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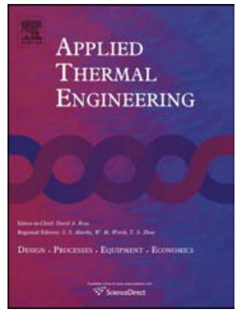


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PII: S1359-4311(14)00016-7

DOI: 10.1016/j.applthermaleng.2014.01.010

Reference: ATE 5310

To appear in: *Applied Thermal Engineering*

Received Date: 24 September 2013

Accepted Date: 7 January 2014

Please cite this article as: A. Modi, F. Haglind, Performance analysis of a Kalina cycle for a central receiver solar thermal power plant with direct steam generation, *Applied Thermal Engineering* (2014), doi: 10.1016/j.applthermaleng.2014.01.010.

# Performance analysis of a Kalina cycle for a central receiver solar thermal power plant with direct steam generation

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## Abstract

Solar thermal power plants have attracted increasing interest in the past few years – with respect to both the design of the various plant components, and extending the operation hours by employing different types of storage systems. One approach to improve the overall plant efficiency is to use direct steam generation with water/steam as both the heat transfer fluid in the solar receivers, and the cycle working fluid. This enables operating the plant with higher turbine inlet temperatures. Available literature suggests that it is feasible to use ammonia-water mixtures at high temperatures without corroding the equipment by using suitable additives with the mixture. The purpose of the study reported here was to investigate if there is any benefit of using Kalina cycle for a direct steam generation, central receiver solar thermal power plant with high live steam temperature (450 °C) and pressure (over 100 bar). Thermodynamic performance of the Kalina cycle in terms of the plant exergy efficiency was evaluated, and compared with a simple Rankine cycle. The rates of exergy destruction for the different components in the two cycles were also calculated and compared. The results suggest that the simple Rankine cycle exhibits better performance than the Kalina cycle when the heat input is only from the solar receiver. However, when using a two-tank molten-salt storage system as the primary source of heat input, the Kalina cycle showed an advantage over the simple Rankine cycle because of about 33 % reduction in the storage requirement. The solar receiver showed the highest rate of exergy destruction for both the cycles. The rates of exergy destruction in other components of the cycles were found to be highly dependent on the amount of recuperation, and the ammonia mass fraction and pressure at the turbine inlet.

*Keywords*: Solar thermal power plant; direct steam generation; Kalina cycle; exergy analysis

## Highlights

- Kalina cycle for a central receiver solar thermal power plant with direct steam generation
- Rankine cycle shows better plant exergy efficiency when heat input is only from the solar receiver
- Kalina cycle is advantageous when heat input is primarily from a two-tank molten-salt storage

## 1 Introduction

In recent times, solar thermal power plants (STPPs) have attracted interest as a large scale, commercially viable way to generate electricity [1]. In an STPP, the heat transfer fluid (HTF) and the working fluid play an important role as the carriers of energy from the collector/receiver to the turbine. This is commonly done in two stages for a plant operating with a Rankine cycle. The HTF (e.g. synthetic oil, molten salt, etc.) first collects the energy from the incident solar radiation. This energy is then passed on to the working fluid (water/steam) which carries it to the steam turbine. The main disadvantage of such two-fluid systems is that the maximum operating temperature of the HTF is limited by the fluid stability concerns (e.g. approximately 400 °C for the synthetic oil), thus resulting in a low turbine inlet temperature and consequently a low cycle efficiency.

Application of direct steam generation (DSG) in STPPs presents the prospect of improving the overall plant efficiency, while simultaneously decreasing the cost of electricity generation [2]. The pressurized steam is generated directly in the receiver and transported to the steam turbine. The advantages of DSG include a higher live steam temperature and the use of one fluid as both the HTF and the working fluid, possibly resulting in a

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