

POTENTIAL OF 16 M² SOLAR SCHEFFLER REFLECTORS FOR THERMAL APPLICATIONS –EXPERIMENTAL INVESTIGATION

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Abstract— The Solar concentrating power (CSP) has advantage to provide heat that, it can provide daylong energy for many process applications; and it has significant potential for technological improvement and significant cost reduction. In this work, an experimental study is carried out on a solar concentrating reflector using Scheffler collectors to study its potential applications in thermal processing application. Scheffler Reflector is one of the most promising CSP system which can be used for variety of applications, where localized quantum of thermal energy is required. The experiments were conducted to measure the pressure and temperature rise in steam header connected to the receivers of the Scheffler reflectors. Two Schefflers were used in the study and distilled water at atmospheric temperature of 29 °C and with initial weight of the water as 40 kg. From the experimental investigating, it was found that, with beam radiation range of 700 to 850 W/m² on horizontal surface, the temperature at the steam header rose to 140 to 180 °C. When the solar radiation starts decreasing in the afternoon, the heat input to the system starts decreasing, and thus heat energy stored in the steam header starts losing its energy through receiver's surfaces and also with other exposed heat exchanging surfaces. The water temperature gradually increased with solar intensity until 10 am in the morning, thereafter sharp rise in the temperature is seen as solar insolation intensifies. The study concludes that the fixed focus concentrators provide an excellent opportunity for low energy applications as they also provide easy installations and operations.

Index Terms— Solar, Solar concentrating power (CSP), Scheffler collectors

I. INTRODUCTION

The key as the deciding factor, driving the selection of appropriate type of solar collector are, thermal efficiency at the desired temperature, energy yield, cost, and space occupancy. From all the possible collector's configurations, a collector which can focus reasonably to a point with the concentration ratio nearer to 100 that can yield the temperature in the range of 100 to 500 (°C) is best suited for many applications such as cooking, laundry operations, distillations, desalination, and other similar applications. From the literature reviewed so far, it was found that the Scheffler reflector has been successfully utilized for solar cooking applications only. Very few studies are available for application of this technology for desalination [1] [2]. Hence, after many deliberations, we have zeroed on to a fixed focus Scheffler concentrator, which we considered as a mile stone in solar thermal utilization. The Scheffler reflector design is a proven design for concentrating sunlight up to concentration ratio close to 100. With this kind of concentration ability makes it suitable for various purposes such as laundry, cooking, and other application. It concentrates sunlight in two dimensions to a "point" or small area, allowing heat flow without a dedicated mechanism such as transfer fluid. The Scheffler reflector is based on a similar principle to satellite dishes, using the side of a rotated parabola instead of the bottom. If the reflector is located directly north or south of the focus, the Scheffler can track on a single axis. [3] As is shown in figure 1, the sun's apparent path through the sky defines a series of planes perpendicular to the earth's

axis of rotation (the polar axis). These planes shift north and south based on the season.

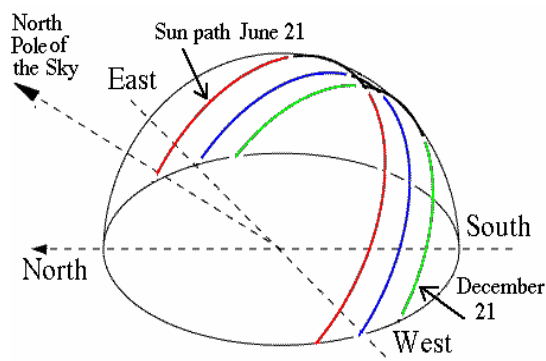


Figure 1 The sun's apparent path across the sky. [3] German Scientist Wolfgang Scheffler has conceptualized a parabolic reflector, which is commercially known as Scheffler reflector, which is set to harness solar energy. Scheffler collector is technically a small cross-section of a much larger paraboloid that can be used as a concentrated reflector. The sunlight that falls onto this section of the paraboloid is reflected sideways to the focus located at some distance from the reflector [4] [5]. Wolfgang Scheffler demonstrates [6], Scheffler reflector as spinning around an axis parallel to that, just in the opposite direction. This is called polar mounting or mounting on a polar axis. The uniqueness of Scheffler design is that its adaptability to any changing seasons. At any season, in order to maintain a fixed focus, the mirror array should be modified and cup shape of the reflectors needs a little bit of change [3]. Wolfgang Scheffler demonstrates the (Figure 2) the mirror modification by season. In the figure 2,

The letter ‘F indicates the focus, where we expect the hotspot, the shaded electrical portion of the parabolic surface is representation of mirrors used by the Scheffler reflector, the darkened circle above the shape represents the apparent cross sectional area of the reflector, and the dotted line represents the axis of the earth’s rotation [6].

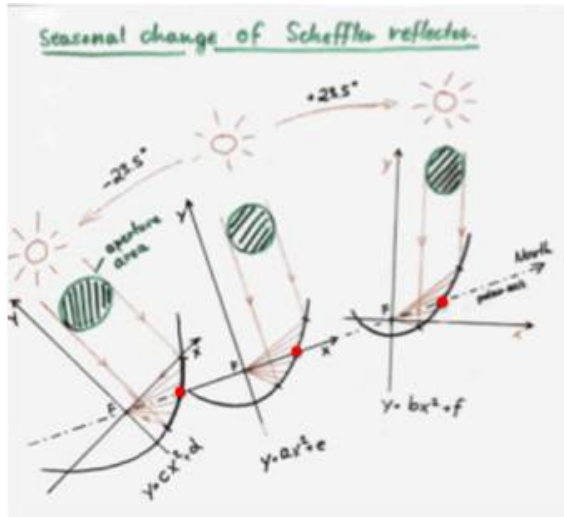


Figure 2 Different parabolas focus the sunlight at different seasons [6]

As seen in from the figure 2, the concentrating primary reflector tracks the movement of the sun, focusing sunlight on a fixed place. The focused light heats up theoretically a point called focus, which can be tapped and rooted for heating. etc. Studies of Rupesh J et al., (2013) indicates that temperature at focus point of a Scheffler reflector dependent on independent variables of the system such as generated temperature gradient, Incident solar irradiation rays, water quantity in the receiver pot, operation time, windspeed, ambient temperature, acceleration due to gravity whereas response variable would be generated water temperature and heat gain [7].

II. SEASONAL ADJUSTMENT FOR SCHEFFLER

Daily tracking of scheduler reflectors can be carried out with the help of a timer mechanism. Further, seasonal tracking, can be performed by means of manually adjusting the telescopic clamp mechanism, which tracks the sun to cover of solar declination . Solar declination varies from -23.5 on December 21 to + 23.5 on June 21 [8]. By modifying the reflector surface to half the solar declination angle with the help of telescopic clamps, results in modifying the shape of parabola to a required shape with the help of three point triangular pivots as shown in figure 3. The point B is the common point for all different parabolas during the year [8]. The focus remains fixed and always lies on the line passing through the axis of rotation of the primary reflector. The distance between the two fixed points B and F always remains constant.

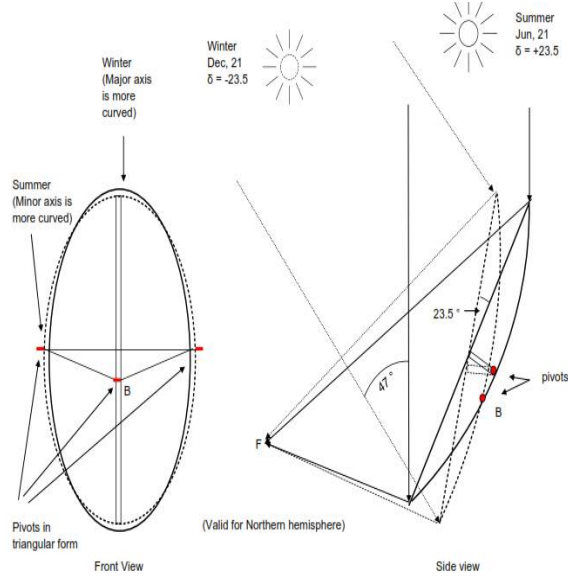


Figure 3 Seasonal adjustments for Scheffler reflector [8]

III. METHODOLOGY FOR PROJECT DEVELOPMENT

The commonly known low temperature industrial process which operate in the temperature range of 60 to 150 °C such as sterilizing, drying, pasteurizing, solar cooling and heating and air conditioning using adsorption technology, as well as decentralized desalination evaporation, may be well suited for the solar thermal applications using Scheffler reflector. The use of solar energy in these industrial sectors would help to attain the required temperature for process with zero carbon emissions. There are has been many pilot studies; where in various kinds of solar concentrators are put to test in these kinds of applications. The quantum of solar energy density in Sultanate of Oman may be considered at par with other countries which are accounted as highest in the world. High solar energy density is available in most part of the Sultanate of Oman. According to a Study on Renewable Energy Resources in Oman carried out by Authority for Electricity Regulation, Oman [9] the average solar global insolation in the country varies from 4.5 to 6.1 kWh/m² per day. With yearly variation in average amounts to about 4 kWh/m² per day for January to about 6.5 kWh/m² per day for May in which the solar global insolation is highest [10]. In this current research, this high amount of solar energy available in sultanate is utilized to generate the steam for its possible application in process. In order to study the temperature rise at the reflector surface as well the quantity of heat energy produced for a given solar insolation, a simple proof of concept of solar concentrator system using Scheffler reflectors was developed and studied at the Caledonian College of Engineering Oman campus. This paper reports the experimental findings of the simple real time tests conducted with developed system during the month of August and also to analyze the results with reference to the readings obtained during testing.

IV. EXPERIMENTAL SET-UP

The line diagram depicting the various system components and flow system is shown in the figure4.

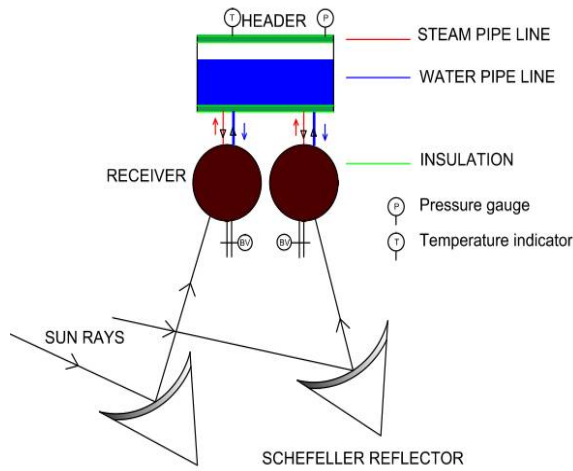


Figure 4 Thermal system components

System consist of two Scheffler reflectors each of 16 m² area focusing on to their respective receivers, and boiler drum where in the known quantity of water is stored. Steam Header Capacity of 42 liters capacity (SS grade 304) which is manufactured using stainless steel seam welded. The necessary pipe fittings along with safety valves and pressure and temperature indicators are incorporated as seen in the figure 1. The water and steam pipes along with boiler drums are insulated to reduce the heat loss to the surroundings. The axis of daily rotation is located exactly in north-south-direction, parallel to earth axis and runs through the centre of gravity of the reflector. That way the reflector always maintains its gravitational equilibrium and the tracking mechanism to continuously follow the Sun throughout the day of operation. The focus is located on the axis of rotation to prevent it from moving when the reflector rotates.

The parameters measured were water temperature and solar radiation. Temperature of the receiver surface was measured using Infrared gun of FLIR make. To record the process variables a customized instrumentation is fabricated and integrated with the test-rig. Further, these data needs to be logged continuously in to a storage device and it should be made available in a format, which should be compatible with MS-Excel or something similar. In this regard, a 32 port data logger to which temperature, pressure, solar insolation sensors were wired and output was calibrated and readings were made to populate in an excel sheet. The details of the instrumentation are shown in the Table 1. A solar Pyranometer used to measure the radiations. The experimentation was carried in the month of August. This month represents of end of summer season in sultanate of Oman. The readings were taken at different time zones between 9 am to 4 pm. for

various days. All readings were taken at the interval of five minutes.



Figure 5 Experimental Setup with instrumentation

Table 1 Major Experimental setup configuration

| Sl.no | Description of the setup |
|-------|--|
| 1 | Scheffler Solar Concentrator : <ul style="list-style-type: none"> • Number of concentrator: 2 • Reflecting surface area: 16 m² • Concentration ratio : 90 • No of mirrors in each concentrator: 400 Size of each reflector mirror : 0.04 m ² <ul style="list-style-type: none"> • Type of regular mirrors : Saint gobain or equivalent standard make |
| 2 | Combined tracking system for Concentrator <ul style="list-style-type: none"> • Timer based automatic day tracking with manual seasonal tracking • adjustment for year-long tracking capabilities |
| 3 | Concentrator receivers <ul style="list-style-type: none"> • Number of receivers: 2 (SS grade: 304) • Each with blow down valves for drain. |
| 4 | Solar Insolation Meter <ul style="list-style-type: none"> • Type: Class 2 apogee solar Pyranometer with silicon dell sensor (SP-212/215 series) one without shading ring and another with shading ring with capability to measure direct and diffuse |
| 5 | Data Logging <ul style="list-style-type: none"> • 32 port data logger to log 4 pressure sensor and 15 temperature sensor inputs • Also to log the solar insolation measurements with customized to the experimental setup inputs with outputs on MS Excel file |

V. RESULTS AND DISCUSSION

During the performance evaluation test, 40 liters of water was charged in to the steam header before the start of the experiments. The distilled water is fed to the steam header and allowed to flow through natural convection through the inlet of the receivers. The cold water enters the receiver through an inlet pipe fitted below the receiver, which gets heated due to the high temperature of the concentrator and the heated water circulates through the hot water pipe and the cycle continues till steam is generated. This generated steam

stored in the upper half of the steam header portion of the water tank building up the working pressure. The experiments were conducted until the maximum solar insolation is reached for that day. This is because, when the solar radiation starts decreasing, the heat input to the system start decreasing, and the heat energy stored in the steam header will start losing energy through receivers and other possible heat exchanging surfaces.

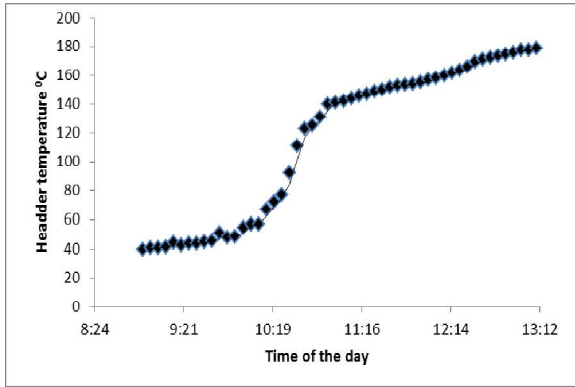


Figure 6 Header temperature profile with reference to time of the day

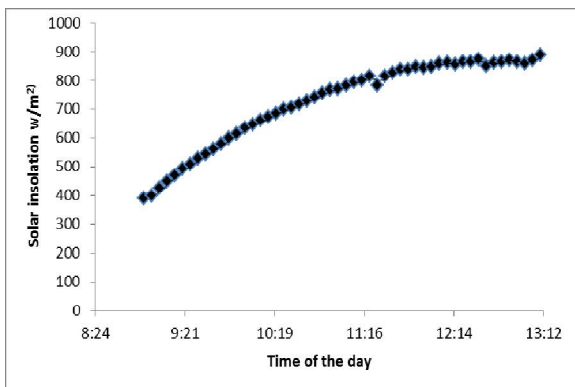


Figure 7 Solar insolation profile with reference to time of the day

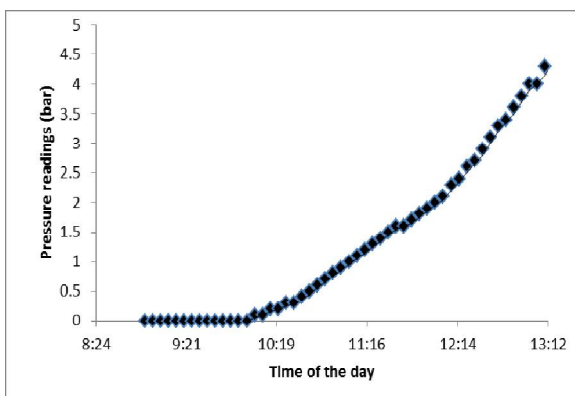


Figure 8 Header Pressure profile with reference to time of the day

Figure 6 depicts the temperature rise in the steam header due to heat input to the system through receivers. As observed in the figure 6, the temperature gradually increases until 10 am, thereafter sharp rise in the temperature is seen as

solar insolation intensifies. The rise in temperature, will aid in improvising the heat transfer convection current, and the flow intensifies, thereby the steam starts to form. This process is clearly depicted in the figure 8 as the pressure curve takes a sharp jump just after 10 am.

The period from the start of the experiment until the first appreciable pressure rise recorded in the header due to steam formation is called lag period. The length of lag period is primarily dependent on the solar insolation falling on to the two receivers. From the experiments, it was found that when the insolation reaches just above 700 W/m^2 , the system comes out of the lag period and will start steam generation. The figure 7 shows the variation of the solar insolation falling on the horizontal surface. The lag period is also dependent on the quantum of water taken at the beginning of the experiments, as well as on other factors such as wind speed, heat loss to the surrounding and initial temperature of the water. For the experiments conducted, the lag period for the system was found to be 75 minutes, when the starting temperature was assumed to as atmospheric temperate of $29 \text{ }^\circ\text{C}$ and initial weight of the water as 40 kg.

The figure 6 and 7 shows the Infrared (IR) camera image of two receivers, which were taken just at the end of the lag period. The temperature the receiver's surface was found to be 10 to $15 \text{ }^\circ\text{C}$ higher than the steam header temperature.

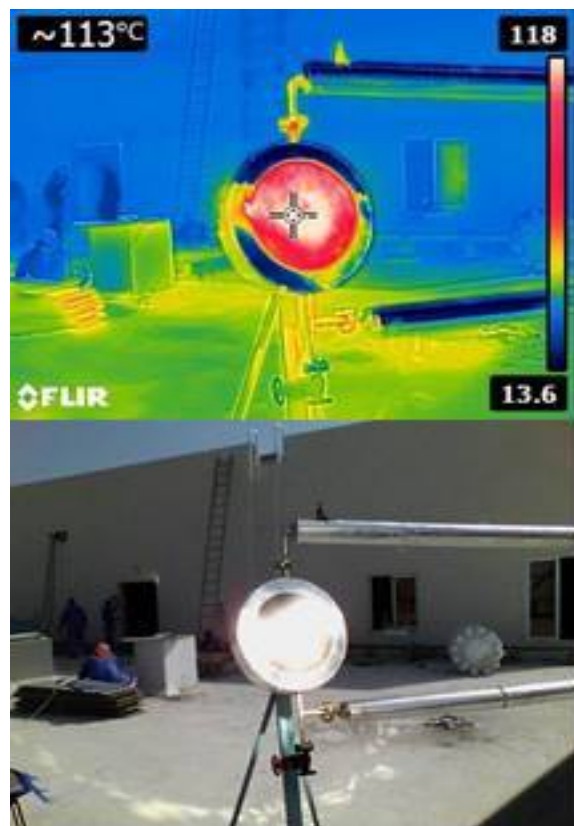


Figure 9 IR image of the Receiver 1

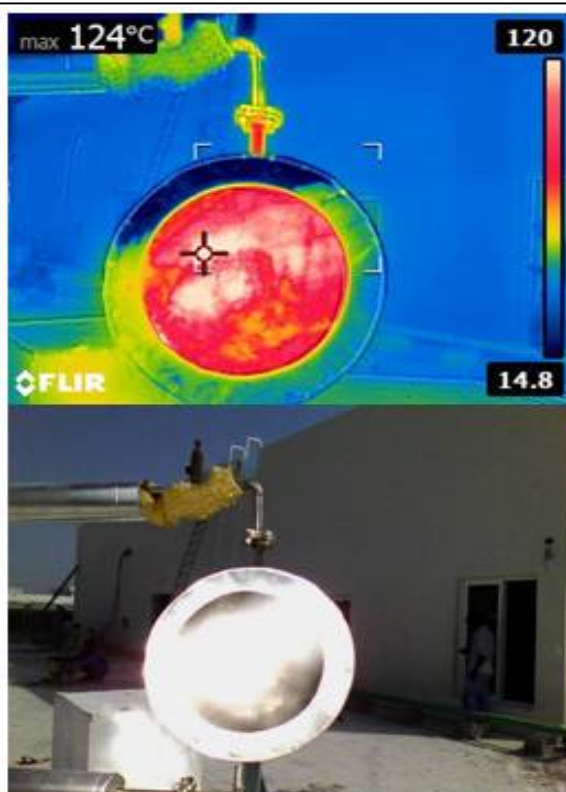


Figure 10 IR image of the Receiver 2

CONCLUSION

From the initial literature studies and from the experimental investigation, it was found that concentrating solar power has vast applications in industrial thermal processing especially at the lower temperature range of 60 to 150 °C . The various technologies such as Compound Parabola, Hyperboloid, Fresnel, internally reflecting surfaces etc. have been studied for various industrial as well as for domestic applications. However, the studies on Scheffler reflectors are marginally reported. From the experimental investigation it was found that Scheffler reflectors has the potential to supply the required energy, especially the low energy requiring applications such as sterilizing, steam washing, or decentralized distillation. The study concludes that the fixed focus concentrators provide an excellent opportunity for low energy applications as they provide easy installations and operations. Within the beam radiation range of 700 to 850 W/m² temperature at the steamheader was close to 140 to 180 °C . Scheffler Reflector is one of the most

promising CSP system which can be used for verity of application, where such quantum of thermal energy is required.

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REFERENCES

- [1]. [1] Chandak Ajay, Somani Sunil K, And Dubey Deepak, "Design, Development And Testing Of Multieffect Distiller/Evaporator Using Scheffler Olar ConcentratorS," *Journal of Engineering Science and Technology*, vol. IV, no. 3, pp. 315-321, 2009.
- [2]. [2] Abhijeet B. Auti, "Domestic Solar Water Desalination System ," *Energy Procedia* , vol. XIV, no. 1, pp. 1774-1779, 2012.
- [3]. [3] Jason Rapp and Peter Schwartz. (2010, November) Cal Poly Physics-Construction an Improvement of a Scheffler Reflector and Thermal Storage Device. [Online]. <http://digitalcommons.calpoly.edu/cgi/viewcontent.cgi?article=1023&context=physsp>
- [4]. [4] Aniket M. Akhade, "Review Of Scheffler Reflector," *International Journal Of Innovations In Engineering Research And Technology*, vol. II, no. 1, pp. 1-5, January 2015.
- [5]. [5] Patil Rupesh J, Awari G.K, and M.P.Singh, "Comparative Study Of Mathematical Modeling And ANN Simulation Of Scheffler Reflector ," *International journal for Advancements in Technical Research and Development* , vol. 2, pp. 1-17, 2013.
- [6]. [6] Wolfgang Scheffler, "Introduction to the revolutionary design of Scheffler reflectors," in *International conference on Solar Cookers*, Spain, 2006.
- [7]. [7] Patil Rupesh, Awari Gajanan K., and Sing Mahendra P., "Formulation of Mathematical Model and Neural Network Analysis of Scheffler Reflector ," *VSRD International Journal of Mechanical, Automobile & Production Engineering*, vol. 1, no. 1, pp. 1-18, 2011.
- [8]. [8] A. Munir and O. Hensel, "On-farm processing of medicinal and aromatic plants by solar distillation system," *Biosystems engineering* , vol. 106, pp. 268-277, January 2010.
- [9]. [9] COWI and Partners LLC, *Study on Renewable Energy Resources in Oman*. Muscat, Oman: Authority for Electricity Regulation, 2008.
- [10]. [10] Sudhir Chitrapady Vishweshwara and Jalal Marhoon AL Dhali, "Study of Excessive Cabin Temperatures of the Car Parked in Oman and its Mitigation," *International Journal Of Multidisciplinary Sciences And Engineering*, vol. IV, no. 9, pp. 18-22, October 2013.

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