Organic Rankine Cycle Cycle
Engines for Solar Power

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Introduction

• More efficient energy conversion makes solar energy more economical and available

• Combined (overall) efficiency most important
Combined Efficiency

- Collector
- Engine
- Combined

Efficiency vs. Temperature
Engine Efficiency

- Maximum and Minimum cycle temperatures determine efficiency
- Carnot efficiency $= \frac{T_{\text{max}} - T_{\text{min}}}{T_{\text{max}}}$
- Maximum set by source - Trough collector system
- Minimum set by environment - river, lake, atmosphere
- Target is for real engine to be 50% of Carnot
Brayton Cycle

- Common gas turbine (jet) engine
- Gas (vapor) cycle
- Aero-derivatives up to 2,700 F
Stirling Cycle

- Most efficient cycle
- Still under development
Rankine Cycle

• Common steam power cycle

• Uses phase change in cycle
  – condense
  – pump up liquid
  – boil
  – expand through turbine

• Steam systems up to 1,200 F & 1,200 psi
Engine Requirements

• Trough collectors improved

• Higher temperatures available to engine

• Engine must be able to utilize higher temperatures
Engine Design Parameters

- Working fluid selection
- Cycle type (subcritical, supercritical, reheat, etc)
- Hardware selection
- System design
Choosing a Fluid

- Desirable properties
  - Low cost
  - Non corrosive
  - Thermally stable
  - Inexpensive
  - High cycle and turbine efficiency

- Steam best choice for high temperature (600 C)

- Organics best choice for lower temperature (100 to 400 C)
Possible Choices

- Refrigerants
- Organics
- Ammonia
- Water
- Toluene (paint thinner) likely candidate
- Mixtures of above
- Fully fluorinated benzene ring fluids
Toluene Experience

- Ford & Osage City program - 750 F TIT
  - limited operating experience
  - No degradation

- Continental White Cap - 700 F TIT
  - thousands of hours
  - some black ‘gunk’
  - operation not degraded
Summary

- Rankine engines can handle current collector temperatures
- More development needed with working fluids
- Current data base of working fluid history would be extremely valuable (follow on to Hank Curran’s work in the early 1980’s)