Solar Refrigeration

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Introduction

- Need refrigeration in areas not connected to power grid
- Need to minimize environmental impact and fuel cost
- Evaluate potential of solar energy to meet these needs
- Evaluate efficiencies of three types of solar refrigeration

Conventional Refrigeration

Vapor Compression Cycle

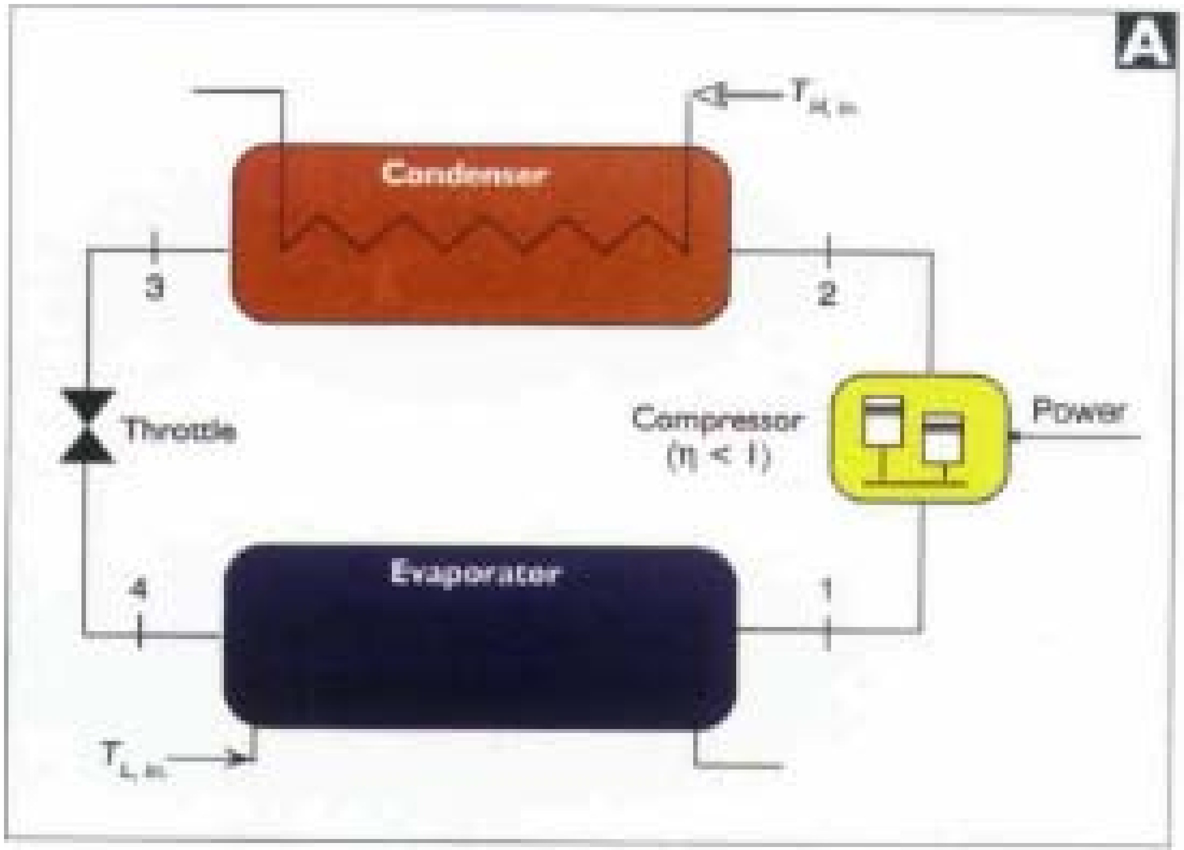


Figure 1a: Schematic of a vapor compression refrigeration sysgtem.

$$\dot{W}_{min} = \dot{m} \int_{P_1}^{P_2} v dP$$

Types of Solar Refrigeration

- Photovoltaic Operated Refrigeration Cycle
- Solar Mechanical Refrigeration
- Absorption Refrigeration

Efficiency metric: $$COP = \frac{Q_{ref}}{E_{rad}}$$

PV Refrigeration

- Vapor compression cycle with power input from Photovoltaic cells
- DC electric power output from PV runs the compressor of a conventional cycle
- Considerations
  - Must match voltage imposed on PV array to the motor characteristics and power requirements of the refrigeration cycle

PV (cont)

- For given operating condition (solar radiation and module temperature), single voltage provides maximum power output
- Must find compressor motor closely matched to the electric characteristics of the PV module

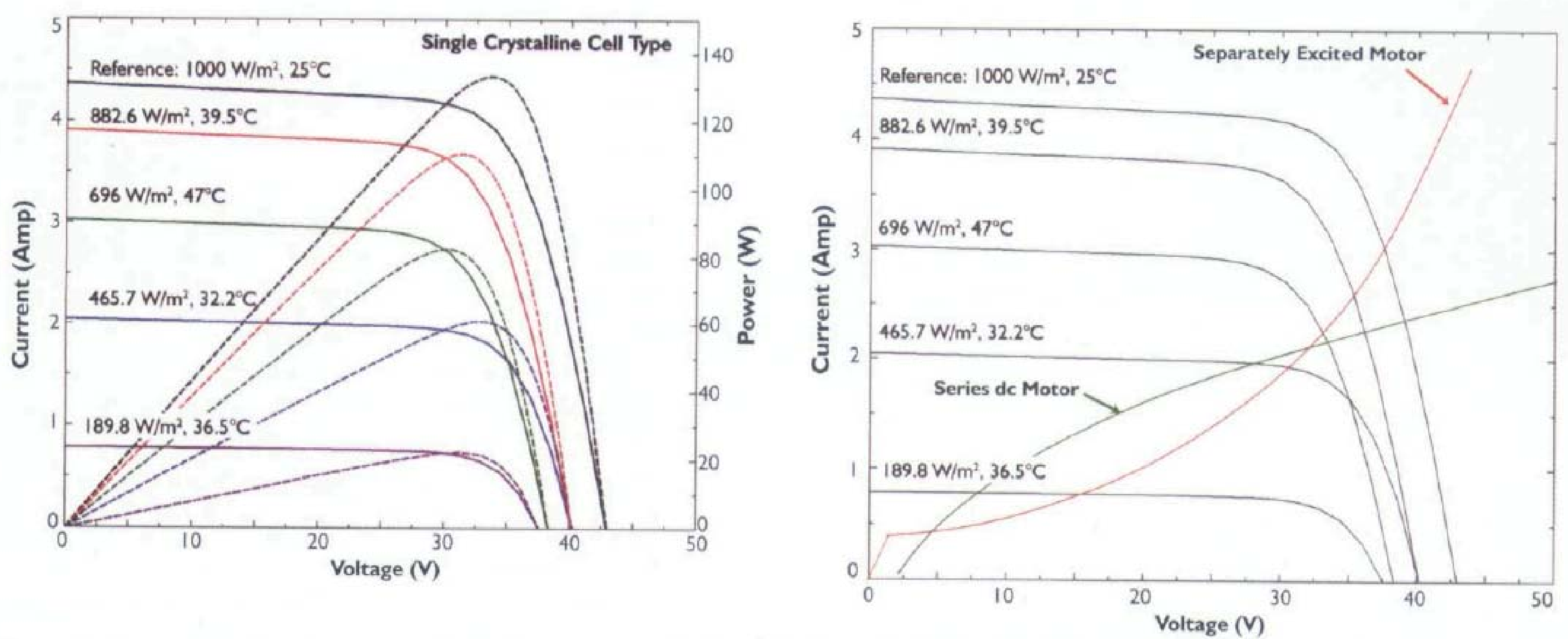


Figure 2 (left): Current (solid lines) and power (dotted lines) vs. voltage for a single crystalline PV module at different operating conditions.
Figure 3 (right): Current-voltage characteristics for a PV module and two dc motor types.

Solar Mechanical Refrigeration

- Vapor compression cycle with power input from solar Rankine cycle
- Considerations
  - Efficiency optimization based on delivery temperature

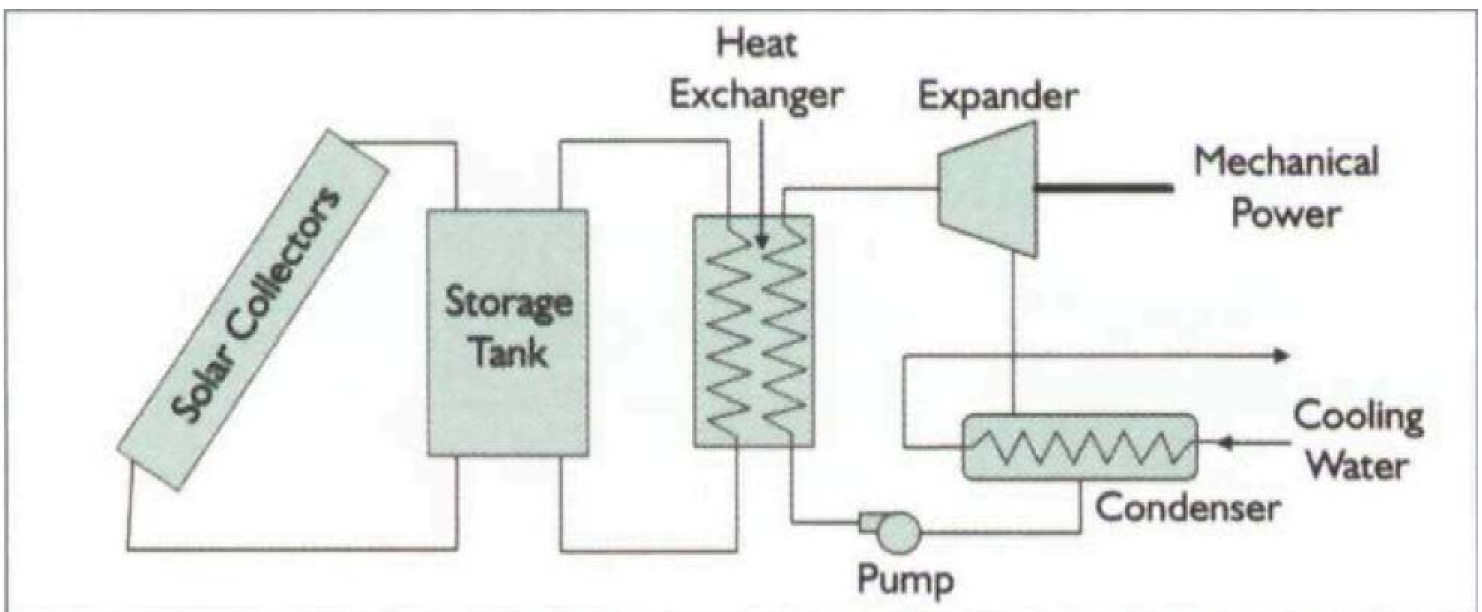


Figure 4: Solar driven mechanical power cycle.

Solar Mechanical (cont)

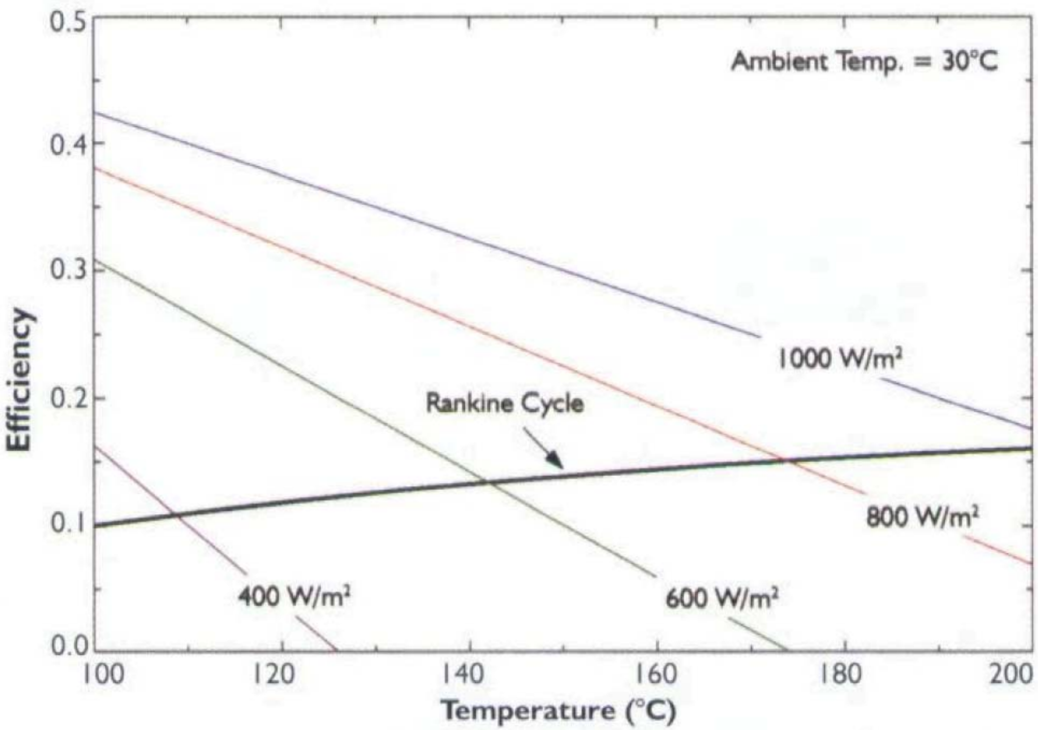


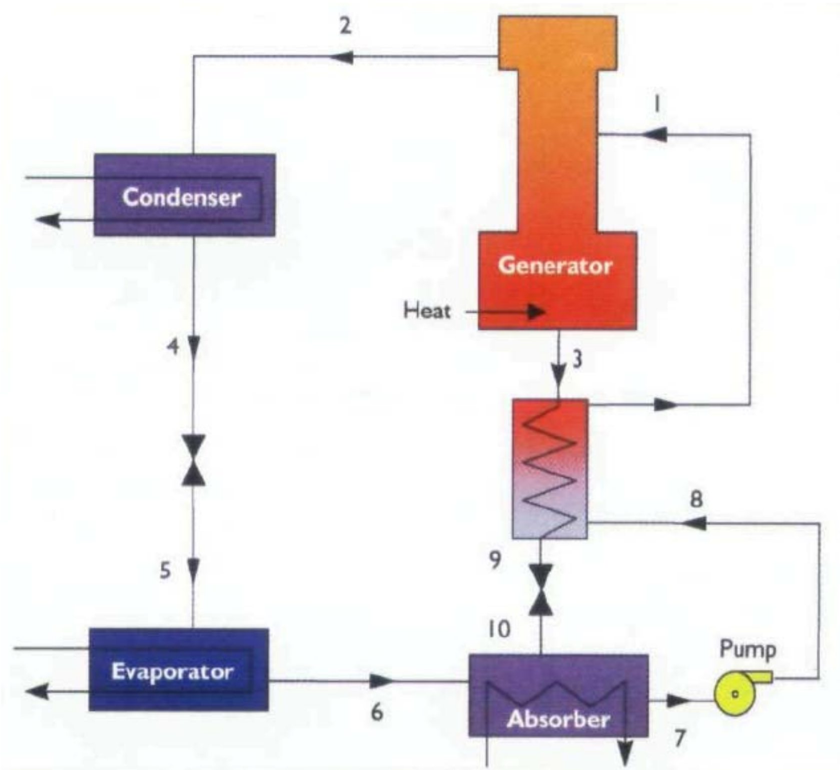
Figure 5: Approximate efficiencies for a Rankine cycle (bold line) and evacuated solar collectors (fine lines) at 30°C (86°F) ambient and differing solar radiation values.

- Efficiency of Rankine cycle increases with increased heat exchanger temperature
- Efficiency of solar collector decreases with increase in temperature

Absorption Refrigeration

- Condenser, throttle, evaporator function exactly the same way
- Replaces compressor with “thermal compression system”
  - Ammonia is working fluid
  - Minimal mechanical power input (pump instead of compressor)
  - In this regard, significantly different and less intuitive than other forms of solar cooling

Absorption (cont)
Thermal Compression System



'igure 6: Ammonia-water absorption refrigeration system.

- Absorption into water solution allows it to be pumped
- Desorbed in generator (rectifier required to separate out water)
- Heat into generator provided by solar collectors
- This system greatly increases complexity

Conclusion

- COP for solar refrigeration systems is low
  - Better metrics: size, cost
  - Complexity of solar ref. systems requires more size, bulkiness
  - Low operating costs do not outweigh high initial investment
- Advantage is that they don’t rely on power grid (PV is most practical for small scale)