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A Study of Absorption Cooling Using Solar Radiation as A Heat Source in The Misrata Region With Varying Solar Data in Each Case

Mohamed Hisain Mohamed Elkiesa*
Faculty of Technical Sciences, Misurata, Libya

دراسة حول التبريد بالامتصاص باستخدام الإشعاع الشمسي كمصدر للحرارة في منطقة مصراتة مع بيانات شمسية متفاوتة في كل حالة

محمد حسين محمد الكيسة *
كلية العلوم التقنية، مصراتة، ليبيا

*Corresponding author: moh12012r@yahoo.com

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Abstract:
In this paper, solar energy has been used to provide a heat source for the absorption cooling system, i.e., studying different types of complete absorption cooling cycles and different thermal cycles, schematic drawings, in addition to performance curves and their various diagrams, and studying Different equations for thermal cycles for each case and the application of a complete system with a change in solar radiation intensity and comparing the results to obtain the best performance for the system. Thermal energy (in the form of hot water) required to be supplied to the absorption cooling machine generator is 15 kilowatts for 10 hours per day and at a minimum temperature of Degrees Celsius during the summer months during which the system can operate. The results have been obtained and compared with graphs.

Keywords: Absorption Cooling, Construction Lines. Coefficient Of Performance, Lithium Bromide, Heat Exchanger.

الملخص
في هذه الورقة، تم استخدام الطاقة الشمسية لتوفير مصدر حرارة لنظام التبريد بالامتصاص، أي دراسة أنواع مختلفة من دورات التبريد بالامتصاص الكاملة والدورات الحرارية المختلفة، والرسوم التخطيطية، بالإضافة إلى منحنيات الأداء ومخططاتها المختلفة، ودراسة المعادلات المختلفة للدورات الحرارية لكل حالة وتطبيق نظام كامل مع تغيير شدة الإشعاع الشمسي ومقارنة النتائج للحصول على أفضل أداء للنظام. الطاقة الحرارية (على شكل مياه ساخنة) المطلوبة لتزويدها لمولد آلة التبريد بالامتصاص هي 15 كيلوواط لمدة 10 ساعات في اليوم وعند درجة حرارة دنيا بالدرجة المئوية خلال أشهر الصيف التي يمكن للنظام العمل فيها. تم الحصول على النتائج ومقارنتها مع الرسوم البيانية.

الكلمات المفتاحية: التبريد بالامتصاص، خطوط الإنشاء، معامل الأداء، بروميد الليثيوم، مبادل حراري.

Introduction
Refrigeration occupies an important place in human daily life, not only for cooling the atmosphere of homes and workplaces, but also for preserving food and many agricultural and industrial products. Therefore, refrigeration in hot regions is considered a primary necessity in economic planning. Solar-powered cooling is distinguished, It

has a unique feature: the more intense the sun's rays, the greater its cooling capacity. Hence, the importance of applying this method in our Arab countries. Solar systems that can be used in the field of cooling can be divided into two main types. The first is called passive solar cooling systems the other is called active solar cooling systems. One type of passive solar system that can be used for both cooling and heating buildings is the solar-powered roof system. Absorption refrigeration systems, which are powered by solar heat, can be one of the most effective solar systems used in refrigeration [1].

1- Absorption Refrigeration Cycle-

An absorption refrigeration cycle is a method that replaces gas compression with liquid pumping to create the required pressure difference. In addition to a liquid pump, an absorption refrigeration cycle uses a generator, an absorption vessel, and a pressure reducing valve, as shown below A diagram in the right half of Figure (1) for the purpose of replacing the compressor. Since the heat addition and heat loss procedures occur in the refrigeration cycles at different temperatures, the compression steam cycle will need to use a compressor to create the required pressure difference between the evaporator and the compressor. Therefore, a relatively large energy expenditure will be required for the unit .The mass flow required to compress a gas compared to the energy required to pump a liquid between the same pressure differences. [3]

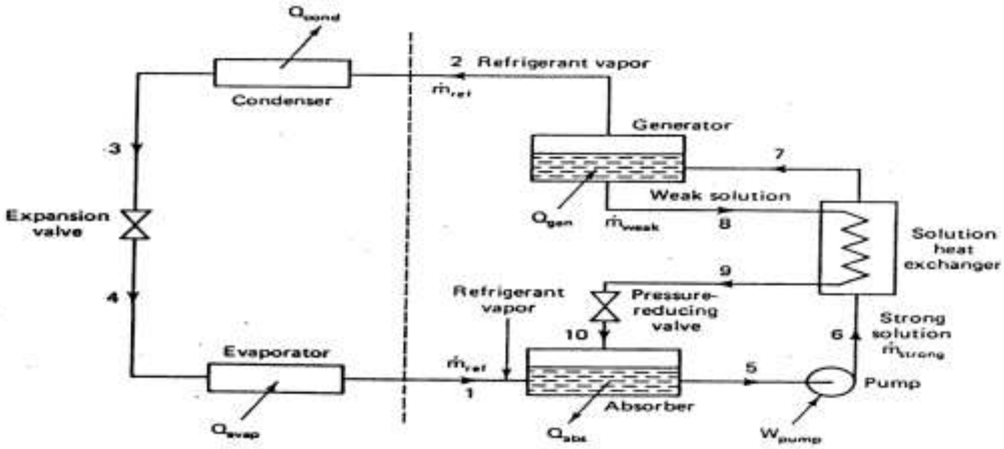

Figure (1) Absorption refrigeration cycle

The solution heat exchanger shown in the figure, located between the generator and the absorber vessel, is merely an energy-saving device and is not an essential part of the successful operation of the cycle. This part of the cycle, referred to above, involves the use of a binary mixture of steam and liquid, .For example, a mixture of ammonia with water, where the ammonia acts as a cooling fluid and the water as an absorbing fluid, or a mixture of water with lithium bromide, where the water acts as a cooling fluid and the lithium bromide as an absorbing fluid. The part represented by the left half of Figure (1) is similar to that part in a compression refrigeration cycle regular, where only a cooling fluid flows through it. At the end of this part of the cycle, the cooling fluid in state 1 enters the absorption vessel, where it is absorbed by the weak solution in state 10 coming from the generator via the solution heat exchanger. In the dilute solution, the liquid solution with a low concentration of the cooling fluid. The absorption process that takes place in the absorption vessel is an exothermic process, and therefore the heat generated from the process the absorbent must be removed from the container to maintain it at a low temperature. A strong solution containing a high concentration of antifreeze will leave the container .Absorbed in phase 5 to be pumped through a heat exchanger, where it gains some of the heat energy from the hot dilute solution flowing from the generator to the absorption vessel. It then flows in phase 7 to the generator. Heat is added to the concentrated solution in the generator .This causes some of the antifreeze to boil and evaporate. The dilute solution remaining in state 8 flows back into the absorption vessel, while pure (or almost pure) antifreeze vapor will be left behind The generator in state 2 heads towards the condenser, then the expansion valve, then the evaporator, and finally returns to the absorption vessel in state 1 to complete the cycle. In order to understand the basic principles of the absorption refrigeration cycle, a quick discussion is required .To behave as a binary mixture of vapor and liquid, a typical temperature-concentration diagram at constant pressure for a two-phase binary mixture is shown in Figure (2-a) [2].

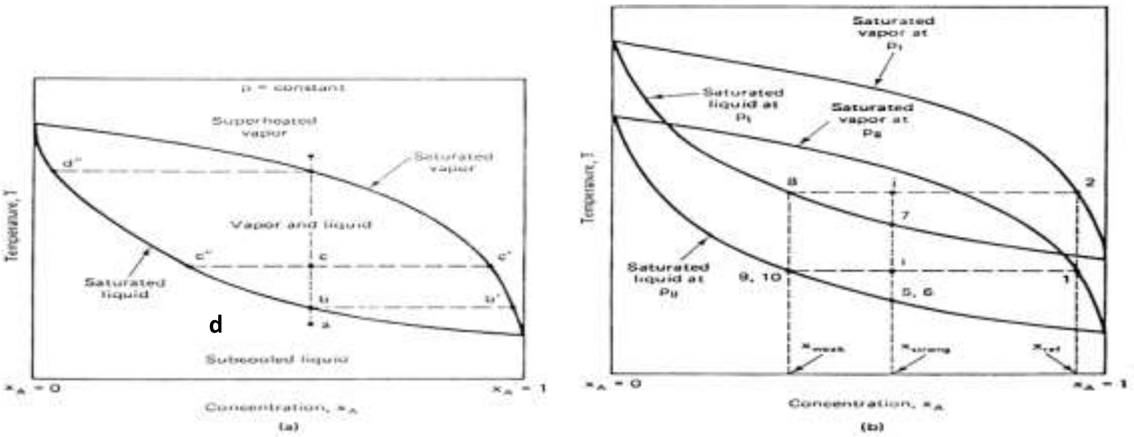

Figure (2): Temperature-concentration diagram for a binary vapor-liquid mixture

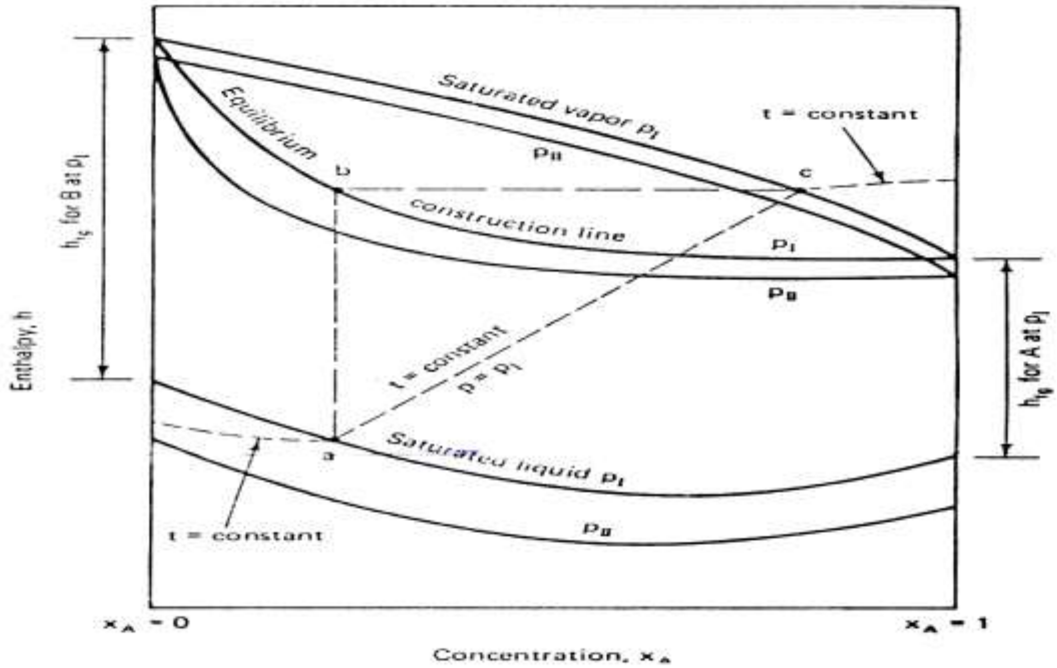

Figure (3): Heat content-concentration diagram for the two-phase region of a mixture for the two-phase region of a binary mixture at two pressures.

The distance between the vapor saturation line and the liquid saturation line in this diagram at any given pressure corresponds to the latent heat of vaporization (hfg) of the pure compound. To facilitate the use of the diagram, a set of imaginary or virtual liquid saturation lines, called construction lines, Equilibrium Construction lines will be added. Knowing the saturation state of the liquid at a certain pressure, which is the pressure PI, for example (point a), a vertical line will be drawn passing through this point to intersect the equilibrium construction line for this pressure at point b. The intersection point of the horizontal line passing through

At point b, with the vapor saturation line at pressure PI (point c) representing the saturation state of the vapor phase. Line ac represents the vapor-liquid equilibrium temperature line. If it is assumed that the flow processes in the absorption cycle are steady-state flow processes, the components of the machine can be analyzed by writing the necessary energy and mass balance equations. Returning to Figure (2) and Figure (2-a) Neglecting changes in kinetic and potential energy, the energy balance equation for the generator gives the following:

$$Q_{gen.} + \dot{m}_{strong}\, h_7 = \dot{m}_{ref.}\, h_2 + \dot{m}_{weak}\, h_8 \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The mass balance equation for the generator is: While the mass balance equation for the cooling medium (component A) in the generator can be expressed as follows: $\dot{m}_{Strong} = \dot{m}_{ref.} + \dot{m}_{weak} \ldots\ldots\ldots (2)$

While the mass balance equation for the icing medium (component A) in the generator can be expressed as follows $\dot{m}_{Strong} \; X_{strong} = \dot{m}_{ref.} \; X_{ref.} + \dot{m}_{weak} \; X_{weak}$ ....(3)

Where: $:\dot{m}'_s$ represents the mass flow rate, $:h'_s$ represents the enthalpy, and $:x'_s$ ت represents the concentration of the refrigerant In the absorption vessel, the mass balance equations are the same as in equations (2) and (3), while the energy balance equation is given as follows

$$\dot{m}_{ref.} \; h_1 + \dot{m}_{weak} \; h_{10} = \dot{m}_{Strong} \; h_5 + Q_{abs} \quad \text{..} (4)$$

In the heat exchanger, the energy balance equation leads to the following:

$$\dot{m}_{Strong} \; (h_7 - h_6) = \dot{m}_{weak} \; (h_8 - h_9) \text{..} (5)$$

In the pressure reducing valve, the energy balance equation can be expressed as follows $(h_9 = h_{10})$

Relationship the energy required to operate the pump and parts of the pumping process can be expressed by the following

$$W_{pump} = \dot{m}_{strong} \; (h_6 - h_5) \text{..} (6) \qquad :$$

It can be noted here that the analysis of components including the condenser, evaporator, and expansion valve will be the same as in the compression refrigeration cycle. Knowing each Q_{evp} ، W_{pump} و Q_{gen} the absorption cycle performance coefficient can be obtained from the following relationship: Neglecting the pumping energy, given that the value of this energy is small, the relationship is:

$$C.O.P = \frac{Q_{evp}}{Q_{gen.} + W_{pump}}$$

The performance factor is abbreviated as follows:

$$C.O.P = \frac{Q_{evp.}}{Q_{gen.}}$$

The coefficient of performance of the absorption refrigeration machine operating with a water-lithium bromide solution is about 0.8, and this machine often operates with a coefficient of performance ranging between 0.6 and 0.7, while the coefficient of performance of the absorption refrigeration machine operating with ammonia-water solution is usually lower than its counterpart in the water-lithium bromide machine [4].

2-qua- Ammonia Absorption System:

In ice-making and food-freezing applications where absorption systems are used, an ammonia-water solution is often used as the working fluid, with the ammonia in the solution acting as the icing medium and the water acting as the absorption medium. A frequently asked question about an ammonia-water machine is: since both ammonia and water are volatile substances, the steam leaving the generator will contain a significant amount of water, and the freezing process of the water will be very difficult In the expansion valve and evaporator, this will cause damage to the machine. To effectively remove water vapor from the steam sent to the condenser, a device called a rectifying column will be placed between the generator and the condenser. This device is an essential part of an industrial refrigeration machine that operates on an ammonia-water solution, as schematically shown in Figure (4).

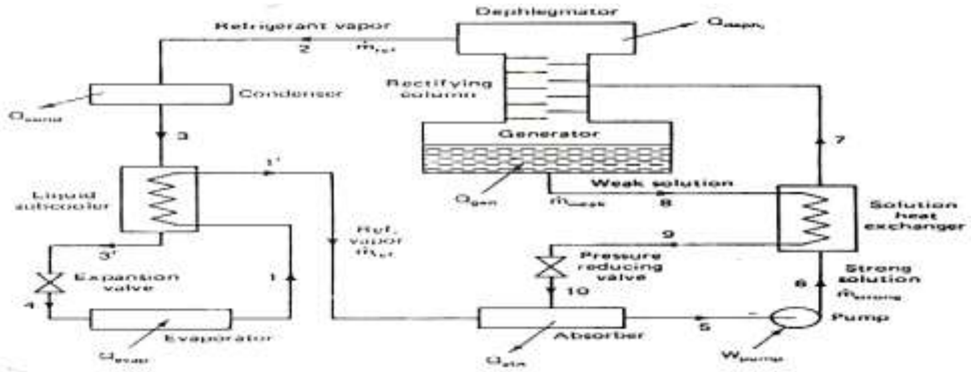

Figure (4) Absorption icing machine operating with ammonia-water solution

The process column's job is to remove heat in the dephlegmator section to the point where it causes water vapor to condense. The condensed water vapor will flow down through the trays in the column where it comes into direct contact with the steam rising from the generator. In this counter-flow process, an exchange of energy and mass will take place. The rising steam shows a constantly increasing concentration of ammonia, while the liquid the descending air carries an additional amount of condensed water back to the generator. The change in heat quantities Q_{gen} , Q_{deph} It can produce steam with any desired concentration of ammonia, ideally very close to unity.

3-Lithium Bromide- Water Absorption System;

In air conditioning applications using absorption refrigeration systems, where the evaporator temperature is relatively high, a solution of water and lithium bromide is often used as the working fluid. The water acts as the refrigeration medium, while the lithium bromide acts as the cooling medium for absorption. At normal temperatures, lithium bromide is a solid, but it is soluble in water to form a liquid solution. Because lithium bromide is non-volatile, only water vapor will boil in the generator, so no additional fuel is needed.

Use of any treatment device Figure (5) shows a schematic drawing of a real absorption icing machine with a capacity of 25 tons of icing operating with a lithium peroxide-water solution

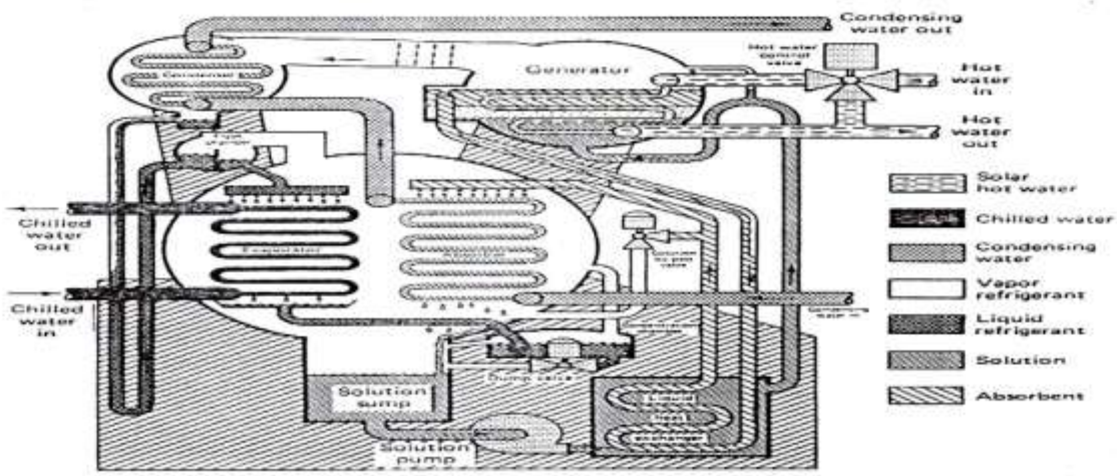

Figure (5) shows a schematic drawing of a real absorption icing machine with a capacity of 25 tons, which icing works with a lithium bromide-water solution.

The input energy source for this machine is solar-heated water, which circulates in a closed loop between the generator and the solar collectors. The operation of this machine is similar to that illustrated in Figure (2), with a U-shaped tube and a flash chamber that act as a valve Expansion. Three improvements have been made to the design of this machine, including the addition of a concentration chamber with a dump valve, a solution bypass valve, and a hot water control valve The concentrating chamber collects and stores a portion of the liquid refrigerant to provide the best solution concentration for the best unit performance when the temperature of the condensate water entering the condenser is within normal limits (between 90 °F and 75 °F). If the temperature of the condenser water drops below 75 °F, the damping valve will open, emptying the refrigerant into the sump solution, which in turn leads to the dilution of the solution, this dilution allows the unit to operate stably and regularly at a low condensate water temperature. The bypass valve allows the solution to pass bypassing the absorption coil and directly back into the solution basin during the first few minutes of any start-up. This allows the evaporator coil to be fully wetted with refrigerant liquid before the absorption vessel becomes active. The control valve, in addition to its function as an on-off device, it models the flow of hot water to the generator based on the inlet and outlet temperatures of the ice water. If one or both of these temperatures fall below the pre-selected values, the valve will reduce the flow rate of hot water entering the generator by diverting part of this water to pass bypass and thus will regulate the internal energy to suit the required icing load. Figure (6) represents a schematic drawing of another absorption machine that operates with a lithium bromide-water solution with a icing capacity of 3 tons, suitable for use in residential buildings and designed to use solar energy in air conditioning. The operating cycle of this machine is similar to the operating cycle of the machine shown in Figure (5), except that it contains fewer performance-enhancing devices

4- Absorption Systems Solar Operation; Figure (7) shows a diagram of a solar-powered absorption refrigeration system. The refrigeration cycle in this system is similar to the refrigeration cycle discussed in the previous section.

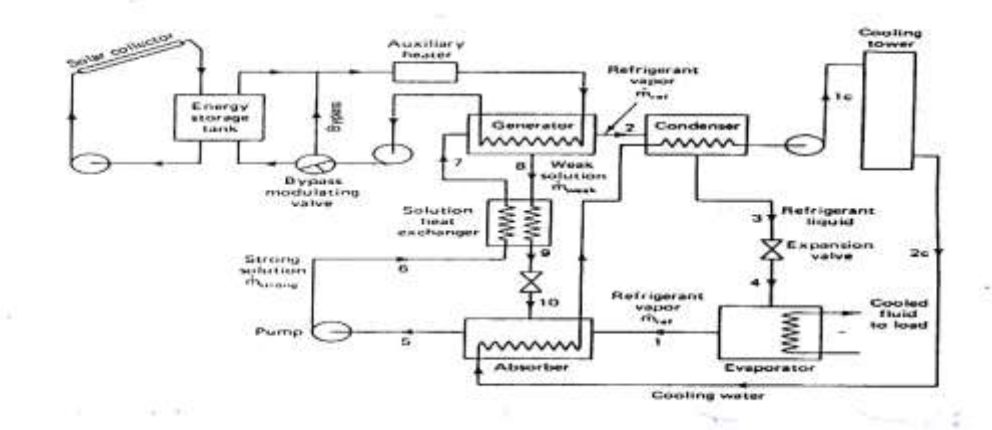

Figure (6) shows a diagram of a solar-powered absorption refrigeration system

It is noted on the left side of the figure that the thermal energy is supplied to the cycle generator by a group consisting of the solar collector, the thermal storage vessel, and the auxiliary heater. If solar radiation is It is then used continuously as available, the collected solar energy will first be stored in the storage vessel, then an energy source in the generator to heat the concentrated solution. In the event that the temperature of the water in the storage vessel drops to the point where it no longer affects the generator heating process, the temperature of this water is raised in the auxiliary heater, which can be powered by electricity or gas.If the storage vessel water temperature is too low due to the long period of no solar radiation, a bypass modulating valve will stop the flow of heating water back from the generator to the storage vessel to avoid raising the temperature of the storage vessel by the auxiliary heater. All the heating load supplied to the generator will then be covered by the auxiliary heater. In the absorption refrigeration cycle, the coolant must be expelled from both the absorber Since the heat generated and the condenser. A suitable water-cooling system must be included in this system. One way to obtain cold water is by using a cooling tower, as shown in Figure (2-8). The cold water emanating from the cooling tower goes first to the absorber and then to the condenser is because the first component requires a lower temperature than the second. Another option in the design of a solar absorption refrigeration system is to have the auxiliary heater placed in parallel with the thermal storage vessel instead of in series, and for the collector circuit to include a heat exchanger, allowing the fluid passing through the solar collector to be different from the fluid in the storage vessel. In this cycle, the solar-heated fluid is supplied directly to the generator without any storage. Therefore, high temperatures can be achieved in the generator. The energy storage method involves storing the cooling medium and the solution in two separate containers. During periods of high radiation intensity, in the solar system, the refrigerant will boil in the generator and then condense in the condenser. After the actual cooling loads are met, the excess refrigerant will be stored in a special storage vessel waiting to be called upon to pass through the expansion valve to meet the new loads of the building .The function of solution storage is to store a sufficient amount of the solution within the permissible concentration limits. The antifreeze storage system offers some important advantages. If the storage is in the form of latent heat, the energy stored per unit volume will be greater than with conventional storage .Sensible, in addition, if storage occurs at a temperature equal to the condenser temperature, which is equal to or close to room temperature, any heat gain from the surroundings will be minimal. For the purpose of analyzing the system shown in Figure (2-10), it will be necessary to write the mass and energy balance equations for the refrigerant storage, the solution, and some of the other components of the system. For the refrigerant storage, neglecting any heat gain from the surroundings, the required relationships are:

$$\frac{dm_{r,s}}{dt} = \dot{m}_3 - \dot{m}_{3a} \ldots\ldots\ldots\ldots\ldots\ldots.(6)$$

$$\frac{d\,(mu)_{r,s}}{dt} = \dot{m}_3\, h_3 - \dot{m}_{3a} h_{3a} - \dot{Q}_{cooling\quad water,r,s} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(7)$$

Where: $: \dot{m}_{r,s}$ mass of the antifreeze in the storage vessel. $: u_{r,s}$ Specific internal energy of the antifreeze in the storage vessel.

١ $: t$ TIMEMass flow rate of refrigerant at the inlet and outlet of the storage vessel, $: \dot{m}_{3a}$ و . respectively.

h_{3a} , h_3 The specific heat content of the refrigerant at the entrance and exit of the storage vessel, respectively. : $Q_{cooling\ water,r,s}$ The rate of heat transferred to the cooling water in the storage vessel., for the case of solution storage, Similarly

$$\frac{dm_{s,s}}{dt} = \dot{m}_5 - \dot{m}_{5a} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

$$\frac{d(mu)_{s,s}}{dt} = \dot{m}_5 h_5 - \dot{m}_{5a} h_{5a} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

Where: : $\dot{m}_{s,s}$ the mass of the solution in the storage vessel. : $u_{s,s}$ The specific internal energy of the solution in the storage vessel. $\dot{m}_5$, : $\dot{m}_{5a}$ The mass flow rate of the solution at the entrance and exit of the storage vessel, respectively. : h_{5a} , h_5 The specific enthalpy of the solution at the entrance and exit of the storage vessel. Where: the mass of the solution in the storage vessel, the specific internal energy of the solution in the storage vessel, the mass flow rate of the solution at the entrance and exit of the storage vessel, respectively, and the specific enthalpy of the solution at the entrance and exit of the storage vessel.

5-Performance evaluation of solar-powered absorption refrigeration systems;:[14] The Utilizability Concept 1-

Minimum temperature required in the convection zone is about 68 °F (20°C). Therefore, all solar energy collected above this temperature is considered useful energy. The f-plot method, however, It can be applied to many other types of systems that require different minimum temperatures in the convection zone, for example solar air conditioning systems using absorption water chillers which require a minimum convection zone temperature of around 80C, or industrial heating procedures which Different load temperatures are required. In this and subsequent sections, we will introduce a useful principle and a more general design method than the f-chart method, so that it can be used in absorption air conditioning systems and industrial heating systems, in addition to conventional heating systems. The first to the utilitarian idea was conceived by Hottel and Whillier and later generalized by Liu and Jordan, then simplified and expanded by Klein and Beckman to form a general design method for solar systems using flat-panel solar collectors, and by Pereira-Collores and RabI .For solar systems that use concentrated solar collectors, utilization is defined as the fraction or portion of incident solar radiation that can be utilized.

$\left(\bar{\tau} = 1 ,\ \bar{\alpha} = 1\right)$ With perfect or complete heat removal cycleThe definition $\left(F_R = 1\right)$

Ideal solar collector with no optical losses In terms of the hourly solar radiation falling on the surface of the collector Hottel – Whillier- Bliss (H_t)The product of transparency and absorbance $(\tau\alpha)$. Utilization can be derived directly from the equation:

$$Q_u = A_c F_R \left[H_t (\tau\alpha) - U_C (T_i - T_a)\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

Where T_i represents the inlet temperature of the collector fluid. According to the equation above, there is a minimum level of solar radiation required to bring the absorbing surface of the collector to a temperature equal to the inlet temperature of the collector fluid. This minimum level of radiation is called the Δ level. The critical level, symbolized by the symbol $H_{t,c}$, can be obtained by making the value Q_u in the equation above equal to zero, i.e.:

$$H_{t,c} = \frac{F_R U_c (T_i - T_a)}{F_R (\tau\alpha)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

This means that the level of incident solar radiation must be higher than the critical level in order for the flat solar collector to be able to provide useful energy. By substituting equation (10) with equation (11), we get: $Q_u = A_c F_R (\tau\alpha).(H_t - H_{t,c})$...(12) :

The hourly useful energy collected in a given hour of a given day and calculated as an average over a long period (usually a month) of N days, can be written as follows:

$$\bar{Q}'_u = \frac{A_c F_R (\tau\alpha)}{N} \sum^{N} (H_t - H_{t,c}) \text{..........(13)}:$$

Assume that $\overline{H}'_t$ it represents the average monthly value of hourly solar radiation at a specific hour on a specific day. Therefore, by definition, the hourly utilization ϕ will be a fraction or part of the amount $\overline{H}'_t$ at the level above the critical level $H_{t,c}$. Therefore:

$$\phi = \frac{1}{N} \sum^{N} \frac{(H_t - H_{t,c})}{\overline{H}'_t} \text{..(14)}$$

The average monthly value of useful energy collected during a given hour of a given day, can be expressed as follows:

$$\overline{Q}'_u = A_c F_R (\tau\alpha) \overline{H}'_t \phi \text{..(15)}$$

To simplify the utilization calculations, the monthly average of the total daily radiation incident on the inclined collector surface $(\overline{H}_t)$ can be used. Accordingly, the monthly average utilization $\bar{\phi}$ can be defined as the portion or fraction of the total solar radiation during a month consisting of N number of days that is at a level above the critical level, where:

$$\bar{\phi} = \sum_{days} \sum_{hours} \frac{(H_t - H_{t,c})}{\overline{H}_t \; N} \text{..(16)}$$

The critical level can be redefined in terms of the monthly average values of the product of the translucency $(\overline{\tau\alpha})$ and the ambient temperature during daytime hours, $\overline{T}'_a$ as follows:

$$H_{t,c} = \frac{F_R \; U_C \; (T_i - \overline{T}'_a)}{F_R \; (\overline{\tau\alpha})} \text{....................................(17)} :$$

The monthly average of daily useful energy collected can therefore be given by the relationship:

$$\overline{Q}_u = A_c F_R (\overline{\tau\alpha}) \; \overline{H}_t \; \bar{\phi} \text{ ....(18)}$$

Klein, Mitchell, and others found that the value of the magnitude ($\bar{\phi}$) can be completely determined in terms of both the monthly clarity index ($\overline{K}_T$) and two other variables, namely the geometric coefficient ($\overline{R}/R_n$) and the monthly average critical radiation ratio ($\overline{X}_c$), according to the following relationship:

$$\bar{\phi} = \exp\left\{\left[A + B(\frac{R_n}{\overline{R}})\right] (\overline{X}_c + C\,\overline{X}_c^2)\right\} \text{..(19)}$$

$$A = 7.10 - 20.00 \; \overline{K}_T \; + 12.08\, \overline{K}_T^2$$
$$B \; = -8.02 + 18.16\, \overline{K}_T \; - 10.68\, \overline{K}_T^2$$
$$C = -1.02 + 4.10 \overline{K}_T - 1.96\, \overline{K}_T^2$$

In the above relationship, $\overline{R}$ the monthly ratio of the solar radiation incident on the inclined surface of the collector to the solar radiation incident on the flat surface,which is known as the monthly R_n average solar radiation coefficient incident on the inclined surface of the collector, represents the ratio of the radiation at the incident radiation on the fluid surface of the collector is equal to the radiation at apogee incident on the horizontal flat surface and drawn on the basis of the monthly average, and can be calculated from the following relationship:

$$R_n = \left(1 - \frac{r_{d,n}}{r_n}\ \frac{\overline{H}_d}{\overline{H}}\right) R_{\mathrm{B},n} + \left(\frac{r_{d,n}}{r_n}\ \frac{\overline{H}_d}{\overline{H}}\right)\left(\frac{1+\cos s}{2}\right) + \rho_g\left(\frac{1-\cos s}{2}\right) \qquad ....(20)$$

$r_{d,n}$ It represents the ratio of the diffuse radiation at apogee to the daily diffuse radiation, r_n and represents the ratio of the total radiation at apogee to the total daily radiation. Since the hour angle h has a value equal to zero at apogee (noon), this leads to:

$$r_{d,n} = \frac{\pi}{24}\left[\frac{1-\cos h_s}{\sin h_s - (\pi/180)\, h_s \cos h_s}\right] ....(21)$$

$$r_n = r_{d,n}\left[1.07 + 0.025 \sin\ (h_s - 60)\right] ....(22)$$

Where h_s the sunset angle on the surface represents the horizontal plane measured in degrees.In the $R_{B,n}$ equation (20) it represents the ratio of the incident solar radiation on the inclined surface of the collector to the incident solar radiation on the horizontal plane at the apogee. When the surfaces are directed directly towards the equator, $R_{B,n}$ its values can be found from the following equation, and when the value of the amount is: $\cos h = 1$

$$R_{B,n} = \frac{\cos(L-S)\cos\delta + \sin(L-S)\sin\delta}{\cos L\ .\ \cos\delta + \sin L\ .\sin\delta} ....(23)$$

In it, δ و S ، L and represent the latitude, the angle of inclination of the solar system from the horizontal, and the angle of inclination of the sun, respectively. $\overline{H}_d / \overline{H}$ The ratio in the relationship (20) represents the monthly average of the daily diffusion fraction, and it can be expressed in terms of the monthly average of the daily clarity index $\overline{K}_T$ as follows:

$$\frac{\overline{H}_d}{\overline{H}} = 1.317 - 3.023\overline{K}_T^2 - 1.769\overline{K}_T^3 ......(24)$$

$$For\ 0.3 \le \overline{K}_T \le 0.8$$

When seasonal variations in the spread breakout are taken into account, the following correction relationships for the seasonal monthly average of the daily spread breakout are: :

$$h_s \le 1.4208\ \text{rad}\,(81.4^{o})\ \text{and}\ \ o.3 \le \overline{K}_T \le 0.8$$

It should be used. It is winter when it is

$$\frac{\overline{H}_d}{\overline{H}} = 1.391 - 3.560\overline{K}_T + 4.189\,\overline{K}_T^2 - 2.137\overline{K}_T^3$$

And for the seasons of fall, spring and summer when it is

$$h_S > 81.4^o \text{ and } 0.3 \le \overline{K}_T \le 0.8$$

so; $$\frac{\overline{H}_d}{\overline{H}} = 1.311 - 3.022\overline{K}_T + 3.427\,\overline{K}_T^2 - 1.821\overline{K}_T^3$$

Where h_S represents the angle of sunset. $\overline{X}_c$ The monthly average of the critical radiation ratio mentioned in the equation (25) represents the ratio of the critical level to the radiation at the apogee for an average day during the month in which the total radiation during the day has a value equal to the monthly average value, and can be expressed as follows:

$$\overline{X}_c = \frac{H_{t,c}}{r_n\ R_n\ \overline{H}} \quad \text{...(25)}$$

$$\overline{X}_c = \frac{1}{r_n\ R_n\ \overline{K}_T\ \overline{H}_o}\left[\frac{F_R U_c\,(T_i - \overline{T}_a')}{F_R\,(\overline{\tau\alpha})}\right] \quad \text{......................................(26)} \quad \text{or}$$

It $\overline{H}_o$ represents the monthly average of daily radiation falling on a horizontal level outside the Earth's atmosphere.

$\overline{\phi}$, f − chart [The $\overline{\phi}$, f − chart Design Method

The utilitarian method mentioned in the previous section $f -$ has been linked to the scheme method proposed by researchers Klein and Beckman. In this system, it is assumed that the storage vessel is under pressure or filled with a fluid with a high boiling point, and therefore there will be no damping process. The energy is supplied by a pressure relief valve, and the auxiliary energy system is placed in series with the solar collector system in cases where the energy supplied to the load area must be higher than the minimum useful temperature (T_{min}).

The above method $\overline{\phi}$, f − chart has been extended by researchers Braun, Klein, and Pearson for use in the design of open-loop solar water heating systems. The minimum temperature in open loop systems represents the temperature of the supply water T_m . The load value changes with time depending on the size of the demand for hot water supplied at that temperature T_w . A regulation valve is usually used to prevent the temperature of the supply water from exceeding

The performance of the closed-loop solar system, which can be used to supply the thermal energy needed to operate an absorption chiller generator and is schematically shown in Figure (7), has been studied and evaluated in this paper using the utility-f-diagram method, by which the solar fraction (solar contribution) in the energy coverage can be calculated the heat required to operate the absorption chiller that can be connected to the system

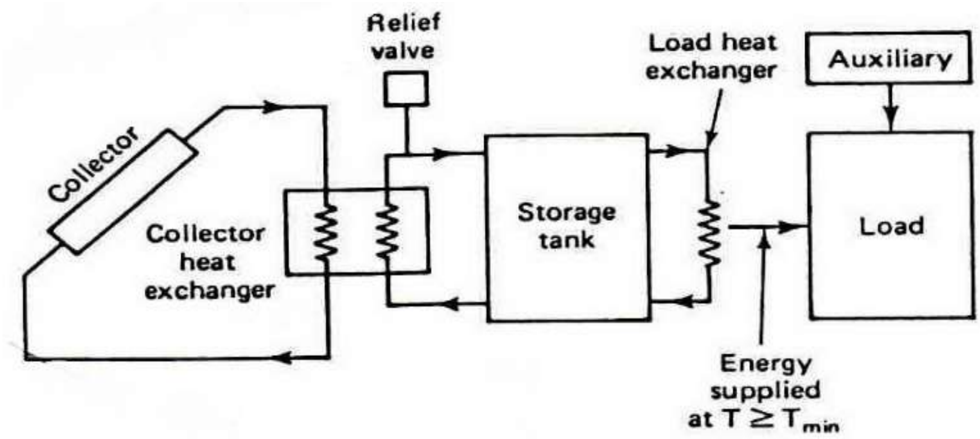

Figure 7: Schematic diagram of a solar system used to supply hot water to an absorption chiller generator.

The solar fraction (f) values for the system were calculated on a monthly basis (for each of the summer months during which the system can operate, namely months 5, 6, 7, 8, and 9). The calculations in this paper were conducted at a selected geographical location in Misrata, Libya, and over a collection area of Different solar panels and different types of solar collectors were used to build a computer program to perform these calculations according to the assumptions and operating conditions listed below. 4: Assumptions and operating conditions of the system used in the study: The thermal energy (in the form of hot water) required to be supplied to the absorption chiller generator is 15 kilowatts for 10 hours per day at a minimum temperature of 82 degrees Celsius during the summer months during which the system can operate. The solar system under study is located in a geographical area $32^{o}07'$ of north latitude with flat solar collectors $(L = 32^{o}07')$ oriented towards the geographical south at an angle $(\text{tilt angle}(s) = 28^{o})$ 28^{o} of inclination from the horizontal of 40 m2, 60 m2, and 80 m2.

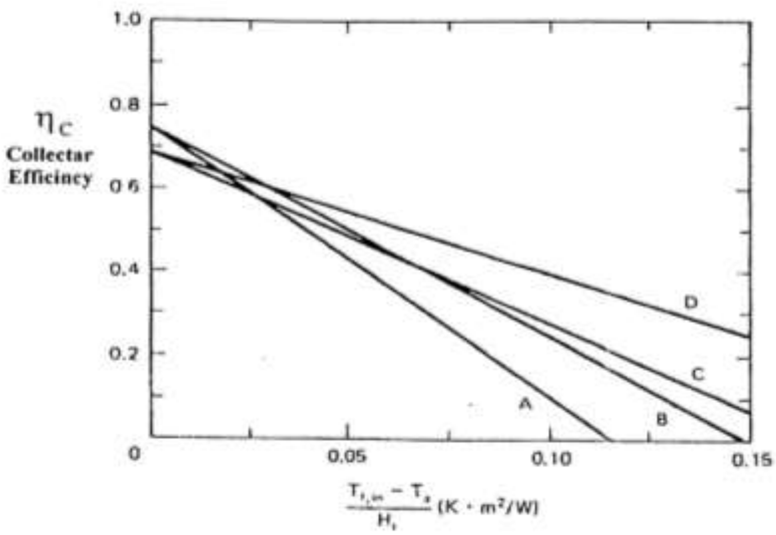

Figure (8): The curves by which the values of the coefficients F_R U_C F_R $(\tau\alpha)_n$ can be obtained for the four solar collectors used in the study.

1-The ratio $\overline{\tau\alpha}/(\tau\alpha)_n$ is 0.96 for solar collectors with a single transparent cover and 0.94 for solar collectors with two transparent covers [5].

2-The ratio,which represents a standard or measure of the thermal performance tax that must F'_R / F_R be paid as a result of using a heat exchanger in the collection cycle, is 0.96.

3-The heat exchanger's efficiency in the convection cycle is 0.7, with a minimum heat capacity $(\dot{m}c)_{min}$ of 3100 W/°K for the fluid passing through it.

4-The mass of hot water in the system's storage vessel is 83.5 kg per square meter of solar collector area, with a temperature of the space surrounding the vessel (Tenv) of 24°C.

5-Solar radiation data and climatic conditions for the geographical location tested for the application are listed in the following table (Table 1).

Table 1. Monthly average of the solar system.

$\overline{T}_a$ °C	$\overline{K}_T$	$\overline{H}$ MJ/m^2	month
23.1	0.753	30.32	) 5May(
27.8	0.745	30.98	) 6June(
30.2	0.650	26.57	) 7July(
28.8	0.650	24.77	) 8Aug.(
26.7	0.673	22.46	) 9Sept.(

Where: $\overline{H}$ The monthly average daily total solar radiation incident on a horizontal surface (MJ/m²).

$\overline{K}_T$ The monthly average clarity index (CLI).

$\overline{T}_a$ The monthly average daily mean outdoor air temperature.

For the solar system shown in Figure (7) are listed in Table (2). For the location at a latitude $32^\circ 07'$ of north and for four types of solar collectors (type A; B; C; D) and for three solar collector areas of 40m2; 60m2; and 80m2.

Table (2): Results of solar fraction (f) calculations

solar fraction (f) months(					Area of collection m2	Types of collection
9	8	7	6	5		
0.346	0.338	0.334	0.366	0.344	40	type A
0.507	0.499	0.493	0.534	0.505	60	
0.647	0.633	0.621	0.675	0.645	80	
0.407	0.399	0.395	0.427	0.406	40	type B
0.589	0.581	0.573	0.618	0.589	60	
0.733	0.727	0.713	0.758	0.740	80	
0.413	0.405	0.401	0.430	0.413	40	type C
0.600	0.591	0.586	0.627	0.600	60	
0.750	0.739	0.739	0.774	0.751	80	
0.558	0.552	0.548	0.572	0.560	40	type D
0.797	0.788	0.783	0.810	0.799	60	
0.966	0.948	0.952	0.960	0.959	80	

Solar Fraction Calculation Form

Collector Type: D. Month: 7. Tolerance: 40 m2. Calculate the monthly average radiation coefficient incident on the fluid surface of the collector $(\overline{R}_B)$.

$$\overline{R}_B = \frac{\cos(L-S)\cos\delta\sin h'_S + (\pi/180)\ h'_S\ (L-S)\sin\delta}{\cos L\cos\delta\sin\ h_S + (\pi/180)h_S\sin L\sin\delta}$$

Where: L: The latitude of the site, equal to). $32^\circ 07'$ (

S: The angle of inclination of the collector from the horizontal plane, equal to: S = L – 4 = 32 – 4 = 28

δ: The angle of inclination of the sun, which can be roughly calculated from the following relationship:

$$\delta = 23{,}45\ \sin\left[\frac{360}{365}(284+n)\right]$$

Where n represents the day of the year, the value of n in July is 199 so:

$$\delta = 23.45\ \sin\left[\frac{360}{365}(284+199)\right]$$

$$\delta = 21.05117^{o}$$

hs: The angle of sunset on the horizontal surface, calculated from the following relationship:

$$h_S = ar\cos(-\tan L \tan\delta)$$
$$= \cos^{-1}(-\tan 32 * \tan 21.05117)$$
$$h_S = 103.9522^{o}$$

h'_S :The sunset angle on the inclined surface of the complex is calculated from the relationship:

$$h'_S = \min\{h_s, ar\cos[-\tan(L-s)\tan\delta]\}$$

$$= \min\{103.9522\ .\ \cos^{-1}[-\tan(32-28)\tan(21.05117)]\}$$
$$= 91.58704^{o}$$

$$\overline{R}_B = \frac{\cos(32-28)\cos(21.05117)\sin(91.58704)}{\cos(32)\cos(21.05117)\sin(103.9522)+(103.9522)\sin(32)\sin(21.05117)} + \frac{(3.14/180)(91.58704)\sin(32-28)\sin(21.05117)}{\cos(32)\cos(21.05117)\sin(103.9522)+(103.9522)\sin(32)\sin(21.05117)}$$

$$\overline{R}_B = 0.8719101$$

Calculate the ratio value,to the total $\overline{H}_d$ which represents the ratio of diffuse radiation $\overline{H}_d / \overline{H}$ radiation intensity incident $\overline{H}$ on a horizontal surface, calculated on the basis of the monthly average.

$$\frac{\overline{H}_d}{\overline{H}} = 1.311 - 3.022\overline{K}_T + 3.427\overline{K}_T^2 - 1.821\overline{K}_T^3$$

Estimated value $\overline{K}_T$ from Table (2) based on July is equal to (0.650).

$$\frac{\overline{H}_d}{\overline{H}} = 1.311 - 3.022(o.650) + 3.427(0.650)^2 - 1.821(0.650)^3$$
$$= 0.2945154$$

Calculate the monthly average radiation coefficient incident on the inclined collector surface $(\overline{R})$.

$$\overline{R} = (1-\frac{\overline{H}_d}{\overline{H}})\overline{R}_B + \frac{\overline{H}_d}{\overline{H}}\left[\frac{1+\cos s}{2}\right] + \rho_g\left[\frac{1-\cos s}{2}\right]$$

Where ρ_g it represents the reflectivity coefficient of the earth, and the value of this coefficient is taken equal to 0.2.

$$\overline{R} = (1-0.2945154)(0.8719101)+(0.2945154)*\left(\frac{1+\cos(28)}{2}\right)+(0.2)\left(\frac{1-\cos(28)}{2}\right)$$
$$= 0.9041084$$

From it,which represents the monthly average of the total daily solar radiation falling on the $(\overline{H}_t)$ inclined surface of the collector and is equal to:

$$\overline{H}_t = \overline{R} * \overline{H}$$
$$= 0.9041084 * 26.57$$
$$= 24.02216\,MJ/m^2.day$$

The ratio of the apogee radiation incident on the inclined surface of the collector to the apogee radiation incident on the horizontal surface, calculated on the basis of the monthly average (Rn), can be calculated from the following relationship, when its value for the earth's reflectivity coefficient ρ_g is equal to 0.2.

$$R_n = (1 - \frac{r_{d,n}}{r_n}\frac{\overline{H}_d}{\overline{H}})R_{B,n} + (\frac{r_{d,n}}{r_n}\frac{\overline{H}_d}{\overline{H}})(\frac{1+\cos s}{2}) + \rho_g(\frac{1-\cos s}{2})$$

$$r_{d,n} = \frac{\pi}{24}\left[\frac{1-\cos hs}{\sin h_S - (\pi/180)hs\cos h_S}\right]$$
$$= \frac{3.14}{24}\left[\frac{1-\cos(103.9522)}{\sin(103.9522)-(3.14/180)*(103.9522)\cos(103.9522)}\right]$$
$$= 0.1153798\,day/hr$$

Whereas:

$$r_n = r_{d,n}\ [1.07 + 0.025\sin(h_S - 60)]$$
$$r_n = 0.1153798[1.07 + 0.025\sin(103.9522 - 60)]$$
$$= 0.125475\,day/hr$$

$$R_{B,n} = \frac{\cos(L-s)\cos\delta + \sin(L-s)\sin\delta}{\cos L\cos\delta + \sin L\sin\delta}$$

$$R_{B,n} = \frac{\cos(32-28)\cos(21.05117)+\sin(32-28)\sin(21.05117)}{\cos(32)\cos 21.05117)+\sin(32)\sin(21.05117)}$$

$$R_{B,n} = 0.9737954$$

$$Rn = (1 - \frac{0.1153798}{0.1254575}*(0.2945154))(0.9737954) + \left(\frac{0.1153798}{0.1254575}*0.2945154\right)\left(\frac{1+\cos(28)}{2}\right) + 0.2\left(\frac{1-\cos(28)}{2}\right)$$

$$R_n = 0.9767502$$

The average monthly calculation of the maximum daily utility $(\overline{\phi}_{max})$ can be calculated from the following relationship:

$$\overline{\phi}_{max} = \exp\left\{\left[A + B\,(\frac{R_n}{\overline{R}})\right](\overline{X}_{c,min} + c\overline{X}^2_{c,min})\right\}$$

$$A = 7.10 - 20.00\overline{K}_T + 12.08\overline{K}_T^2 \qquad B = -8.02 + 18.16\overline{K}_T - 10.68\overline{K}_T^2$$
$$= 7.10 - 20.00(0.650) + 12.08(0.650)^2 \qquad = -8.02 + 18.16(0.650) - 10.68(0.650)^2$$
$$= -0.7962004 \qquad = -0.7283001$$

$$C = -1.02 + 4.10\overline{K}_T - 1.96\overline{K}_T^2$$

$$\overline{X}_{c,min} = \frac{1}{r_n R_n \overline{H}}\left[\frac{F_R' U_c (T_{min}' - \overline{T}_a')}{F_R'(\overline{\tau}\alpha)}\right] \quad \begin{aligned} &= -1.02 + 4.10(0.650) - 1.96(0.650)^2 \\ &= 0.8169 \end{aligned}$$

(85.78969)The default value (T_{min}') is

$$\overline{X}_{c,min} = \frac{1*3600}{(0.1254575)(0.9767502)(26.57*10^6)} * \left[\frac{2.7(85.78969-30.2)}{0.66*0.94}\right]$$

$$\overline{X}_{c,min} = 0.2672979$$

$$\overline{\phi}_{max} = \exp\left\{\left[-0.7962004 + (-0.7283001)(\frac{0.9767502}{0.9041084})\right]*(0.2672979 + 0.8169(0.2672979)^2\right\}$$

$$\overline{\phi}_{max} = 0.5971832$$

Calculate the actual energy collected monthly (Q_u) from the following relationship

$$Q_u = Q_{max} - a[\exp(bf) - 1][1 - \exp(cx)][\exp(dz)]D$$

$$Q_{max} = A_c F_R' (\overline{\tau}\alpha)\overline{H}_t N \overline{\phi}_{max}$$

Where:The number of days in the month. N : The area of the complex is (40m2). : A_c

$$Q_{max} = 40(0.66*0.94)(24.02216)(31)(0.5971832)$$
$$Q_{max} = 10181.13\,MJ$$
$$a = 0.015\left(\frac{M_s C_p}{350}\right)^{-0.76}$$

$$b = 3.85 \qquad a = 0.015\left(\frac{83.5*4.19}{350}\right)^{-0.76}$$
$$c = -0.15 \qquad a = 0.0150044$$

$$d = -1.959$$

$$X = A_c F_c' U_c (100C^o)(\frac{\Delta t}{D})$$

$$D = (0.015MW)(10h/day)(30\,day)(3600s/h)$$

Where $= 16200\ MJ$

$$X = 40(2.7*10^{-6})(100)(\frac{31*24*3600}{16200})$$
$$= 1.728$$

$$C_L = \in(\dot{m}C_p)_{min} \qquad Z = \frac{D}{C_L\,(100C^o)}$$

$$C_L = (0.70)(3100\,w/^oK)(3600s/h)(10h/day)*(30\,day/month)\ (10^{-6}\,MJ/J)$$

$$C_L = 2343.6\,MJ/K$$

$$Z = \frac{16200}{2343.6(100)} = 0.06912442$$

$$f = \frac{2343.6(85.78969-82)}{16200} = 0.5422921 \quad f = \frac{C_L(T'_{min} - T_{min})}{D}$$

$$Q_u = Q_{max} - a\,[\exp(bf) - 1][1 - \exp(cx)][\exp(dz)]D$$

$$Q_u = 10181.13 - (0.0150044)[\exp(3.85*0.5422921) - 1]$$

$$*[1 - \exp(-0.15*1.728)][\exp(-1.959*0.06912442)]*16200$$

$$Q_u = 9838.566\,\text{MJ}$$

Calculate the temperature value (T_S):

$$T_S = T'_{min} + g[\exp(Kf) - 1]\exp(hz)$$

$$g = (0.2136)\left(\frac{83.5*4.19}{350}\right)^{-0.704} \quad g = (0.2136C^o)\left(\frac{M_s\,C_p}{350}\right)^{-0.704}$$

$$K = 4.702 \quad g = 0.213658C^o \; h = -4.002$$

$$f = \frac{Q_u - (UA)_S\,(T_S - T_{env.})\,\Delta t}{D}$$

$$f = \frac{(9838.566) - (5.8*10^{-6})(87.66129-24)(31*24*3600)}{16200}$$

$$f = 0.5482413$$

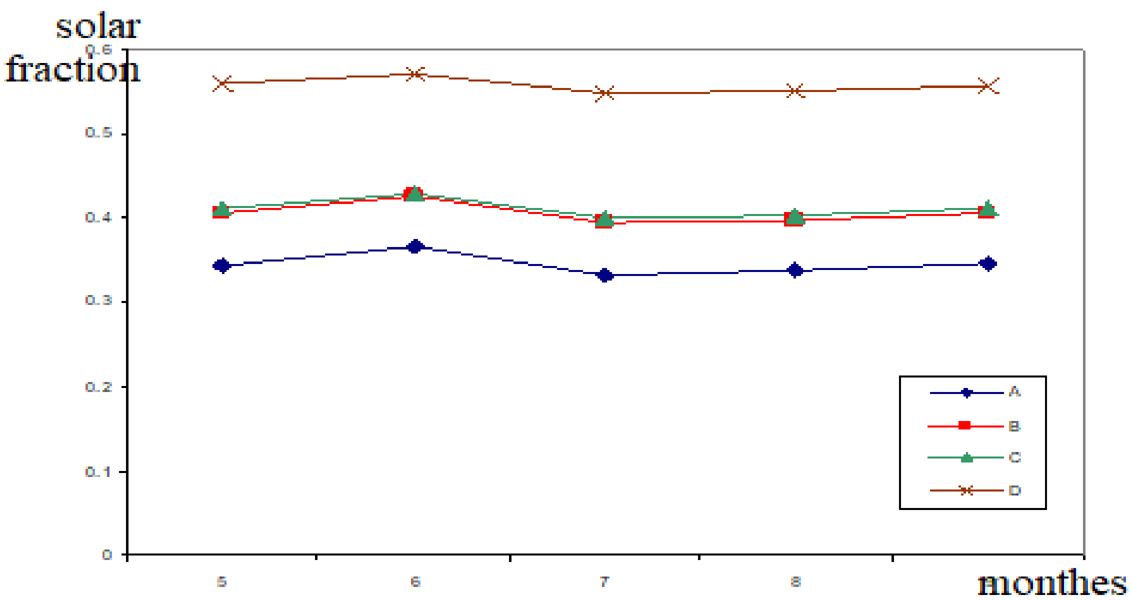

Figure 9: Changing the solar fraction values of the solar collectors during the months of use (the solar collector area is equal to 40 square meters)

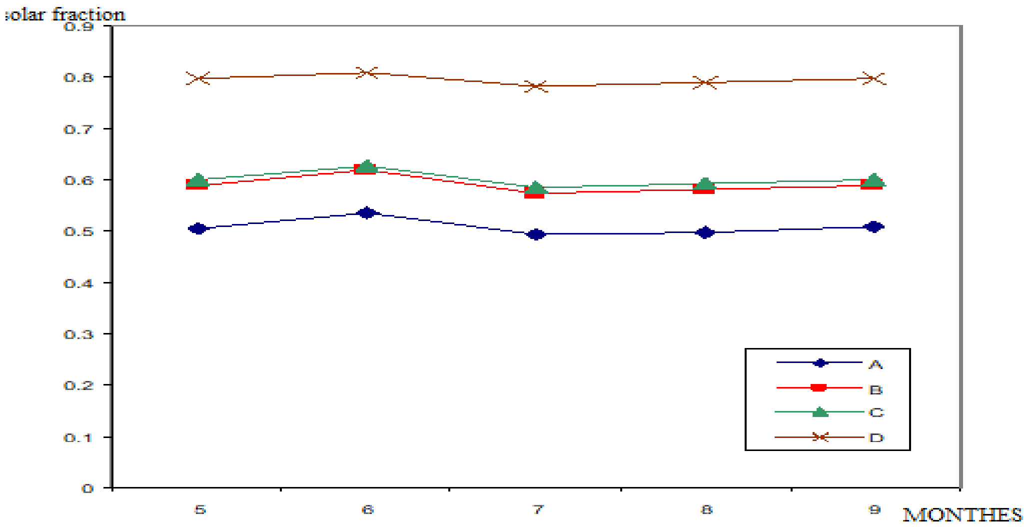

Figure 10: Changing the solar fraction values of the solar collectors during the months of use (the solar collector area is equal to 60 square meters)

Results of solving the mathematical model to evaluate the performance of the solar system used to supply hot water to an absorption cooling machine, shown in Figure (1), using the utilization method - where the monthly values of the solar fraction (f) were included in this table, which represents the percentage of solar energy contribution when using the aforementioned system in the equation The heat requirement required to operate the absorption machine. The study of the performance of the solar system in this paper was conducted under different operating conditions. The program applied the system performance to a geographical location with the same latitude north, which is the latitude of the city of Misurata / Libya We also assumed in the study that The solar system uses four different types of solar collectors designated A, B, C, and D. These collectors differ in the number of transparent surfaces they contain and the type of black paint applied to the radiation- absorbing surface of the collector. These collectors have different collection areas: 40, 60, and 80 square meters. The impact of the various operating conditions mentioned above on the performance of the solar system will be discussed below.

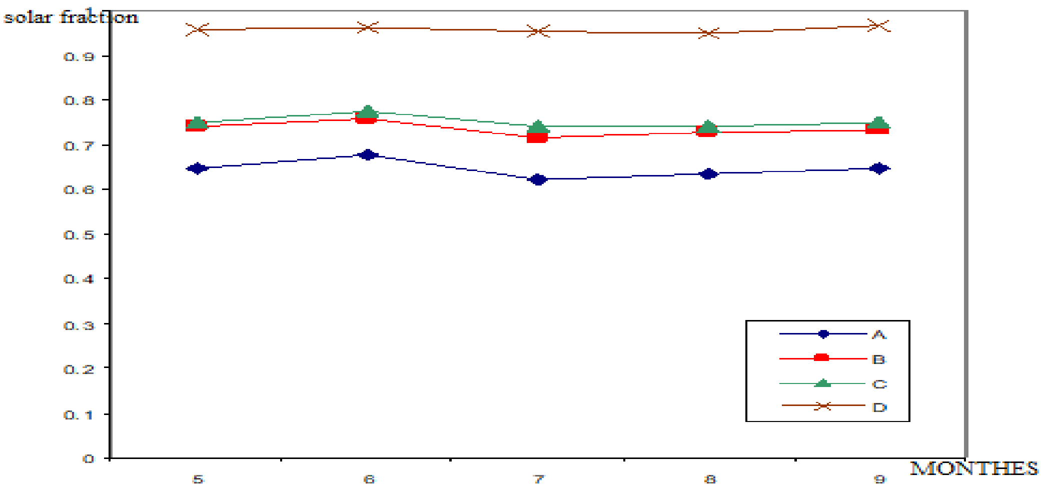

Figure 11: Changing the solar fraction values of the solar collectors during the months of use (the solar collector area is equal to 80 square meters)

Effect of the type of solar collector used:

By looking at the results obtained and listed in Table (2), it is noted that the D-type solar collector gives the best solar fraction values during the study period, which is represented by months 5, 6, 7, 8, and 9, as this collector is characterized by a low value of heat loss from it to the outside through convection and radiation, as It has two transparent surfaces and a selective black coating on the absorbing plate, which significantly increases the absorbing capacity of this surface compared to a conventional black-coated absorbing surface. It has two transparent surfaces and a selective black coating on the absorbing plate, which significantly increases the absorbing capacity of this surface compared to a conventional black-coated absorbing surface .It has two transparent surfaces, and the radiation-absorbing plate is coated with a selective black paint, significantly increasing the surface's ability to absorb incident solar radiation compared to a conventional black-coated absorbing surface. The results also show that the system's performance is generally comparable when using a Type B collector or a Type C collector. This means that using either these two types of solar collectors in a solar system offer comparable performance. Type A collectors, which are among the cheapest liquid solar collectors available, offer reasonable performance with large collection areas. Results have shown that the solar fraction of the system using this type of collector is approximately 65% with collection areas of approximately 80 square meters.

Effect of solar collector area (area of solar collectors used)

Increasing the solar collection area means increasing costs. Therefore, the solar system designer must strike an economic balance between the high initial costs of the system when using large solar collection areas and the operating costs of the system when using small collection areas but with a greater need to use auxiliary power to offset the thermal loads required for the application.

It is noted from the results obtained and listed in Table (2) that the solar fraction value of the system increases with the increase in the solar collection area and for the different types of solar collectors used. For a solar collection area of approximately 80 square meters and for a type D solar collector, for example, it is noted that the average value of the fraction during the months of use, the solar energy is approximately 95%. This means that increasing the collection area, even slightly, beyond the limit mentioned above, enables the solar system to completely cover the entire thermal demand required to operate the absorption machine.

Conclusion:

The use of a solar water heating system has significantly contributed to providing the thermal energy required to operate an absorption chiller, especially when this system is used for solar collectors with high thermal performance and reasonable collection areas. Increasing the solar collection area significantly increases the solar fraction value of the system. The solar efficiency of the system also increases with the quality of the solar collectors used. Furthermore, in regions characterized by high solar radiation in the summer, including Arab regions, the use of solar energy for absorption cooling is very economically acceptable.

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