INTERNATIONAL JOURNAL OF GREEN ENERGY
2022, VOL. 19, NO. 13, 1415–1427
https://doi.org/10.1080/15435075.2021.2005604



# Strategic integration of single flash geothermal steam cycle (SFGSC) and ejector assisted dual-evaporator organic flash refrigeration cycle (EADEOFRC) for power and multi-temperature cooling: 2nd law performance study

Subha Mondal[a], Chitta Sahana[a], and Sudipta De[b]

[a]Department of Mechanical Engineering, Aliah University, Kolkata, India; [b]Department of Mechanical Engineering, Jadavpur University, Kolkata, India

**ABSTRACT**

In the present study, an ejector-assisted dual-evaporator organic flash refrigeration cycle (EADEOFRC) is integrated with a single flash geothermal steam cycle (SFGSC). The EADEOFRC also consists of a two-phase expander extracting power from the high pressure fluid before the flashing. Isopentane and n-pentane are used as the working fluid of the EADEOFRC. It is observed that EADEOFRC can be operated at an organic fluid flash pressure corresponding to which refrigeration effects of both evaporators are equal. Corresponding to this operating condition of EADEOFRC, the integrated cycle yields higher second law efficiency compared to that of the SFSC. However, this yielded second law efficiency is lower than that of the dual flash steam cycle (DFSC). In the absence of the flash chamber, the ejectors and the evaporators, the EADEOFRC becomes merely a trilateral cycle (TLC), yielding only power output. Integration of SFSC and TLC yield substantially higher second law efficiency compared to that of the DFSC. Performance of the combined cycle slightly improves if n-pentane is used as the working fluid instead of isopentane.

**ARTICLE HISTORY**
Received 23 November 2020
Accepted 3 November 2021

**KEYWORDS**
Geothermal steam cycle; Organic flash refrigeration cycle; 2nd law efficiency; cooling effects; Isopentane

## 1. Introduction

Decentralized energy system driven by naturally available thermal energy, such as geothermal heat is gaining interest due to the increasing emission from fossil fuel-based power plants. Flash geothermal steam cycle is a conventional avenue to harness power from a geothermal field. Dagdas (2007) reported that a geothermal field supplying 200 kg/s of geo fluid at 210°C was capable of producing 11,488 kW of electricity through an optimized double flash steam cycle. Pambudi et al. (2014) showed that the exergy efficiency of the Dieng single-flash geothermal power plant was close to 36.48%. Zarrouk and Moon (2014) reported that the thermal efficiency of a geothermal based steam cycle is significantly low due to the lower operating temperature. However, the performance of any geothermal based steam cycle could be enhanced appreciably by increasing the number of flashes. Ratlamwala and Dincer (2012) showed that the exergy efficiency of a geothermal flash cycle could be enhanced from 6.52% to 47.29% by increasing the number of flash from one to quintuple.

Performance of a single flash geothermal power cycle can be improved by integrating an organic Rankine cycle with it. The integrated power cycle is designated as the flash binary geothermal power cycle. Yari (2010) concluded that a flash binary geothermal power cycle would yield higher first and second law efficiencies compared to those were yielded by the single flash and the double flash geothermal steam cycles operating under identical operating condition. Shokati, Ranjbar, and Yari (2015) reported that though the first law efficiency of the single flash steam cycle/ORC combined cycle was higher than that of a double flash steam cycle, the double flash cycle yielded a lower unit cost for the generated power. Pasek, Soelaiman, and Gunawan (2011) showed that a flash binary geothermal cycle with I-Pentane yielded higher power output compared power outputs of flash binary geothermal cycles using n-Pentane, I-butane and n-butane as secondary working fluids. Zeyghami (2015) recommended the use of R152a, Butane and Cis-butane as organic working fluids of flash binary power cycles for 150, 200 and 250°C geo-fluid temperatures respectively. A study conducted by Abdolalipouradl, Mohammadkhani, and Khalilarya (2020a) revealed that the single flash-ORC configuration with R123 working fluids exhibited the best thermo-economic performance among four configurations of geothermal cycles considered for the Sabalan geothermal field. Zhou et al. (2019) integrated a dual evaporator organic Rankine cycle with the single flash geothermal steam power cycle to enhance the exergy efficiency. Wang et al. (2015) demonstrated that a flash binary geothermal power cycle using an ammonia and water mixture as the secondary working fluid would yield close to 37.01% exergy efficiency. Mokarram and Mosaffa (2018) conducted the thermo-economic analyses of the geothermal steam flash cycle integrating to different kalian cycle layouts.

A substantial part of global secondary energy is expensed for refrigeration. Thus, the development of an efficient refrigeration system is gaining interest in recent time. Many of the researchers are proposing refrigeration systems with dual evaporators to ensure greater flexibility. Gao et al. (2020) proposed an R290 based dual evaporator refrigeration device using a two-phase ejector as the expansion device. Liu, Liu, and Yu (2020) presented an ejector assisted dual evaporator $CO_2$ refrigeration system yielded about 19.6% higher COP

**CONTACT** Subha Mondal subhamondal53@gmail.com Department of Mechanical Engineering, Aliah University, Kolkata, India