Electricity Production

Note; • 12 assemblies of T/E convertors (see figure)

• Each panel is 10 cell rows wide and 32 cells/row = 320 cells/panel, or 640 cells/each of 12 assemblies

• In each panel, half of the cells (160) are in series

• Each cell produces 14.375 $W_e$ at 0.63 V

• Total output per assembly
  
  = 640 X 14.4 $W_e$
  
  = 9,200 $W_e$

• Total Voltage = 160 cells x 0.63 V/cell
  
  = 100.8 V

--------------------------------------------

Exploded View of a Cell

See Figures

Note; The LaS$_x$ has a large (14 x 10^{-6}/°K) expansion coefficient. Ni and Forsterite are chosen to match the expansion

Note; Operation at 100 V or 200 V is possible by series or parallel connections
Note; Need more than 100 $\text{kW}_e$ for load, auxiliary power is $\approx 5-10 \text{kW}_e$.

**Reference Operating Performance**

- **Power** = 110 $\text{kW}_e$
- **Voltage**, 100/200 V
- **Convertor efficiency** = 6.6 %
- **Heat source temperature** = 1323 °K
- **Hot junction temperature** = 1290 °K
- **Cold junction temperature** = 842 °K
- **Heat sink interface temp** = 824°K
Power Converter Assembly (PCA)

PACKAGING CONCEPT

- Cold Side Inlet Manifold
- TCA 6 Places
- Cold Side Outlet Manifold
- Cold Side Core Headers (12 Places Per Side)
- Cold Side Outlet Manifold
- Hot Side Outlet Manifold
- Cold Side Core Headers (6 Places Per Side)
- Hot Side Inlet Manifold

VII - 8
Thermoelectric Converter Assembly (TCA)

- DIMENSIONS IN INCHES

0.226 - TYPICAL FOR BOTH HOT AND COLD SIDE HEAT EXCHANGERS

COLD SIDE HEAT EXCHANGER

HOT SIDE HEAT EXCHANGER

COLD SIDE HEAT EXCHANGER
SP-100 2 x 2 Cell Array Converter Test Assembly
Figure 2.2-14. Thermoelectric Cell Construction Details
Figure 26. TE Cell Evolution

- **PD-1**
  - **Cell Operating Temperatures, °K:** 1110/625
  - **No. of Couples:** 6
  - **T/E Material:** SiGe
  - **Electrode:** SiMo
  - **Stress Relief:** Graphite Buffers + Compliant Pad (0.010 mm, All Niobium)
  - **High-Voltage Insulator:** Sapphire (0.25 mm)
  - **Low-Voltage Insulator:** 0.18 mm Glass

- **PD-2**
  - **Cell Operating Temperatures, °K:** 1350/875
  - **No. of Couples:** 6
  - **T/E Material:** SiGe
  - **Electrode:** SiMo
  - **Stress Relief:** Dual Facesheet Compliant Pad (0.010 mm, Filament)
  - **High-Voltage Insulator:** Sapphire (0.25 mm)
  - **Low-Voltage Insulator:** 0.18 mm Glass

- **TA-1**
  - **Cell Operating Temperatures, °K:** 1350/875
  - **No. of Couples:** 8
  - **T/E Material:** SiGe
  - **Electrode:** SiMo
  - **Stress Relief:** Dual Facesheet Compliant Pad (0.005 mm, Filament)
  - **High-Voltage Insulator:** Sapphire (0.13 mm)
  - **Low-Voltage Insulator:** 0.05 mm Glass

Figure 27. Status of SiGe Efficiency Improvement

- **ΔT = 700°C (RTG)**
- **ΔT = 400°C (SP-100)**
- **HOT SHOE TEMPERATURE = 1000°C**

- **SP-100 Goal**
- **SP-100 Improved SiGe (June, 1991)**
- **Standard SiGe**

- **Combined Figure of Merit, °K x 10^3**

<table>
<thead>
<tr>
<th>Conversion Efficiency, Percent</th>
<th>Conversion Efficiency, Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>14</td>
<td>14</td>
</tr>
</tbody>
</table>
Thermoelectric Materials Improvement

IMPROVEMENT IN SILICON ALLOY THERMOELECTRIC MATERIAL

CONVERSION EFFICIENCY, PERCENT
$T_H = 1000^\circ$C, $T_H - T_C = 400^\circ$C

Z = 0.62
SP-100 SDR

Z = 0.72
Optimum p-type doping with gallium
(increased boron dopant)

Z = 0.66

Z = 0.79
Reduced TC in p-type with scattering centers
(single sample only)

Z = 0.85 (B.O.L.)
SP-100 GOAL

REduce Thermal Conductivity

Optimize Electrical Properties

Z = Combined TCE Figure of Merit x 1000

CALENDAR DATE

Thermoelectric Converter Assembly (TCA) Power Conversion Subassembly (PCA) - Electrical Diagrams

TCA ELECTRICAL CIRCUIT

PCC&D INTERFACE

(+)(-) (+)(-)

208.6 V 208.6 V

+104.3 V +104.3 V

TCA NO. 1 TCA NO. 2

+34.8 V +34.8 V

TCA NO. 3 TCA NO. 4

-34.8 V -34.8 V

TCA NO. 5 TCA NO. 6

-104.3 V -104.3 V

+69.6 V +69.6 V

PCA TE ARRAY ELECTRICAL CIRCUIT

10 CELLS

+34.8 VOLTS

6 CELLS

ATM 92 - Space Subsystems

II - 6
COMPARISON OF SP-100 WITH COMMERCIAL REACTORS

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SP-100</th>
<th>TYPICAL COMMERCIAL REACTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>POWER OUTPUT (MWd)</td>
<td>2.5</td>
<td>3500</td>
</tr>
<tr>
<td>POWER OUTPUT (KWe)</td>
<td>100</td>
<td>1,000,000</td>
</tr>
<tr>
<td>LIFE (YRS)</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td>NO. OF FUEL PINS</td>
<td>978</td>
<td>64,000</td>
</tr>
<tr>
<td>CORE HEIGHT (FT)</td>
<td>1.3</td>
<td>12.5</td>
</tr>
<tr>
<td>CORE DIAMETER (FT)</td>
<td>1.1</td>
<td>15.0</td>
</tr>
<tr>
<td>FISSION PRODUCTS (Ci)*</td>
<td>12 x 10^6</td>
<td>17.5 x 10^9</td>
</tr>
</tbody>
</table>

*CUMULATIVE DURING POWER OPERATION
## Lunar Surface Power System Mass Breakdown

<table>
<thead>
<tr>
<th>Item</th>
<th>100 kWe LPSM Mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Power Assembly</strong></td>
<td></td>
</tr>
<tr>
<td>Reactor</td>
<td>650</td>
</tr>
<tr>
<td>Shield</td>
<td>890</td>
</tr>
<tr>
<td>Primary Heat Transport</td>
<td>310</td>
</tr>
<tr>
<td>Reactor I &amp; C</td>
<td>190</td>
</tr>
<tr>
<td>Power Conversion</td>
<td>440</td>
</tr>
<tr>
<td>Heat Rejection</td>
<td>700</td>
</tr>
<tr>
<td>Cavity Cooling</td>
<td>450</td>
</tr>
<tr>
<td>Power Assembly Enclosure</td>
<td>150</td>
</tr>
<tr>
<td>Structure</td>
<td>400</td>
</tr>
<tr>
<td><strong>LSPS Monitoring and Control</strong></td>
<td></td>
</tr>
<tr>
<td>Operator Assembly</td>
<td>100</td>
</tr>
<tr>
<td>Fiber Optics Cable</td>
<td>100</td>
</tr>
<tr>
<td>MUX/DEMUX Assemblies</td>
<td>80</td>
</tr>
<tr>
<td>MUX Cabling</td>
<td>40</td>
</tr>
<tr>
<td>Shunt Dissipator</td>
<td>40</td>
</tr>
<tr>
<td>Shunt Cabling</td>
<td>80</td>
</tr>
<tr>
<td>Governor Assembly</td>
<td>600</td>
</tr>
<tr>
<td><strong>LSPS Power Management</strong></td>
<td></td>
</tr>
<tr>
<td>Dc/dc Converter</td>
<td>900</td>
</tr>
<tr>
<td>Power Switchgear</td>
<td>800</td>
</tr>
<tr>
<td><strong>Auxiliary Equipment</strong></td>
<td>300</td>
</tr>
<tr>
<td>Cavity Liner</td>
<td>50</td>
</tr>
<tr>
<td>Cavity Drill</td>
<td>90 (Required for the first unit only)</td>
</tr>
<tr>
<td>Shield Blanket</td>
<td>160</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>7220</td>
</tr>
</tbody>
</table>