# Attempt to obtain the Best Organic Fluid to improve the Performance of a Solar Power Plant

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## Abstract

Away from environmental pollution and the problems of fuel combustion to produce energy from gas turbines or steam turbines from converting water into steam, now the alternative to solar energy has become facilitated. Because the temperatures generated by was solar collectors do not reach the temperatures of heat exchangers, it necessary to use a different flow fluid from water with lower evaporation temperatures and higher heat transfer efficiency, such as organic matter. This paper explores the search for the best working fluid to enhance the efficiency of the solar organic Rankine cycle. The current research tries to identify the greatest circulation fluid to enhance the casting ability of the Rankine cycle powered by concentrated solar energy. A concentrated solar collector was designed, assembled, and operated to produce enough steam into a heat exchanger that contains a brine solution to operate the Rankine cycle, which operates with organic fluid. Many liquids, such as R22, R123, R433a, R143a, R40, R601, R600a, RC318, R1270 and R290, have been tested from 90°C to 300°C. The results showed optimum system performance when using R601 as the Rankine cycle flow fluid, with a capacity improvement of approximately 24.6%. Additionally, R290 produced an estimated 10% increase in the power produced by the turbine at higher temperatures above 240°C.

## Keywords:

Concentrated solar energy complex. Heat Exchanger; organic liquid; Power plant; Best performance.

## Highlights:

- Solar Energy Application.
- Parabolic trough collector.
- Organic Rankine Cycle.
- Optimum choice of the organic working fluid for best thermal efficiency.

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## 1. Introduction

Recently, as a result of industrial development and population growth, the global demand for energy has increased, leading to a steady rise in primary energy consumption in all sectors, as fossil fuels account for the majority of energy consumption in most industries worldwide [1-3]. Many studies [4-7] suggested that the most efficient power cycle requires a liquid with high energy sources. Numerous researchers [8-9] have suggested that using organic fluid in, which operates with low thermal sources such as solar energy or waste heat, is an easy-to-build, easy-to-maintain, and highly reliable option. An analytical power cycle coupled with solar collectors was conducted by Mahlia et al. [10], Daniarta and Kolasińsk [11], Jouhara and Olabi [12], Zhar et al. [13], Yadav and Sircar [14], Wenyu and Xiang [15], and Kong et al. [16]. Quilon et al. [17] made an analysis for a solar thermal power. In addition, Mahmoudi et al. 2018, investigated the scheme performance by changing the working fluid.

Khaljani et al. [18], Pethurajan et al. [19], Braimakis et al. [20], Yagli et al. [21], Hemadri and Subbarao [22] have implemented ORC systems in various applications, including industrial processes, organic product fermentation. Feng et al. [23] and Anvari et al. [24] stated that ORC is a reliable and less complex alternative to water for medium/low-temperature heat sources. Tian et al. [25], Gevel et al. [26], Loni et al. [27], Reyhaneh et al. [28], Liu et al. [29] and Gang [30] presented a conclusion of some practical results that ORCs are efficient technologies that can produce electricity from low-thermal energy sources.

Some theoretical models have been implemented on ORCs by Liu et al. [31], Sinian et al. [32], Cunha et al. [33], Ming et al. [34] and Timofey et al. [35] the differences between water traditional thermal cycles and organic fluids with the ORC. Samia [36], Behar et al. [37], Sen and Yilmaz [38], Faye [39], and Jinglu et al. [40], illustrated that choosing the operating fluid carefully is greatly important to improve the efficiency of ORCs. Esteban et al. [41], Jahar and Bhattacharyya [42], Jacek K. [43], Marcia et al. [44], Sylvain et al. [45], Fang et al. [46] and Magro et al. [47], simulation of ORCs through numerical analysis requires implementing equations for mass, and energy balance.

Ijaola et al. [48] review, develop and apply various biogas production technologies described in the literature. It also provides a framework for matching the biogas quality required for each potential application, allowing for the updating of quality achieving technologies. This review also considers future work in biogas production, development and utilization, as well as government policies that may encourage its implementation.

## 2. Apparatuses and alternative fluids

The ORC (Organic Rankine Cycle) system is composed of a collector, with a length of 11.8 meters, a central length of 2.6 meters, an edge angle of 85 degrees, a hollow cylinder diameter of 7 centimeters, and an automatic orientation. The ORC scheme has two closed loops: the first loop captures the energy of solar radiation through the parabolic trough and transfers it to the organic working fluid in a heat exchanger. The second cycle includes evaporator which works with a pump which transfers the liquid to the engine. Molten salt, with a concentration of 1% AG, was used as an effective nanomaterial heat absorption. This station was designed, implemented, and tested under all weather conditions in the city of Jazan in the Kingdom of Saudi Arabia to ensure the possibility of operation at appropriate temperatures.

The operating hours vary according to the seasons around the year, Oyekale et al. [49], Piotr K. [50], Zhen et al. [51], Xueling et al. [52], Soulis et al. [53], Evangelos et al. [54], Nishith and Haglind [55], Evangelos et al. [56], Geanette et al. [57], Nikolaos [58] and Guangli et al. [59]. According to the results of some studies (Daniel et al. [60], Mahmoud et al. [61], Shaikh et al. [62], and Mattia, et al. [63], the system produced about 4576 watts by one dish. The recorded measurements of temperature distribution over five days is shown in Fig.2. The results recorded over these days indicate mean temperatures of 315 to 320 degrees Celsius achieved from this solar system.

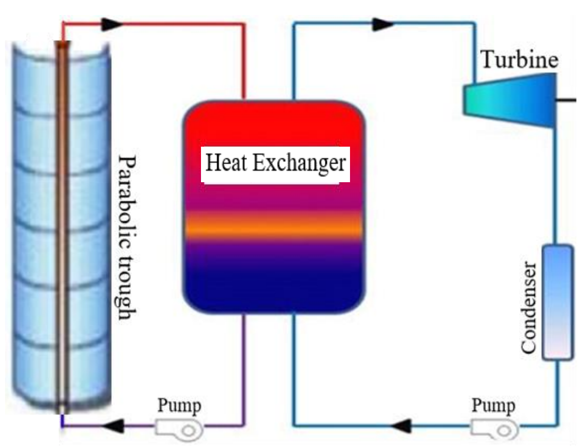


**Fig. 1.** System test outline Heat Exchanger

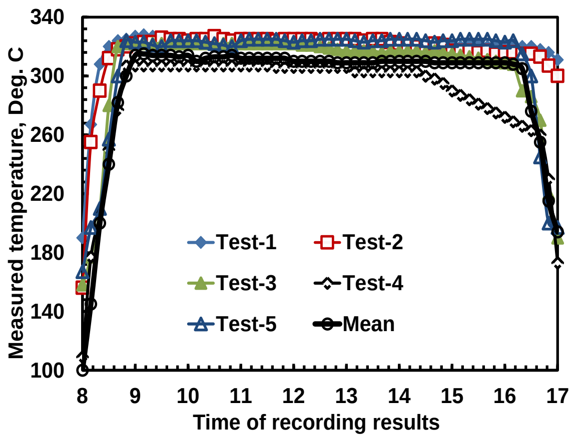


**Fig. 2.** System test outline Heat Exchanger

## 3. Calibrate the results and calculate the transmission characteristics.

COM, J2EE and NET podium, active link library and submission driver were used. Back to Fig.1, energy balances for individually element of present cycle organization are:

$$Q - W = m_e h_e - m_i h_i \quad (1)$$

Where W and are Q the power and balminess, i and e are the inlet and exit settings. The parabolic trough heat rate, qH similar to Oyekale et al. 2019, and Tian, et al. 2022 is:

$$q_H = [\alpha\tau I_g - (T_i - T_o)U_g]A_C = mC_p(T_s - T_c) \quad (2)$$

Applying the exergy equation in sequence apparatuses identical to Liu et al. 2021, Soulis, et al 2022, Bellos, et al. 2022, Nishith and Haglind 2020 is:

$$Ex_i = Ex_e + Ex_d \quad (3)$$

Where $Ex_e$ and $Éx_i$ are heat transfer at inlet and exit respectively, and $Ex_d$ exergy destruction. The irreversibility according to Georgousis et al. 2022, and Guangli et al. 2022 is:

$$(m_i x_i + Ex_o)\text{i} = (m_e x_e + Ex_w + Ex_d)\text{e} \quad (4)$$

For a continuous flow motion, the irreversibility rate is:

$$I = T_0 dS/dt = T_0 m_{ORC}[(S_e - S_i) + dS_{ORC}/dt + q_i/T_i] \quad (5)$$

The turbine isentropic work is:

$$\dot{W}_{Ts} = \dot{m}(h_3 - h_{4s})\eta_{sT} \quad (6)$$

The net power extracted from system is:

$$\dot{W}_{net} = \dot{W}_T - \dot{W}_P \quad (7)$$

The power plant performance is:

$$\eta_{th-c} = C_f \rho C A_b V(T_{fo} - T_{fi})/G_e A_a \quad (8)$$

Where ρ is the fluid density, $C_f$ heat transfer coefficient, and $G_e$ collector heat gain. Using Equ. (8), the plant performance [Mattia et al. 2023, and Weather 2023] is:

$$\eta_{th-ORC} = (\dot{W}_{net} + Q_{eva})/(Q_{geo} + Q_{solar}) \quad (9)$$

## 4. Results and discussion

The solar-powered cycle presented in Fig. 1 used several organic fluids. To obtain the best fluid that gives the highest thermal efficiency, a theoretical model was created, and the heat energy behavior of the evaporator is shown in Fig. 3. The experiments were conducted to determine heat produced in the evaporator with varying temperatures entering the turbine. The findings, as presented in Figure 4, show that using liquid labeled as R601 resulted in the highest enthalpy gain in evaporator heat generation. Figure 5 shows effect of different organic liquids on the output power of the turbine with increasing evaporator temperature. The optimal capacity for the turbine was observed with R290, followed by R601 and R600. Using other fluids with the cycle decreases its capabilities. Also clear in the figure that the gas called R290 generates the highest heat production in the cycle, as presented in figure 6.

The power generated in the cycle is significantly affected by the choice of working fluid. For instance, the R290, R1270, and R433 give high ORC power output. Conversely, using R143 and R433 fluids results in lower power output. However, R123 is more effective, and the fluid R601 is suitable at temperatures above 180 degrees Celsius. Finally, some liquids (R290 and R143) perform well at all temperatures. Examining Figure 7 confirms the previous results that using R601 flow fluid gives the highest overall efficiency with an improvement rate of up to 58%.

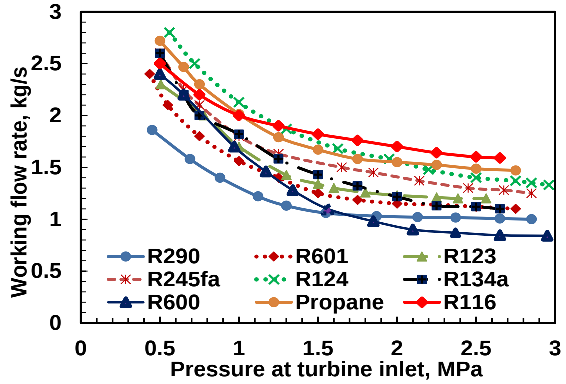


**Fig. 3.** Influence of organic fluid type on its mass flow rate

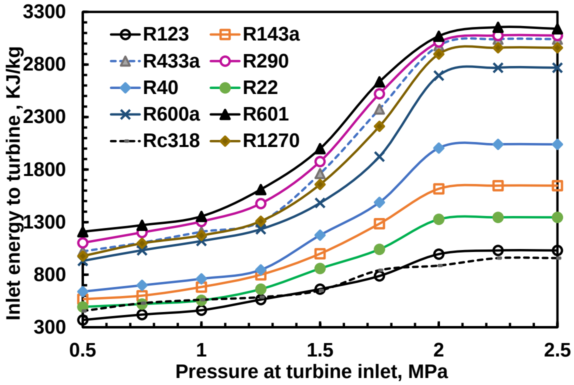


**Fig. 4.** Influence of evaporator pressure turbine energy

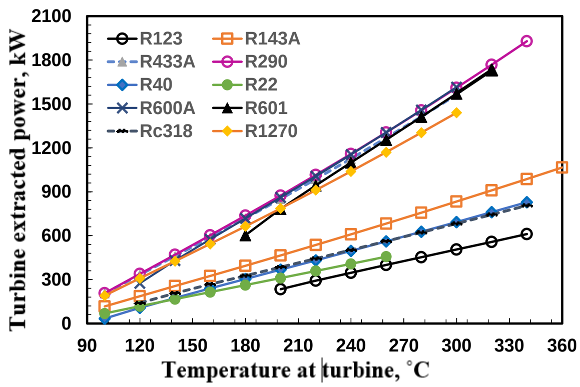


**Fig. 5.** Influence of turbine power by inlet temperature (Pi =2 MPa)

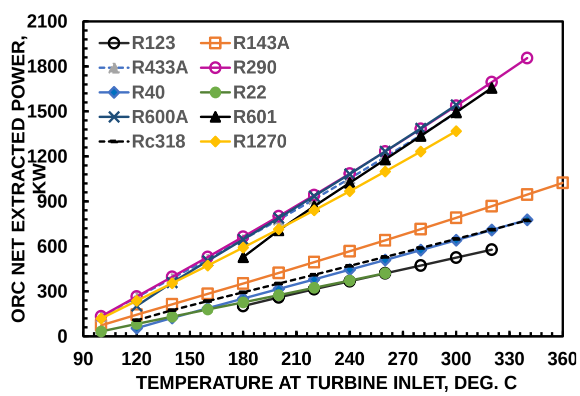


**Fig. 6.** Effect of evaporator temperature on system output power at Pi =3 MPa

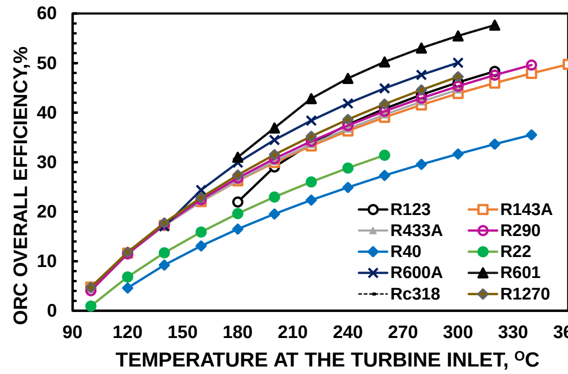


**Fig. 7.** Influence of temperature at turbine inlet on the efficiency, at Pi =2 MPa

## 5. Conclusion

Extensive research has been conducted using concentrated solar collectors to harness solar energy. In this research, different organic working fluids were tested to obtain the best power output. A parabolic solar collector was designed, and the absorbed heat was stored in an insulated tank filled with salt solution. Characteristics were evaluated based on net power production, thermal efficiency, and evaporator temperature. The tested fluids included R123, R143a, R433A, R290, R40, R22, R600a, R601, RC318, and R1270, to determine the best cycle performance and confirm the most optimal fluids. Using the liquids R 290 and R601 offered the highest efficiency compared to other fluids, with an improvement rate of up to 24.6%. At higher temperatures above 240°C, R290 is estimated to increase turbine output by 10%.

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