

# **Addendum: ANALYSIS OF BERKEN ENERGY THERMOVOLTAIC GENERATOR TECHNOLOGY**

*Since Dr Ahrenkiel's report on November 18, 2013 Berken Energy has continued to improve on the product design and process. I have compiled a list of improvements and comparison of the device analyzed by Dr Ahrenkiel with current progress.*

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## **Product Design**

The finalized design of the Berken Energy Thermovoltaic *Cartridge* has been optimized for best use of resources as well as with large-scale production in mind.

### **Dimensions**

The finalized Thermovoltaic *Cartridge* now has a footprint of 152x76mm (6x3" nominal). The use of automated manufacturing has allowed us to increase the size. This has been increased to yield the best use of space while remaining flexible.

### **Active Area ("Fill Factor")**

Active Thermovoltaic area has been increased. Every Thermovoltaic leg contributes additional voltage in series. This means that for every extra Thermovoltaic leg that you put within the packaging increases the power output. We are limited in how closely these Thermovoltaic legs can be packed with the hand assembly. With geometric layout modifications and use of automated equipment for much tighter tolerances we can get an increased use of space. The cartridge now consists of 276 Thermovoltaic legs that are 6x6mm. This represents an active area of 86%.

## **Technical Improvements**

### **Contact Resistance**

Contact resistance has been drastically decreased. Through improved processing for metallization, we have improved voltage drop due to contact resistance by almost 70%.

### **Voiding**

Due to automation equipment, flux changes and improved reflow pattern, we will decrease voiding within the interface between the Thermovoltaic legs and electrical interconnects. This is projected to decrease device resistance by approximately 10%.

### **Temperature**

Dr Ahrenkiel's report shows the roughly linear correlation between temperature and power output. With this consideration, a cartridge will produce 22% more power at a  $\Delta T$  of 80°C and 53% more power at a  $\Delta T$  of 100°C than at 65.5°C.

## **Comparison**

With the improvements we have made in contact resistance alone since Dr Ahrenkiel's report, we have seen an increase in performance to  $36.3\text{W}/\text{ft}^2$  ( $31.1\text{mW}/\text{cm}^2$ ) at a  $\Delta T=65.5$  over what Dr Ahrenkiel reported of  $20.4\text{W}/\text{ft}^2$ . We also expect to benefit from an additional 10% gain due to lower occurrence of voiding in production.

In addition to the contact resistance, with the use of automated equipment in production, we will increase active area from 55.1% to 86.0%. This alone is a projected increase in power density of 56%.

## **Summary**

With the improvements made and projected improvements of automated manufacturing, we expect the Berken Energy Thermovoltaic Cartridges to produce approximately  $76\text{W}/\text{ft}^2$  at a  $\Delta T=80^\circ\text{C}$ .