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DESIGN AND FABRICATION OF DOUBLE PASS SOLAR DRYING SYSTEM WITH SMOOTH AND ROUGH SURFACES AT DIFFERENT CONDITION

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Abstract: An indirect, active-type, environmentally friendly, low-value sun dryer changed into designed to dry numerous Agricultural products. The dryer changed into constructed with the aid of using domestically available, biologically degradable, low-value materials. The dryer Consists of sun flat plate air heater with 2 layers of insulation, drying chamber and a fan with a regulator to induce required air glide with inside the system. Tomato is the selected crop for the experimentation given that it's miles excessive in manufacturing and additionally has enormous loss in India. Also, dried Tomatoes are having right nutritive price which makes it as crucial diet. In this work dry Tomato slices and to take a look at its drying traits like price of Drying and excellent of dried Tomato in phrases of taste, coloration and shape. The dryer has the subsequent features: Different air go with the drift configurations (air go with the drift among glass cowl and absorber plate known as because the pinnacle go with the drift and air go with the drift Between absorber plate and the lowest insulation of sun collector known as the lowest go with the drift), compelled go with the drift with Variable go with the drift charges from 0–3 m/s and unique mounting schemes (traditional trays and wood skewers).The drying fee become located to growth whilst timber skewers had been used as opposed to traditional trays. At the stop of the day, the overall distinction in moisture content material is located to be 3.1 % that's tremendous understanding that The fee of drying appreciably decreases with time. Tomato dried at 1 m/s air waft fee become of the first-rate nice in phrases of Colour, flavor and form whilst as compared to drying at 0.five and a pair of m/s air waft fee whilst the climate circumstance and Ambient situations had been nearly the equal for all of the instances with negligible distinction.

Keywords: Solar drying; Design of sun dryer; Thermal analysis; Experimentation; Top glide and backside glide; Conventional trays and wood skewers; Varying air glide rate.

I. INTRODUCTION

In many elements of the world, recognition is developing approximately renewable strength which has an essential position to play in extending era to the farmer in growing nations like India to growth their productivity. Poor infrastructure for storage, processing and advertising in many nations of the Asia-Pacific area consequences to a excessive percentage of waste, which common among 10 and 40 % . Although India is a primary manufacturer of horticultural plants, many Indians are not able to acquire their every day requirement of culmination and veggies and the Human Development Index (HDI) could be very low. Considerable portions of culmination and veggies produced in India visit waste due to wrong postharvest operations and the shortage of processing . This consequences in a great hole among gross meals manufacturing and internet availability . Reduction of postharvest losses is vital in growing meals availability from current manufacturing [2]. Traditional strategies utilized in meals upkeep are drying, refrigeration, freezing, salting (curing), sugaring, smoking, pickling, canning and bottling. Among those, drying is mainly ideal for growing nations with poorly mounted low-temperature and thermal processing facilities. It gives a relatively powerful and realistic approach of upkeep to lessen postharvest losses and offset the shortages in supply. Drying is a way of dehydration of meals merchandise because of this that decreasing the moisture content material from the meals to enhance its shelf existence through stopping bacterial growth [3]. It remains utilized in home as much as small business length drying of plants, agricultural merchandise and nutrition including culmination, veggies, fragrant herbs, timber etc. contributing therefore substantially to the financial system of small agricultural groups and farms [4–6]. Hii et al.

Literature Review Sun oriented drying might be characterized into immediate and roundabout sunlight based dryer. In direct sun oriented dryers the air warmer contains the grains and sun powered energy which goes through a straightforward cover and is consumed by the grains. Basically, the hotness needed for drying is given by radiation to the upper layers and ensuing conduction into the grain bed. Be that as it may, in backhanded dryers, sun based energy is gathered in a different sun oriented gatherer (air warmer) and the warmed air then, at that point, goes through the grain bed, while in the blended mode sort of dryer, the warmed air from a different sunlight based authority is gone through a grain bed, and simultaneously, the drying bureau assimilates sun based energy straightforwardly through the straightforward dividers or the rooftop.

The erratic ascent and successive shortage of petroleum derivative sped up the constant quest for an elective power source. Sun based is one of the inexhaustible and practical wellsprings of force that pulled in an enormous local area of analysts from everywhere the world. This is to a great extent because of its plentiful in both immediate and roundabout structure. As such the improvement of effective and cheap gear for the drying of agrarian and marine items utilizing sun based power advanced in this way working on the nature of the items just as working on the personal satisfaction. The utilization of sunlight based dryers in the drying of horticultural items can essentially lessen or dispose of item wastage, food contamination and at the at some point upgrade usefulness of the ranchers towards better income inferred. A sun based yield drying framework doesn't exclusively rely upon sunlight based energy to work; it consolidates fuel igniting with the energy of the sun, along these lines decreasing petroleum product utilization. In this paper an audit of the sun based dryer is introduced. The different plan of the sun based dryer is accounted for in the writing up to this point is introduced.

Dronachari M.1* and Shriramuluet. et al Due to exponential rise in the price of fuel and depletion of fossil fuel, there is a need to look for other alternatives like nonconventional energy resources viz. solar energy. India is blessed with good sunshine hours. A review paper is made to use solar energy for drying of agricultural food products with different dryers available, such as direct type, indirect type, mixed mode and hybrid solar dryers, also reviews about different heat storage material used in solar dryers after sunshine hours. In India most of rural areas follows the open sun drying method for drying of agricultural material like grains, fruits and vegetables, but it has some disadvantages like time consuming, labour demanded and environmental contamination.39

Megha S. Sontakke1, Prof. Sanjay P. et al Sunlight based drying is one of the utilization of sun powered energy. Drying implies dampness expulsion from the item. Drying is useful in protecting food item for long time; it keep item from defilement. Direct sun powered drying, aberrant sunlight based drying, and blended mode sun oriented drying these are distinctive sun based drying strategies. Essentially open to the sun or direct sun drying method is utilized. In any case, it has a few hindrances. These inconveniences can be dispensed with by backhanded sort of dryer which is utilized for drying items as utilization of sun oriented energy. In this paper, we concentrated on the distinctive procedure of drying and different methods of sunlight based drying [40].

EL- Amin Omda Mohamed Akoy et al, developed a natural convection solar dryer (Cabinet Type) to dry mango slices. The designed dryer had a collector area of 16.8m2. They dried 195.2 kg of fresh mangoes from 81.4% to 10% wet basis. They dried mangoes in two days under ambient conditions during harvesting period of April to June.

Sharma, A., Chen, C. R., Vu Lan, N. et. Al Solar drying is often differentiated from ―sun drying by the use of equipment to collect the sun‘s radiation in order to harness the radiative energy for drying applications. Sun drying is a common farming and agricultural process in many countries, particularly where the outdoor temperature reaches 30^{O}C or higher. In many parts of South East Asia, spice s and herbs are routinely dried. However, weather conditions often preclude the use of sun drying because of spoilage due to rehydration during unexpected rainy days. Furthermore, any direct exposure to the sun during high temperature days might cause case hardening, where a hard shell develops on the outside of the agricultural products, trapping moisture inside. Therefore, the employment of solar dryer taps on the freely available sun energy while ensuring good product quality via judicious control of the radioactive heat. Solar energy has been used throughout the world to dry products. Such is the diversity of solar dryers that commonly solar-dried products include grains, fruits, meat, vegetables and fish. A typical solar dryer improves upon the traditional open-air sun system in five important ways [12].

PROBLEM STATEMENT : Food researchers have observed that by lessening the dampness content of food to somewhere in the range of 10 and 20%, microorganisms, yeast, form and compounds are kept from ruining it. The character and the vast majority of the healthy benefit is safeguarded and thought [16]. At every possible opportunity, it is conventional to reap most grain crops during a dry period or season and straightforward drying techniques, for example, sun drying are sufficient. Nonetheless, development of the harvest doesn't generally correspond with a reasonably dry period. Moreover, the presentation of high-yielding assortments, water system, and further developed cultivating rehearses have prompted the requirement for elective drying practices to adapt to the expanded creation and grain gathered during the wet season because of multi-editing.

PROBLEM STATEMENT OBJECTIVES:-The objective of present study is to construct a solar air dryer in which the vegetables are dried simultaneously by direct radiation through the transparent walls and roof the solar collector. The problems of low and medium scale processor could be alleviated, if the solar dryer is designed and constructed with the consideration of overcoming the limitations of direct and indirect type of solar dryer. So therefore, this work will be based on the importance of a solar dryer which is reliable and economical, design and construct a mixed mode of double pass solar dryer using locally available materials and to evaluate the performance of this solar dryer. This project presents the design, construction and performance of a double pass solar dryer for food preservation. In the dryer, the heated air from a separate solar collector is passed through a vegetable bed, and at the same time, the drying cabinet absorbs solar energy directly through the transparent roof. The outcomes got during the trial uncovered that the temperatures inside the dryer and sun powered gatherer were a lot higher than the encompassing temperature during most hours of the sunlight. The temperature ascend inside the evaporating bureau was to 70% for around three hours following 12.00h (early afternoon). The dryer displayed adequate capacity to dry food things sensibly quickly to a protected dampness level and all the while it guarantees an unrivaled nature of the dried item.

PROBLEM CONSTRAINTS

Drying processes assume a significant part in the protection of farming items. They are characterized as a course of dampness evacuation because of concurrent hotness and mass exchange. The point of this undertaking is to introduce the turns of events and possibilities of sun based drying advances for drying grains, organic products, vegetables, flavors, restorative plants.

In planning of sun oriented dryer an originator have underlined air warming rather than drier ventilation while encompassing air is dry enough a large portion of year to give adequate drying. The impact of wind on driers that of residue and creepy crawly on drying item have additionally been not seen that is the reason the greater part of the sun based dryer has been fizzled.

PROBLEM JUSTIFICATION AND OUTCOMES:

As discussed in the above point about issue requirements the current work is defended to take care about each direct remember toward defeat every one of the imperatives. This task presents the plan, development and execution of a double pass sun based dryer for food safeguarding. In the dryer, the warmed air from a different sun based gatherer is gone through a grain bed, and simultaneously, the drying bureau assimilates sun powered energy straight forwardly through the straightforward dividers and rooftop. The outcomes acquired during the trial uncovered that the temperatures inside the dryer and sun oriented gatherer were a lot higher than the surrounding temperature during most hours of the sunshine

DESIGN APPROACH AND METHODOLOGY

Solar drying refers to a technique that utilizes incident solar radiation to convert it into thermal energy required for drying purposes. Most solar dryers use solar air heaters and the heated air is then passed through the drying chamber (containing material) to be dried. The air transfers its energy to the material causing evaporation of moisture of the material.

DRYING MECHANISM

Drying is a phenomenal way of protecting food, and sun oriented dryers are a proper food safeguarding innovation for an economical world. Drying jam food sources by eliminating additional dampness from the food to forestall rot and waste. Water content of appropriately dried food shifts from 5%–25% relying upon the sort of food. Effective drying relies upon the accompanying.

1. Enough hotness to draw out dampness, without preparing the food;

2. Dry air to retain the delivered dampness; and

3. Satisfactory air dissemination to take away the dampness

CLASSIFICATION OF DRYING SYSTEMS

Solar dryers are available in a range of size and design and are used for drying of various agricultural products. Various types of Dryers are available in the market as per requirement of farmers. Primarily all the drying systems are classified on the basis of their operating temperature ranges that is High Temperature solar dryer and Low Temperature Solar dryer.

A. High Temperature Solar Dryer

B. Low Temperature Dryer

DESIGN SPECIFICATIONS AND ASSUMPTIONS

The dryer turned into built the usage of plywood, , wood skewers, clean glass, galvanized iron sheet and axial fan for operation of the dryer which can be locally to be had with low cost. The thickness of Tomato slices turned into decided on to be 4–5 mm [17, 27, 29]. An oblique form of sun dryer turned into taken into consideration because it does now no longer have an effect on the shade and nutrient content material of the produce as with inside the case with an instantaneous type. Also, the drying is uniform without any localized heating. Flat plate collector is used since it is straightforward to manufacture and additionally economical. The collector is made of GI sheet of 0.6 mm thick because it is a superb conductor and economical.

COMPONENTS OF SOLAR DRYER

The solar dryer consists of the solar collector (air heater), the drying cabinet and drying trays:

SOLAR HEAT COLLECTOR (AIR HEATER):

The heat absorber (inner box) of the solar air heater was constructed using 2 mm thick cast iron plate, painted black, is mounted in an outer box built from plywood. The solar collector assembly consists of air flow channel enclosed by transparent cover (glazing). An absorber mesh screen midway between the glass cover and the absorber back plate provides effective air heating because solar radiation that passes through the transparent cover is then absorbed by both the mesh and back-plate. The glazing is a single layer of 4 mm thick transparent glass sheet; it has a surface area of 609 mm by 914 mm and of transmittance above 0.7 for wave lengths in the rage 0.2 – 2.0 μm and opaque to wave lengths greater than 4.5 μm. The effective area of the collector glazing is 0.556 m^2. One end of the solar collector has an air inlet vent of area 0.018273 m^2.

The Drying Cabinet

The drying cabinet together with the structural frame of the dryer was built from well-seasoned woods which could withstand termite and atmospheric attacks. An outlet vent was provided toward the upper end at the back of the cabinet to facilitate and control the convection flow of air through the dryer. Access door to the drying chamber was also provided at the back of the cabinet. This consists of three removable wooden panels made of 13 mm plywood, which overlapped each other to prevent air leakages when closed. The roof and the two opposite side walls of the cabinet are covered with transparent glass sheets of 4 mm thick, which provided additional heating.

DRYING TRAYS

The drying trays are contained inside the drying chamber and were constructed from a double layer of fine chicken wire mesh with a fairly open structure to allow drying air to pass through the food items.

THE ORIENTATION OF THE SOLAR COLLECTOR

The flat-plate solar collector is always kept and oriented in such a way that it receives maximum solar radiation during the desired season of used. The best stationary orientation is due south in the northern hemisphere and due north in southern hemisphere. Therefore, solar collector in this work is oriented facing south and tilted at 30 º -45º to the horizontal. This inclination is also to allow easy run off of water and enhance air circulation.

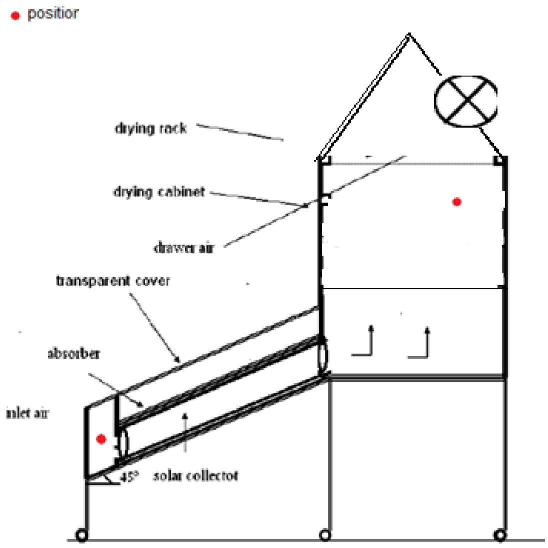


Fig. sectional view of double pass solar dryer

EXPERIMENTAL PROCEDURE

The sun dryer changed into positioned over the roof pinnacle of a building primarily based totally at the design (Fig. 3.2). Axial glide fan changed into constant at the pinnacle of the drying chamber and tested. The experiments had been performed with inside the month of March, from daily nine am to five pm. The sun radiation become measured using pyranometer. The K-kind thermocouples have been used for the dimension of temperature within side the collector assembly. The temperature become measured for every hour from nine am to 5 pm at 3 points, particularly entry, center and exit of the glass cover, absorber plate and backside insulation as it may be visible in Fig. 4. The temperature of the air with inside the drying chamber and the surroundings has been measured by the thermometer. A vane-kind anemometer is used to degree the air velocity. The weight of the Tomato is measured using a digital weighing pan. All the experiments were repeated to confirm the repeatability of the data obtained. The following experiments are carried out:

DESIGN PARAMETERS

Table 4.1 Design parameter of solar collector

Overall length	**0.609 m**
Overall height	**0.609m**
Absorber plate dimension	**0.609 × 0.904 m**
Glass cover thickness	**0.004 m**
Insulation total thickness (bottom)	**0.06 m**
Gap between absorber plate and glass cover	**0.05 m**
Gap between absorber plate and insulation	**0.05 m**
Number of trays	**3**
Tray dimension	**0.3 × 0.6 m**
Distance between trays	**0.15 m**
Tilt angle of the collector	**40° due south**

RESULT AND DISCUSSION

This project presents the design, construction and performance of a double pass solar dryer for food preservation. In the dryer, the heated air from a separate solar collector is passed through a grain bed, and at the same time, the drying cabinet absorbs solar energy directly through the transparent walls and roof. The results obtained during the test period revealed that the temperatures inside the dryer and solar collector were much higher than the ambient temperature during most hours of the day-light. The temperature rise inside the drying cabinet was up to 73°C for about three hours immediately after 12.00h (noon). The dryer exhibited sufficient ability to dry food items reasonably rapidly to a safe moisture level and simultaneously it ensures a superior quality of the dried product.

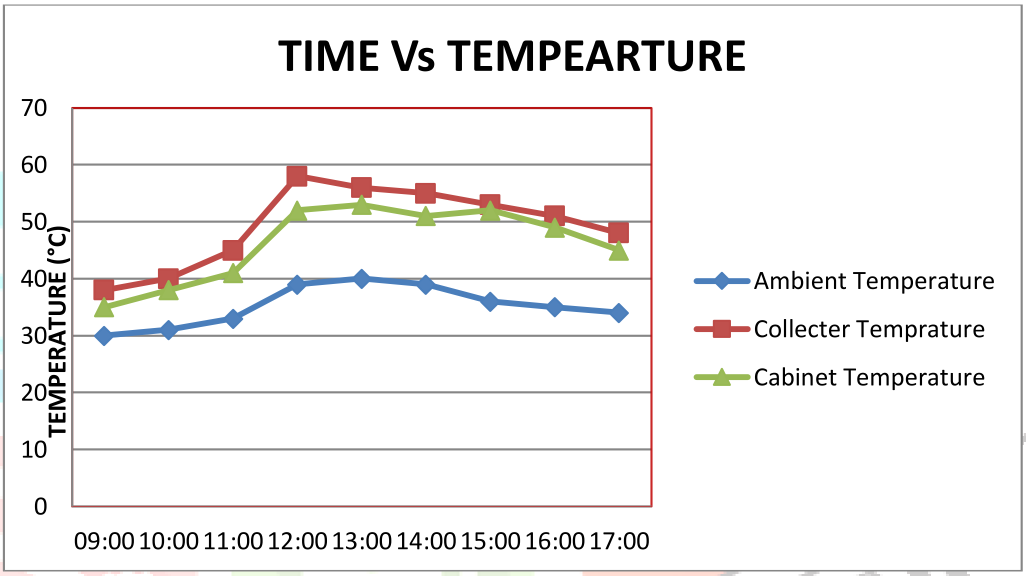
Variation of the temperatures in the solar collector and the drying cabinet compared to the ambient temperature.

TABLE 4.1 shows a typical day results of the hourly variation of the temperatures in the solar collector and the drying cabinet compared to the ambient temperature. The dryer is hottest about mid-day when the sun is usually overhead. The temperatures inside the dryer and the solar collector were much higher than the ambient temperature during most hours of the daylight. The temperature rise inside drying cabinet was up to 24ºC (74%) for about three hours immediately after 12.00h (noon). This indicates prospect for better performance than open-air sun drying.

DATE 12-10-2021

Table 4.2 without Black Paint on Solar Collector

Sl. No.	Time	Ambient Temperature(°C)	Collector Temperature (°C)	Cabinet Temperature (°C)
1	9:00	30	38	35
2	10:00	31	40	38
3	11:00	33	45	41
4	12:00	39	58	52
5	13:00	40	56	53
6	14:00	39	55	51
7	15:00	36	53	52
8	16:00	35	51	49
9	17:00	34	48	45

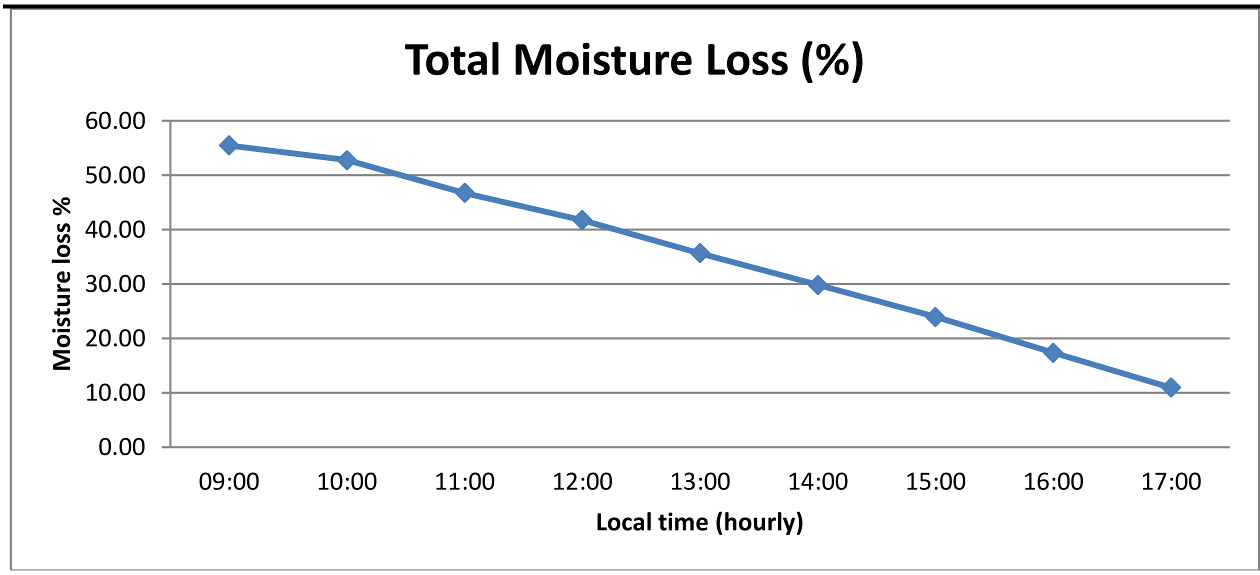


DATE 13-10-2021

WITHOUT BLACK PAINT ON SOLAR COLLECTOR

Table 4.3: Hourly Moisture Loss and Mass of the Tomato

Time	Mass of Tomato (g)	Moisture Loss (g)	% Moisture Loss	Total Moisture content (%)
9:00	575	0	0	55.48
10:00	560	15	2.68	52.80
11:00	528	32	6.06	46.74
12:00	503	25	4.97	41.77
13:00	474	29	6.12	35.65
14:00	448	26	5.80	29.85
15:00	423	25	5.91	23.94
16:00	397	26	6.55	17.39
17:00	373	24	6.43	10.96



CONCLUSION

From the test completed, the accompanying ends were made. The sun powered dryer can raise the encompassing air temperature to an extensive high worth upto 70°C for expanding the drying pace of rural harvests. The item inside the dryer requires less considerations, similar to assault of the item by downpour or nuisance (both human and creatures), contrasted and those in the open sun drying. Albeit the dryer was utilized to dry Tomato, it very well may be utilized to dry different harvests like sweet potatoes, cassava, maize and plantain and so forth There is ease in observing when contrasted with the regular sun drying strategy. The capital expense engaged with the development of a sun powered dryer is a lot of lower to that of a mechanical dryer. the current work additionally assess the effectiveness investigation after number of analysis like without dark covering ,with covering and unpleasant surface as result shows 51% proficiency as displayed in outcome.

Also from the test carried out, the simple and inexpensive mixed-mode solar dryer was designed and constructed using locally sourced materials. The hourly variation of the temperatures inside the cabinet and air-heater are much higher than the ambient temperature during the most hours of the day-light. The temperature rise inside the drying cabinet was up to 39ºC for about three hours immediately after 12.00h (noon). The dryer exhibited sufficient ability to dry food items reasonably rapidly to a safe moisture level and simultaneously it ensures a superior quality of the dried product.

APPENDICES

Calculation for Date 15/10/2021

1. **Inlet vent area**

$$A = LB$$

L=484.5 mm

B = 102mm
then
A= 0.0494 m^2.

2. **Mass flow rate of air**

$$\mathbf{m=\rho AV}$$

m=0.029 kg/s
where,
ρ=density of air
A= area of inlet vent
V=velocity of air

3. **Heat transfer coefficient**

h_i= heat transfer coefficient for convection in side of collector W/m^2K
h_o= heat transfer coefficient for convection in side of collector W/m^2K

$$h=2.512(\Delta T)^{1/4}$$

h=2.512$(70-32)^{1/4}$
h=6.19W/m^2K

4. $\mathbf{Q_L=U_L A_C \Delta T}$

QL = Qcond + Qconv + QR
$U=\frac{1}{\frac{1}{h}+\frac{L}{K}}$
$\mathbf{Q_L}$**=190.541 W**
I = rate of total radiation incident on the absorber's surface (W/m2);
Ac = collector area (m2);
Qu = rate of useful energy collected by the air (W);
Qcond = rate of conduction losses from the absorber (W);
Qconv = rate of convective losses from the absorber (W);

QR = rate of long wave re-radiation from the absorber (W);
Qρ = rate of reflection losses from the absorber (W).

5. **Qu = τ ITAc (1 – ρ) – QL**
   Q_u=377.634 W
6. **The collector heat removal factor, FR**

$$F_R = \frac{\dot{m}_a C_{pa}(T_c - T_a)}{A_c[\alpha\tau I_T - U_L(T_c - T_a)]} \qquad (10)$$

   F_R=0.90881

7. **Qg = AcFR[(ατ)IT – ULAc(Tc – Ta)].**
   Qg=343 W
8. The thermal efficiency of the collector is defined

$$\eta_c = \frac{Q_g}{A_c I_T}. \qquad \eta_c = 51.07\%$$

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