INTEGRATED MICROCOMBUSTOR/THERMOELECTRIC GENERATOR

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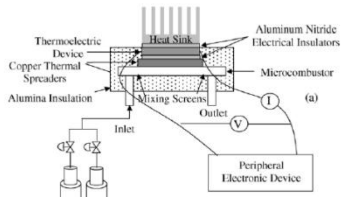
Motivation

- The big picture: Development of small scale portable power generation technology that can utilize the high power density of hydrocarbon fuels
- . Micro-combustor utilizing catalytic combustion coupled with thermoelectric devices to generate power.
- Use of catalysts for combustion in the small scale provides several advantages over homogeneous combustion reactors.

Objectives

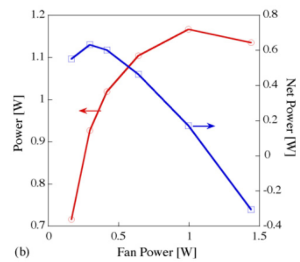
- Design an integrated microcombustor/ thermoelectric system to obtain higher efficiency compared to previous work .
- Construct an energy balance model of the device to understand the capabilities and limitations of the device.

Previous Work

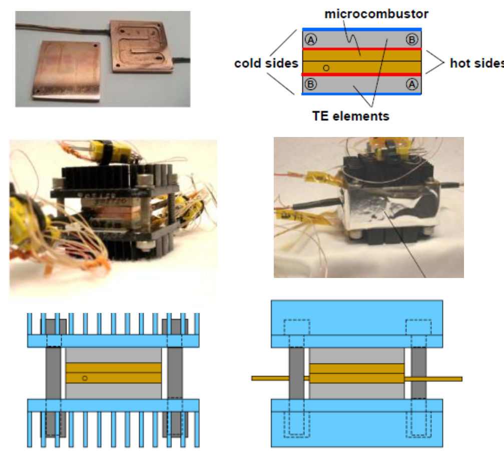


- Single-channel stainless-steel reactor. Pt/alumina catalyst wafers

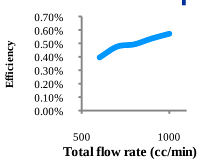
- Coupled with a single thermoelectric placed on one side of the reactor.
- Approximately 59% of the energy input is lost as convective heat losses from the surface.



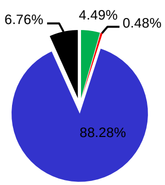
Integrated Device



Integrated Device - Experiment



- Heat losses from the device surfaces has been drastically reduced in the new device.
- However, efficiency is less than that of the previous design.

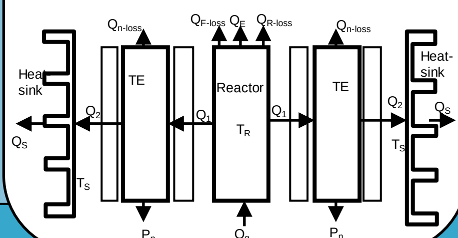


Flow = 700cc/min

- heat loss from exhaust (W)
- power output (W)
- heat loss from heat sink (W)
- heat lost from other surfaces (W)

Integrated Device – Model

- Need to understand the flow of energy in the device.
- Helps in making a cost-effective and efficient decision for the next design iteration.



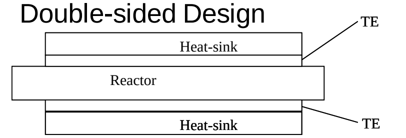
Integrated Device – Model

Energy Balance Model

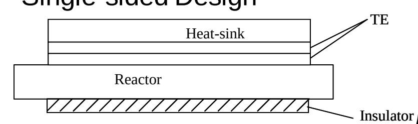
- Use MATLAB to solve for temperature at each interface and iterate until energy balance is achieved
- 1-D thermal conduction through TE, ceramic wafers and insulation
- Heat loss from non-heat sink surfaces – Used natural convection model
- Thermal resistance model for heat loss from heat-sink
- Seebeck coefficient and Internal resistance of TE got from experimental data
- Manufacturer data for heat-sink thermal resistance, TE thermal conductivity, and component geometry

Integrated Device – Model

Double-sided Design



Single-sided Design



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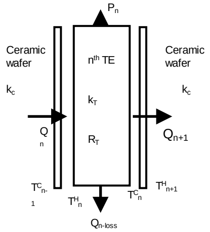
Integrated Device - Model



Assume a reactor temperature to calculate Q_1

$$Q_1 = \frac{1}{b}[Q_g - Q_E - Q_{R-loss} - Q_{F-loss}]$$

$$T_1^H = T_R - \frac{L_c Q_1}{k_c A_{c-face}}$$

At the n^{th} thermoelectric

$$Q_n = S_n I_n T_n^H + \frac{k_t A_{t-face}}{L_t}(T_n^H - T_n^C) - \frac{I_n^2 R_T}{2}$$

$$Q_{n+1} = S_n I_n T_n^C + \frac{k_t A_{t-face}}{L_t}(T_n^H - T_n^C) + \frac{I_n^2 R_T}{2} \quad (1)$$

$$I_n = \frac{S_n (T_n^H - T_n^C)}{R_T + R_L}$$

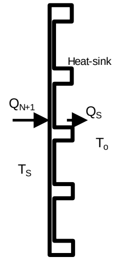
On the cold side

$$Q_{n+1} = Q_n - Q_{n-loss} - P_n$$

$$Q_{n+1} = Q_n - \left(\frac{1}{Tres_{TE}}\right)\left(\frac{T_n^H + T_n^C}{2} - T_{amb}\right) - \left(\frac{S_n (T_n^H - T_n^C)}{R_T + R_L}\right)^2 R_L \quad (2)$$

- **Solve sequentially for the hot and cold-side temperatures of each thermoelectric**

Integrated Device - Model



At the heat-sink

$$Q_{N+1} = \frac{k_c A_{c-face}}{L_c}(T_N^C - T_S^H)$$

$$Q_{N+1} = h_{\sin k} A_{\sin k}(T_S - T_o)$$

- Solve for T_o and iterate until T_o equals the ambient temperature

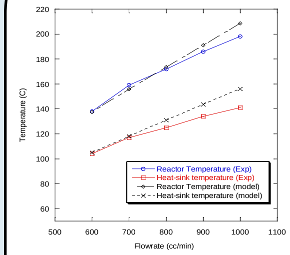
The output power of the system

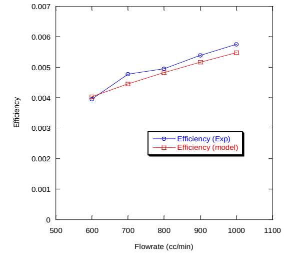
$$P_s = \sum_{n=1}^{bN} I_n^2 R_L$$

The thermal efficiency of the system

$$\eta_s = \frac{P_s}{Q_G}$$

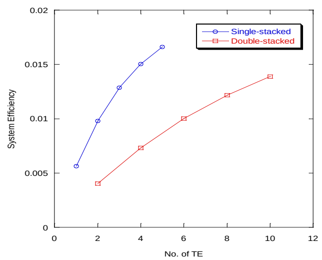
Integrated Device – Model Comparison





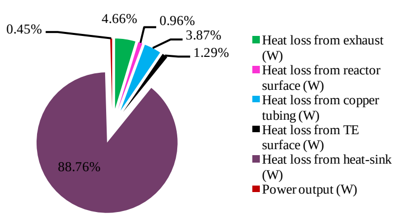
Difference in temperature between the model and experiment at higher flow rates is due to the incomplete conversion of reactants in the experiment, which is not accounted for in the model.

Integrated Device – Model Results



Single stacked design has a higher efficiency than the double-stacked design for the same number of TEs

Integrated Device – Model Results



♦Inefficiency in double-sided design due to reduction of heat flux across each TE.
♦Need to minimize heat loss from copper tubing

Future Design Improvements

- ♦ Switch to single-sided design
  - Need to adequately insulate one side of the reactor
- ♦ Stack more thermoelectrics
  - Size and cost limitations
- Use more efficient heat-sinks and redesign reactor to accommodate higher flow-rates.
- Reduce heat loss from copper tubing

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