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New engineering design of Scccs1 solar collector with direct absorption surface (corrugated-convex) for solar water heating and sterilizing

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A B S T R A C T

The Scccs1 solar collector was designed with a direct absorber surface (wavy-convex) to mimic the horizontal movement of the sun. It was integrated with a solar heater to form a natural circulation solar system for heating and sterilizing water using solar energy. The performance and efficiency of the Scccs1 were studied theoretically and practically under various weather conditions in Basra. This model features a new engineering design. The Scccs1 features a direct absorber surface made of aluminum, coated in a matte black color to enhance the surface's heat absorption capacity. The solar collector is integrated with a heat storage system (water tanks within the collector A1 and A2). The water is stored and heated using the thermal energy collected from the heat acquisition stages of the solar system. This system was experimentally evaluated under various loading conditions. The Scccs1 demonstrated efficient performance, recording temperatures of 81 to 105°C for the output water and 50 to 90°C for the storage water from November 2024 to June 2025. This temperature is sufficient for water sterilization. The system does not require horizontal rotation toward the sun. Experimental testing demonstrated that the undulation-convexity of the absorption surface and the convex front surface of the system mimics the horizontal movement of the sun during daylight hours. The Scccs1 operated efficiently in cloudy and partly cloudy conditions with low temperatures. In partly cloudy conditions, the output water temperature was 81°C, and A2 was 56°C. In full cloudy conditions, the output water temperature was 54°C, and A2 was 34°C.

1. Introduction

Using solar energy is a practical solution to major global challenges in the energy production and management sector. Climate change, dwindling fossil fuel reserves, and increasing energy demand can be addressed through the use of renewable energy sources, most notably solar power. One of the main methods for harnessing solar energy is the use of solar collectors. In recent years, extensive research has been conducted on various types of solar collectors, which perform diverse and different functions depending on their type and design [1]. The half-conical, groove absorber and surface

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absorber designs of flat plate air solar collectors provide for performance criteria [2]. An analysis of the specific factors influencing the proficiency of solar systems was presented by [3].
The escalation in global energy demand and the utilization of non-renewable energy sources, such as fossil fuels, have diminished the availability of these resources, which will be depleted upon complete consumption [4, 5]. As fossil fuel reserves diminish globally, alternate energy sources have gained significance [6]. Renewable energy sources are an appropriate option since they offer clean energy and mitigate significant adverse environmental impacts, like air pollution and global warming, while being a cost-effective energy solution [7-11]. Renewable energy originates from natural processes that are continuously renewed. In its diverse manifestations, renewable energy is sourced directly from solar radiation, wind, precipitation, oceanic tides, biomass, and geothermal energy originating from the Earth's internal heat [12, 13].
Solar energy is a crucial form of renewable energy that harnesses the sun's rays, providing heat and light; this energy can be utilized in various applications [14- 17]. Solar energy can be used for water heating; a solar heater can convert solar irradiation into hot water [18]. Solar water heaters serve as an auxiliary system to diminish the reliance on conventional fuels by preheating water in both industrial and home sectors [19]. Currently, solar heaters are utilized globally to supply hot water for residential and commercial use and industrial purposes to produce energy [20, 21]. Solar energy is a significant renewable energy source; hence, approaches for converting solar energy into usable forms have garnered considerable interest in scientific literature [22].
A solar heater typically comprises a glass-covered box containing painted steel tubes, through which water is heated as it circulates by thermo-gravity in the hot water tank [21, 23]. The surface that captures solar energy is a crucial element of the solar heater and is coated with various absorbent materials. Solar energy can be readily harnessed using a surface coated with a thin coating of black paint [24].

2.Materials and methods

2.1 Solar Collector Manufacturing Process

The tools and materials shown in Table 1 were used in the different work steps to build the new design of the solar collector Scccs1.

Table 1. Shows the materials used in the manufacture of the Scccs1.

Materials used in the manufacture of the Scccs1 solar collector
Copper tube with a diameter of 0.95 cm and a length of 1200 cm.
High-pressure plastic hose extends from the tank to the solar collector.
A set of valves to control the speed of water flow from the solar collector
2 galvanized iron cylindrical tanks with a capacity of 3 L, diameter 9.8 cm, height 40 cm, and tank wall thickness 0.3 cm.
Aluminum plate is rolled into a convex sine wave shape with size (length 155 cm, width 60 cm, thickness 0.2 cm) to manufacture the absorber surface of the Scccs1
Mercury thermometer and electronic thermometer
Graduated glassware, Screws of different sizes, Matte black paint.
3 locking casters for the iron base on which the Scccs1 solar collector rests, for easy horizontal movement and rotation of the Scccs1.
The iron base on which the Scccs1 solar collector rests is manufactured using a square iron tube with a side length of 3.81 cm and different lengths.
Clear glass panels:
2 pieces (length 64 cm, width 24 cm, thickness 0.4 cm).
2 pieces (length 64 cm, width 41.5 cm, thickness 0.4 cm).
Iron plate for manufacturing the Scccs1 solar collector frame:
Two sides (60 cm long, 25 cm wide, 0.2 cm thick).
One back deck (115 cm long, 60 cm wide, 0.2 cm thick).
Two roof and base decks:

Straight back rib (115 cm long, 0.2 cm thick).
Convex front rib (112 cm long, 0.2 cm thick).
Two side ribs (25 cm long, 0.2 cm thick).
external tank (500L) for supplying water to the Scccs1 with a 500 cm plastic hose.
Adhesive (silicone rubber).
A white 90-degree aluminum ruler in various lengths attaches to the edges of the glass cover to give the collector a neat appearance.

2.2 Fabrication of the structure of the solar collector Scccs1

Iron plates with a thickness of 0.2 cm and different areas were used to manufacture the structure of Scccs1 in a parallelogram shape as in Figure (1), and the front surface of the parallelogram is convex. The absorption surface is fixed inside the iron structure on the convex side at 9 cm from the convex edge, as the absorption surface of solar collector is a corrugated-convex aluminum plate measuring (155 cm long, 60 cm wide, 0.2 cm thick). A copper tube (diameter 0.95 cm, length 1200 cm) is fixed on the absorption surface in a path similar to the letter **Z** [25]. using aluminum clips, with a distance of 5 cm between each coil. The copper tube also follows the path of the absorption plate (corrugated-convex) to match the collector design. The copper tube, absorption surface, and tanks A1 & A2 were painted matte black to increase the absorption of solar radiation and raise the efficiency of the collector, as shown in Figure 1.

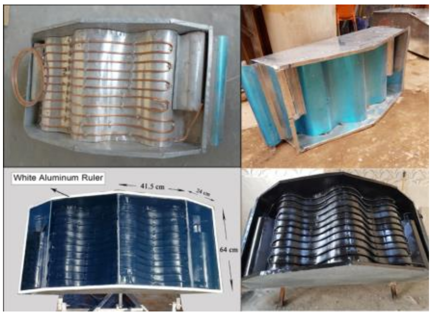

Fig. 1. Shows the structure of the Scccs1 solar heater and the location of the absorption plate and copper tube

The remainder of the parallelogram is an air chamber behind the absorbing surface of Scccs1, as will be shown later. The iron frame was manufactured using iron plates according to the following measurements, as shown in Figure 2:

1. The sides of the iron frame measure (60 cm long, 25 cm wide, and 0.2 cm thick).
2. The rear surface measures (115 cm long, 60 cm wide, and 0.2 cm thick
3. Roof and base:

- The straight rear rib measures 115 cm in length and 0.2 cm in thickness.
- The convex front rib measures 112 cm in length and 0.2 cm in thickness. The convex rib is measured 50 cm from the midpoint of the rear rib to the midpoint of the convex rib (center of convexity) parallel to it.
- The two side ribs measure 25 cm from the rear rib to the ends of the convex rib.

The body parts were assembled in a local fabrication workshop using brass welding, lead soldering, and electric welding.

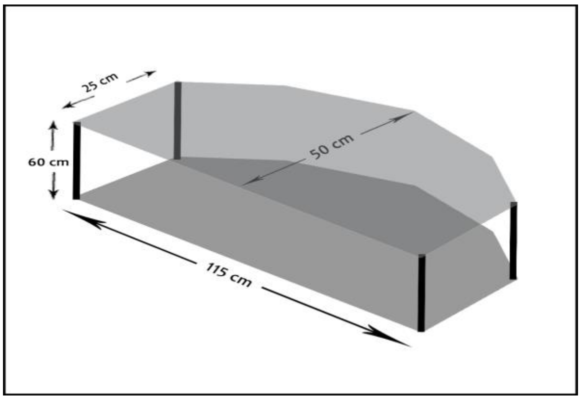

Fig. 2. Shows the shape and dimensions of the iron structure

2.3 The Insulating Air Chamber

The Scccs1 solar collector contains an air chamber between the absorber surface and the rear surface of the collector. This chamber is tightly sealed, preventing the greenhouse effect. The benefit of the air chamber behind the corrugated-convex absorber surface (due to the greenhouse effect within the chamber and the thermal balance) is to reduce and prevent the loss of thermal energy from the rear surface of the collector. In other words, it acts as a thermal insulator, instead of using expensive and environmentally harmful thermal insulators after their deterioration. Figure 3 shows this chamber's dimensions, the absorber surface's location, and the drilling of a 0.8 cm diameter hole in the upper surface of the air chamber to measure the chamber temperature by inserting an electronic thermometer sensor into this hole.

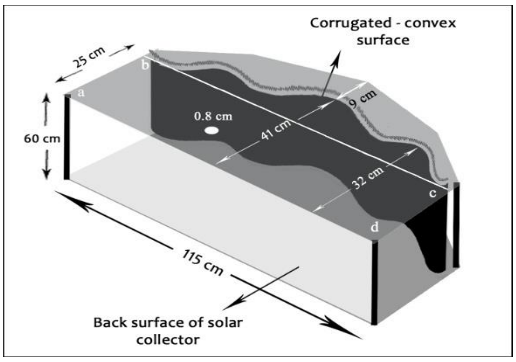

Fig.3. Shows the location of the absorption surface installation and the air chamber enclosed between the corrugated-convex surface and the solar collector's back surface

2.4 Convex collector shape and absorption surface (corrugated-convex).

In this research, a new design for a solar collector (integrated with a solar heater) with a convex front surface and a (corrugated-convex) absorption surface was fabricated. The absorption surface was fixed inside the collector 9 cm from the front surface, as shown in Figure 3. The reasons for this design are:

1. The horizontal movement of the sun from sunrise to sunset takes a convex path due to the sphericity of the Earth and its rotation around itself. This requires the researcher to constantly orient the solar collector to be perpendicular to the sun, either by installing a solar sensor and a motor that continuously changes the direction of the solar collector to be perpendicular to the sun (this is expensive and requires energy), or by constantly moving the collector manually during daylight hours (this is difficult, tiring, and impractical). To avoid this, the front surface of the Scccs1 was fabricated in a convex shape.
2. The absorber surface and the front surface of the solar collector were made convex to scientifically harmonize the sun's convex motion with the collector's shape.

3. Solar radiation falling on the convex absorber surface may cause the radiation not to reach some surface areas, so this surface was made corrugated.
4. The wavy surface of the absorber has several advantages:

i) It addresses the problem of solar radiation not reaching the entire convex surface.
ii) It increases the surface area of the absorber plate while maintaining the size of the solar collector, increasing the thermal energy gain and thus increasing the solar collector's efficiency.
iii) By increasing the surface area, the length of the copper tube in the solar collector increases, allowing the water passing through the copper tube to gain a greater amount of thermal energy and thus increasing the efficiency of the solar collector.

2.5 Absorption Surface.

The absorption surface was designed as a sine wave using a metal sheet folding machine in a local workshop. Its dimensions were a corrugated-convex surface length of 155 cm, a width of 60 cm, and a thickness of 0.2 cm. It consists of three wave convexities and four concave surfaces, as shown in Figures (3, 4).

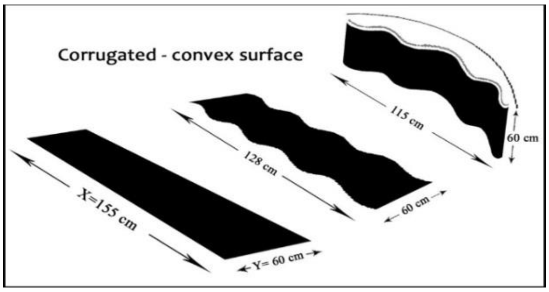

Fig. 4. Shows the measurements and stages of manufacturing the corrugated-convex absorption surface

2.6 Cylindrical Tanks Inside the Solar Collector Scccs1 .

A cylindrical tank (made of galvanized iron) was used to store water in the solar collector. Two cylindrical tanks (3 L capacity, 9.8 cm diameter, 40 cm height, and 0.3 cm wall thickness) were installed inside the solar collector at either end of the absorption surface, as shown in Figure 5. The first tank, Scccs1-A1, is designated to receive the water supplied from the solar collector source, whiles the second tank, Scccs1-A2, is designated to collect the hot water coming out of the solar collector tubes Scccs1.

Fig.5. Shows the location of the two tanks installed inside the Scccs1

A copper pipe (diameter 0.95 cm, length 25 cm) is fixed on the roof of the tank Scccs1-A1 to be the outlet for water to enter Scccs1 from the source via a plastic hose. The copper pipe fixed on the absorber surface is connected to the tank wall A1 from below. After passing through the absorber surface, it branches into two pipes. The first pipe exits the solar collector via valve V2, and the second pipe is connected to the tank roof A2 to exit the tank via a pipe connected to the tank wall A2 below via valve V3 to outside the solar collector. As shown in Figure 6.

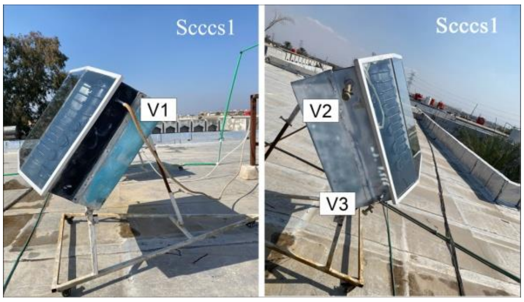

Fig. 6. Shows the diodes V1, V2, and V3 in the solar collector Scccs1

Then, transparent glass panels (0.4 cm thick) were fixed on the convex surface of Scccs1 as a cover to keep the collector clean and generate heat in the pipe and tank room. The dimensions of these panels are shown in Figure 1. The Scccs1 is as shown in Figure 7.

Fig. 7. Shows the final shape of the solar collector, Scccs1

A square iron tube with a side length of 3.81 cm, of different lengths, was used to manufacture an iron base with wheels on which the solar collector Scccs1 rests. The rear support is of variable length to control the angle of inclination of the collector concerning the horizon (summer 15º, winter 45º) [25, 26, 27]. meaning that this base can move the solar collector Scccs1 horizontally and vertically to be perpendicular to the sun, as in Figure 8.

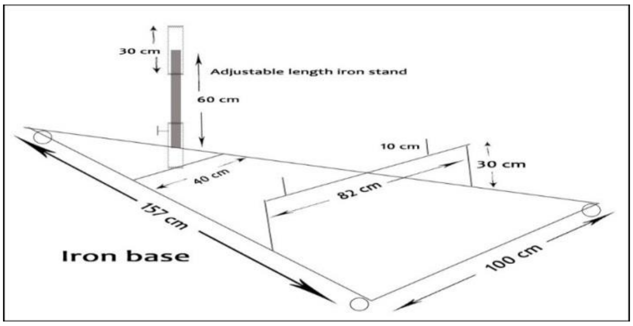

Fig. 8. A diagram showing the iron base on which the solar collector Scccs1 is based

2.7 Solar collector orientation Scccs1

Traditionally, solar collectors of all types are aligned horizontally and vertically with the sun to maintain the concentration of sunlight on the collector and solar heater. This increases the absorption and storage of these rays and thus increases the efficiency of the collectors and solar heaters.

Studies and research have proven that the perpendicular position with the sun differs in the summer from the winter (summer 15°, winter 45°) [25, 26, 27], as shown in Figure 9. This has prompted researchers to find solutions to achieve this perpendicularity. These solutions include manual orientation, which requires continuous effort and monitoring throughout the solar system's operation. Alternatively, they can install a motor that works with a solar sensor to rotate and orient the solar system so that it is perpendicular to the sun. This is usually expensive. Alternatively, they can adopt a flat collector without rotation, but with weak results.

This research is a starting point for finding engineering solutions to dispense with orienting the solar system perpendicular to the sun, provided that it produces the same practical results as when orienting the solar collector. The new design of Scccs1 (corrugated-convex) eliminates horizontal orientation during the solar array's daytime operation. The collector's orientation remains fixed horizontally, meaning the collector's convex front surface faces the sun at 11:00 am, after the angle with the horizon is fixed (summer, winter), as shown in Figure 9. This means the system remains fixed in this horizontal orientation without rotation or orientation.

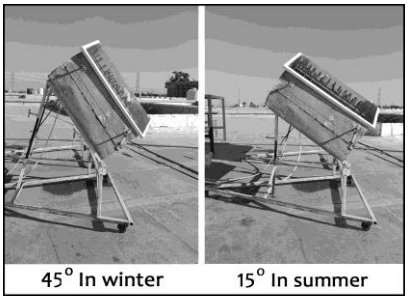

Fig. 9. Shows the solar collector's angle of inclination with the horizon perpendicular to the sun in the city of Basra

2.8 Measuring Instruments

- **thermometer**

Mercury The mercury thermometer was invented by Daniel Gabriel Fahrenheit in 1714. It consists of a glass cylinder with a mercury reservoir at one end. Temperature is measured based on the mercury level in the cylinder. The thermometer works by expanding mercury with increasing temperature and contracting with decreasing temperature. The mercury thermometer is used to calibrate electronic thermometers and to measure temperatures.

- **Electronic thermometer**

This locally manufactured, portable device is used to measure temperature and humidity. It is highly accurate, small in size, lightweight, easy to store, and has a practical design. It provides instant, effortless readings and can measure multiple temperatures simultaneously. It is calibrated using a mercury thermometer, as shown in Figure 10.

Fig. 10. Shows the electronic thermometer used to measure temperature

- **AWOS solar radiation measurement system**

The AWOS automatic station at Basra International Airport was utilized. This modern meteorological station measures atmospheric elements, including solar radiation. The Finnish company Vaisila equipped and installed it in 2024 at Basra Airport, as shown in Figure 11.

Fig. 11. Shows the AWOS system for measuring atmospheric elements and solar radiation

3. RESULTS AND DISCUSSION

The Scccs1 has been designed with a new engineering approach to efficiently absorb heat, ensuring the best design suitable for the climate and atmosphere of Basra (latitude 30° 33' 56.55"N, longitude 47° 45' 5.86"E) and similar climates. The solar collector, Scccs1 were tested under different weather conditions and exposed to solar radiation for six hours daily, from 9:00 a.m. to 2:00 p.m.

Scccs1 is supplied from an external tank (the external tank is higher than the solar collector to ensure smooth water flow in the solar system) using flexible plastic pipes through valve V1 to supply water to the solar collector. This water reaches tank A1, then passes through the copper tube fixed on the absorber plate. The copper tube is coiled in a Z shape as explained above. It then reaches tank A2, which are fixed at the end of the copper tube on the other side of the solar collector. After supplying Scccs1 with water from an external tank, this is exposed to solar radiation during daylight hours from 9:00 am to 2:00 pm for November 2024 to June 2025.

The solar collector has two valves Scccs1- (V2, V3) to record the temperature of the water coming out of the solar collector T_{out}, an opening in the roof of the metal air chamber to measure the room temperature T_b, and an opening in the side surface of the solar collector under the glass cover to measure the temperature under the cover T_f. To record the temperature of the metal air chamber and the glass chamber, electronic thermometer sensors were used after every hour of exposure to solar radiation during the day for eight months (from November 2024 to June 2025). The average daily and monthly temperatures were recorded for solar collector, to monitor the behavior of Scccs1.

Table 2 and Figure 12 show the results of the monthly average water temperature generated by the Scccs1 during the test period, measured in (ºC), along with the monthly average solar radiation (Solar Radiation (I) W.h/m2).

Table 2. Show the average monthly solar radiation intensity and the monthly average temperature of the waters produced from Scccs1, A2, and the source water T-in

Jun-25	**May-25**	**Apr-25**	**Mar-25**	**Feb-25**	**Jan-25**	**Dec-24**	**Nov-24**	**Month**
43	40	30	19	15	13	12	10	T-in ºC
101	99	91	88	82	82	83	85	Scccs1-T(out) ºC
88	85	72	70	54	62	57	62	A2-T(tank) ºC
3365	3121	2175	3256	2619	2175	1526	1757	Solar Radiation (I) W.h/m^2

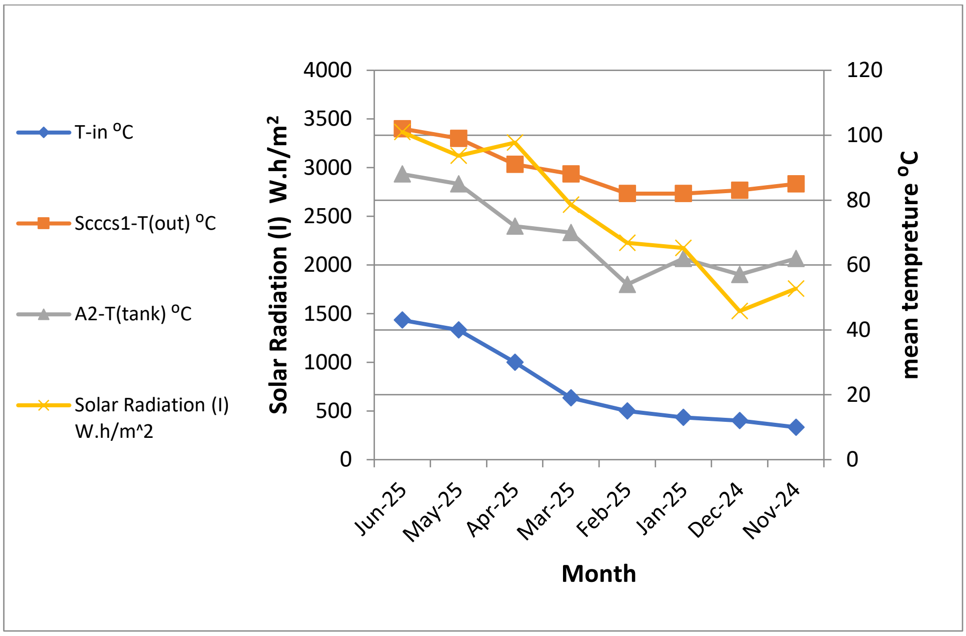

Fig. 12. Illustrates the average monthly solar radiation intensity and the monthly average temperature of the water produced from Scccs1, A2 and the source water T-in

The operating behavior of the Scccs1 is clear from the Figure 12 and the data in Table 2. The thermal efficiency of the solar collector model Scccs1 is high. That is, the solar collector Scccs1 is the most optimal and suitable for the weather conditions of Basra city and cities with similar climates.

Comparing the results obtained by the Scccs1 solar collector with those of some commercially available collectors or those used in well-known studies and designs, such as evacuated tube collectors or flat-plate collectors (box, C1, C2, Z1, Z2, H) [25], we find that:

1- Average temperature of the produced water: In the (box, C1, C2, Z1, Z2, H) collectors, the average water temperature ranged between (65-75) °C during the summer months and between (40-65) °C during the winter months. The Scccs1 solar collector, however, recorded temperatures of (88-101) °C during the summer months and (82-85) °C during the winter months.

2- Collector orientation towards the sun: During operation, the (box, C1, C2, Z1, Z2, H) collectors are rotated horizontally every half hour to ensure they are perpendicular to the sun, If flat or vacuum collectors are not moved, they will give poor results. The Scccs1 collector is installed horizontally so that it is perpendicular to the sun at 11:00 AM without rotation, resulting in higher efficiency.

3- Thermal Insulation and Environmental Impact: Glass wool is used as thermal insulation in collectors (box, C1, C2, Z1, Z2, H) to prevent the loss of absorbed heat. However, this material is harmful to the environment after deterioration and difficult to dispose of. The Scccs1 solar collector, on the other hand, uses an insulating air chamber to prevent the loss of absorbed heat, making it environmentally friendly.

Scccs1 operated efficiently from November 2024 to June 2025, demonstrating the engineering design's ability to capture, absorb, and retain heat, achieving optimal results. Recorded temperatures exceeded 100°C, rendering the produced water sterile [28]. This is an important feature in solar energy systems.

On October 13, 2025, water samples were taken from the Scccs1 solar collector at valve V2 for laboratory testing to determine their physical and biological (bacterial) properties and whether they were sterile or non-sterile, as shown in Table (3).

Table 3. shows the physical and biological examination of water samples produced at different temperatures

Avg heating time (h)	water temp ('C)	No. of tubes positive for coliforms in five 10-ml samples	PH	TDS ppm	Conductivity µs/cm	Chloride	NaCl	HCo3	Total Suspended Solids TSS Mg/L	Salt content in water %
0	25	6	8.1	3510	6938	1773	2923	122	35.2	35
0.5	55	4-5	8.1	3499	6901	1843	3039	116	35.6	35
1	60	3-3.5	8	3403	6700	1560	2571	110	29	30
1.5	67	1-1.5	7.9	3100	5804	1205	1987	109	28.2	28
2	72	0	7.7	3213	5833	1064	1753	91.5	26.2	27
4	85	0	8.2	3555	6001	1701	2805	112.8	29.5	31
6	100	0	8.1	3455	5834	1630	2688	118.9	31.7	31

The results in Table 3 show that bacterial contamination of the water produced by the solar collector decreases with increasing temperature, and the water becomes sterile after its temperature exceeds 65°C, at which point bacterial contamination becomes zero.

Scccs1 solar collector; the temperature of the resulting water ranges from 81°C to 105°C, and it is sterile water. After the water was heated and stored in A2, the temperature of the tank water was recorded between 50°C to 90°C. The water is heated to boiling point, producing sterile water suitable for many applications. Thus, one of the research's main objectives was achieved. As shown in Figure 13.

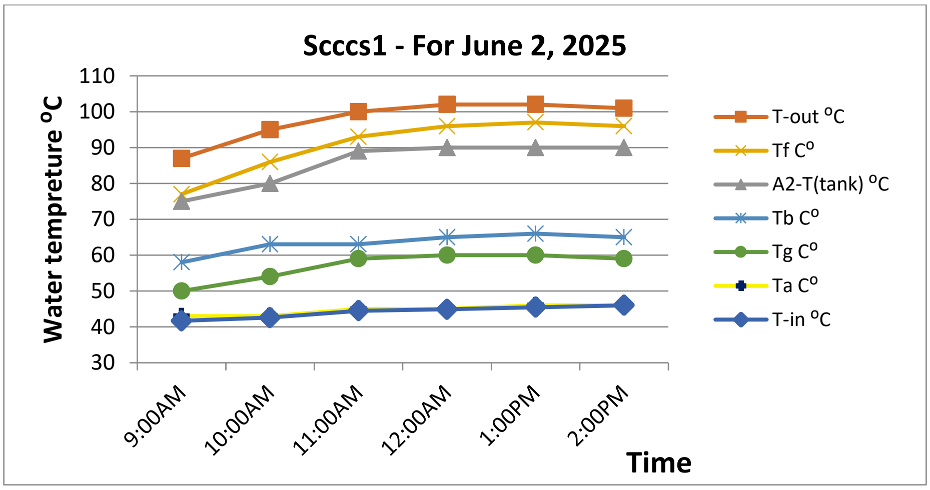

Fig. 13. shows the behavior of the solar collector on June 2, 2025, when the water temperature reaches boiling point

The behavior of the solar collector on June 2, 2025, provides a clear picture of the efficiency of the solar collector in absorbing and retaining thermal energy, and converting it into useful energy. Figure 13 shows that the absorbed heat rises rapidly within the collector from the beginning of the day, and therefore the water temperature rises to boiling point at midday. Thus, sterile water was obtained.

From studying the results in Table 2 and the graph in Figures 12 and 13, we find that the geometric design of the Scccs1 collector, the corrugated-convex surface of the absorption surface, and the presence of the insulating air chamber have greatly helped in obtaining these results.

3.1 Solar collector efficiency in different weather conditions

To determine the efficiency and behavior of Scccs1, this is tested in partly cloudy weather on December 23, 2024, and completely cloudy weather on December 24, 2024. The collector recorded the readings shown in Tables (4, 5) and the graphs in Figures (14, 15).

Where Scccs1 recorded (81°C), and the temperature of tank water A2 = 56°C, which is the highest temperature recorded for the produced water on 23/12/2024 (partly cloudy), as shown in Table 4 and Figure 14.

On 24/12/2024 (totally cloudy), the solar collector Scccs1 recorded the highest temperature of the produced water (54°C), and the temperature of the water tank A2 = 34°C, as shown in Table 5 and Figure 15.

Tables 4. Show the hourly water temperature from Scccs1 for a partly cloudy day, 23/12/2024.

The weather partly cloudy windy						
Scccs1 on 23/12/2024						
2:00pm	1:00pm	12:00am	11:00am	10:00am	9:00am	Time
16	16	15	13	12	10	T-in °C
79	81	80	79	72	66	Scccs1-T(out) °C
54	56	56	52	40	29	A2-T(tank) °C

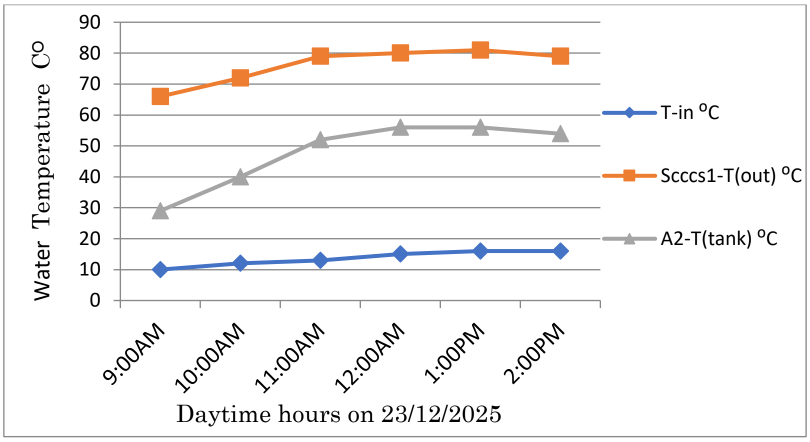

Fig. 14. Shows the behavior and temperature of the hourly water produced by Scccs1 on a partly cloudy day, 23/12/2024

Table 5. Shows the hourly water temperature resulting from Scccs1 on a completely cloudy day on 24/12/2024

Cloudy weather						
Scccs1 on 24/12/2024						
2:00pm	1:00pm	12:00am	11:00am	10:00am	9:00am	Time
16	16	16	15	13	11	T-in °C
29	32	54	55	51	22	Scccs1-T(out) °C
28	33	34	33	24	11	A2-T(tank) °C

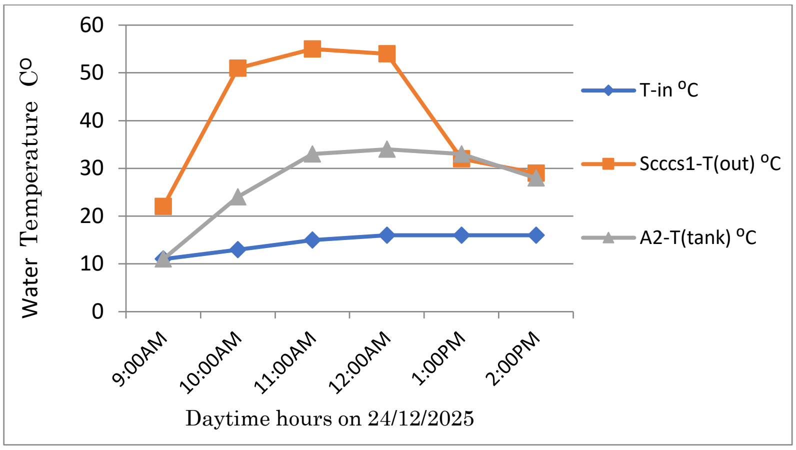

Fig. 15. Shows the behavior and temperature of the hourly water produced by Scccs1 on a completely cloudy day, 24/12/2024

From observing Figure (14, 15), and analyzing the results in Table (4, 5), it is clear that the solar collectors, Scccs1 operate in partially cloudy and completely cloudy weather. This feature gives the model efficient operation in different conditions. From the recorded results, it was observed that Sccs1 works efficiently in various weather conditions, even if clouds partially or completely block the sun.

3.2 Stages of Water Heat Gain in Scccs1

Since ancient times, humans have harnessed the sun's light and heat for their benefit. They have employed various methods, both small and complex, to achieve this goal. One such method is solar collectors, which concentrate and collect solar thermal energy. In this research, the basic principles of heat transfer methods were used are as follows [29, 30]:

a) Heat transfer by radiation.
Solar collectors of all shapes and sizes collect and increase the absorption of solar radiation, converting it into energy that can be used and stored in various fields. This energy is electromagnetic radiation with wavelengths between long infrared rays and short ultraviolet rays. Exposing Scccs1 to sunlight achieves this principle.

b) Heat transfer by conduction.
Heat is transferred by conduction between the absorber surface and the copper tube, and between the walls of the tanks (A1, A2,) and the water inside them. Heat is also transferred in the same manner between the copper tube and the water flowing through it.

c) Heat transfer by convection.
After the water inside the tank is heated by absorbing direct solar radiation, the hot, low-density water rises to the upper section of the tanks (A1, A2), while the cold, high-density water descends to the lower section due to convection currents.

There are several stages to raise the water temperature in Scccs1 as follows:

1 .Heat is acquired and stored in the two Scccs1 tanks (A1, A2) within the Scccs1 solar collector.
2 .Heat is absorbed and gained through the copper tube's exposure to direct solar radiation.
3 .Heat is gained from the direct contact of the copper tube with the absorber plate.
4. Heat is gained from the greenhouse effect generated within the Scccs1 solar collector.

3.3 Inspection and Testing

The experimental work was conducted in Basra, Iraq (latitude 30° 33' 56.55"N, longitude 47° 45' 5.86"E). Scccs1 was tested and inspected from October 2024 to March 2025, from 9:00 am to 2:00 pm, with the readings being checked and recorded every hour. There are two testing methods to determine the design's effectiveness in simulating the horizontal movement of the sun:

• The first method: Rotating the Scccs1 system horizontally after fixing the angle with the horizon (15° in summer, 45° in winter) during daylight hours to be perpendicular to the sun. This is the scientific method used to inspect and test solar systems of this type to determine their operating efficiency, record the results, and discuss them.

• The second orientation: The system is installed horizontally in the sun's direction at 11:00 am after fixing the angle with the horizon (15° in summer, 45° in winter). This means that the system remains fixed in this horizontal orientation without rotation. This inspection and testing method aims to prove that the new geometric shape of the system (corrugated-convex) gives the same results as the first inspection method. Thus, this study has proven one of its goals theoretically and practically, and that the new geometric shape of the Scccs1 solar system works efficiently. This project will be a new and promising starting point in sustainable energy through the innovation of new engineering designs that protect the environment, meet needs, provide better results, are at a lower economic cost, and overcome the obstacles facing sustainable energy.

- **Inspection and Testing of the Stability of the Solar Collector (Scccs1)**

At the beginning of each inspection day at 9:00 am, the Scccs1 are aligned perpendicular to the sun by manually adjusting the tilt angle of the Scccs1 relative to the horizon for optimal performance. Without rotation, Scccs1 remain horizontally aligned with the sun at 11:00 a.m

The Scccs1-A2 tanks are emptied of water (3 liters each), and the emptiness process is repeated after each hour of inspection during the daytime. The Scccs1 receives water from the external tank via a plastic hose connected to the solar collector through the inlet valve Scccs1-V1 (the water is connected from the equipment to the tank Scccs1-A1 via a rubber hose). After the tank Scccs1-A1 is filled with water, it flows through the copper pipes, gaining heat until it reaches the branching point of the copper pipe inside Scccs1. The water exits the Scccs1 via the valve Scccs1-V2 for inspection and use, or it is collected in the tank Scccs1-A2 via the branching of the second copper pipe. It then exits the Scccs1 via the valve Scccs1-V3 for inspection or use.

The hourly temperature of the weather (T_{air}), the inlet water of the solar collector through valve V1 (T_{in}) (the supplied water source), the water leaving the solar collector through valve V2 (T_{out}), the water leaving the solar collector through valve V3 (T_{tank}) (the water coming out of the tank Scccs1-A2), the temperature of the room (T_f) containing the copper tube and the two tanks Scccs1-A (the space between the glass cover of the front surface and the absorber surface), the temperature of the glass T_g (the glass cover of the convex front surface of the Scccs1), and the temperature of the air room (T_b) (the area between the absorber surface and the back surface of the Scccs1) was recorded. The graphs in Figures (16), (17), (18) and (19) of the recorded readings showed the operating behavior of the Scccs1 when they was stable on 1/12/2024 (sunny 20ºC), 23/12/2024 (partially cloudy 20ºC), 20/1/2025 (sunny 20ºC), and 10/2/2025 (sunny 18ºC), respectively.

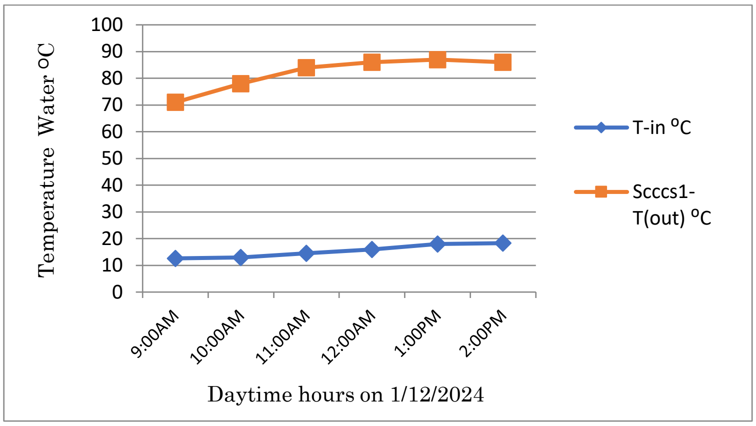

Fig.16. The graph shows the behavior of the operation and water temperature of the Scccs1 on 1/12/2024 (sunny 20 ºC) When it is fixed

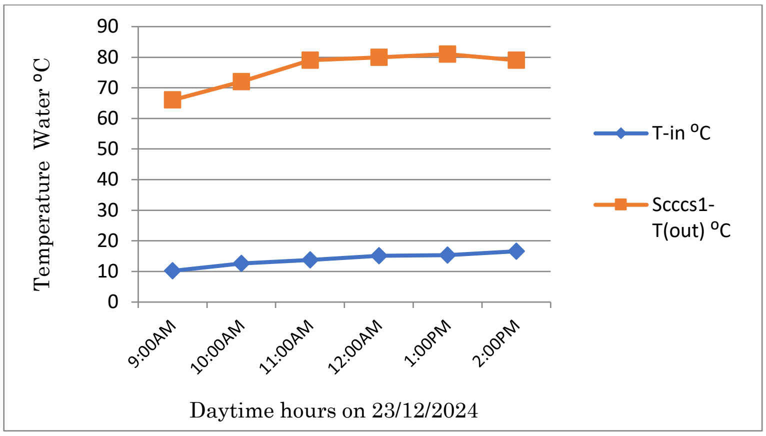

Fig.17. The graph shows the Scccs1 operating behavior and water temperature on 23/12/2024 (partly cloudy, 20 ºC) When it is fixed

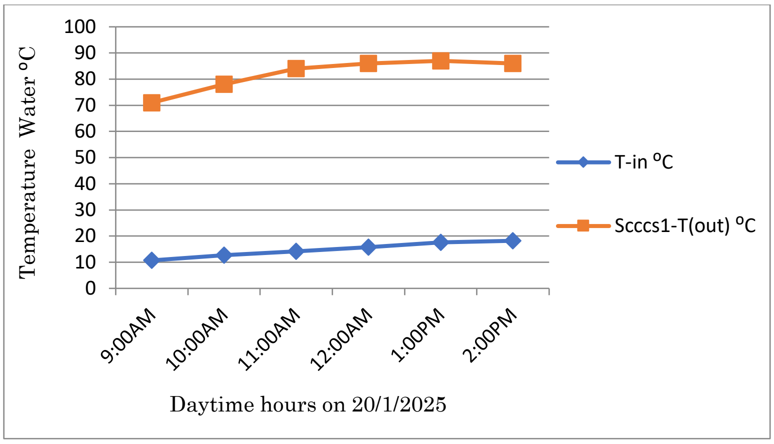

Fig.18. The graph shows the behavior of the operation and temperature of the water of the Scccs1 on 20/1/2025 (sunny 20 ºC) When it is fixed

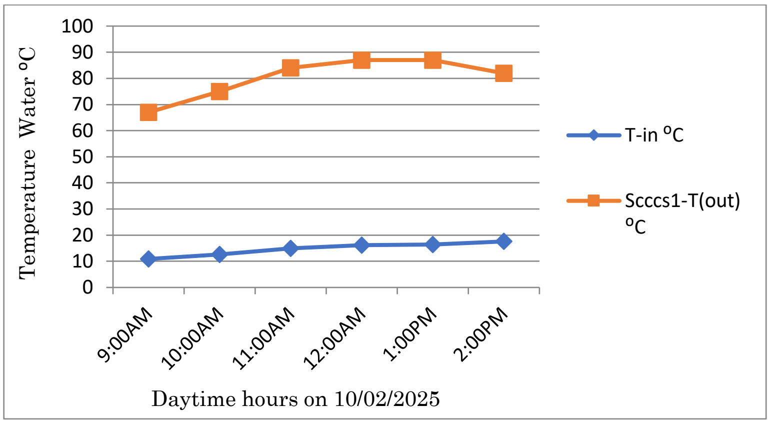

Fig.19. The graph shows the behavior of the operation and water temperature of the Scccs1 on 10/2/2025 (sunny 18 ºC) When it is fixed

Figure (16), (17), (18), and (19) illustrate the operating behavior of the solar collector Scccs1, and the water temperatures generated by the solar collector. It was observed that the operation of the Scccs1 was stable under various weather conditions, with its remaining horizontally aligned toward the sun at 11:00 am without rotation. In winter, the solar collector Scccs1 recorded the highest midday temperature (87ºC) on 1/12/2024 via the Scccs1-V2 valve. It recorded (81ºC) on 23/12/2024, (90ºC) on 20/1/2025, and (87ºC) on 10/2/2025 via the same valve.

By observing and studying the temperature of the water produced by the solar collector Scccs1, the results show that the thermal efficiency of the Scccs1 solar collector is high. We will later compare these results with the readings recorded by the model when this is rotated horizontally toward the sun.

- **Inspection and Testing When Rotating the Solar Collector (Scccs1)**

At the beginning of each inspection day at 9:00 am, the Scccs1 is oriented perpendicular to the sun. Manually adjust the tilt angle of the Scccs1 (15° in summer and 45° in winter) relative to the horizon for optimal performance. Scccs1 is also oriented horizontally during daylight hours. The water tank Scccs1-A2 is emptied, and the emptying and orientation process is repeated after each inspection hour during daylight hours. The solar collector Scccs1 receives water from the external tank via a plastic hose connected to the solar collector through the inlet valve Scccs1-V1 (the water is connected from the equipment to the tank Scccs1-A1 via a rubber hose). After the tank Scccs1-A1 is filled with water, it starts to flow in the copper tubes, gaining heat until it reaches the branching point of the copper tube inside Scccs1. The water exits from the Scccs1 via the valve Scccs1-V2 for inspection and use, or it is collected in the tank Scccs1-A2 via the branching of the second copper tube, and then exits from the Scccs1 via the valve Scccs1-V3 for inspection or use.

The hourly temperature of the weather (T_{air}), the inlet water of the solar collector through valve V1 (T_{in}) (the supplied source water), the outlet water of the Scccs1 via the valve Scccs1-V2 (T_{out}), the outlet water of the Scccs1 via the valve Scccs1-V3 (T_{tank}) (the outlet water of the tank Scccs1-A2), the temperature of the room (T_f) containing the copper tube and the tank Scccs1-A (the space between the front glass cover and the absorber surface), the glass temperature T_g (the front convex glass cover of the Scccs1), and the air temperature of the room (T_b) (the area between the absorber and the back surface of the Scccs1) was recorded. The graphs in Figures (20), (21), (22), (23) of the recorded readings showed the operating behavior of Scccs1 when it was rotated horizontally towards the sun on 2/12/2024 (sunny 20 ºC), 22/12/2024 (partially cloudy 19 ºC), 21/1/2025 (sunny 20 ºC), and 9/2/2025 (sunny 18 ºC), respectively.

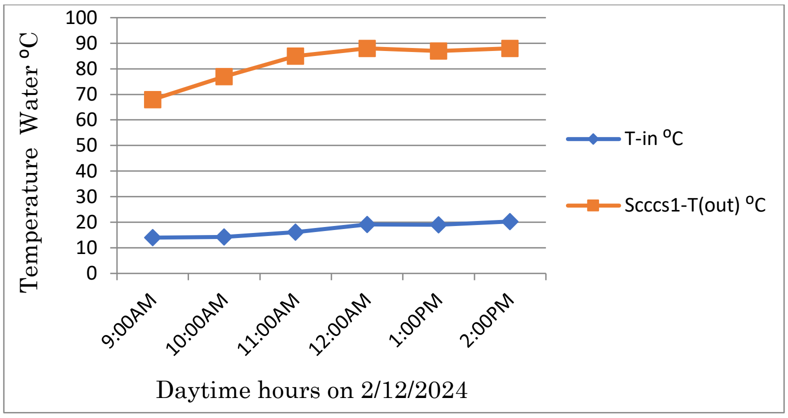

Fig.20. The graph shows the behavior and temperature of the water of the Scccs1 on 2/12/2024 (sunny 20 ºC) when the collector rotates horizontally to be perpendicular to the sun

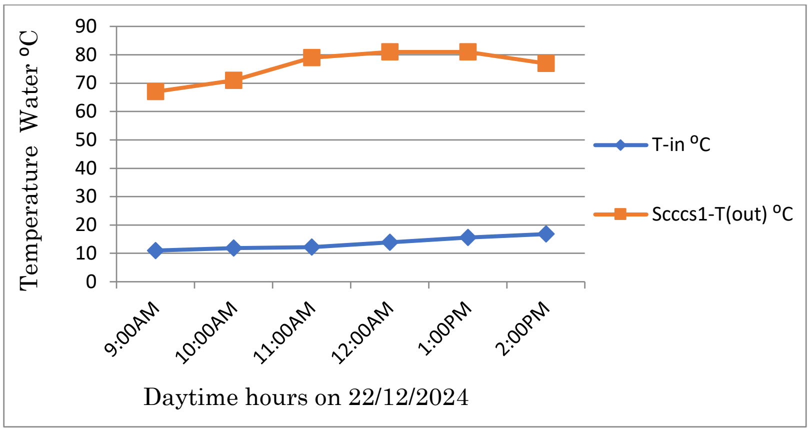

Fig.21. The graph shows the behavior and temperature of the water of the Scccs1 on 22/12/2024 (partly cloudy, 19 ºC) when the collector rotates horizontally to be perpendicular to the sun

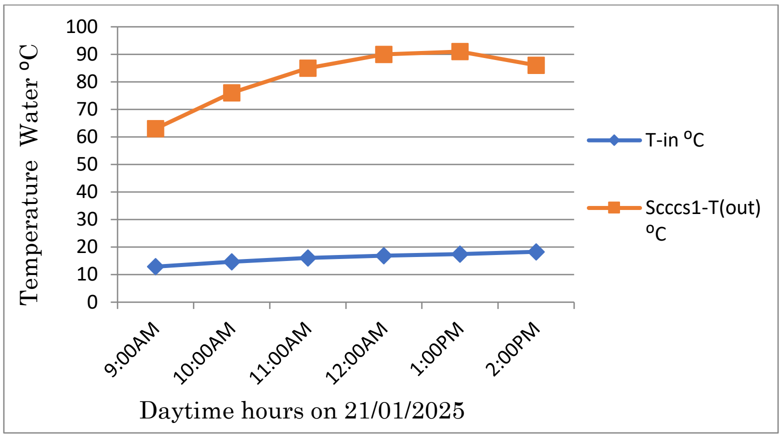

Fig.22. The graph shows the behavior and temperature of the water in the Scccs1 on 21/1/2025 (sunny 20 ºC) when the collector rotates horizontally to be perpendicular to the sun

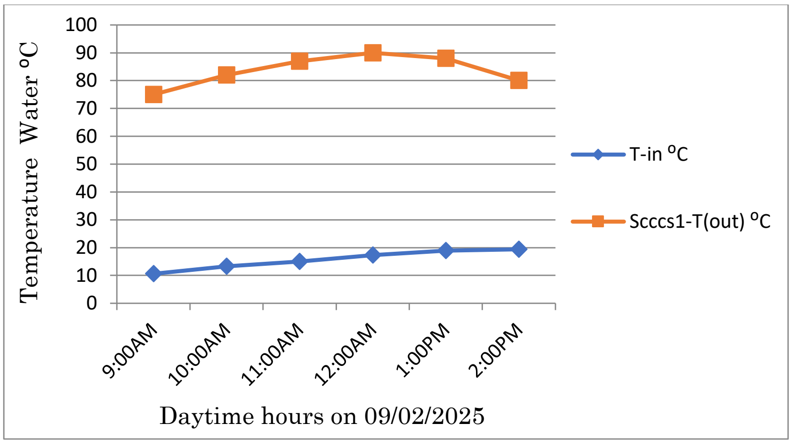

Fig.23. The graph shows the behavior and temperature of the water in the Scccs1 on 9/2/2025 (sunny 18 ºC) when the collector rotates horizontally to be perpendicular to the sun

Graphs (20), (21), (22), (23) show the operating behavior of Scccs1, and the water temperatures generated by the Scccs1. It was observed that the operation of the Scccs1 was stable under different weather conditions, with them being continuously rotated horizontally towards the sun during their daytime operation, so that the front surface was perpendicular to the sun. In winter, the solar collector

Scccs1 recorded the highest midday temperature (88ºC) on 2/12/2024 via the valve Scccs1-V2, and (81ºC) on 22/12/2024, and (91ºC) on 21/1/2025, and (90ºC) on 9/2/2025 via the same valve.

By observing and studying the temperature of the water produced from the solar collector Scccs1, the results show that the thermal efficiency of the solar collector Scccs1 is high. We find that the result is almost identical by comparing the results and readings recorded in Table (6) by the model, Scccs1, when rotated or fixed horizontally. We conclude from this that the success of the (corrugated-convex) geometric design in simulating the horizontal movement of the sun, and there is no need to rotate this model horizontally to be perpendicular to the sun, which is proof of one of the most important objectives of the study. This increases the use of this design in remote locations such as oil field laboratories, remote oil sites, agricultural laboratories in agricultural fields, and countless other uses.

Table 6. Shows the results recorded by the solar collectors in the rotating and stationary conditions

Condition of the collector	Date	Weather conditions and temperature (°C)	Scccs1 (Tout Cº)
When rotating the collector towards the sun	02/12/2024	sunny 20 ºC	88
	22/12/2024	partially cloudy 19 ºC	81
	21/1/2025	sunny 20 ºC	91
	09/02/2025	sunny 18 ºC	90
When installing the collector toward the sun at 11:00 am	01/12/2024	sunny 20 ºC	87
	23/12/2024	partially cloudy 20 ºC	81
	20/1/2025	sunny 20 ºC	90
	10/2/2025	sunny 18 ºC	87

3.4 The Air Chamber as a Thermal Insulator and the Rate of Thermal Energy Loss

Not all of the absorbed thermal energy can be useful. A portion of the energy is lost due to heat loss from the solar collector to the surrounding environment. Effective thermal insulator can reduce this loss

The loss of thermal energy from the rear surface of solar collectors is of great importance because it causes the solar collector to lose a significant amount of the acquired thermal energy, reducing its efficiency. Therefore, researchers have used several expensive and environmentally harmful thermal insulators.

To reduce or prevent thermal energy loss from Scccs1, an air chamber was constructed in the geometric shape of the Scccs1. This chamber acts as a thermal insulator by taking advantage of the greenhouse effect generated within it, as it is completely insulated, preventing air from entering or exiting. To determine the efficiency of the air chamber as an alternative thermal insulator to known insulators (glass wool, foam, etc.), the following mathematical calculations were performed by applying the Equation for the rate of thermal energy loss [30] .for the collector:

$$Q = K \, . \, A \, \frac{\Delta T}{\Delta X} \tag{1}$$

$$\Delta T = (T2 - T1) \tag{2}$$

Where K is the thermal conductivity coefficient in W/m. K, A is the surface area between the two loss zones in m^2, ΔT is the temperature difference between the two loss zones measured in K (Kelvin), and equals (T2 - T1), ΔX is the thickness of the heat loss zone. As shown in Figure 4. Equations (1) and (2) were applied to the readings recorded for 20/1/2025, and the results were as shown in Table 7.

q_1 is the loss between the front chamber facing the sun (the area between the glass cover and the absorption surface) and the insulating air chamber (the area between the absorption surface and the back surface of the solar collector), i.e., the thickness of the absorption surface represents ΔX.

q_2 is the loss between the insulating air chamber (the area between the absorber surface and the back surface of the solar collector) and the outside weather, where ΔX is the thickness of the back surface of the solar collector.

q_3 is the loss between the front chamber facing the sun (the area between the glass cover and the absorption surface) and the outside weather, considering the insulating air chamber's thickness being ΔX.
q_4 is the loss between the front chamber facing the sun (the area between the glass cover and the absorption surface) and the outside weather if there is no air chamber behind the solar collector, i.e., the thickness of the absorption surface represents ΔX.

Table 7. Shows the amount of thermal energy loss from the back surface of the Scccs1

Type of Solar Collector	Time	Date	q_1 W/m^2	q_2 W/m^2	q_3 W/m^2	q_4 W/m^2
Scccs1	12:00pm	20/01/2025	32647650	8107569	13	35148792

By comparing the results of q1, q2, q3, q4 to know the efficiency of the air chamber as an alternative insulator, it is clear that the rate of thermal energy loss from the back surface of the solar collector Scccs1 in the presence of the air chamber is much less than the loss in the absence of the air chamber, and this proves the work of the air chamber as an alternative insulator to the used insulators and reduces the thermal energy loss from the back surface of the collector to the minimum possible, Where (q4 >> q3). The heat loss rate is almost zero. Since the insulating air chamber wall is made of metal, it has the ability to absorb heat from the outside environment. This raises the temperature of the back side of the absorption surface, which further increases the temperature of the copper tube carrying the water inside the collector. This helps the water reach a boiling temperature of +100 degrees Celsius, producing sterile water.

3.5 Thermal Efficiency of Solar Modules (Scccs1)

Thermal efficiency is an essential factor determining collector performance. Incident solar radiation, collector area, and heat retention affect the collector's thermal efficiency.
The thermal efficiency of the manufactured solar collector, Scccs1, was calculated at specific times of the day after measuring the hourly temperature of the incoming and outgoing water using electronic thermometers, the quantity of water inside Scccs1, and the solar radiation using the AWOS solar radiation measurement system. To calculate the efficiency, the Equation [31, 32] was used:

$$\eta = m.\ C_p\ (T_{out} - T_{in}) /\ I.A \qquad (3)$$

Where: η is the thermal efficiency of the solar collector, m= 6.85 kg, C_P is the specific heat of water (4.186 J/kg.°C), T_{out} is the temperature of the water leaving the solar collector in °C, T_{in} is the temperature of the water entering the solar collector in °C, I is the incident solar radiation intensity in W.h/m^2, and A is the collector area in m^2. The collector surface area is calculated in [33] units:

$$A = 2\ (2.\ \pi.\ r_1.\ h_1 + \pi.\ r_1^2 + \pi.\ r_1^2) + (2.\ \pi.\ r_2.\ h_2) \qquad (4)$$

A: Surface area exposed to solar radiation. It includes the tanks A1&A2, and copper tube areas. A = 0.64 m^2.
r_1 is the radius of the cylinder (tanks A1, A2), and h1 is the height of the tank.
r_2 is the radius of the copper tube, and h2 is the length of the copper tube.
By applying equations (6) and (7) to the readings recorded by Scccs1, Table 8 shows the thermal efficiency η for each collector.

Table 8. Shows the thermal efficiency of the solar collector Scccs1

Type of Solar Collector	Time	Date	Tout °C	Tin °C	I(W.h/m2)	η %
Scccs1	12:00pm	28/11/2024	90	17	1757	**86**
		02/12/2024	88	17	1526	**90**
		20/01/2025	89	15	2175	**53**
		09/02/2025	90	16	2227	**49**
		10/03/2025	93	20	2618	**25**
		23/04/2025	94	36	3256	**80**
		22/05/2025	100	46	3121	**78**
		02/06/2025	105	46	3365	**77**

From a study of Table 8, it is observed that the Scccs1 solar collector operates in a stable manner. There is a convergence in the temperature of the produced water (T_{out} ºC) between winter and summer, despite differences in weather temperature, wind speed, and solar radiation intensity. This indicates that the Scccs1's engineering design is successful in collecting and retaining heat and producing high-temperature water, and that this design is interesting.. The variation in thermal efficiency is due to differences in solar radiation intensity. Therefore, the Scccs1 can be operated in many countries around the world.

Nomenclature

Symbol	Symbol Definition	Unit of Measurement
Scccs1	Solar collector with direct absorbing surface (corrugated-convex)	
Scccs1-A1	The tank that receives water coming from the source (external tank) through valve V1 and the water is inlet to Scccs1	
Scccs1-A2	Hot water collection tank from Scccs1	
Scccs1-V1	Source water inlet valve to Scccs1 and connected to tank A1	
Scccs1-V2	Scccs1 hot water outlet valve	
Scccs1-V3	Water outlet valve from hot water collection tank A2 to outside Scccs1	
Scccs1-H1	Room temperature gauge hole behind the glass cover	
Scccs1-H2	Insulated air chamber temperature gauge port	
T (in) = Tin	Source water temperature	**ºC**
T(air) = T_a	Air temperature	**ºC**
T(out) = T_{out}	Temperature of the water leaving the solar collector through valve V2	**ºC**
T(Tank) = T_{tank}	Temperature of water leaving the tank (A2) via valve V3	**ºC**
T(glass) = T_g	Collector glass cover temperature	**ºC**
T(behind)= T_b	Insulating air room temperature	**ºC**
T(Front)= T_f	Room temperature behind the glass cover	**ºC**
m	Water mass inside the solar collector	**Kg**
C_p	Specific heat of water	**J/Kg.ºC**
T_1	Heat-gaining area temperature	**ºC**
T_2	Heat loss zone temperature	**ºC**
I	The intensity of incident solar radiation multiplied by the number of hours of exposure to radiation.	**W .h/m^2**
A_c	Solar complex area	**m^2**
r_1	Radius of cylindrical tank (A1, A2)	**m**
r_2	Copper tube radius	**m**
h_1	Tank height (A1, A2)	**m**
h_2	Length of copper tube	**m**
K	Thermal conductivity coefficient	**W /m . K**
A	Surface area between the two heat loss zones	**m^2**
ΔT	temperature difference between the two loss zones	**K**
ΔX	Thickness of the heat loss zone	**m**
q	thermal energy loss	**W/m^2**
η	Thermal efficiency of the solar collector	

3.6 Economic Cost

Raw materials available in the local market were used, according to the current price of materials (1 US dollar = 1320 Iraqi dinars). Table 9 shows the manufacturing costs of Scccs1 in detail.

Table 9 .shows the details of the manufacturing cost of the Scccs1.

Materials	**Number & Details**	**The cost I.D.**
		Scccs1
Copper tube (diameter 0.95 cm)	12 m	12000
high pressure plastic hose	5 m	1250
Valve to control the speed of water flow	3	1500
Galvanized iron cylindrical tank (3L capacity)	2	6000
Aluminum plate (0.2 cm thickness)	0.93 m^2	7250
Screws of different sizes	///	1500
Matte black paint	3	3000
spinning wheels	3	3000
A square iron pipe with a side length of 3.81 cm	8.76 m	9000
Clear glass sheet (0.4 cm thickness)	0.84 m^2	5000
Iron plate (0.2 cm thickness)	2.5 m^2	7500
Adhesive (silicone rubber)	1	1000
Aluminum ruler with a 90-degree angle	3.5 m	3000
Aluminum brackets for fixing the copper tube	48	3000
Total		64000 I.D.

From Table 9, it is noted that the cost of manufacturing the solar collector is 64000 I.D. The cost of manufacturing the Scccs1 is much lower than that of any other solar, electric or gas heater. A study of the operational lifespan of the materials used in manufacturing the Scccs1 solar collector (galvanized iron, copper, aluminum, and glass) revealed that the collector's lifespan ranges from 5 to 10 years, a long period compared to other water heaters available on the market. This supports individual income, thus bolstering the national economy and saving foreign currency.

Maintenance costs are reasonable in terms of spare parts. The largest component in the collector is the absorber plate, and the cost of replacing an absorber plate is 25250 I.D., which is affordable for all segments of society. It is important to note that the materials used in manufacturing the collector are readily available in local markets, as well as being produced within the country. The economic return from using the Scccs1 solar collector will save users a lot of money.

Alternatively, the copper tube can be replaced with an aluminum tube to reduce the cost of producing the solar collector to 50,000 Iraqi dinars, or the absorber plate and copper tube can be made of galvanized iron (the same galvanized iron used in water coolers). We used the copper tube because it is easy to bend in local workshops. Manufacturing the Scccs1 solar collector in large factories will certainly reduce the manufacturing cost to 35,000 Iraqi dinars.

4. Conclusion

Through design study and practical experience of Scccs1, it was shown that the convexity of the front surface and the convexity of the corrugated absorption surface gave this model a special advantage, eliminating the need for continuous horizontal orientation of the collector to be perpendicular with the sun (i.e., Scccs1 remained in the same direction from sunrise to sunset, and it remains horizontally fixed towards the sun at 11:00 am without rotating). This feature is a new addition to sustainable energy that should be considered independently. The iron base upon which Scccs1 rest allowed them to rotate horizontally and vertically toward the sun easily. The presence of an air chamber behind the absorption surface significantly reduced thermal energy loss from the collector's rear surface, eliminating the need for expensive and environmentally harmful thermal insulators. The engineering design has succeeded in enabling the air chamber behind the absorber surface to act as an effective thermal insulator by applying basic principles of thermal physics, thus reducing thermal energy loss. Scccs1 operated efficiently in cloudy and partly cloudy weather. The Scccs1 solar collector produces sterile water at a temperature of 100°C.

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تصميم هندسي جديد لمجمع الطاقة الشمسية Scccs1 ذو سطح امتصاص مباشر (مموج-محدب) لتسخين المياه بالطاقة الشمسية وتعقيمها

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الملخص

صُمم المجمع الشمسي Sccs1 بسطح امتصاص مباشر (متموج-محدب) لمحاكاة الحركة الأفقية للشمس. دُمج مع سخان شمسي لتشكيل نظام شمسي ذي دوران طبيعي لتسخين وتعقيم المياه باستخدام الطاقة الشمسية. دُرست كفاءة وأداء Sccs1 نظريًا وعمليًا في ظل ظروف جوية مختلفة في البصرة. يتميز هذا النموذج بتصميم هندسي جديد. يتميز Sccs1 بسطح امتصاص مباشر مصنوع من الألومنيوم، مطلي بلون أسود غير لامع لتعزيز قدرة السطح على امتصاص الحرارة. تم دمج المجمع الشمسي مع نظام تخزين حراري (خزانات مياه داخل المجمع A1 وA2). يتم تخزين المياه وتسخينها باستخدام الطاقة الحرارية المجمعة من مراحل اكتساب الحرارة في النظام الشمسي. تم تقييم هذا النظام تجريبيًا في ظل ظروف تحميل مختلفة. أظهر جهاز SCCCS1 أداءً فعالاً، مسجلاً درجات حرارة تراوحت بين 81 و105 درجات مئوية لمياه الإخراج، وبين 50 و90 درجة مئوية لمياه التخزين، وذلك خلال الفترة من نوفمبر 2024 إلى يونيو 2025. هذه الحرارة كافية لتعقيم المياه. لا يتطلب النظام دورانًا أفقيًا نحو الشمس. وقد أظهرت الاختبارات التجريبية أن تموج سطح الامتصاص والسطح الأمامي المحدب للنظام يحاكيان الحركة الأفقية للشمس خلال ساعات النهار. عمل جهاز SCCCS1 بكفاءة في ظروف غائمة وشبه غائمة مع انخفاض درجات الحرارة. ففي الظروف الغائمة جزئيًا، كانت درجة حرارة مياه الإخراج 81 درجة مئوية، و56 A2 درجة مئوية. أما في الظروف الغائمة تمامًا، فكانت درجة حرارة مياه الإخراج 54 درجة مئوية، و34 A2 درجة مئوية.

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