Thermal Energy Storage with Supercritical Fluids (Super TES)

Gani B. Ganapathi

Jet Propulsion Laboratory, California Institute of Technology

Richard Wirz

University of California, Los Angeles

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UCLA NASA SCG

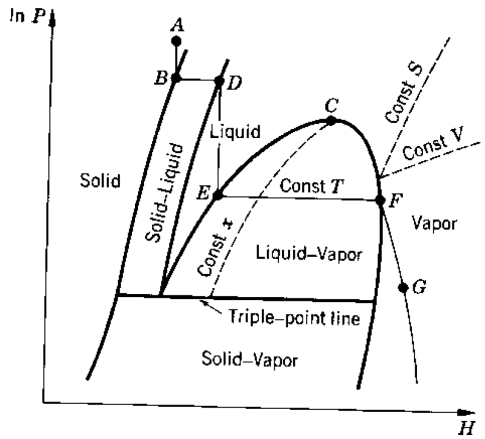
State of Art Practice

- Current technologies such as two-tank direct, two-tank indirect, single-tank thermocline and other storage media such as concrete, castable ceramics rely on sensible heat
  - DOE had studied possibility of using Phase Change Materials in the 1980's but had abandoned it due to complexities and life-time issues.
  - DOE has funded several projects in 2008 to the tune of $68M to look at thermal energy storage concepts and heat transfer fluids
    - For the most part, approaches were either sensible-heat based or very advanced technologies
    - Not clear that any will solve the critical metric of cost/kWh
  - Discussions with NREL indicate a breakthrough is needed to meet $20/kWh cost goal

Current approaches don't deal well with critical metric of $/kWh

Supercritical Fluid TES – A New Approach

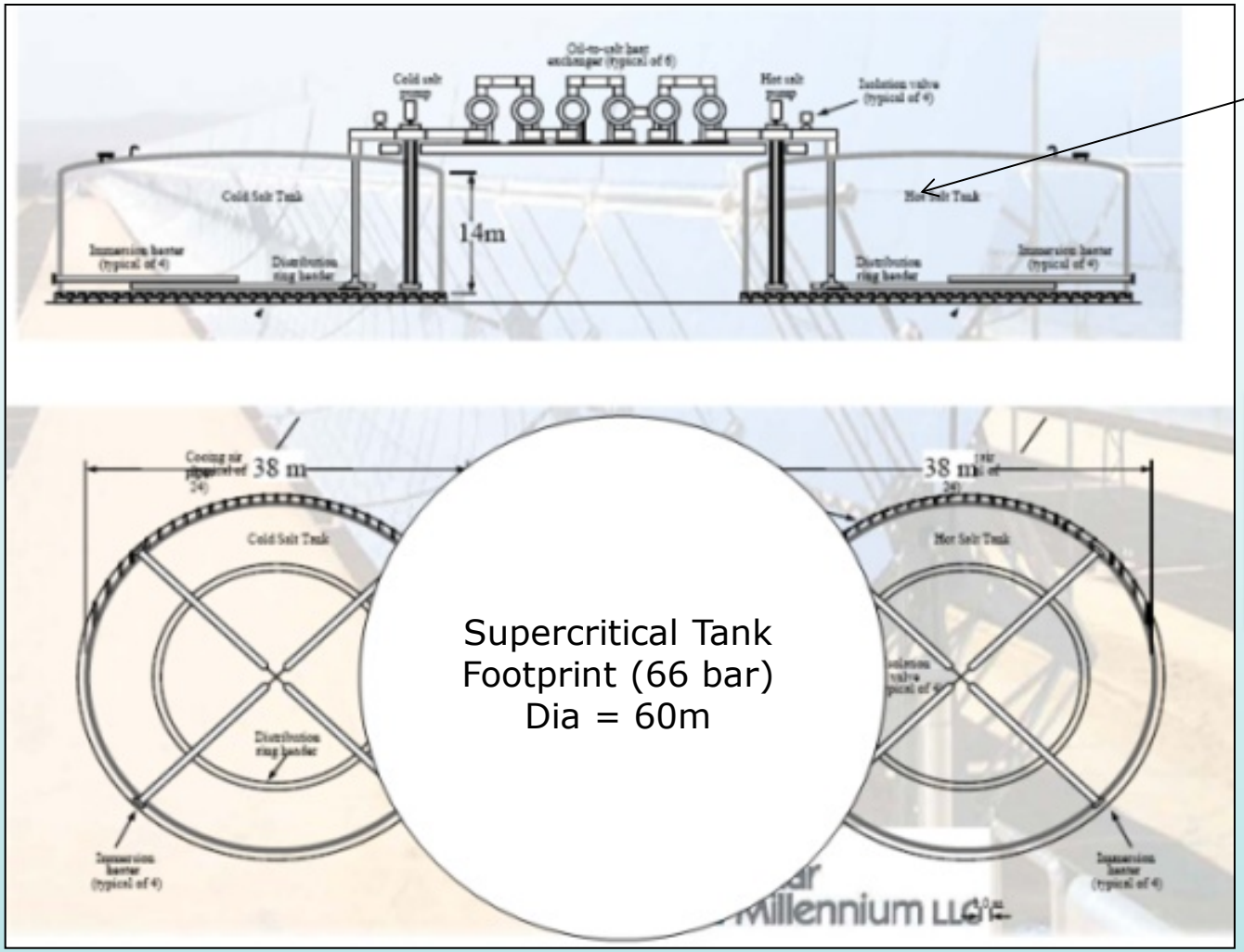
- Supercritical operation permits capturing and utilizing heat taking advantage of latent and sensible heat, both in the two-phase regime as well as in supercritical regime while at the same time, reducing the required volume by taking advantage of the high compressibilities



- Storage performance and pressures can be optimized by judicious selection of fluid with the following key properties
  - High Latent Heat of Vaporization, ΔH_{vap}
  - High specific heat, C_p (C_v)
  - High T_c, T_b
  - Low vapor pressure

Supercritical optimization is highly dependent on right fluid selection

Proposed Technology vs State of the Art



State of the Art 2-tank Molten Salt Storage for 1 GWh

1 GWh Fluid Costs
Molten Salt = $25M to $50M

Proposed Fluid= $2.5M to $5.0M

A Breakthrough Cost Reduction for Thermal Energy Storage

ARPA-E Mission Area Impact

Dramatic reduction in CO_2 emissions enabled by deeper penetration of solar thermal for baseload power production, hot water, and cooling needs

High temperature Tower and Parabolic Trough

Moderate temperature micro-CSP

Deeper Penetration of solar thermal technologies enabled

Transition Strategy

- **Partnership is designed specifically for technology transfer.** Includes: a university (UCLA, low TRL), FFRDC (JPL, mid TRL), power utility (Southern California Gas Co., high TRL).
- SCG has interests in **licensing** the technology once it has been demonstrated at their micro-CSP test facility in Downey, CA.
- SCG and business partners will work with Caltech (holder of patent) and other partners (JPL & UCLA) to **transition the technology from field demo to real-world applications**.

Partnership covering range of TRLs

Program Summary

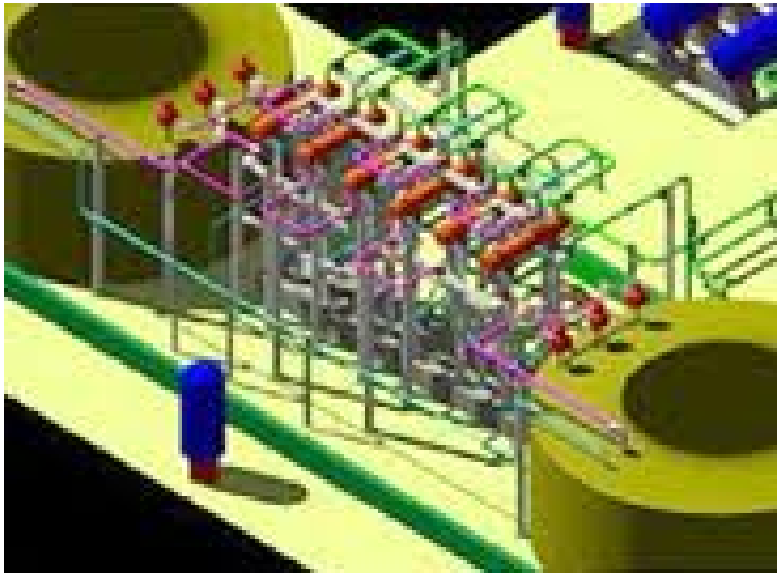
- Period of performance: 36 months
- Phase 1 (1.5 yr): Technology Feasibility (UCLA/JPL)
  - Fluid selection – identify/synthesize TES fluid with cost target of < $10/kWh (current baseline is ~ $25 - $50/kWh)
  - Material compatibility – identify material compatible with fluid at high temperatures and pressures
  - Systems Analysis
  - Small tank demo to validate concept – 5 kWh
- Phase 2 (1.5 yr): Field Demo Experiment with micro-CSP
  - 10 kWh prototype testing at JPL at supercritical conditions
  - Performance characterization of micro-CSP with and without TES
  - 30 kWh SCG field test demo with max operating conditions consistent with micro-CSP application

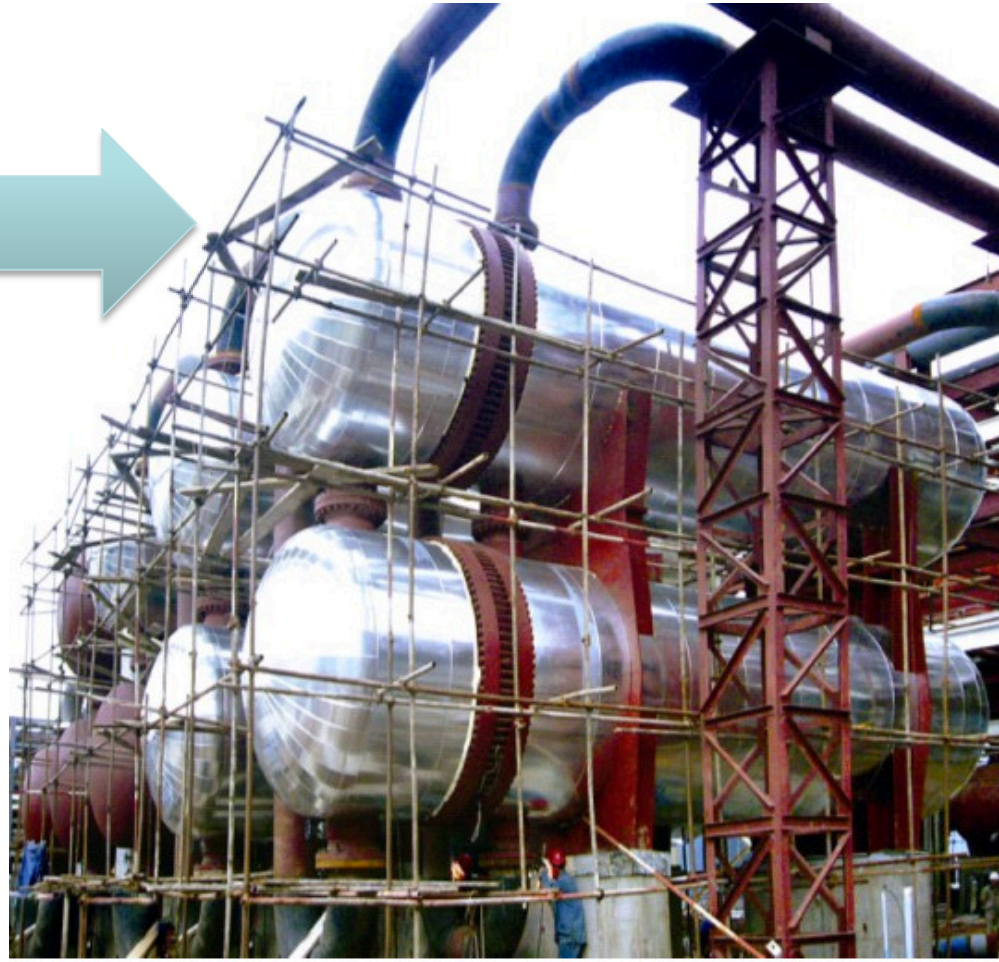
Two phase program to include early phase feasibility and field demo

Meeting Cost Challenge

- Two candidate fluids costs x10- x20 less than molten salt
- Need to address system cost = low cost high pressure/temperature storage approach
  - Optimization of operating conditions and appropriate storage material needed
- With SS 316, we have a design approach which could be at least 30% or more cheaper than traditional design

2-Tank Molten Salt vs SC Fluid





Markets benefiting from Super-TES

- Large scale Solar Thermal power generation plants for load leveling
- Nuclear plants peaking capability
- Commercial sector harvesting of waste heat for HVAC
- Electric vehicles
- Distributed power generation
- Space applications (interplanetary travel, planetary bases)
- Grid storage (in lieu of batteries)

Summary

- Project is in an early stage
  - Proof of concept of thermal stability done for sample fluid
  - Prelim cost analysis comparing with State of Art done
  - Design of small 5 kWh storage system completed
- The ARPA-E Program Manager is very excited about the potentials of this technology
- A whole new program "High Energy Advanced Thermal Storage" was potentially inspired by this project
  - Was invited to be on review panel in Washington D.C.
  - Awardees informed on 9-29-11