## Heat Rejection

<table>
<thead>
<tr>
<th>Power Source</th>
<th>$\eta-%$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radioisotope</td>
<td>5-10</td>
</tr>
<tr>
<td>Thermionic</td>
<td>10-15</td>
</tr>
<tr>
<td>Rankine</td>
<td>$\approx20$</td>
</tr>
<tr>
<td>Brayton</td>
<td>20-30</td>
</tr>
<tr>
<td>Stirling</td>
<td>$\approx25$</td>
</tr>
</tbody>
</table>

**Burst Mode Operation:** Could use thermal inertia, or phase changes

**Steady State Operation:** Transport waste heat to radiators is only solution

### How Do We Get The Heat From The Power Source to The Radiator?

- **Conduction** (Mass)
- **Convection** (No gravity)
- **Heat Pipe** (Effective thermal conductivity $> 1000 \times$ Ag)
Fig. 4.7  Heat pipe operating principle. *Courtesy of Los Alamos National Laboratory.*
History

1944  R. Gaughler Proposed Capillary Pumping For Refrigeration Application

1962  L. Trefethan Proposed Capillary Pumped Device For Satellite Application


Heat Pipes now operate from cryogenic temperatures to 2000 °C.

General Performance Factors of Heat Pipes

\[
Q_0(z) = \lambda \dot{m}_v(z) \quad \text{Watts}
\]

\[Q_0(z) = (z/l_e) Q_e \quad \text{for} \ 0 < z < l_e \quad \text{Input}
\]

\[= (L-z) \left( \frac{L-l_e}{L-L} \right) Q_e \quad \text{for} \ l_e < z < L \quad \text{Ht Rejection}
\]

Latent Heat
Vapor Mass Flow rate

Total Heat Flow to Evaporator
Liquids Commonly Used in Heat Pipes

- Freon-II: 190 J/g
- Hg: 291 J/g
- Cs: 512 J/g
- Acetone: 564 J/g
- Methanol: 1178 J/g
- Ammonia: 1263 J/g
- K: 2040 J/g
- Water: 2492 J/g
- Na: 4370 J/g
- Li: 20525 J/g
Figure 3.3. Liquid transport factor at boiling point versus boiling point.
Figure 3.2. Operating temperature ranges of various heat pipe fluids.
Typical Operating Regimes For Heat Pipe Fluids

Temperature (°C) vs. J/g

- Hg
- Cs
- K
- Na
- Ammonia
- Acetone
- Freon-II
- Water
- Li
Wick Characteristics

Can be:

- Woven Cloth
- Metal screen
- Grooves in Wall
- Porous Solid
- Packed Spheres

Figures (2)

Effectiveness of Wick Determined by:

- Mean pore radius
- Liquid volume fraction
- Permeability
Figure W-1. Cases for Which the Effective Pore Radius can be Estimated
ALTERNATIVE HEAT PIPE WICK CONFIGURATIONS

POWDER METAL TUNNEL WICK

SCREEN WICK WITH SEGMENTED ANNULUS

SCREEN WICK COVERED GROOVES