SAND2012-4875P

**Statement of Work for Study on Scale-Down of Super Critical Steam Turbines**
**Sandia National Laboratories**
**Albuquerque, NM**
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## Objective

The purpose of this study is for an experienced steam turbine manufacturer* to evaluate the potential of scaling down supercritical steam turbines to a size where they can be integrated into baseload molten salt power towers. Currently supercritical steam turbines are sized at 400 MWe or larger. For baseload molten salt power towers (at 70% capacity factor), the largest practical turbine size is approximately 160 MWe-gross rating.

*An experienced steam turbine manufacturer is a company that has developed/designed, manufactured, and deployed supercritical steam turbines.

## Background

A molten-salt central receiver power system uses a tubular-type receiver mounted on top of a tower. Reflected solar energy from a field of heliostats heats the receiver; molten salt is the heat-transfer fluid, and it also cools the receiver. Figure 1 shows a flow schematic of this system. Current systems employ a molten salt comprised of 60 wt% sodium nitrate and 40 wt% potassium nitrate. It is heated from 290 °C to 565 °C in the receiver and then flows in pipes to thermal storage. Next-generation targets include 600 °C and above as the receiver exit temperature. Hot salt is extracted from the storage system to generate steam within a molten-salt steam generator. The steam can feed a Rankine-cycle turbine to produce electricity. The cooled salt is returned through the thermal storage system to the receiver.

In the configuration shown in Figure 1 the thermal storage system buffers the steam generator from solar transients and also supplies energy during periods of no insolation, at night or on partly cloudy days. Since the salt remains in a single liquid phase throughout the process, and because of its relatively high heat capacity, it can be stored in compact storage tanks. The hot-salt temperature of 565 °C enables steam production at temperatures and pressures typical of those used in conventional subcritical Rankine plants. Depending on the availability of cooling water at the site, the condenser in a Rankine plant is cooled with either wet or dry cooling towers. Wet-cooled plants are somewhat more efficient than dry ones (43% versus 41%).

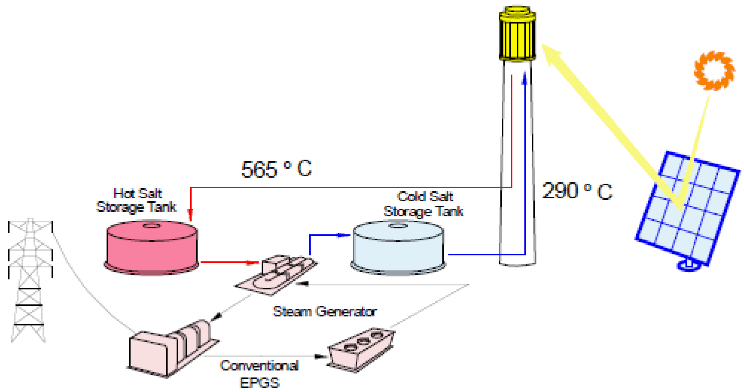


*Figure 1. Flow schematic of a molten-salt central receiver system.*

In an effort to reduce the Levelized Cost of Energy (LCOE) of concentrating solar power plants, Sandia National Laboratories and the US DOE are interested in exploring more efficiency thermodynamic cycles as part of the SunShot Initiative [1]. One key goal of the SunShot Initiative is to reduce the LCOE of Concentrating Solar Power plants to 6¢/kWh by 2020. By increasing the gross cycle efficiency (conversion of heat to electricity), the size of the solar field can be reduced, which reduces the LCOE.

One such possibility for increasing the gross-cycle efficiency is integrating supercritical steam turbines into power towers. The typical size of supercritical steam turbines used in coal power plants is 400 MWe or larger. For a baseload (70% capacity factor) molten salt power tower, the turbine size can be up to 160 MWe, where its limitation is due to the maximum practical size of the heliostat field and receiver (rated at approximately 1000 MWt). Most of the energy collected during a typical day is stored in a thermal storage tank and dispatched throughout the day and night. In the summer, the turbine operates 24 hours a day.

Based on a recent system study of coupling a supercritical steam turbine with molten salt power tower technology [2], it was concluded that

1. if the receiver outlet temperature were increased to 600°C, a gross-cycle efficiency of 48.4% could be achieved with a supercritical steam turbine, and
2. to achieve the LCOE reduction possible with supercritical power towers will likely require a scale-up of today's solar technology and a scale-down of today's steam-power blocks.

All the subcritical and supercritical plants investigated in [2] are comprised of a 1000-MWt receiver, 15 hours of storage (5000 MWht), and a steam power block with a nominal rating between 140 and 165 MWe. Not all the technologies needed to build a plant of this type currently exist. For example, the world's largest molten-salt power tower now under construction in Nevada consists of a 585-MWt receiver and a 2900-MWht thermal storage system. Thus, the receiver/storage technologies studied here are 1.7X larger than today's technology. Subcritical steam-power blocks with an output of ~150 MWe currently exist. However, the smallest supercritical power blocks available today are ~400 MWe. Thus, the supercritical power blocks studied here are about 1/3 the size of today's technology.

Since it may not be practical to thermally cycle a supercritical-power block on a daily basis, it will need to operate nearly 24/7, much like it does in a coal plant. This is because the much higher steam pressures (≥300 bar supercritical versus 125 bar subcritical) will result in very thick pipe walls and turbine casings, which would increase startup time relative to a subcritical plant.

The bulk hot salt temperature is 565°C in the hot thermal storage tank for the current molten salt power tower technology. We are interested in higher bulk hot salt temperatures up to 600°C. Advanced molten salt receivers are being proposed to achieve higher temperatures by using nickel alloys for the receiver tube materials. There is a limit to the upper temperature of nitrate salts, which irreversibly decompose above approximately 620°C. The return cold salt temperature (from the steam generator) is another variable with which to optimize the power block efficiency.

**Scope of Work**

This scope of work is divided into the following major tasks:

1. Define feasibility and challenges (including quantitative analysis where applicable) of scaling down supercritical steam turbines or modifying subcritical steam turbines to achieve supercritical conditions to approximately 160 MWe or less (e.g., 100 MWe). Define other challenges associated with integrating a supercritical turbine with molten salt technology, such as development of once-through supercritical steam generators, daily startup and shut down and the implications to equipment life and performance.
2. Determine impact on gross cycle efficiency of a 160 MWe and a 100 MWe supercritical steam turbine and its efficiency relative to a 400 MWe supercritical steam turbine. Consider effects of pressure (e.g., 230 to 265 bar), steam temperature (approximately 545 to 580°C), and final feedwater temperature to the molten salt steam generator (approximately 290 to 320°C).
3. Develop heat balance diagrams for each configuration.
4. Provide an estimate of the development costs to produce the 160 MWe and 100 MWe (if feasible) turbine and estimates of a production-scale cost for 160 and 100 MWe turbine and costs of the entire power block relative to a subcritical power block of the same size.

**Deliverables and Timeline**

1. Subcontract report summarizing the above results, drawings, heat balances delivered to Sandia, DOE and a third party for review
    a. Draft report submitted in September 1, 2012 (or 2 months after contract signed)
    b. Final report submitted in September 21, 2012 (or 2 months 3 weeks after contract signed)
2. Submit peer-reviewed journal article summarizing above work.
    a. Submission September 30, 2012 (or 3 months after contract signed)

**References:**

1. SunShot Vision Study, http://www1.eere.energy.gov/solar/pdfs/47927_chapter5.pdf

2. Kolb, G. J., *An Evaluation of Possible Next-Generation High-Temperature Molten-Salt Power Towers*, Sandia National Laboratories Report, SAND2011-9320, December 2011.

**Proposal Document Elements**

**1. Technical Approach (3 pages max):**

Provide a clear proposed approach to accomplish the above statement of the work and how the team will meet the deliverables.

**2. Summary of the Team and Company's Qualification (2 pages max)**
a. Describe team expertise and company's prior experience designing or deploying supercritical steam turbines.
b. Prior recent work for the PI and all the key personnel (co-investigators) in the relevant field of work.

**3. Project Schedule and Budget with Budget Justification (2 pages max)**
a. Provide a timeline for the project
b. Provide a budget including loaded labor charges by person, materials and supplies (if any), and 1 trip to Albuquerque for PI.
c. Provide a brief justification for labor hours, and materials and supplies.

**Appendix**
a. CV for the Lead PI and Key Personnel (not to exceed 2 pages per person)
b. List of company's past deployment of supercritical steam turbines

**Selection Criteria:**

Criterion 1: Technical approach (50%)

- Proposed approach to accomplish statement of work
- Ability to deliver a report and journal article in the required timeframe.

Criterion 2: Applicant Qualifications and Capabilities (25%)

- Capability of the lead and team to address the proposed work with a good chance of success
- Past experience of the team/company designing or analyzing supercritical steam turbine cycles
- List of company's past deployment of supercritical steam turbines for the generation of electricity in the utility market

Criterion 3: Project Schedule and Budget (25%)

- Project tasks are reasonable and logical leading to deliverables
- Budget is reasonable for the scope proposed and enough details are given to assess adequacy.