THERMOELECTRIC TECHNOLOGY READINESS FOR LARGE-SCALE COMMERCIALIZATION

Lon Bell, PhD
BSST

DOE/EPRI High Efficiency Thermoelectrics Workshop
19 February 2004

Large-Scale Commercialization Technical Process

- Functional requirements drive subsystem and component design
- Materials (“chips” or “elements”) are mass-producible to specifications determined by users
- Assembly is by dedicated, integrated production equipment
- Integrated subassemblies have specified input/out, size and shape
- Capable manufacturing and quality control processes are available

Key Factors Influencing Technology Readiness

Material capability

- Figure of merit (ZT) value
- Material stability, cost and environmental impact

Operating cycle

- Thermodynamic efficiency at subsystem level
- Cycle complexity and cost

Power density

- Cost per watt of delivered thermal power
- Efficiency of thermal and electrical power transfer

Design capability

- Availability of accurate CAD tools
- Design to specifications

Manufacturing

- Availability and maturity
- Cost, quality predictability

Material Capability

Four categories of readiness:

ZT	Status	Production Readiness
0.7 to 1.0	Available worldwide, proven and understood	Can use now
1.3 to 1.5	Anticipated in laboratory quantities in 2004. Not commercially available	Suitable for longer developing designs
1.8 to 2.4	Anticipated in 2005 – 2006	Only suitable for the longest developing design
2.5 +	Availability uncertain	Can use for long-term strategic guidance only

Operating Cycles

Standard Cycle

- Suitable for electronic chip cooling, refrigeration and temperature control of sensors and instruments.
- Commonly available, mature technology.

Advanced Cycles

- About 2X efficiency of standard cycle in air and liquid temperature conditioning and heat transfer applications.
- Uses include HVAC, environmental control, electronic system cooling, industrial process control.
- Emerging, not widely available technology.

Power Density

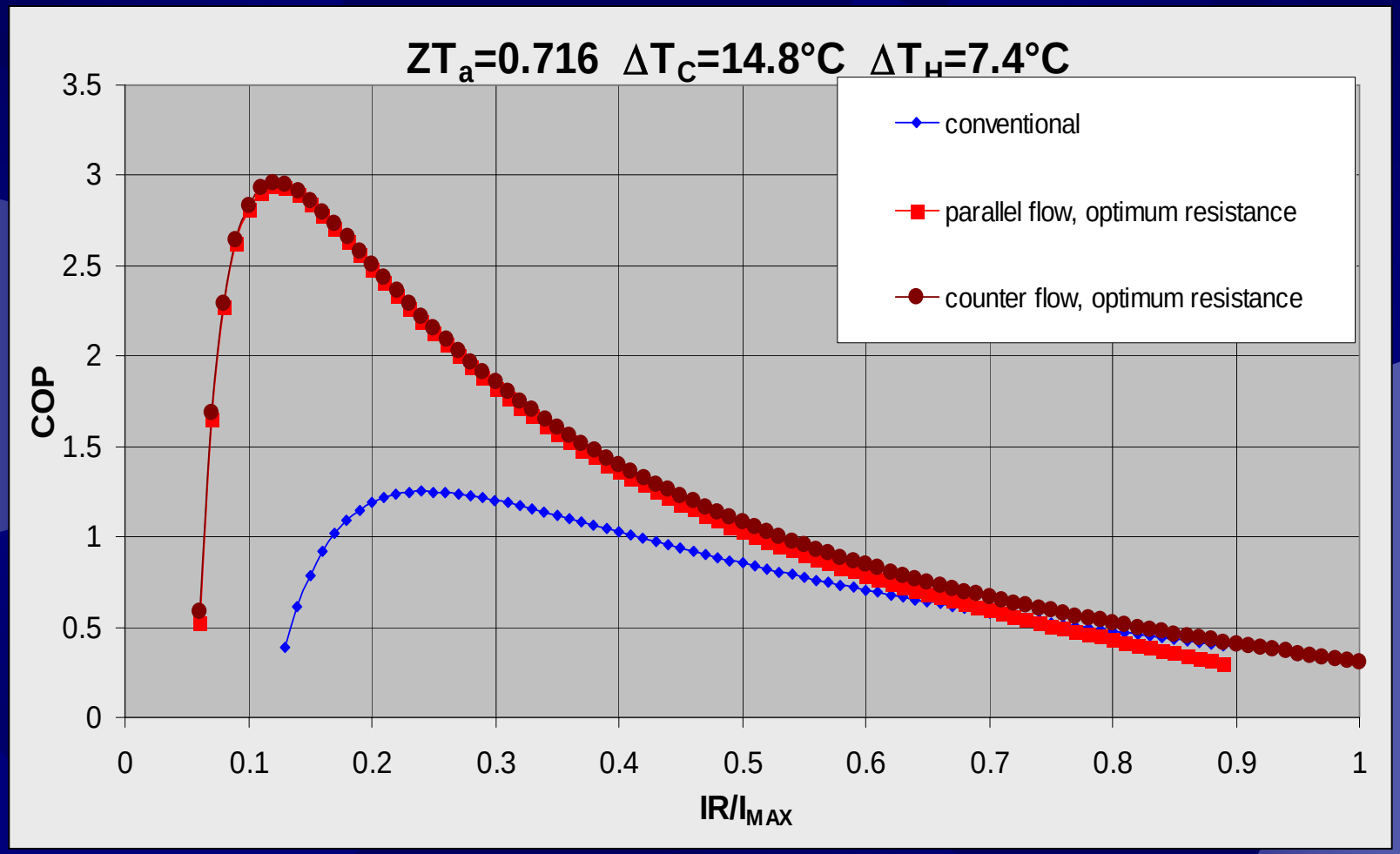
Standard power density TE modules are not likely to play a significant role in near-term, large scale commercialization

- Basic technology is 40+ years old
- Performance is not likely to increase significantly in the near future

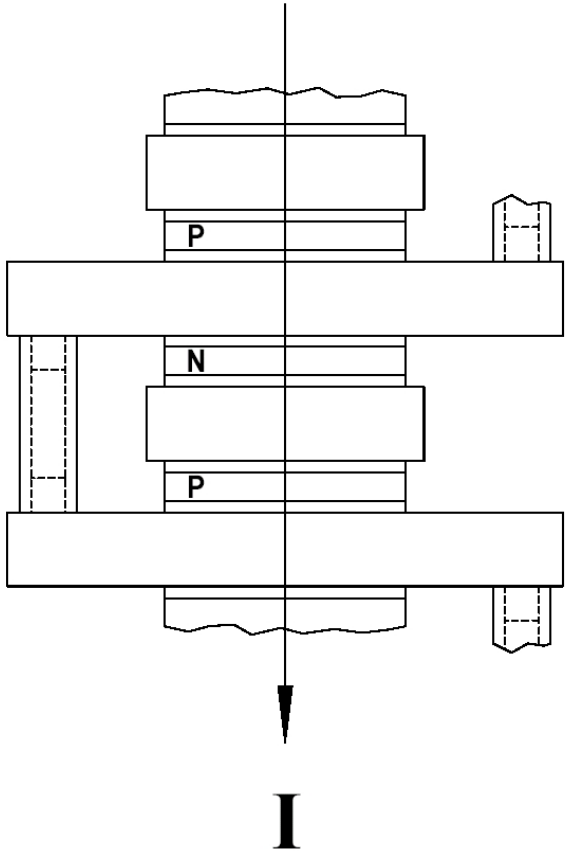
High power density subsystems are likely to be employed in new large-scale applications

- 1/10 to 1/25 the amount of TE material required
- The high power density leads to substantial size and cost reductions.
- Facilitates operation at maximum thermodynamic efficiency

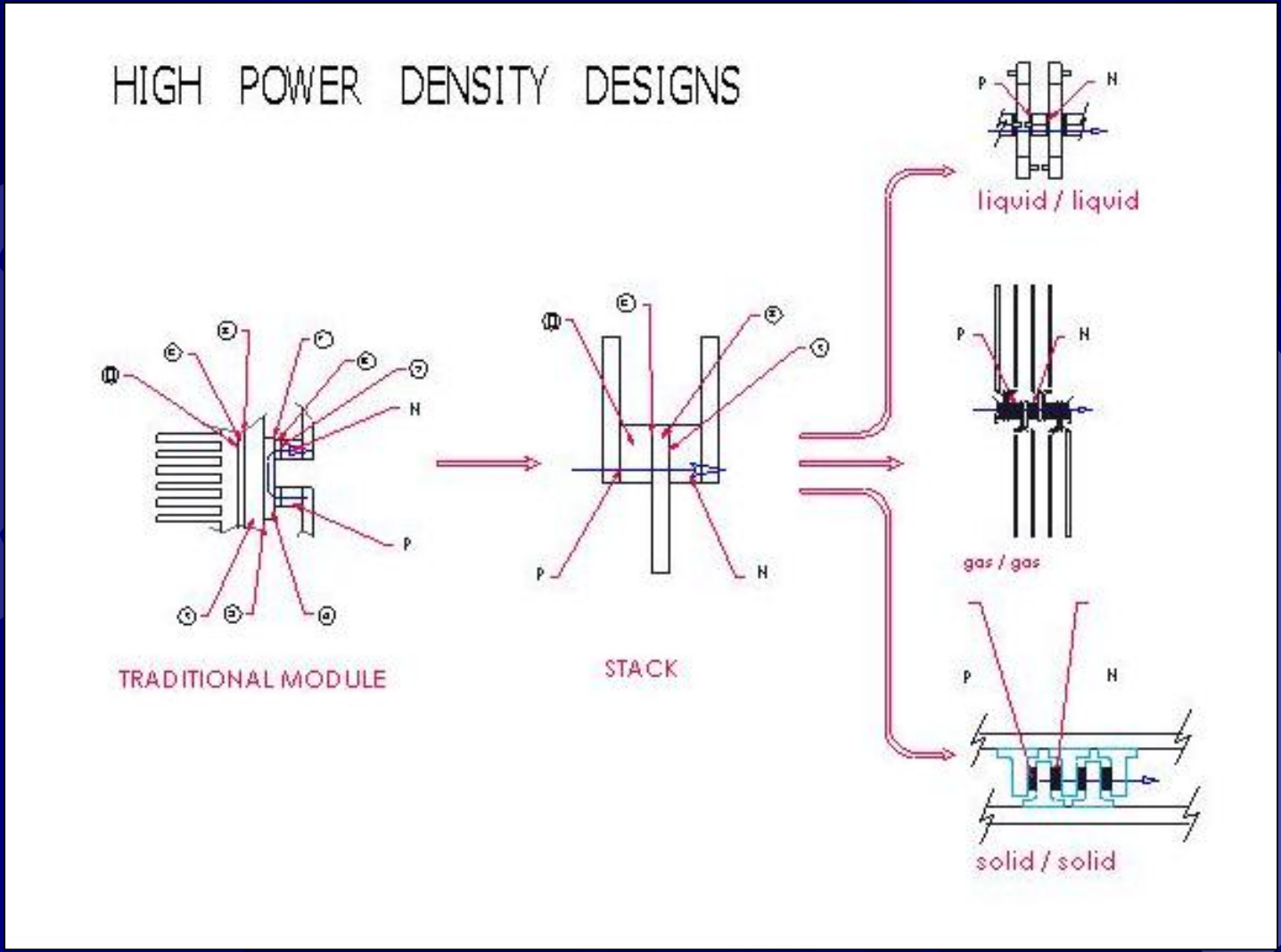
COP for Different Configurations



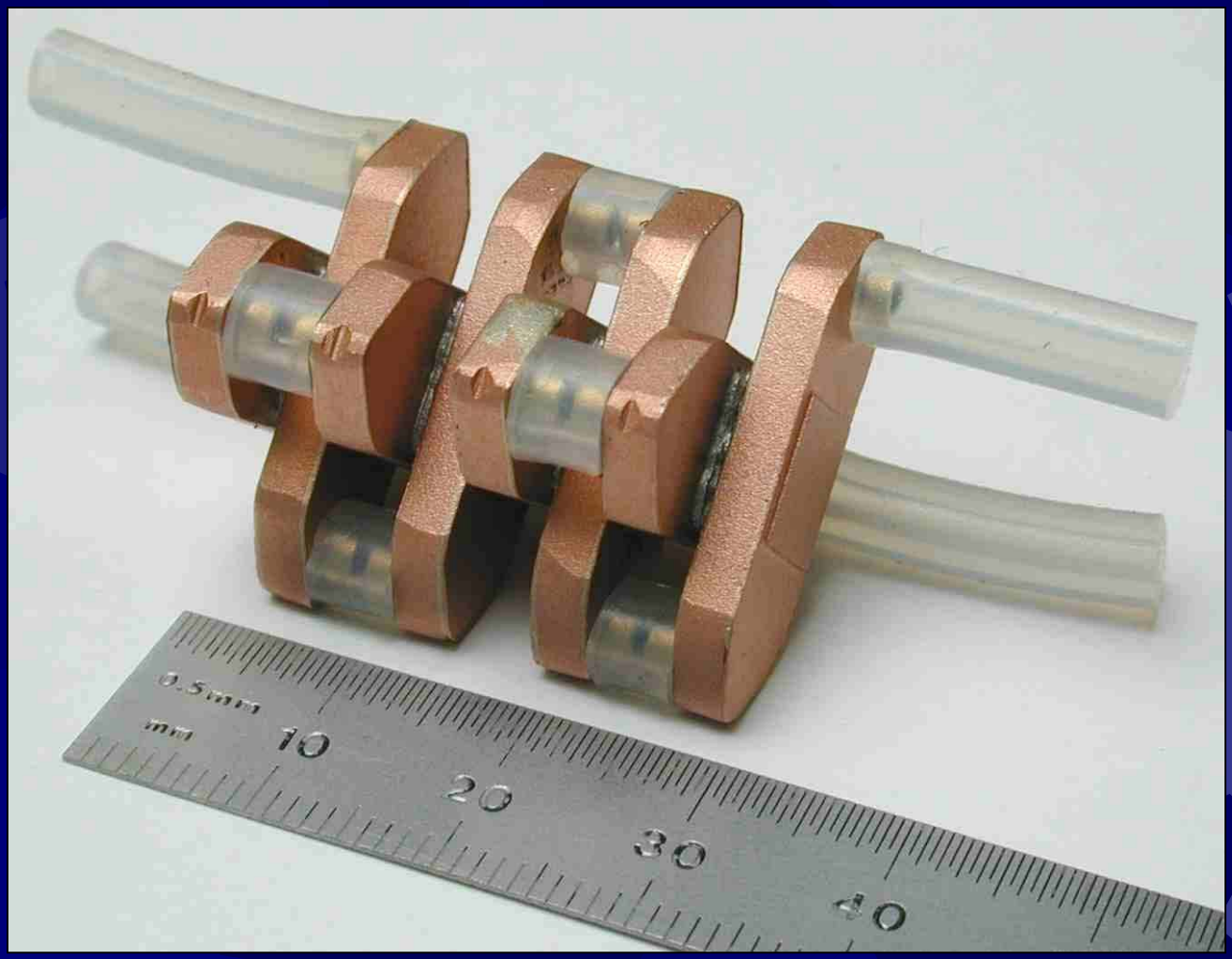
High Power Density Design



High Power Density Designs



High Power Density Stack Module



Development Tools

Standard module based design:

- Limited applicability for high volume new applications
- Experience and design guidance is limited to module suppliers, present users and design services

Advanced integrated designs:

- Supporting design tools are proprietary with very limited availability
- Advanced cycles have restricted availability

Manufacturing Capability

Standard modules are fabricated worldwide in moderate volumes. Production is mature and expandable.

Custom fabrication is under development

- Various approaches are under development
- Approaches are considered highly proprietary and are not easily accessed
- Technology is generally under-funded

Examples of Possible Near-Term High-Volume Applications (ZT=0.7 to 1.0)

- Laser diode and other electron chip cooling
- Vehicle ancillary temperature control systems
- Quiet room HVAC and heat pump systems
- Electronic equipment, computer equipment and cabinet coolers

High-Volume Applications Enabled by Improved Materials

ZT = 1.3 to 1.5

- HVAC for small hybrid/fuel cell/ electric vehicles
- HVAC for home heat pump systems in moderate climates
- Office water cooler/heaters
- Hotel, laboratory, industrial mini-refrigerators

ZT= 1.8 to 2.4

- HVAC for residential, industrial and vehicular uses
- Personal comfort systems
- Industrial process temperature management

ZT = 5.0 to 9.0

- Home and industrial refrigeration

Restraints and Barriers to Large-Scale Commercialization

The technical supply chain does not reside generally within a single entity.

Further, that chain does not reside within the product manufacture distribution, sales and service chain.

The relevant activities need to be brought together, so as to allow rapid large-scale commercialization.

The ability is needed to understand and plan for the evolution of the technology and incorporate the results into long-term plans.

Resolution

Connect the need to the solution using a mutually understandable process.

Some solutions to the connection problem:

- Supply contract
- Joint ventures
- License arrangements
- Acquisition by one of the parties involved

Solutions to the mutually understood process problem:

- Create common, available development tools
- Conduct demonstration programs
- Learn from related successful commercializations

Summary and Conclusions

The limited understanding of, and access to, high power density and advance cycle design technologies affect perceived technical readiness for significant near-term, large-scale commercialization opportunities.

Readiness for other large-scale applications awaits materials in the ZT=1.3 to 1.5 and 1.8 to 2.4 ranges.

Large-scale commercialization is slowed by the fragmentation within the technical supply chain and the state of understanding of thermoelectric technology by large potential commercial users.