The Experiment, [1]

Figure 4 shows the temperature of the heat chamber, turbine chamber and the receiver as a function of heat input to the heat chamber.

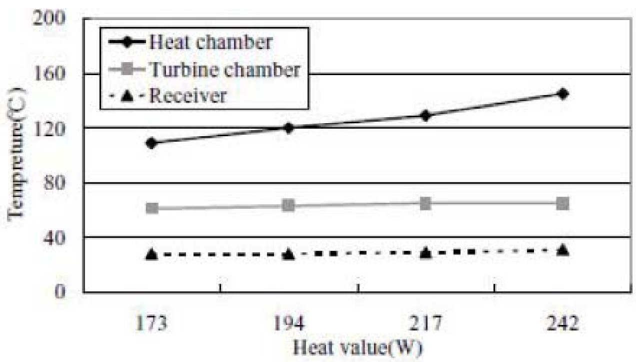

Figure 4. Temperature Change In Different Sections Of The Experiment, [1]

Figure 5 shows the differential pressure between the heat chamber and the condenser and the rotational speed of the turbine blade as a function of heat input. As is evident from this figure, these two values increase with the increase of heat value.

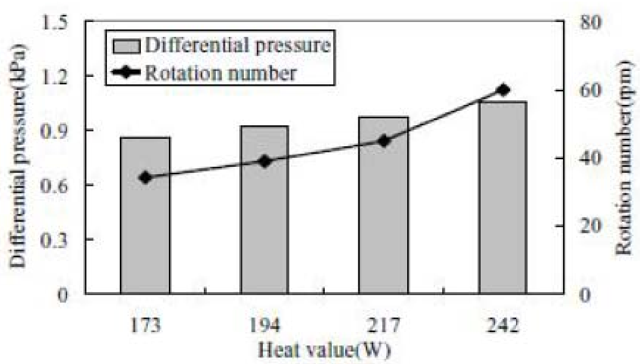

Figure 5. Differential Pressure And Rotation Speed As A Function Of Heat Value, [1]

At around 242 W, the temperature of the heat chamber has reached 150ºC and the rotation speed of the turbine is about 60 rpm. In another experiment, Ishizuka et al [1] used the aluminum turbine with different nozzle bore diameters to determine the effect of the nozzle size. They dismounted the inner and outer rings of the magnetic coupling. They also used 300 W of heat to raise the temperature of the heating chamber. Figure 6 shows the differential pressure and RPM of the turbine for different size nozzles. The graph shows that a nozzle diameter of 2.5 mm would result in the best RPM at around 650.

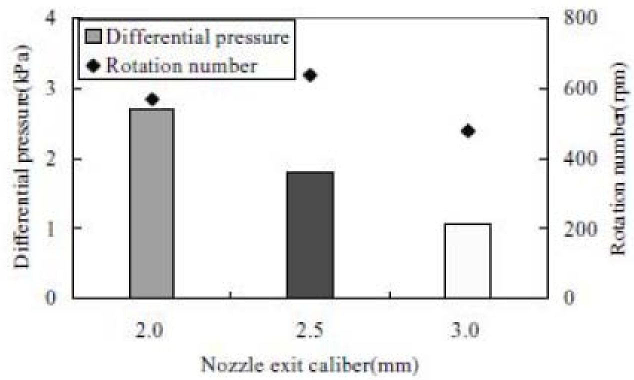

Figure 6. Differential Pressure And RPM Of The Aluminum Turbine For Different Size Nozzles, [1]

In another experiment, they [1] conducted the measurement for the 2.5 mm nozzle size at 3 different heat values of 300, 310 and 320 W for the aluminum turbine with the outer ring of the magnetic coupling dismounted. An RPM of 209 is realized at 320 W. However, this RPM drops to 31 RPM when the outer ring of the magnetic coupling is mounted. The differential pressure and RPM increase steadily with increase of heat as shown in figure 6.

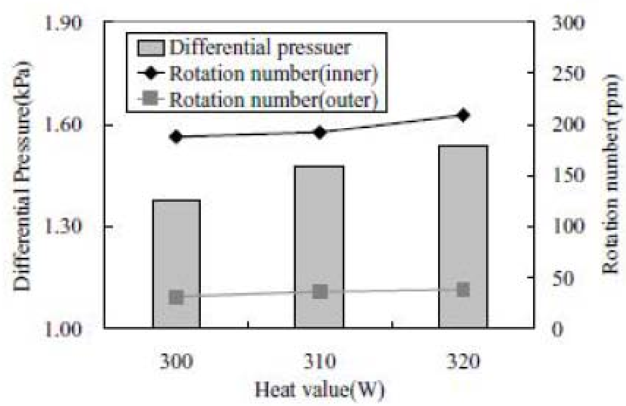

Figure 7. Differential Pressure And RPM Of The Aluminum Turbine For Different Size Nozzles, [1]

The measured output in terms of useful work was about 3.98 W for an input power 300 W. This value can drop by about 80% when the outer ring of the magnetic coupling is mounted. The calculated efficiency of the system, after accounting for the heat losses, was measured at 1%, which is the ratio of the output work to the heat input.

It would be interesting to compare the efficiency of this system to a Carnot cycle. The hot side temperature, which is the heater, in the heat chamber is T_H = 67ºC. The cold side, which is the condenser, is about 21ºC. The Carnot cycle efficiency is calculated as :

$$\eta = 1 - \frac{T_C}{T_H} = 1 - \frac{273+21}{273+67} = 13.5\%$$

The efficiency of this system is about 8% of the Carnot cycle. One might also ask, if we had used the two hot and cold temperatures on a TEC power generator, what would be the efficiency. The efficiency of a TEC generator can be calculated as follows [2]

$$\eta = \left[\frac{T_H - T_C}{T_H}\right] \frac{m}{\frac{(m+1)^2}{ZT_H} + (m+1) - \left[\frac{T_H - T_C}{2T_H}\right]}$$

Where m = R_{load}/R Assuming m =1 when the generator resistance R matches with the resistance of he attached electrical load and figure of merit Z = 0.2, the efficiency becomes:

$$\eta = 0.135\%$$

This is by far below the efficiency of the system, since the temperature difference between hot and cold is not very high. The TECs work best when the temperature difference is very high. Even though the efficiency of the proposed system is very low for any practical application, it shows promise for future development and improvements as to maximizing the efficiency and possibly the viability of harnessing the wasted heat from electronics' components.

References:

1. Ishizuka, I., Nakagawa, S., Koizumi, K. "Development Of a Self-Cooling System Utilizing Waste Heat From Electronic Equipment", 2006, IEEE

2. www.marlow.com