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Innovative Technology Solutions for Sustainability

Advanced Baseload Molten Salt Tower

SunShot Concentrating Solar Power Program Review 2013

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Project Details

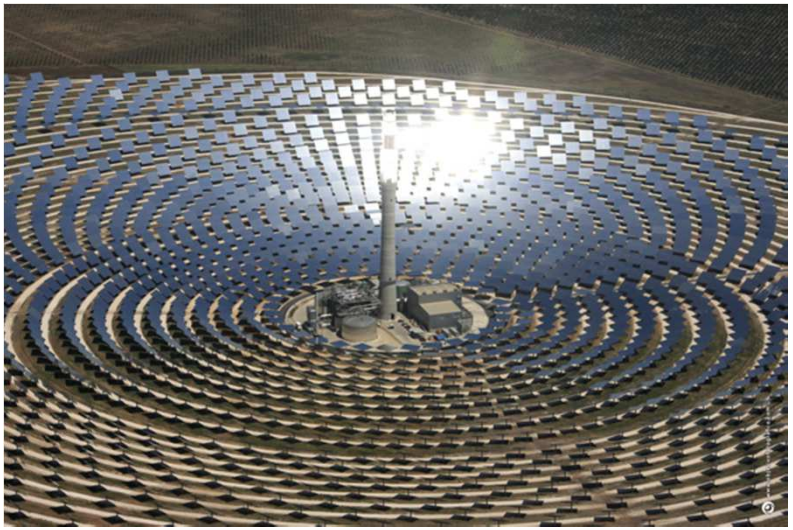
- Title: "Development of Baseload CSP Advanced Nitrate Salt Central Receiver Power Plant"
- Award: DE-EE0003596
- Project Term: 9/1/2010 to 6/30/2014
- Project Plan:
  - Phase 1: develop and evaluate near-term molten salt tower as baseline. 9/1/2010 – 3/31/2012
  - Phase 2: engineering design and prototyping of advanced technologies. 4/1/2012 – 6/30/2014
- Partners:
  - Foster Wheeler
  - Tietronix
  - Sandia National Lab

Objectives

- Demonstrate a 100 MWe molten salt tower that can:
  - Operate, at full load, for 6,400 hours each year using only solar energy
  - Satisfy the DOE levelized energy cost goal of $0.09/kWhe (real 2009$).
- Tasks to achieve objectives:
  - Develop a new more manufacturable higher temperature nitrate salt receiver technology.
  - Develop high temperature air-stable selective coating for use on a nitrate salt receiver.
  - Develop a lower cost heliostat design.
  - Optimize heliostat size, heliostat field configuration, tower height, and receiver size.
  - Develop an optimized nitrate salt thermal storage, steam generator and power cycle configuration utilizing new passive dry cooling design.

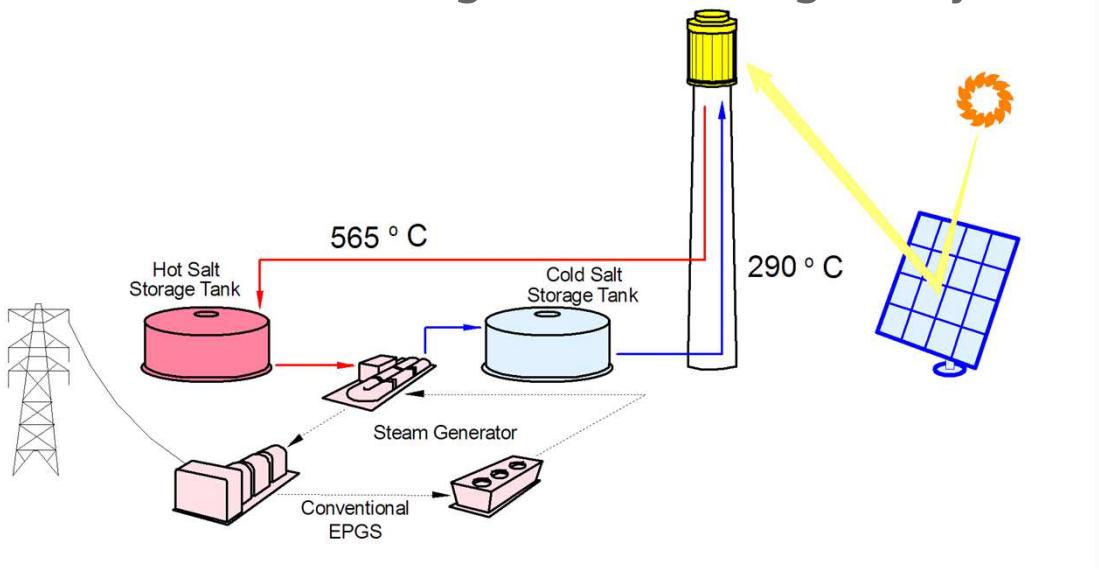
Background

- Molten Salt Tower
  - Inexpensive energy storage allows plant to economically operate as baseload power
  - Technology demonstrated in 90s by 10MWe Solar Two DOE project
  - Sener 17MWe Gemasolar plant in Spain with 17hrs of storage started commercial operations in 2011
  - SolarReserve currently constructing 110MWe Crescent Dunes project in Nevada with 10hrs of storage



Phase 1 Work

- Basic engineering of near-term baseline molten salt plant:
  - Rankine cycle is a 112 MWe / 125 bar / 540 C / 540 C commercial steam turbine with an air cooled condenser
  - Nickel alloys, such as Inconel 625 LCF and Haynes 230, are suitable as the receiver material
  - Stabilized 300-series H-grade stainless steels are used for the hot side equipment
  - Forced recirculation steam generator, designed by Foster Wheeler

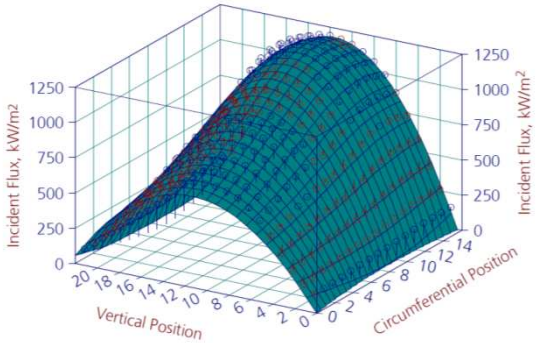


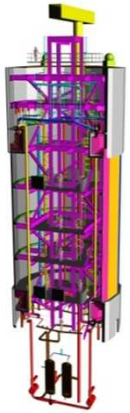
Phase 1 Key Findings

- Analyzed technical and economic feasibility of near-term baseline molten salt plant
- Below initial LCOE cost goal of $0.14/kWh (real 2009$)
- Using the time of use pricing structures from the 3 principal California utilities, the highest IRR was a plant design with a solar multiple of 1.8 and a thermal storage capacity of 6 hours
- No technical barriers have been identified regarding the design, construction, or operation of a 100 MWe baseload molten salt tower operating at full load for 6,400 hours each year
- Although a baseload tower with 75% capacity factor is possible, the optimum size for a molten salt tower in a market without time of use pricing is closer to 72% capacity factor

Phase 1 Key Findings

- The receiver designed by Foster Wheeler, using standard design procedures, was also shown to be significantly below $170/kWt cost target





- Initial work was conducted on creating a unique heliostat that was shown to beat the $120/m^2 project goal
- To meet cost goals plant efficiency must be improved through:
  - Reduced emissivity receiver coating
  - Increase in the receiver outlet temperature to 600°C to power a more efficient Rankine cycle.

Phase 2 Tasks

- Advanced Receiver Design
- Receiver Prototype
- Selective Coating Development
- Advanced Heliostat Design and Prototype
- Advanced Salt Technology
- Advanced Tower Estimate

Phase 2 Work

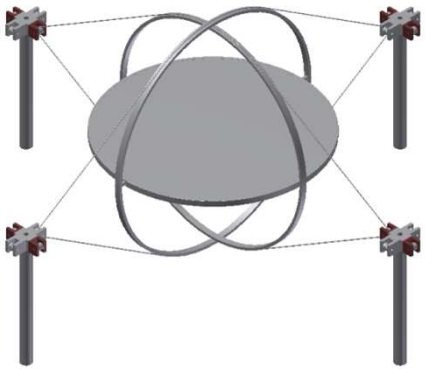
- Advanced receiver
  - The advanced receiver being developed by project partner Foster Wheeler has a thermal power rating over 40% larger than the largest commercial receiver (currently being used by SolarReserve)
  - Designed for 600°C bulk salt temperature and improved solar selective coating to reach high efficiency >90%
- Receiver prototype
  - Full length receiver tubes will be tested for cycle fatigue failure in a large oven for 30,000 cycles
  - Oven will use radiant heaters, with empty tubes, to simulate the tube strains on a North-side panel
  - Confirm the low cycle fatigue life at the anticipated strains, and the effectiveness of the tube supports for maintaining the tubes in the required locations
  - Results of this test will validate the life time of the receiver design as well as various manufacturing techniques

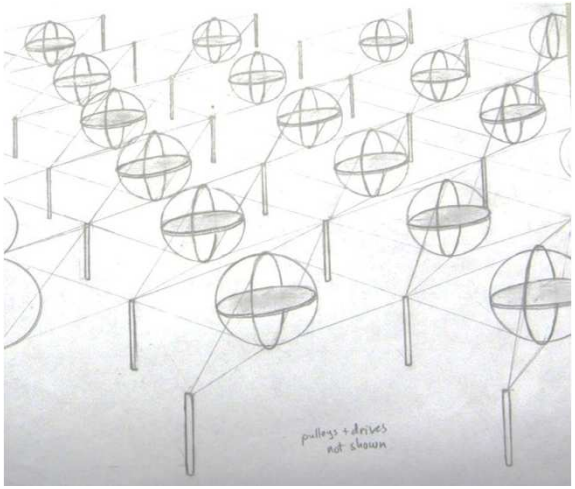
Phase 2 Work

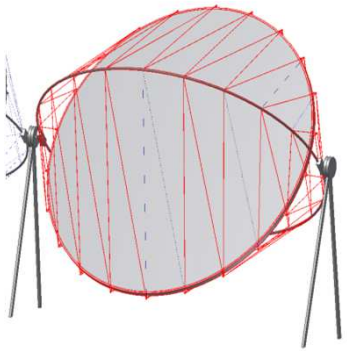
- Selective coating development
  - Current technology: Pyromark 95% absorptivity, 88% emissivity
  - New coating goal: 95% absorptivity, 20% emissivity (@ 450°C)
  - High absorptivity, low emissivity physical vapor deposition coating (PVD) developed by NREL will be tested for high temperatures and durability
  - Alternative thermal spray coatings will also be tested

Phase 2 Work

- Advanced heliostat
  - Down selected from more than 40 promising concept ideas







Phase 2 Work

- Advanced heliostat design process conclusions:
  - Able to design low cost heliostats large and small
  - A stretched membrane heliostat was studied in detail and was shown to have cost benefits for very large heliostats, but less practical for small heliostats
  - Pedestals are expensive to install, especially for small heliostats
  - Small heliostats allow for ballast type foundations
  - Small drives are abundant and cheap
  - Custom heliostat controllers are available at very low prices, which makes a small heliostat practical
  - Final design is 18m^2 heliostat, < \$120/m^2 cost goal (details confidential)

Phase 2 Work

- Advanced Salt Technology
  - Standard binary nitrate solar salt will be tested in a simulated receiver with a bulk temperature of 600°C at Sandia National Lab
  - Salt film temperatures to reach 670°C
  - Salt stability test will simulate non-equilibrium salt decomposition chemistries in the latter panels of the receiver
  - The test will include iron and nickel alloy coupons to measure corrosion rates under non-equilibrium salt chemistries
  - Results from the test will guide the design of salt maintenance systems to maintain oxide levels within acceptable values

- Advanced tower estimate
  - At the end of the project a final cost estimate incorporating the advanced designs will validate the design relative to the cost objectives

Phase 2 Work

- Summary of Advanced Tower:
  - 115 MWe / 165 bar / 585 C / 585 C commercial steam turbine with an air cooled condenser
  - 72% capacity factor, 14hrs of storage
  - 308°C cold salt, 600°C hot salt
  - Receiver coating with 95% absorptivity, 20% emissivity (@ 450°C)
  - Low cost drop-in-place heliostat

- The advances explored in Phase 2 of this project will lead to lower cost solar power with storage to better compete with current baseload energy

Questions?

Thank You