

## Experimental Study of the Performance of Fluorescence Collector

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### ABSTRACT

The luminescent concentrator which used consisting of organic fluorescence dyes such as Rhodamine 6G doped in article Polyvinyl alcohol (PVA) to configure a specific membrane thickness, and then put these films on the glass plate solar collector model with energy halogen Lamp (1000 Watt) as a source of light to represent of fluorescence collector.

Examining the effect of these pigments on the efficiency of the solar collector as a function of the temperature difference between the water inside and outside of the solar collector. Where the increasing in the amount of the difference between the temperature refers to increasing the efficiency of the performance of solar collector. Results showed that the efficient performance of the solar collector increases with the increase in the intensity of incident light with existence the luminescent concentrator ,where the rising water temperature of (24 K) compared with (20 K) when there is not existence the luminescent concentrator when the intensity of radiation falling (1500 W/m<sup>2</sup>) and increasing efficiency of solar collector to 20% .

**Keywords:** Solar energy, Fluorescence collector, Luminescent concentrators, Fluorcent solar, Rhodamine, Polyvinyl alcohol (PVA)

### دراسة تجريبية لاداء المجمع الوميضي

#### الخلاصة

المركز الوميضي المستخدم مكون من صبغات عضوية متفلورة كمادة الرودامين 6جى المطعم بمادة البولي فينول الكحولي (بي في أي) لتكوين غشاء بسمك معين , ثم وضعت هذه الاغشية على اللوح الزجاجي لمجمع شمسي نموذجي واستخدام مصباح هالوجيني طاقتة (1000 واط) كمصدر للضوء لتمثيل المجمع الشمسي الوميضي

درست تأثير هذه الصبغات على كفاءة المجمع الشمسي كدالة لفرق درجات الحرارة بين الماء الداخل والخارج من المجمع الشمسي . حيث أن الزيادة في مقدار هذا الفرق بين درجات الحرارة يشير الى زيادة كفاءة أداء المجمع الشمسي. النتائج أظهرت ان كفاءة الاداء للمجمع الشمسي تزداد مع زيادة شدة الضوء الساقط بوجود المركز الوميضي حيث ارتفعت درجة حرارة الماء الى (24 كلفن) مقارنة مع

( 20 كلفن ) عند عدم وجود المركز الوميضي وذلك عند شدة أشعاع ساقطة (1500 واط/م<sup>2</sup>) وزيادة كفاءة المجمع الشمسي 20%.

## INTRODUCTION

The first publications on LSCs first appeared in the late 1970s [1,2], and the technology was studied intensely through the early 1980s until limitations of fluorescent organic dyes hindered further development [3,4]. The application of organic and inorganic luminescent materials to the field of photovoltaic's (PVs) involves many interesting challenges for scientists and engineers. The LSC is a unique nonimaging optical device that can be used to concentrate sunlight onto a small area of solar cells. A typical design consists of a polymer plate doped with a luminescent material, such as a fluorescent organic dye, with solar cells optically matched to the plate edges. A luminescent solar concentrator (LSC) consists of a sheet or plate of a transparent material which is doped with a luminescent moiety and to the sides of which are attached solar cells. The bottom is covered with a mirror. The luminescent moieties absorb incident light and re-emit it at a red shifted wavelength. Due to total internal reflection most of the light is trapped inside the plate and guided to the edges, where it is absorbed by the solar cells and converted into electricity [5]. This is shown schematically in **Fig. 1**.

Light is concentrated onto the solar cells because the plate's thickness is small compared to its length and width, the materials cost is low, because the active surface (cheap plastic) is larger than the solar cell surface (expensive semiconductor) and the red-shifted incident light is more efficiently transformed into electricity in the solar cells. In this way the three cost-reducing paths defined above are combined in one device. Additionally, an LSC has the advantage of being able to utilize diffuse as well as direct (sun)light.

In their 1977 paper, Goetzberger and Greubel first "proposed a new principle for solar energy conversion" [6], which was, as they called it, the "fluorescent collector". They identified three practical difficulties to be solved: 'synthesis of dyes with stringent requirements, identification of plastic materials with high transparency and development of solar cells with higher band gaps.' Mainly due to the first of these difficulties, interest for their idea waned because it became clear that the luminescent species used (dyes) had stability issues under illumination. In recent years the subject has again gained some attention, partly due to the promise of quantum dots as luminescent species, and partly in the framework of the Fullspectrum project, which is 'a new PV wave making more efficient use of the solar spectrum'[7]. The three difficulties foreseen by R.Kinderman, Goetzberger and Greubel [8] have been addressed extensively in the recent past. For instance, the quality of dyes on the market today has been shown to be much higher than in was thirty years ago. Secondly, transparent polymer plates have been produced with absorption loss of

the order  $0.5 \text{ m}^{-1}$ . Thirdly, the development of solar cells with higher band gaps has been looked into which has already led to interesting results, such as a 7.1% efficiency achieved with an LSC with four GaAs cells attached to the sides [9].

The aim of this work is to present a technique that can be noted to evaluate the performance of fluorescent collector in term luminescent concentrator to increase the efficiency of solar collectors.

## MATERIALS

In our research used fluorescence dyes that absorb solar radiation in a particular region of the solar spectrum and inspires in other areas, depending on the internal structure of the organic fluorescence dye. In **Fig.2** chart shows the transitions between electronic energy levels where they appear and clear transitions and fluorescence and phosphorescence changes of internal and external [10].

Rhodamine 6G usually comes in three different forms. Rhodamine 6G chloride is a bronze/red powder with the chemical formula  $\text{C}_{27}\text{H}_{29}\text{ClN}_2\text{O}_3$  **Fig.3**. Although highly soluble, this formulation is very corrosive to all metals except stainless steel. Other formulation are less soluble, but also less corrosive. Rhodamine 6G Perchlorate, ( $\text{C}_{27}\text{H}_{29}\text{ClN}_2\text{O}_7$ ), comes in the form of red crystals, while rhodamine 6G tetrafluoroborate, ( $\text{C}_{27}\text{H}_{29}\text{BF}_4\text{N}_2\text{O}_3$ ), appears as maroon crystals [11].

While **Tab. 1**, shows the properties of this dye.

Rhodamine 6G is also used as a laser dye, or gain medium, in dye lasers, and is pumped by the 2nd (532 nm) harmonic from an Nd:YAG laser or nitrogen laser. The dye has a remarkably high photostability, high quantum yield (0.95) [12,13], low cost, and its lasing range has close proximity to its absorption maximum (approximately 530 nm). The lasing range of the dye is 555 to 585 nm with a maximum at 566 nm.

Polyvinyl alcohol (PVA) is one of the most important polymeric materials by its many applications in industry, relative low cost and environmental goodness. PVA is a dielectric material with very high dielectric strength and good charge storage capacity, which, besides is resistant to oil, grease and solvent with good film-forming, emulsifying and adhesive properties. The films obtained with PVA present flexibility, malleability and strain strength. The PVA physical-chemical properties and subsequent applicability depend on degrees of polymerization and hydrolysis and the presence and distribution of its hydroxyl group [13,14].

The composites of PVA with inorganic acids form **Fig.4** a simple system that introduces changes on the electrical conductivity, which adds other properties and have the possibility of very useful applications [15]. This mixture produces bonded complexes and constitutes a relevant base for more complex compounds, which eventually can be used for film preparation. In general, the blends obtained can keep physical properties of polymeric matrix and incorporate new properties from the dopant. Intense researches have been carried out on acid-polymer complexes, which have had good performance in solid state applications such as polymer electrolyte

membrane fuel cells, in solid state electro chromic display , solid state photocells and others, with relatively low-cost material and processing [16,17].

Other names: PVOH; Poly(Ethenol), Ethenol, homopolymer;

PVA; Polyviol; Vinol; Alvyl; Alkotex; Covol; Gelvatol; Lemol; Mowiol

Polyvinyl alcohol (PVOH, PVA, or PVAl) is a water-soluble synthetic polymer (not to be confused with polyvinyl acetate, a popular wood glue).

The properties of Polyvinyl alcohol has excellent film forming **Tab.2**, emulsifying, and adhesive properties. It is also resistant to oil, grease and solvent. It is odorless and nontoxic. It has high tensile strength and flexibility, as well as high oxygen and aroma barrier properties. However these properties are dependent on humidity, in other words, with higher humidity more water is absorbed. The water, which acts as a plasticizer, will then reduce its tensile strength, but increase its elongation and tear strength. PVA is fully degradable and is a quick dissolver. PVA has a melting point of 230°C and 180–190°C for the fully hydrolyser and partially hydrolyser grades, respectively. It decomposes rapidly above 200°C as it can undergo pyrolysis at high temperatures.

PVA is an a tactic material but exhibits crystalline as the hydroxyl groups are small enough to fit into the lattice without disrupting it. PVA is close to incompressible. The Poisson's ratio has been measured to between 0.42 and 0.48 [17].

The infrared spectra of pure of polyvinyl alcohol show in **Fig5**. which indicate the variation of transmittance with wave number [17].

## EXPERIMENTAL WORK

The investigated samples were made in the form of thin films. This was achieved by dissolving a certain weight of Polyvinyl alcohol (PVA) (0.2g m) in a fixed volume of Chloroform (20ml.) was used as a solvent for the dye and PVA. **Fig.6** show the transmission curve for the chloroform .

Rhodamine 6G was added to Polyvinyl alcohol (PVA) solution by constant concentration ( $10^{-5}$ ) in chloroform are prepared. The solution was then stirred for three hour until a clear solution was obtained. The solution was paused in Petri dish and left to dry in air at room temperature to obtain the desired films , the films were then stripped from the dish to ensure complete dissolution. After the plates were removed from the mould, the sides were polished to obtain good, optically flat surfaces **Figs.7,8,9**.and then were prepared using chloroform as a solvent for each of the dye and polymer was prepared models form a range membrane thickness of 1 mm and a concentration  $1E-5$ .

The absorption spectrum and fluorescence of the model consisting of solid dye Rhodamine 6G doped in an article Polyvinyl alcohol (PVA) and concentration ( $1E-5$ ). Which shows that the top of absorption at a wavelength 528 nm and the top of the fluorescence at 550 nm and the degree of stock shift is 22 nm towards the red wavelengths **Fig.10** . The material Rhodamine 6G absorb wavelengths in the

ultraviolet region and visible that are not useful for solar collector, while sending the dye spectrum in the visible and near-infrared, and this last part is useful for increasing the efficiency of solar collector.

The solar collector model (laboratory) which used during the experiment shows in **Fig.11** , consists of recipient solar rays which is coated black substance ( galvanized iron plate absorber , coefficient of thermal conductivity =  $66.99 \text{ W / m}$ , type of coating it black chrome, absorptive coefficient = 0.95 and emission factor = 0.1) and contains a water reservoir which be stored the temperature , in addition to the presence two thermometer to measure the temperature of the water inside and outside of the solar collector and can control flow rate of water through the valves. Halogen was used power ( $1000 \text{ W / m}^2$ ), and to measure the intensity of energy falling on solar collector was used instrument measure (STE Measurement) from company (ASRO) .

In the first experimental from solar collector laboratory was measured the temperature of the water at inside and outside from solar collector with change intensity of energy falling (  $250\text{-}1500 \text{ W/m}^2$ ), and without using luminescence concentrator, these measurements shows in **Tab.3** . In the second experiment was used luminescence concentrator a membrane fluorescence thickness 1 mm were prepared Rhodamine 6G doped in an article Polyvinyl alcohol (PVA) , after that putting the membrane and adjacent to the windows solar collector and measured water temperatures at inside and outside from solar collector with change intensity energy ( $250\text{-}1500 \text{ W/m}^2$ ) which falling on solar collector , these temperature measurements shows in **Tab.4** .

## RESULTS AND DISCUSSION

**Fig.12** Shows the relationship between temperature difference and the intensity of solar radiation to solar collector without using luminescence solar concentrator , and seen where the solar collector exposed intensity of solar radiation between ( $250\text{-}1500 \text{ W/m}^2$ ). The measured temperatures of water at input between ( $300\text{-}303 \text{ K}$ ), while the measured temperatures of water at output to solar collector between ( $318.7\text{-}323 \text{ K}$ ), different water temperatures between input and output for solar collector is ( $18.7 - 20.0$ ) K ,this means that increasing the temperature of the water with the progressive increasing in the intensity of the energy falling .

**Fig.13** Shows the relationship between temperature difference and the intensity of solar radiation to solar collector with using luminescence solar concentrator , and seen where the solar collector exposed intensity of solar radiation between ( $250\text{-}1500 \text{ W/m}^2$ ). The measured temperatures of water at input between ( $300\text{-}303 \text{ K}$ ), while the measured temperatures of water at output to solar collector between ( $320.2\text{-}327 \text{ K}$ ), different water temperatures between input and output for solar collector is ( $20.2\text{-}24.0$ ) K, and increasingly with the increase in the intensity of energy falling on the solar collector .

**Fig.14** Represents compared between temperature difference of solar collector without luminescent concentrator and with luminescence concentrator at different intensity, it was observed when applying the luminescence concentrator the maximum different in temperature of up to 24 K , while in solar collector system without luminescent concentrator the maximum different in temperature of up to 20 K .Which indicates the importance of using luminescence concentrator to increase the efficiency of solar collectors. From figure shows that the performance of the solar collector improves the rate of (20%)

### CONCLUSIONS

In our work confirms the importance of using luminescence concentrator to increase the efficiency of solar collectors ,and the laboratory results showed improvement and increasing the efficiency to 20% for the conventional solar collector.

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**Table 1 Properties of Rh6G dye.**

Molecular formula	Molar mass	Appearance	Density	Solubility in water	Solubility in methanol
$C_{28}H_{31}N_2O_3Cl$	479.02 g/mol	dark reddish purple, brown or black crystalline solid	1.26 g/cm <sup>3</sup>	20 g/l (25 °C)	400 g/l

**Table 2 Properties of Polyvinyl alcohol (PVA)**

Molecular formula	Density	MSDS	Flash point
$C_2H_4O$	228 °C	External MSDS	79.44 °C

**Table 3 Represents the results of temperature measurements without using luminescent concentrator**

Intensity (W/m <sup>2</sup> )	Input Temperature (K)	Output Temperature (K)	Temperature Difference (K)
250	300.0	318.75	18.75
400	300.5	319.40	18.90
625	301.0	320.12	19.12
750	302.0	321.25	19.25
1000	302.0	321.50	19.50
1500	303.0	323.00	20.00

**Table 4 Represents the results of temperature measurements with using luminescent concentrator**

Intensity (W/m <sup>2</sup> )	Input Temperature (K)	Output Temperature (K)	Temperature Difference (K)
250	300.0	320.22	20.22
400	300.5	321.09	20.59
625	301.0	322.28	21.28



750	302.0	323.67	21.67
1000	302.0	324.45	22.45
1500	303.0	327.00	24.00

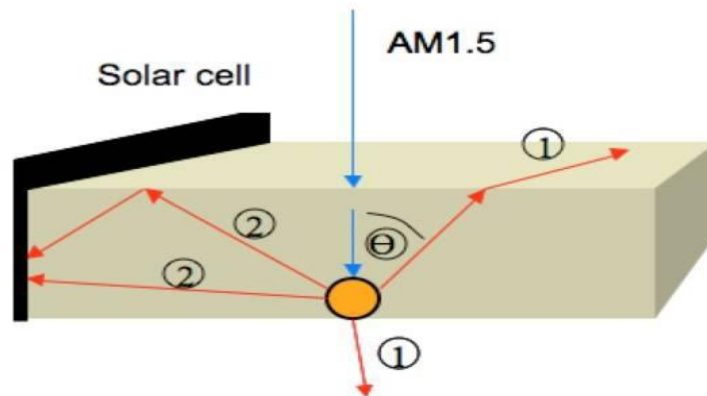


Figure (1) Schematic Representation of a LSC without mirrors. Incident light that is absorbed by a luminescent particle will upon re-emission escape from the plate if it stays within the escape cone (rays 1). Otherwise total internal reflection will guide the light to the cell (rays 2). [5]

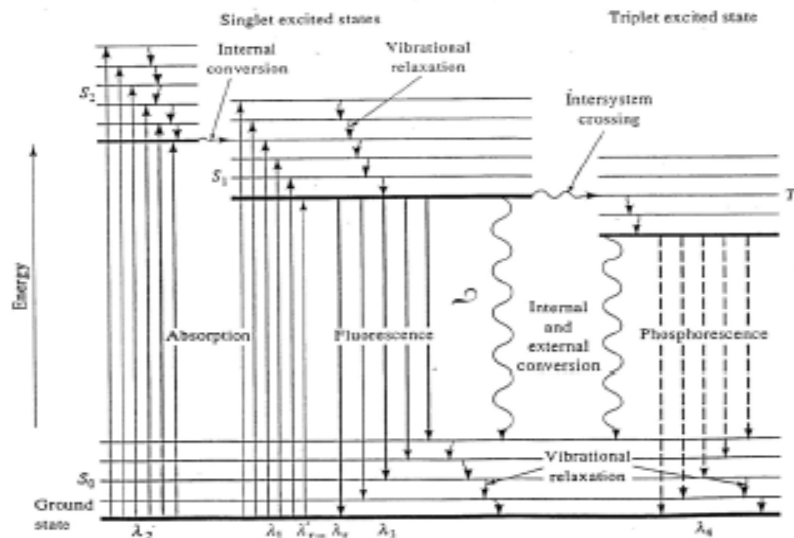


Figure (2) Electronic transition energy level diagram [10]



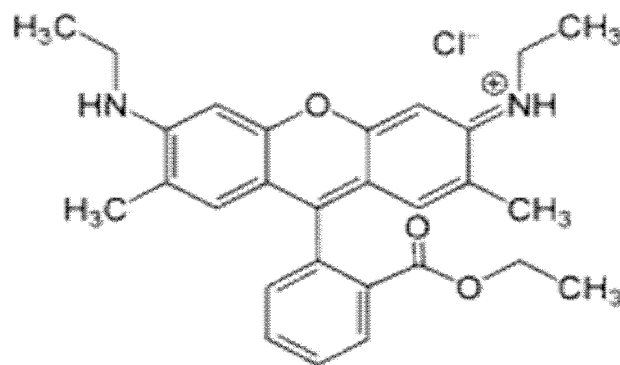


Figure (3), indicate the chemical formula for rodamine 6G (Rh6G).the other names for this dye are ( Rhodamine 590, R6G, Rh6G, C.I. Pigment Red 81, C.I. Pigment Red 169, Basic Rhodamine Yellow , C.I. 4516 ) .[11]

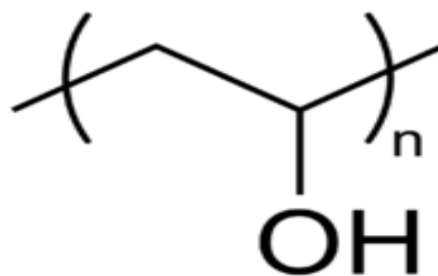


Figure (4) polyvinyl alcohol [15]

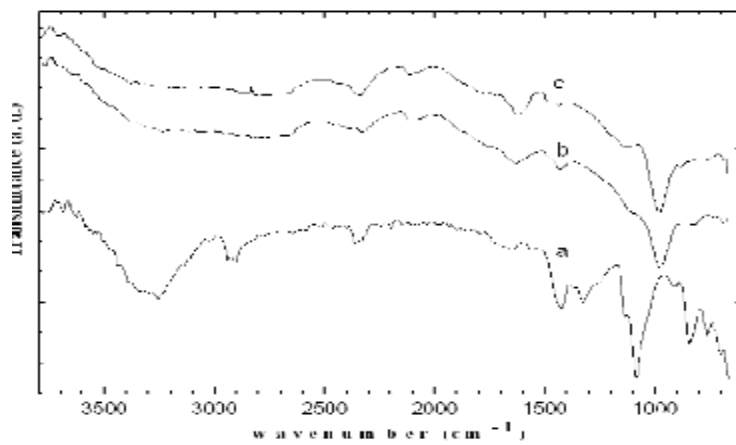


Figure (5) infrared spectra of pure PVA (a) PVA+PA with  $x=0.5$  and with  $x=2$  (c) [17]

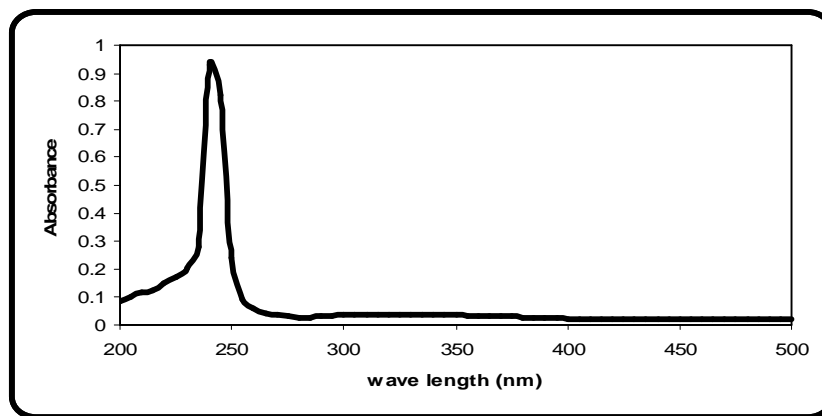


Figure (6) Absorption for chloroform  $\text{CHCl}_3$

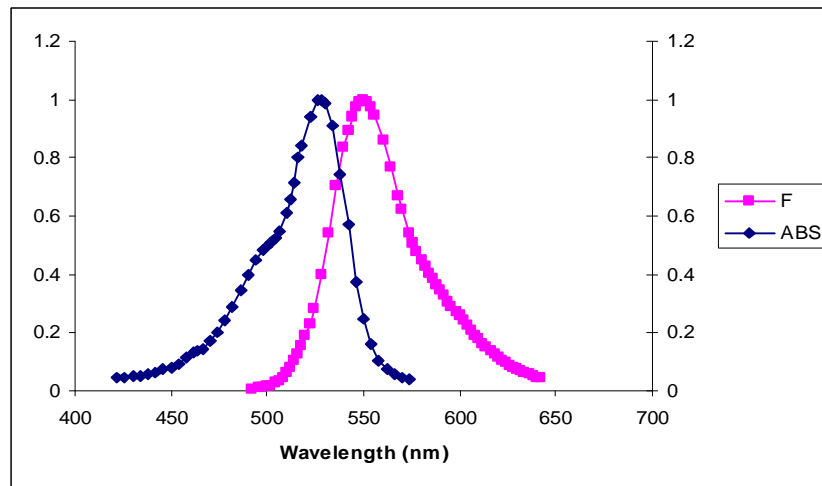


Figure (7) Fluorescence and Absorption spectra for Rd6G in Chloroform solvent (Concentration= $1 \times 10^{-5}$ )

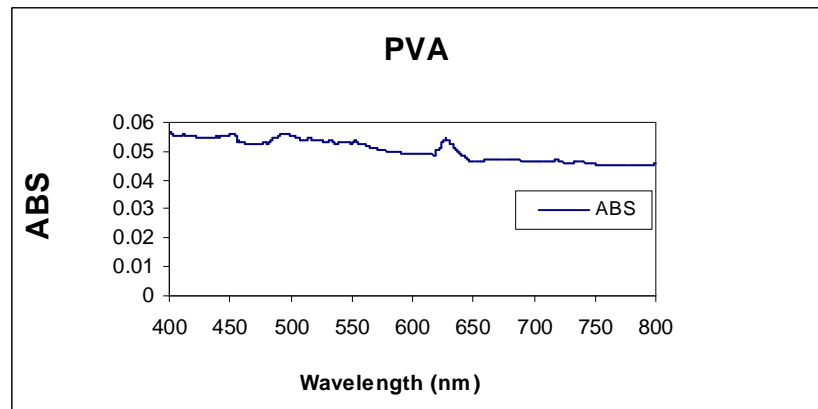


Figure (8) Shows the absorption spectrum and fluorescence for PVA

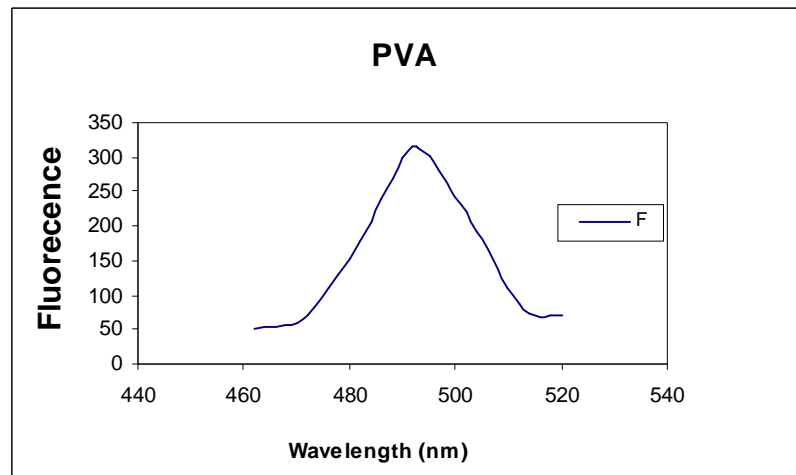


Figure (9) Shows the absorption spectrum and fluorescence for Rd6G

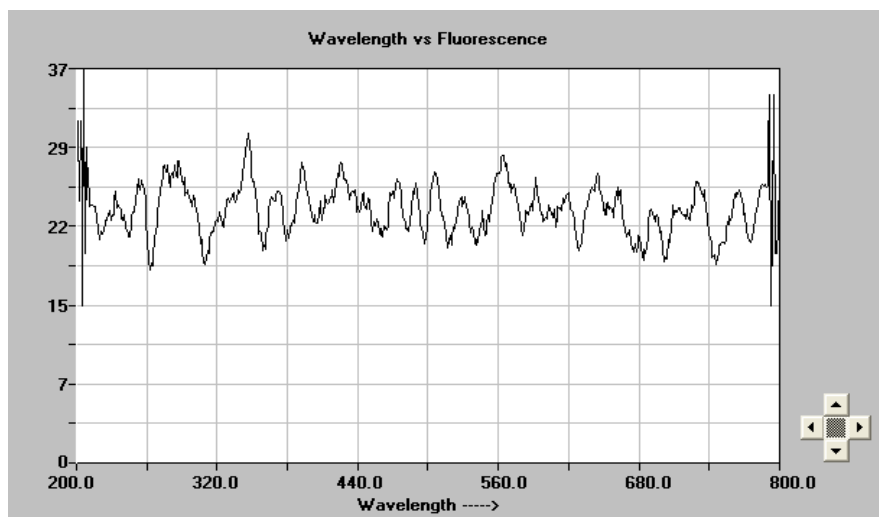


Figure (10) Fluorescence for Chloroform solvent

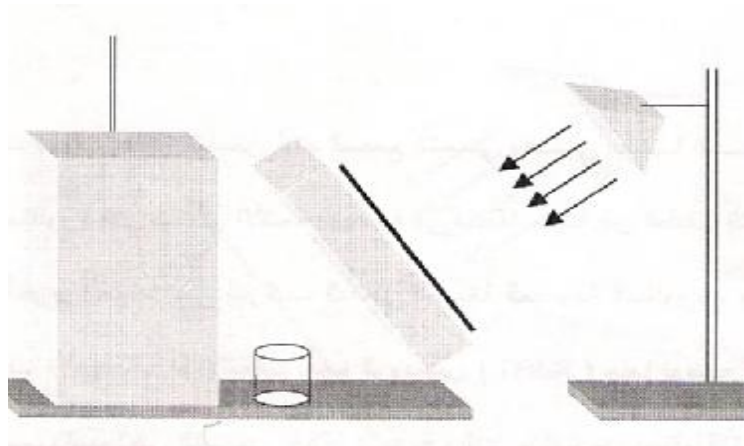


Figure (11) represents a scale model of the planned solar heater Model

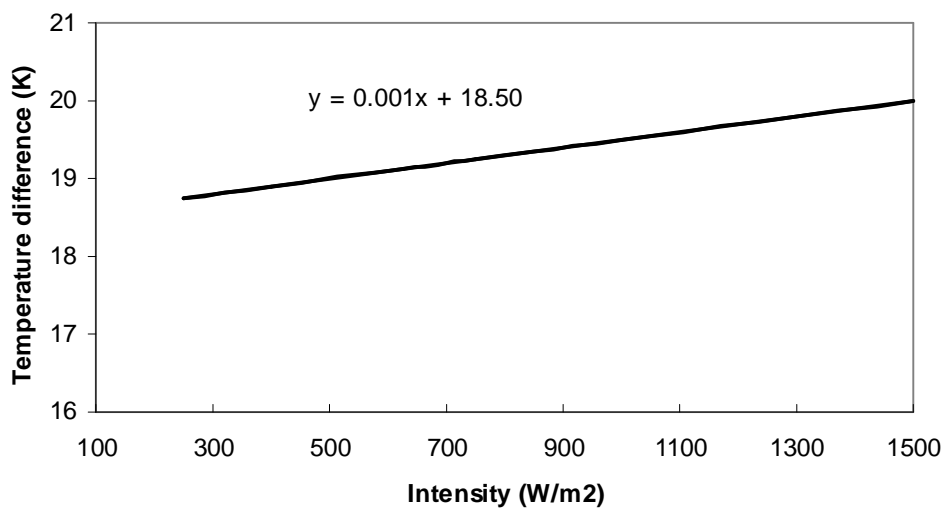
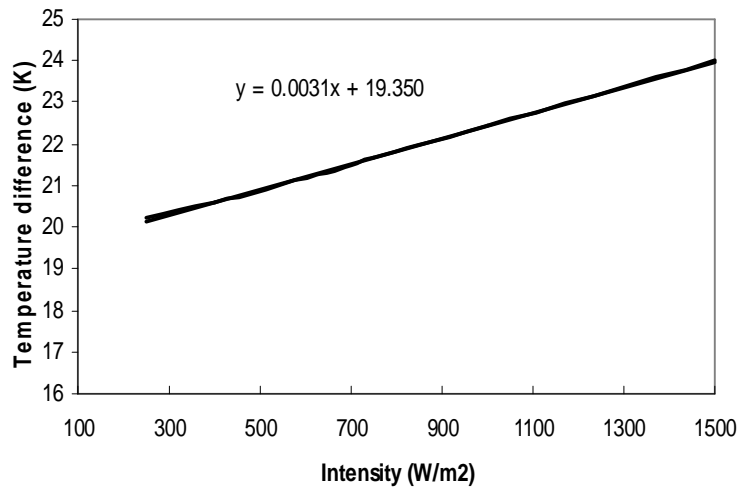


Figure (12) The relationship between temperature difference and the intensity of solar radiation without using luminescent concentrator



Figure(13) The relationship between temperature difference and the intensity of solar radiation with using luminescent concentrator

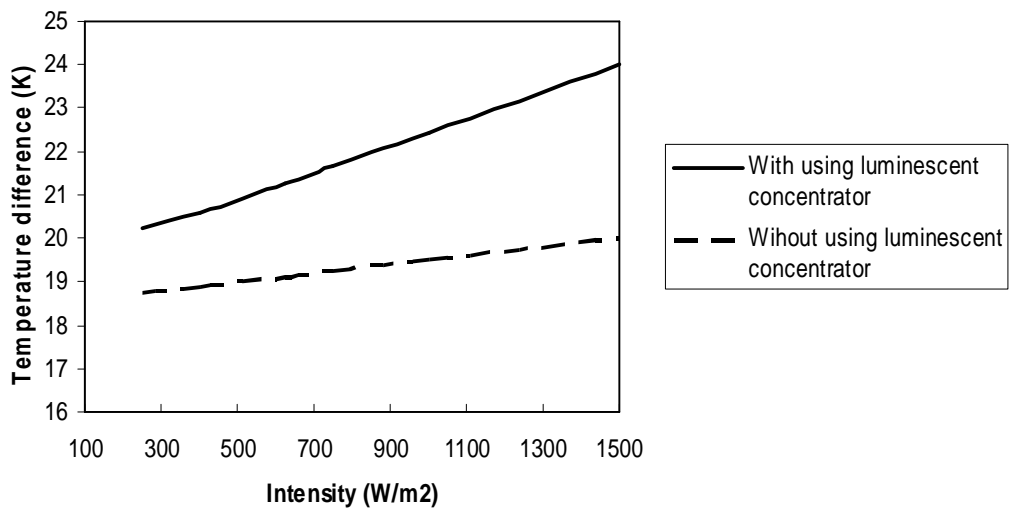


Figure (14) Represents compared between temperature difference of solar collector without luminescent concentrator and with luminescent concentrator at different intensity