

PAPER • OPEN ACCESS

## Experimental investigation for solar thermal hybrid installs to inverter air conditioning vapour-compression cycle system

To cite this article: Ahmed Al-Rubaye 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **557** 012079

View the [article online](#) for updates and enhancements.

# Experimental investigation for solar thermal hybrid installs to inverter air conditioning vapour-compression cycle system

Ahmed Al-Rubaye<sup>1,2</sup>

<sup>1</sup> Department of Mechanical Engineering, University of Al-Qadisiyah, Al-Qadisiyah, Iraq

<sup>2</sup> Corresponding author. Email : ahmed.alrubaye@qu.edu.iq

**Abstract.** This study is designed a new development and integration for the solar hybrid system connected to an inverter air conditioning system. This experimental system will provide an essential addition to the renewable energy future. The device is supplying the same cooling load with significantly less electricity demand. Apparatus system has the solar unit and solar collector with DC compressor that was used to compress the refrigerant in an air conditioning system, and that will effectively reduce the air conditioning electricity consumption. The solar collector unit is installed between the compressor and condenser, which provide part of compression pressure and heating by further superheating the refrigerant. The higher pressure and more substantial temperature difference enhance the condensation process in the condenser, resulting in the high-pressure liquid refrigerant. This configuration really reduces energy consumption by reducing the load on the electric compressor.

**Keywords:** Compressor Solar Assisted, DC Compressor, Inverter Air Conditioning, Solar Collector, Vapour-Compression Cycle.

## 1. Introduction

The increasing demand for electric power by the consumer has led to higher tax rates for electricity during the hot summer season in Iraq [1] & [2]. In Iraq, the renewable energies that available from solar energy with wind energy have not effectively invested due to excessive heat that reaches 55°C [3] & [4]. This heat leads to the reduction of solar cell capacity to 45% from real capacity processed. There is an actual need to air-conditioning using the compression systems with high power consumption of electricity [5] & [6]. Many solutions and applications use solar energy in air conditioning [5] & [7]. In Iraq, the maximum and minimum value of solar radiation yearly average is 5596 Wh/m<sup>2</sup>/day and 4266 Wh/m<sup>2</sup>/day [8]. Solid Desiccant, reduce moisture content in pure ambient air wheel rotates sluggishly, air flows through by separated into two sectors to be dehumidified and other sectors to renew the wheel [9]. Liquid Desiccant, same behave solid desiccants, the water vapor pressure is a role of temperature with moisture content [10] & [11] Most of the applications of air conditioning are derived from renewable energy, which has not achieved as an alternative to traditional compression cycles with the effect on the coefficient of performance [12] and the cooling of temperatures at increasing temperatures in the summer, and with the exceptional situations of heat such as Iraq.

The aim of this experimentally to improve performance coefficient and reduce the power consumption of the air conditioner to less than of the original value by using a solar heat exchanger with the system and using of an air conditioner split inverter device (12000Btu/h). In this work, a solar thermal radiation has been used to make up the energy provided to the system, that is the same value required (12000 Btu/h), after lowering the energy required from the compressor that connected to regular



power supply to minimum speed (3105Btu/h). The solar thermal radiation has been achieved by the heat exchanger placed after compressor DC.

## 2. The apparatus described

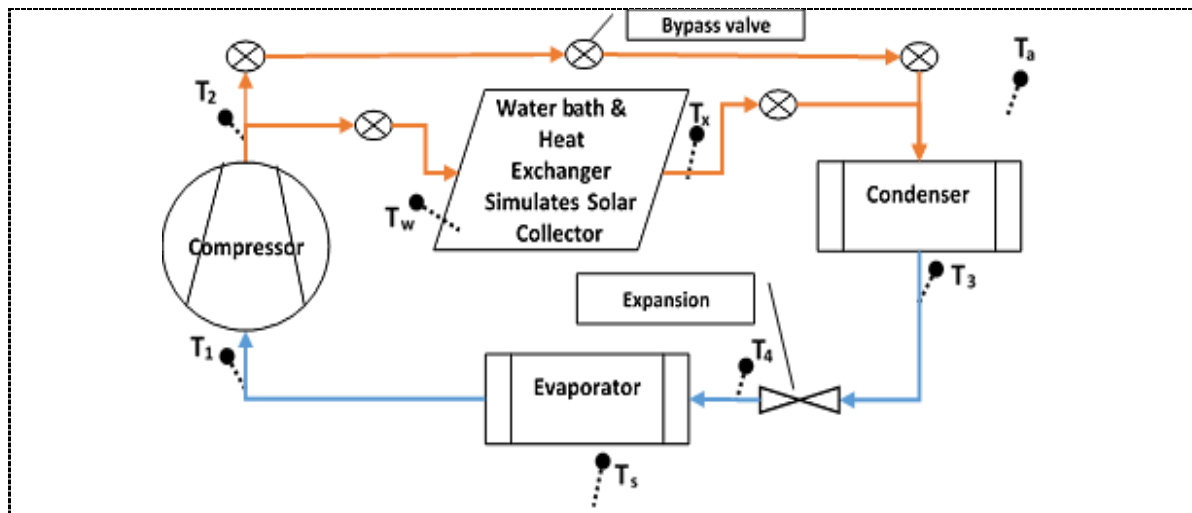
Experimentation was completed and installed on the Laboratory Unit at the Faculty of Engineering / University of Qadisiyah, Iraq [13]. Used vapor-compression cycle compressor DC (wall type split unit). External heat exchanger immersed in water path connected between DC compressor and condenser. Control the cooling fluid flow by valve between in and out heat exchanger, and bypass valve to closed recycle to pass flow before heat exchanger see Table 1. The LM35 temperature sensor was used as a semiconductor with very high accuracy ( $\pm 0.5$ ) where the linear relationship between voltage and temperature was assumed. Table 2 demonstrated the eight sensors distribution that use micro-shape processing unit (Arduino), calibration of sensors that a connection with the computer and output data as an Excel file for recording readings. Measuring power consumption and the value of voltages and current are shown in 'figure 1', 'figure 2' and 'figure 3'.

**Table 1.** Shows the specifications of the device and parts experimental

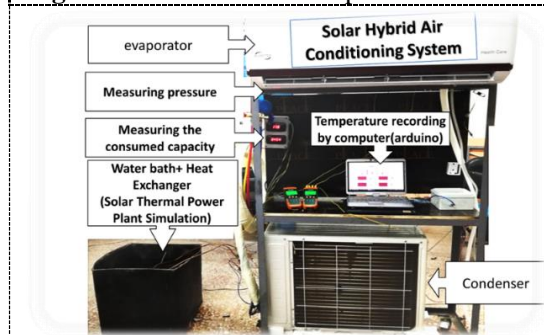
Category	Unit
Min. Cooling Capacity	3105Btu/h
Max. Cooling Capacity	13000Btu/h
Starting Current	1.25 A
Running Cooling	5A
Refrigerant / Charge	R410A /1.2kg
Power Compressor/type Structure	DC Power / Twin Rotary
Heat Exchanger	Pipe Coil coper 10 m $\square$ 1/4"
Valve Pipe $\square$ 1/4"	5 Parts
water path	heat water (65 $\square$ 90) °C

**Table 2.** Shows the name of the sensor with its location in the device.

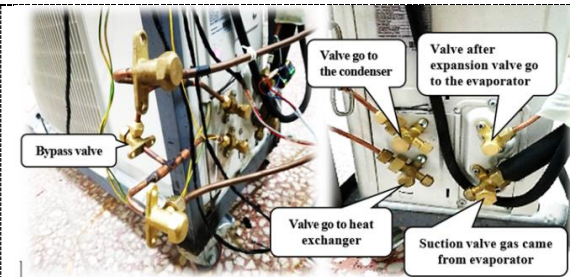
Site	Label temp. sensors
T <sub>1</sub>	Before the compressor. Discharge pipe
T <sub>2</sub>	After compressor charging tube
T <sub>3</sub>	After the condenser. Before expansion
T <sub>4</sub>	After expansion. Before the evaporator
T <sub>x</sub> =T <sub>5</sub>	After the heat exchanger before the condenser
T <sub>a</sub> =T <sub>6</sub>	Ambient temperatures
T <sub>s</sub> =T <sub>7</sub>	The processed temperatures of the condenser
T <sub>w</sub> =T <sub>8</sub>	Heat the heated water in the water bath



**Figure 1.** Scheme device experimental.



**Figure 2.** Actual structure cycle.



**Figure 3.** Connect the pipe structure with the valve.

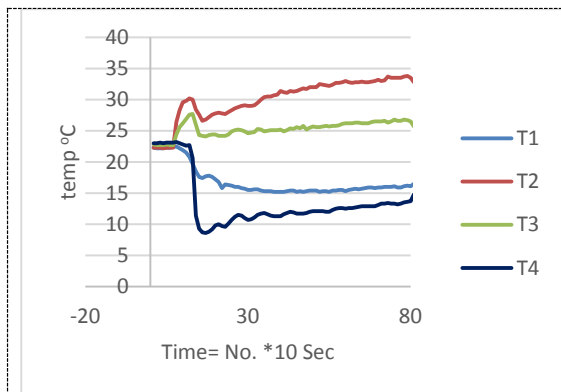
### 3. Experimental procedure

The experiment was conducted by recording readings of temperatures from all sensors in standard laboratory. The first case is to completely closure of the cycle by open the bypass valve and close in-out valves in the external heat exchanger. The second case closes the bypass valve and completely closure of the cycle through open in-out valves in the external heat exchanger.

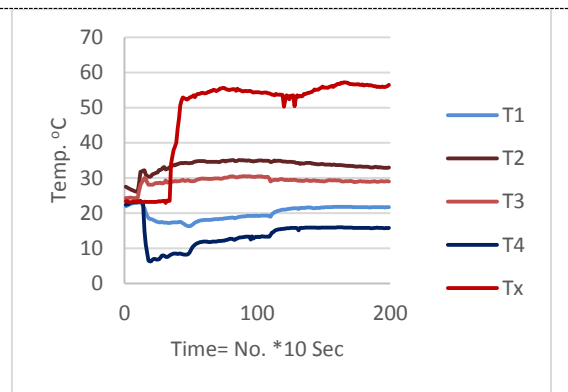
#### 3.1. Measurements

The readings and record were taken in two stages, with and without a water bath. That records the temperature, high and low pressures for cycle cooling, and power consumption. The recording temperature time from unstable primary state to a stable state to show two state 'figure 4' and 'figure 5'.

The text of your paper should be formatted as follows:



**Figure 4.** It shows the temperature readings with time, where each number represents 10 seconds without the thermal solar collector enters with automatic mode of operation.



**Figure 5.** It shows the temperature readings with time, where each number represents 10 seconds with the thermal solar collector enters with automatic mode of operation.

#### 4. Calculations and results

The experimental procedure showed the effect on the cooling cycle and the performance factor with the consumption in the processed capacity. Used for calculations engineering equation solver (EES) software [14].

##### 4.1. Calculations without Compressor Solar Assisted in standard comfort conditions

The voltage of the compressor with the current used (voltage = 130 volt & current = 1.87 A). The enthalpy values were calculated from the intersection of high and low pressure values used equation (1-5) with the recorded temperatures before and after each part of the compressive system. The diagram was then drawn and the results obtained for the completed work were calculated from the plan, taking into account the efficiency of the compressor and the calculation of the real work extracted from the plan. Calculation of Performance Factor Cooling from Freon Cooling Scheme shows in the 'figure 6'.

Case 1:

$$P_1 = 12(\text{bar})$$

$$T_1 = 16(^{\circ}\text{C})$$

$$h_1 = h_{R410a}, T = T_1, P = P_1$$

Case 2:

$$P_2 = 23(\text{bar})$$

$$T_2 = 55(^{\circ}\text{C})$$

$$h_2 = h_{R410a}, T = T_2, P = P_2$$

$$W_{\text{comp}} = h_2 - h_1 = 23.2 \text{ kJ/kg} \quad (1)$$

Case 3:

$$P_3 = 24(\text{bar})$$

$$T_3 = 26(^{\circ}\text{C})$$

$$h_4 = h_{R410a}, T = T_3, P = P_3$$

Case 4:

$$P_4 = 12(\text{bar})$$

$$T_4 = 15(^{\circ}\text{C})$$

$$h_4 = h_3$$

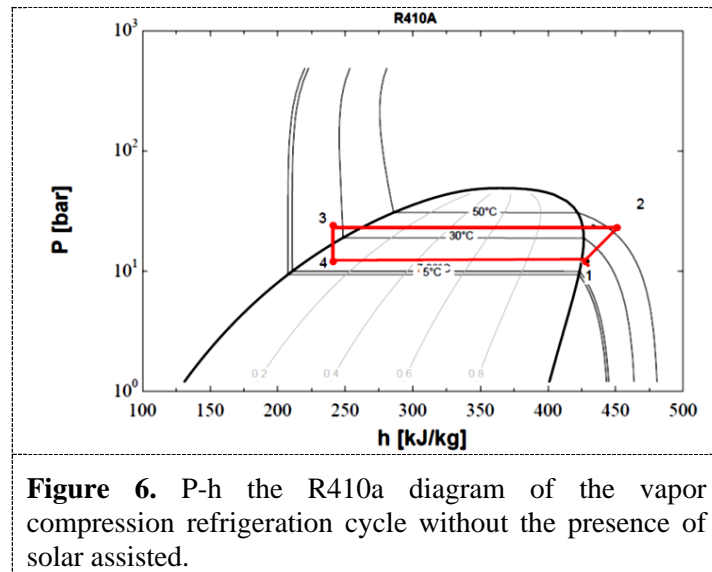
$$\eta = 0.85$$

$$W_{\text{comp,Real}} = \frac{W_{\text{Comp}}}{\eta} = 27.29 \text{ kJ/kg} \quad (2)$$

$$Q_{\text{Con}} = h_2 - h_3 = 210 \text{ kJ/kg} \quad (3)$$

$$Q_{\text{Evap}} = h_2 - h_4 = 186.8 \text{ kJ/kg} \quad (4)$$

$$\text{COP}_R = \frac{Q_{\text{Evap}}}{W_{\text{Comp,Real}}} = 6.844 \quad (5)$$



**Figure 6.** P-h the R410a diagram of the vapor compression refrigeration cycle without the presence of solar assisted.

#### 4.2. Calculations with Compressor Solar Assisted in standard comfort conditions

The voltage of the compressor with the current used (voltage = 104 volt & current = 1.178A). The enthalpy values were calculated from the intersection of high and low pressure values used equation (6-13) with the recorded temperatures before and after each part of the compressive system with the solar assisted. The diagram was then drawn and the results obtained for the completed work were drawn from the plan, taking into account the efficiency of the compressor and the calculation of the real work extracted from the plan and the calculation The solar assisted from the solar collector, the networking calculation, the recording voltage and the current consumed by the compressor, and the calculation of the cooling coefficient of the cooling Freon show the 'figure 7'.

Case 1:

$$P_1 = 12(\text{bar})$$

$$T_1 = 16(^{\circ}\text{C})$$

$$h_1 = h_{R410a}, T = T_1, P = P_1$$

Case x:

$$P_x = 23(\text{bar})$$

$$T_x = 55(^{\circ}\text{C})$$

$$h_x = h_{R410a}, T = T_x, P = P_x$$

$$W_{\text{Comp}/x} = h_x - h_2 = 16.02 \text{ kJ/kg} \quad (6)$$

Case 2:

$$P_2 = 21(\text{bar})$$

$$T_2 = 40(^{\circ}\text{C})$$

$$h_2 = h_{R410a}, T = T_2, P = P_2$$

$$W_{\text{Comp}} = h_2 - h_1 = 7.175 \text{ kJ/kg} \quad (7)$$

Case 3:

$$P_3 = 24(\text{bar})$$

$$T_3 = 26(^{\circ}\text{C})$$

$$h_3 = h_{R410a}, T = T_3, P = P_3$$

Case 4:

$$P_4 = 12(\text{bar})$$

$$T_4 = 15(^{\circ}\text{C})$$

$$h_4 = h_3$$

$$\eta = 0.85$$

$$W_{\text{Comp}/\text{Real}} = \frac{W_{\text{comp}}}{\eta} = 8.442 \text{ kJ/kg} \quad (8)$$

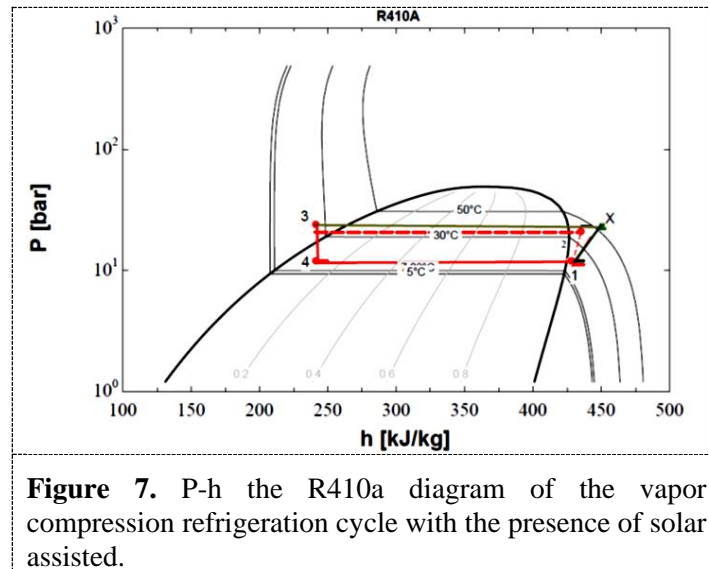
$$Q_{\text{Con}} = h_2 - h_3 = 194 \text{ kJ/kg} \quad (9)$$

$$Q_{\text{Con}/x} = h_x - h_3 = 210 \text{ kJ/kg} \quad (10)$$

$$Q_{\text{Evap}} = h_1 - h_3 = 186.8 \text{ kJ/kg} \quad (11)$$

$$W_{\text{Net}} = W_{\text{Comp,Real}} + W_{\text{comp,X}} = 24.46 \text{ kJ/kg} \quad (12)$$

$$\text{COP}_R = \frac{Q_{\text{Evap}}}{W_{\text{Net}}} = 7.635 \quad (13)$$



The thermal performance coefficient values were obtained in both cases with and without the solar assisted when the comparison was made. The high coefficient of thermal performance in the case of running the solar assisted and the low pull of the current consumed by the compressor that reduced compressor consumption from the planned cooling cycle for Freon R410a as shown in Table 3.

**Table 3.** The final results with and without the compressor Solar Assisted show the thermal performance values, the processed capacity, and the conventional compressor.

State	current I (A)	Voltage V (V)	$W_{\text{compReal}}$ (kJ/kg)	$Q_{\text{Evap}}$ (kJ/kg)	$\text{COP}_R$ From chart R410a
Without Solar	1.87	130	27.29	186.8	6.844
With Solar	1.178	104	8.442	186.8	7.635

## 5. Conclusions

The solar air conditioning system is a great innovation that drives solar energy leaps while enhancing the positive effect on the environment. This project provides a comprehensive energy-saving comparison that can be achieved for various air-conditioner capacities ranging from Btu / h 2388 Btu / h to 24,000 Btu / h. The system is capable of achieving up to 45% energy saving during the day and thus dramatically reduces the peak load of electricity during the day. At the same time, the DC compressor will contribute up to 25% energy saving overnight. The main modifications needed are the compressor (DC). In addition, thermal storage and photoelectric system proposed to provide future cycle performance.

## References

- [1] Al-Salihi, A. M., Kadum, M. M., & Mohammed, A. J. 2010 *Estimation of global solar radiation on horizontal surface using routine meteorological measurements for different cities in Iraq*. (Asian Journal of Scientific Research) vol 3 (4) p 240-248.
- [2] Al-Rubaye R T A, Al-Rubaye A T A and Al-Khuzai M M 2018 *Optimal Design of Hybrid Renewable Energy System off grid in Al-Diwaniyah*, (Iraq IOP Conf. Ser. Mater. Sci. Eng 454 012103)
- [3] Al-Abidi, A. A., Mat, S. B., Sopian, K., Sulaiman, M. Y., Lim, C. H., and Th, A. 2012 *Review of thermal energy storage for air conditioning systems*. (Renewable and Sustainable energy reviews) No vol 16 (8) p 5802-5819.
- [4] Patil, M., Jahagirdar, R., & Deore, E. 2012 *Experimental investigation of heat loss from hemispherical solar concentrator receiver* (Frontiers in Heat and Mass Transfer) 3(3).
- [5] Daut, I., Adzrie, M., Irwanto, M., Ibrahim, P., and Fitra, M. 2013 *Solar powered air conditioning system* (Energy Procedia) vol 36 p 444-453.
- [6] Boulahia, Z., Wakif, A., Chamkha, A. J., & Sehaqui, R 2017 *Numerical study of natural and mixed convection in a square cavity filled by a Cu–water nanofluid with circular heating and cooling cylinders* (Mechanics & Industry) vol 18 (5) p 502.
- [7] Al-chlahawi K, Al-farhany K and Al-Rubaye A 2018 *Experimental Investigation of Solar Thermal Collector on the Open Parabolic Trough* (Journal of Engineering and Applied Sciences) vol 13 no 16 p 6873-6878.
- [8] Rehman, S., Alam, M. M., Meyer, J. P., & Al-Hadhrani, L. M. 2012 *Feasibility study of a wind–pv–diesel hybrid power system for a village* (Renewable energy) vol 38 (1) p 258-268.
- [9] Hussein, A. K. 2015 *Applications of nanotechnology in renewable energies—A comprehensive overview and understanding* (Renewable and Sustainable Energy Reviews) vol 42 p 460-476.
- [10] Maouassi, A., Baghidja, A., Douad, S. and Zeraibi, N. 2018 *Heat exchanges intensification through a flat plat solar collector by using nanofluids as working fluid* (Frontiers in Heat and Mass Transfer) 10.
- [11] Assadi, M. K., Gilani, S. I., & Yen, T. J. 2016 *design a solar hybrid air conditioning compressor system* (In MATEC Web of Conferences) Vol. 38 p. 02001 EDP Sciences.
- [12] Al-Rubaye A, Al-farhany K and Al-chlahawi K 2018 *performance of a portable thermoelectric water cooling* (International Journal of Mechanical Engineering & Technology) vol 9 p277–85.
- [13] Al-Rubaye, A., Abas, K., Jaleel, Z., Nadhim, A., Khulaibs, G. 2017 *Design of solar hybrid air conditioning system* (Graduation Project in Department of Mechanical Engineering, University of Al-Qadisiyah).
- [14] Yunus, C. A., & Afshin, J. G. 2011 *Heat and mass transfer: fundamentals and applications* (Tata McGraw-Hill, New Delhi, India).

## Acknowledgments

We are thankful to all supported by Faculty of Engineering at University of Qadisiyah. We have to express out appreciation to the Dr. Khaled Al-Farhany for sharing their pearls of wisdom with us during the research. We are also immensely grateful to Zain Alabdien Jaleel, Karrar Abas, Ahmed Nadhim, and Ghufraan Khulaibs for their help. We are also grateful to Dr Rana Alrubaye who moderated this paper and in that line improved the manuscript significantly.