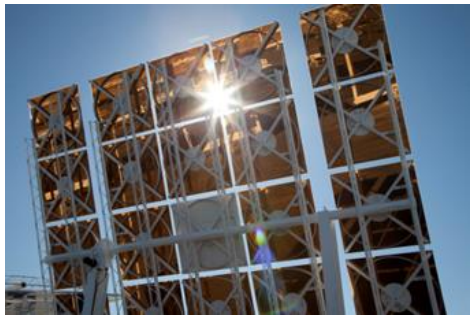
SAND2015-5068PE

Exceptional service in the national interest

Sandia National Laboratories

solar.sandia.gov



Latent Sodium:

Unleashing the Power of Phase Change

Chuck Andraka

Concentrating Solar Power Department

SunShot U.S. Department of Energy

U.S. DEPARTMENT OF ENERGY

National Nuclear Security Administration

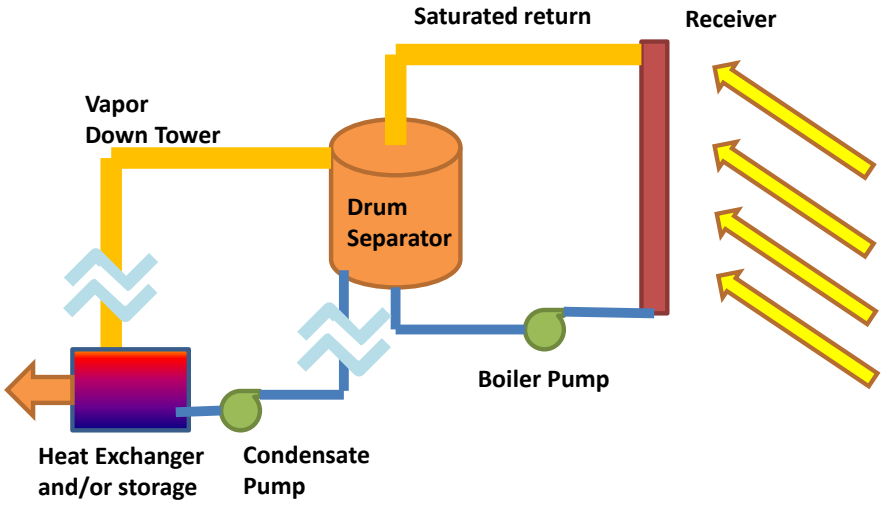
Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000

Introduction

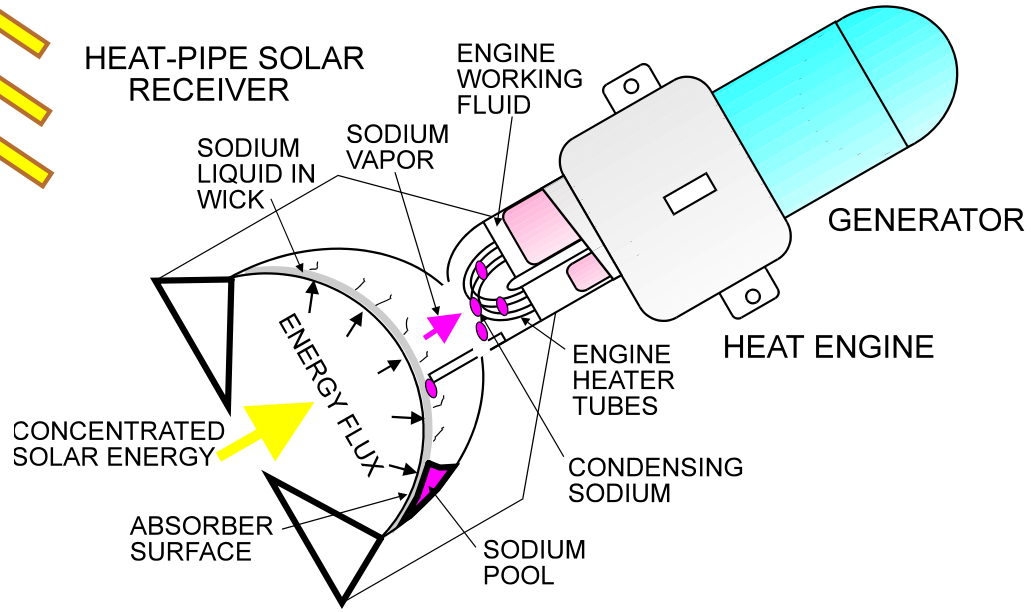
- Latent Sodium Receiver and Transport
  - Phase change: Liquid to vapor
  - Energy absorbed/released isothermally
  - Temperatures 550°C to 900°C
- Why Latent Sodium: Power cycles
- Latent Sodium Experience at Sandia
- Latent Sodium Advanced Applications
- Collaboration potential

Latent Sodium Receivers

- Tower Receiver
  - Pump-assisted

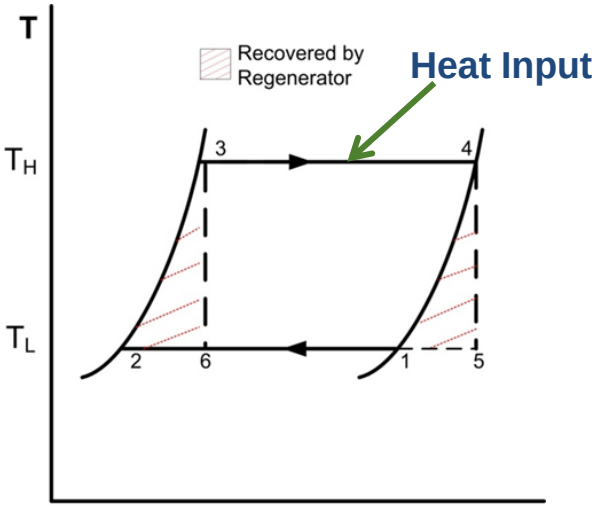


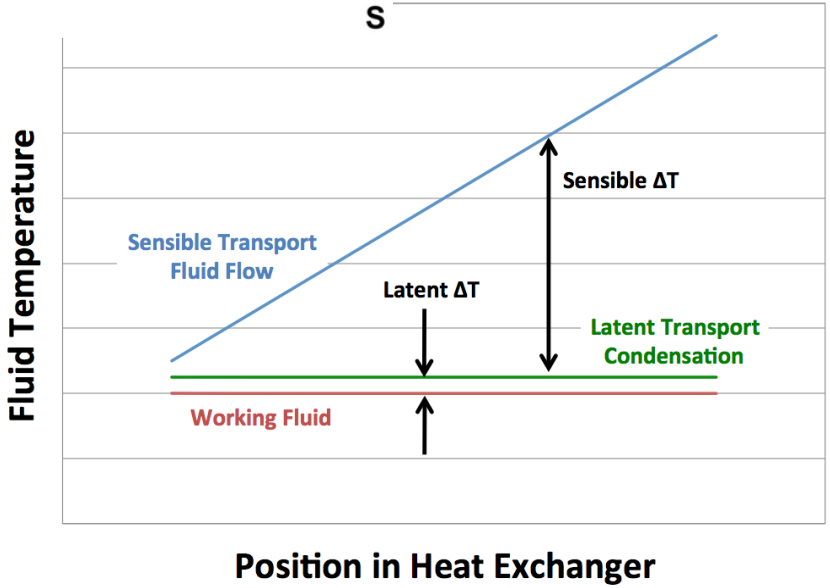
- Dish Receiver
  - Fully passive
  - Gravity assisted
  - Heat pipe or boiler



Why Latent?

- Isothermal Input to power cycles
  - Stirling cycle (dishes)
  - SCO_2 with reheat (towers)
- Exergy matching
  - "Thermal Value" of energy
  - Sensible transport has either high delta-T or high flow rate
- Demonstrated performance
  - 20% system efficiency improvement on dish Stirling

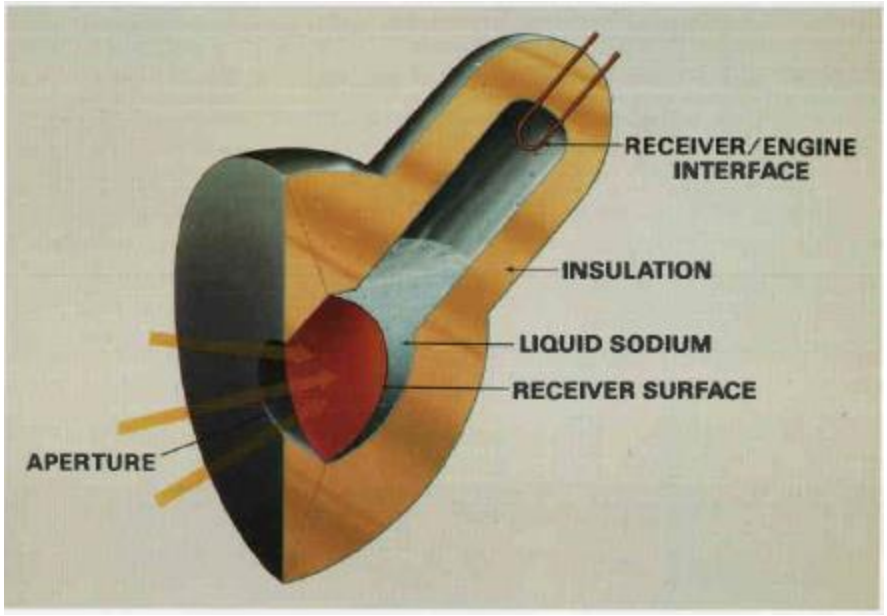




Sandia Latent Sodium Experience

Pool Boilers

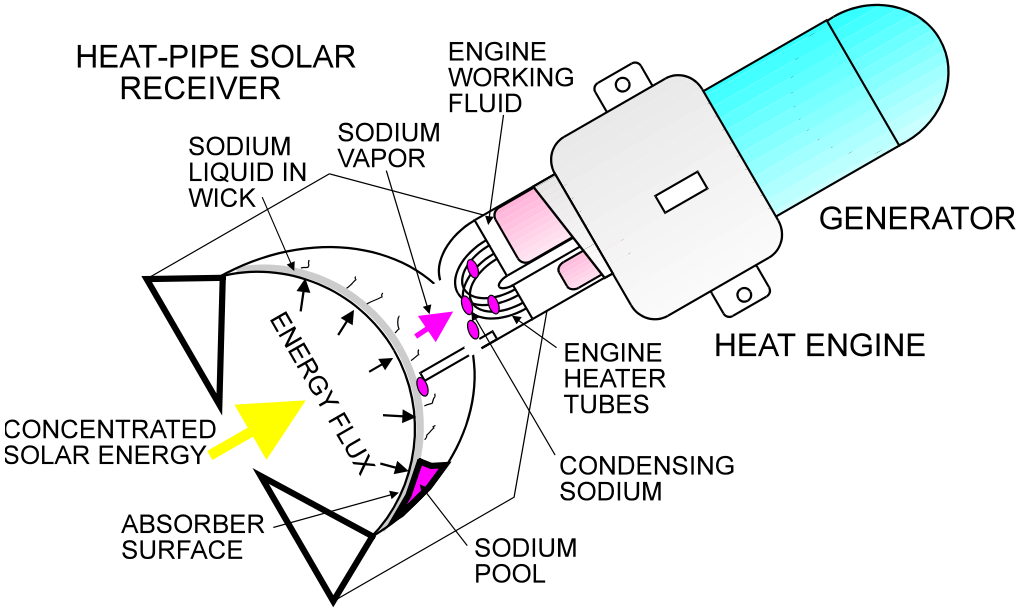
- Key challenge: Stabilization of boiling
  - Aggressively wetting
  - Highly conductive
  - Intermittent explosive boiling
- Successful outcome
  - Very small quantity of Xenon
  - Provided nucleation source
- Limitations
  - 70W/cm²
  - Vapor blanketing
  - Large inventory
- Scalable



Sandia Latent Sodium Experience

Heat Pipes

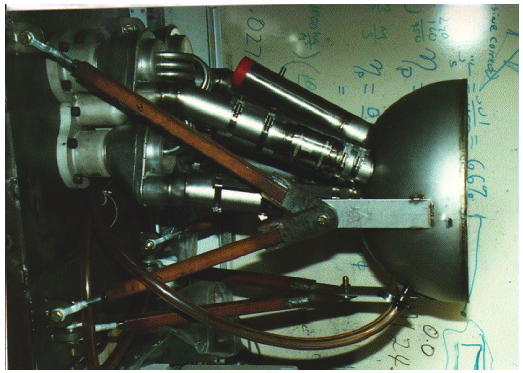
- Key challenge: Throughput Scaling
  - Peak flux vs. throughput
  - Capillary capability
  - Durability
- Successful outcome
  - Advanced felt wick with variable pore size
  - Robust versions recently developed
- Limitations
  - Scalability beyond dish

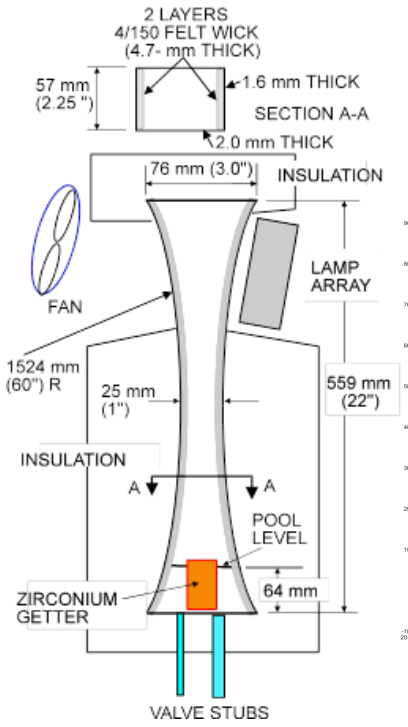


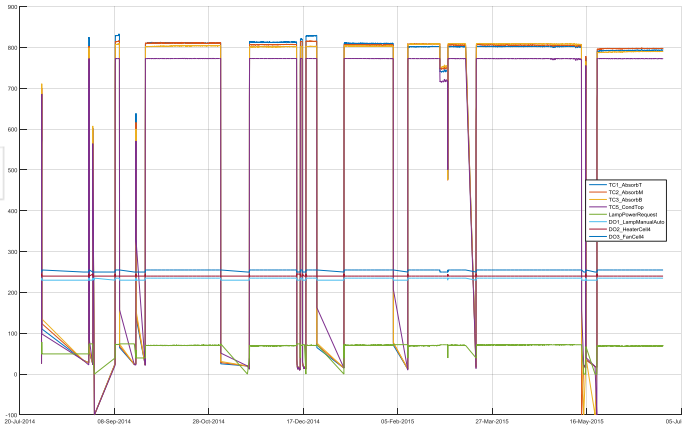
Sandia Latent Sodium Experience

Heat Pipe Results

- Coupled with Stirling engine
  - 20% system performance enhancement
- Tower limit test
  - 116kW$_{th}$
  - Matched model
- Advanced felt wick
  - Robust mechanical design
  - Maintain performance
  - 80kW$_{th}$ equivalent
  - 5500 hours so far

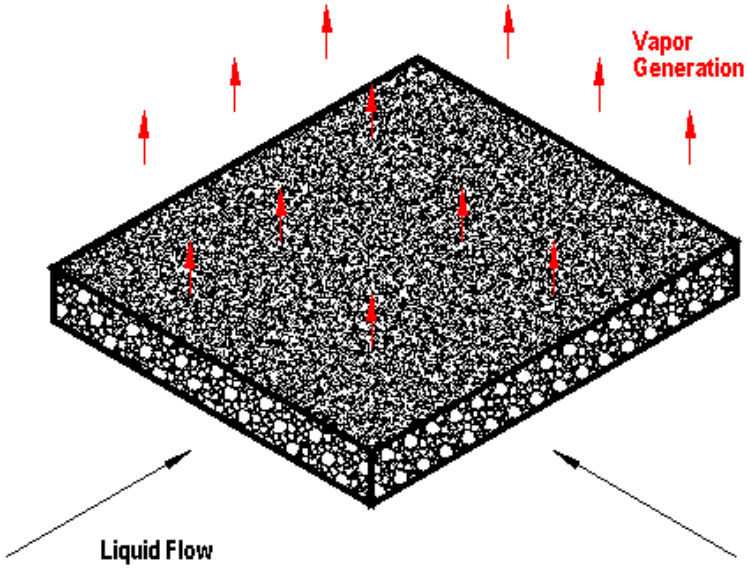


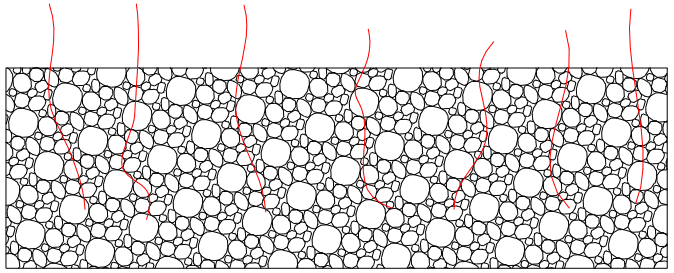




Heat Pipe Wick Model

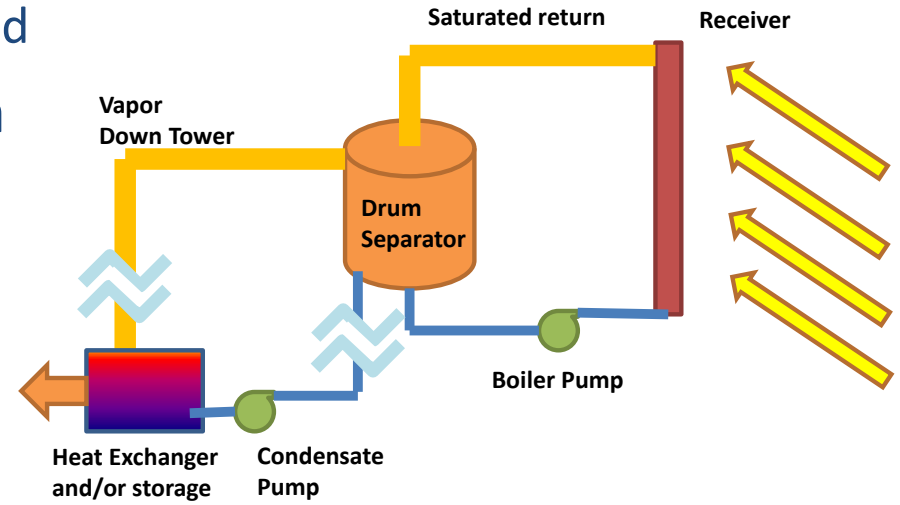
- High performance felt wick
- Vapor generation scheme differs from traditional heat pipes
  - Generation within wick
  - Vapor escapes through largest pores
  - Liquid flows in small pores
  - Gradient of pore diameters
- Wick only
  - Key element in solar systems
  - Vapor flow area not limited





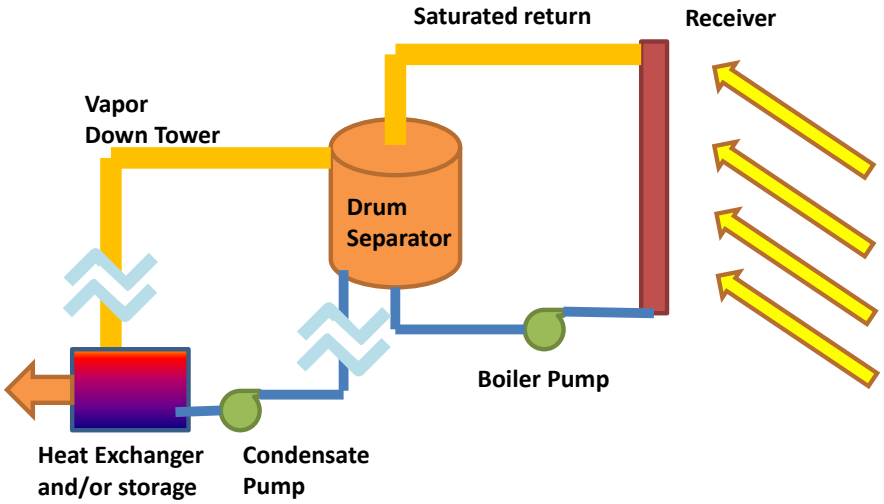
Latent Sodium Future

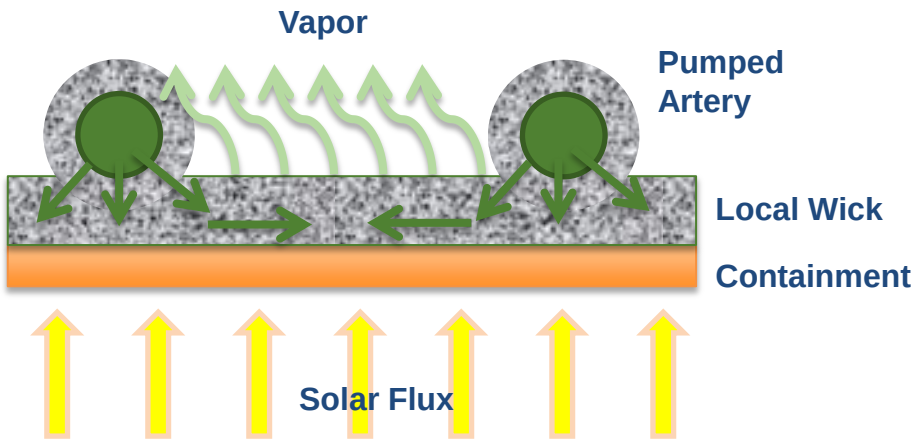
- SCO_2 Tower Application
  - Multi-MW throughput required
- Advantages of latent sodium
  - High heat transfer rates
    - Smaller receiver
    - Lower losses
  - High heat of vaporization
    - Low flow rates (pumping)
    - Low volume (safety)
  - Isothermal system
    - Exergy match



Latent Sodium Tower Approaches

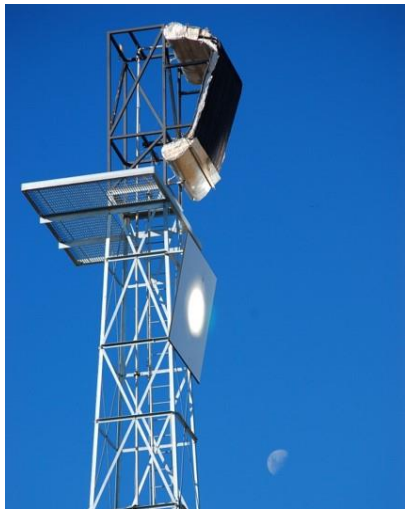
- Forced convection boiler
  - Similar to steam boiler
  - Pumped (low head) circulation
  - Drum separator
  - Challenges
    - Stability
    - Peak flux
    - Limited literature data
- Pump-assisted heat pipe
  - Pumped arterial global distribution
  - Passive wick local distribution
  - Leverage electronics cooling





Collaboration Potential

- ANU
  - Joe Coventry
  - Joint proposals to DOE and ARENA
- Vast Solar
  - Existing experience with sensible loop
- DOE SCO2 Brayton team
  - Coupled development approaches



Latent Sodium Summary

- Sandia has a rich history of Latent Sodium development
  - Heat Pipes
  - Pool boilers
- Latent Sodium has distinct advantages with certain power cycles
  - Isothermal
  - High heat transfer rates
  - Commodity HTF
- Extension to tower systems needs significant scale-up development
  - Collaboration opportunities