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Research Paper :

Design and development of roof integrated forced convection type solar dryer for drying industrial product

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ABSTRACT

Roof integrated forced convection type solar dryer for drying 2500 kg/day dibasic calcium phosphate (DCP) has been designed and installed at M/S Phosphate Pvt. Limited, Jhamar Kotra Road, Udaipur. In this paper attempt has been made to design and development of roof integrated forced convection type solar dryer for drying DCP. The arrangement has been made to circulate air within drying chamber using exhaust fan of 2 kW capacity. The study showed that DCP took eight hours to dry at 10% (wb) moisture content. The average temperature inside the drying chamber was about 65^0C.

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Key words : Heat utilization factor, Forced convection dryer, DCP

In India many industries are using conventional energy for drying *i.e.* electricity, coal and diesel fired hot air generator etc. Considering sharp increase in fuel prices, uncertainties in supplies, research work was conducted to design and develop a simple and efficient roof integrated forced convection type solar dryer for drying dibasic calcium phosphate (DCP) from 40% moisture content to 10% moisture content. This material is being used as animal feed since it is rich in phosphorus and calcium for poultry bird. The whole system was designed and installed at M/s Phosphate Zinc Pvt. Limited, Jhamar Kotra Road, Udaipur for drying 2 ton of DCP per day.

The rotary dryer is a type of industrial dryer employed to reduce or minimize the moisture content of the material by bringing it into direct contact with a heated gas or air. The hot air required for drying of produce in rotary dryer can be supplied by various means. When solar air heaters are used for heating air for drying, orientation and space for installation of solar air heaters are important parameters. Roof space can be effectively utilized for installation of solar air heaters with minimum obstacles to receive solar energy.

Forced convection solar drying system designed and fabricated comprising of an array of 40 solar collectors and three drying cabinets with a blower to yield 300 kg of dry product of custard powder in a normal sunshine day in Pune. It was found that such a system is feasible and has an ability to save large amount of conventional fuel. It was also observed that forced convection solar drying systems are suitable in food and chemical industries where large scale drying is required (Panwar *et al.*, 1995).

Roof integrated forced convection solar dryer has developed for drying herbs and spices using hot air from solar collector having area of 72 m^2. The performance of the dryer was conducted to dry four batches of rosella flower and 3 batches of lemon grass. For drying of 200 kg of rosella flowers and lemon grasses total 4 and 3 days were required, respectively. The solar air heater has an average daily efficiency of 35 %. (Janjai and Tung, 2005).

An indirect forced convection solar dryer integrated with sensible heat material (gravel) has developed and its performance was tested for drying of pineapple slices. The moisture content (wet basis) of pineapple was reduced from about 87.5% to 14.5% in about 29 h in bottom tray and 32 h in top tray (Mohanraj and Chandrasekar, 2009).

A forced convection solar cabinet dryer was designed for drying cashew kernel for 60 kg per batch capacity. The economics of forced convection solar cabinet dryer indicated its feasibility, with a payback period of 1 year and 10 months, for drying of cashew kernels (Mohod, 2010).

METHODOLOGY

System design:

The different associated parameters required for designing purpose are tabulated in Table 1:

Table 1 : Assumptions made for design of forced convection type solar dryer

Design parameters		Particulars
Type of material	:	Di-basic calcium phosphate
Initial moisture content, $M_{i,}$	:	40% (wb)
Final moisture content, $M_{f,}$	:	10 % (wb)
Weight of material, W_g	:	2500 kg
Location	:	Udaipur
Ambient air temperature, T_a	:	30^0C
Ambient air relative humidity, RH_a	:	50 %
Average sunshine hours	:	8 hr
Drying period, t_d	:	9.00 to 17.00 h
Drying air temperature, T_f	:	80^0C
Efficiency of dryer, η	:	25 %
Specific heat of DCP, C_p	:	2.17 kJ $kg^{-1}\,{}^0C^{-1}$
Density of material, ρ_m	:	533 kg m^{-3}
Global radiation at Udaipur, I_{sc}	:	720 Wm^{-2}

The designed roof integrated forced convection type solar drying system was installed and tested at M/S Phosphate India Ltd., Zamar Kotra Road, Udaipur. The system was oriented to face the south to maximize the incident solar radiation on the solar collector. There were 36 units of solar air heaters connected in series and parallel combination (Fig. 1). The area of whole assembly of

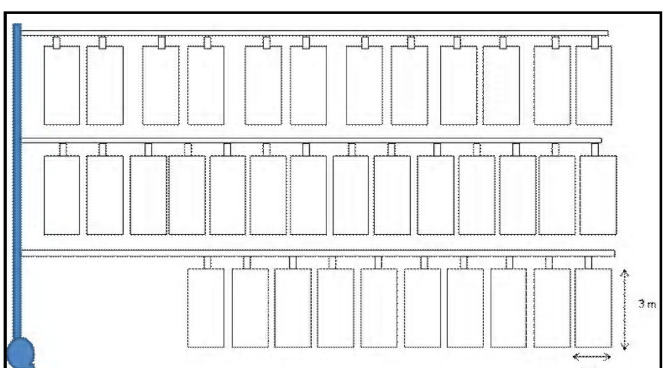

Fig. 1 : Layout of air heating units installed on the roof

collectors was 162 m^2. The view of flat plate collectors for heating air is shown in Plate 1.

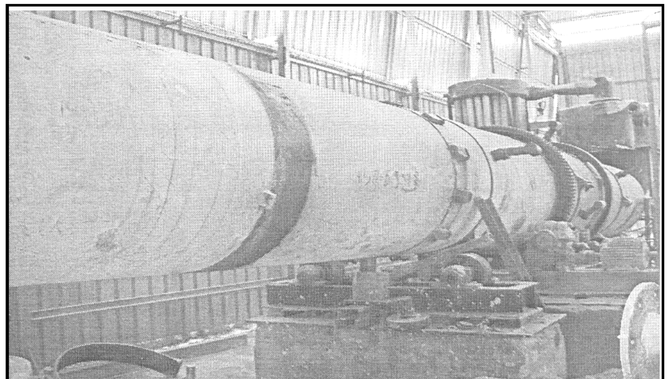

Plate 1 : Rotary kiln as drying chamber

The drying chamber was also designed and developed. Drying chamber was a rotary dryer, which is 9.5 m long made up of MS sheet. The hot air from flat plate collectors was fed to rotary dryer from one side and exhausted by exhaust fan situated on the exit door of the drying chamber. The hot air from flat plate collector was sucked by using a blower of 7.5 kW capacity and it is fed to rotary kiln. The arrangement was made to circulate air within drying chamber using exhaust fan of 2 kW capacity. To avoid heat losses 2 inch insulation (glass wool) was provided around the rotary kiln

Instrumentation:

For drying of DCP, experiments were conducted in the summer months of 2011 under climatic conditions of Udaipur (27° 42' N, 75° 33' E). The global solar radiation incident on flat plate collector was measured by solarimeter. Wind speed and exit air velocity at drying chamber outlet were measured by using Lutron Anemometer Model no. AM-4822 and hot wire anemometer Model no. LM-4204, respectively. Calibrated NiCr-Ni thermocouples connected to a multi channel Emcon – Digital Solar Data Monitor (Environmental Measurement and Control, Cochin) were used to measure the temperatures at three different location of developed system. The hourly data was taken. Relative humidity was measured by using hygrometer.

RESULTS AND DISCUSSION

The results of the present study have been summarized under following heads:

Thermal performance of drying system:

The drying test was conducted from 24^{th} to 29^{th}

Table 2 : Technical specification of roof integrated forced convection type solar drying system

Flat plate air heating unit specification	
Length	:4.5 m
Width	: 1 m
Surface area	: 4.5 m^2
No. of units	: 36
Total area	:162 m^2
Connecting ducts	
Diameter of duct	:0.1 m
Blower	:7.5 kW
Dryer specification	
Diameter of dryer	:0.8 m
Length of dryer	: 9.5 m
Diameter of central stationary hollow shaft	: 0.1 m
Exhaust fan	: 2 kW
Insulation	:2" Glass wool

March, 2011. To study the temperature profile at collector outlet and inside the drying chamber, temperature at three different locations inside the dryer was measured. Fig.2 shows the temperature variation at collector outlet and inside the drying chamber.

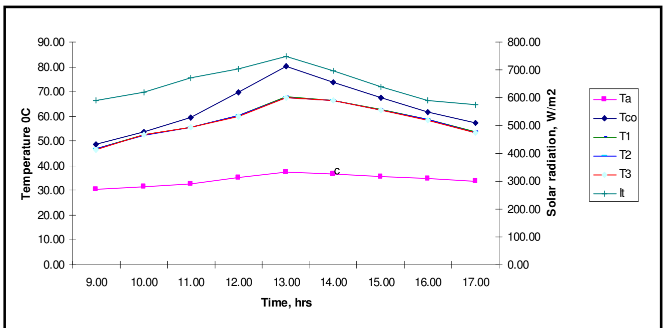

Fig. 2 : Performance curve during no load testing

The maximum temperature attained at the collector and drying chamber inlet was 80.3 ^{0}C and 67.8 ^{0}C at 13:00 hr, respectively, when the insolation was also maximum *i.e.* 750 W/m^2.

The temperature variation during full load test is shown in Fig.3. It was observed that during the full load testing the maximum temperature at ambient, collector outlet and inlet of drying chamber was 38.2 ^{0}C, 81.0 ^{0}C, 66.6^{0}C and 64.8^{0}C, respectively. The maximum solar insolation was 757 W/m^2 at 13:00 hrs.

Performance of solar collector:

The performance of solar collector was evaluated in terms of hourly collector efficiency with respect to time.

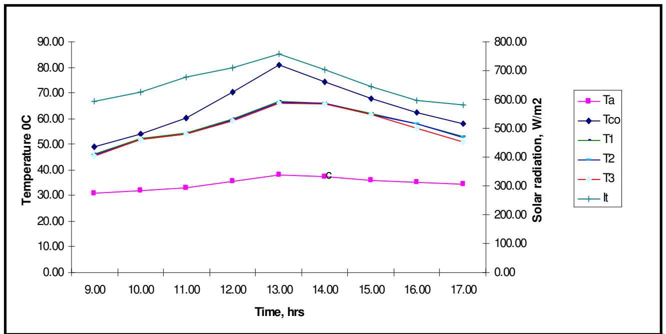

Fig. 3 : Performance curve during full load test

The average collector efficiency during the test is represented in Fig. 4. During the no load test and full load test the collector efficiency varied in the range of 22 per cent to 41 per cent with an average of 36.2 per cent

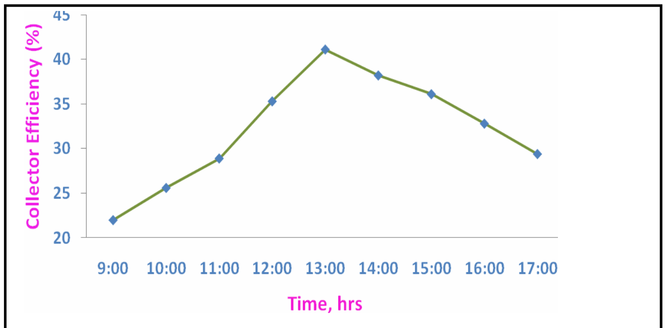

Fig. 4 : Variation in collector efficiency

Drying characteristics:

The moisture content was reduced from 40 per cent (wb) to 10 per cent within 8 hours. The average heat utilization factor for no load test varied in the range of 0.02 to 0.08 and for full load test varied in the range of 0.05 to 0.10.The drying rate during full load condition was varied in range of 0.39-0.57 g water evp. /g of dry matter hr.

From Fig.5 it is cleared that drying rate curves

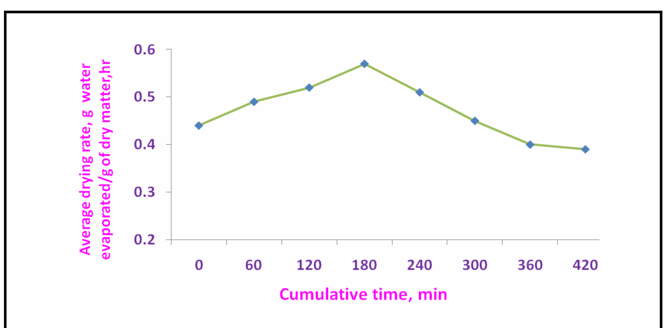

Fig. 5 : Variation in drying rate

showed nearly constant rate drying during the drying period, though product contains high initial moisture of about average 40 per cent. This may be due to fact that the dryer was continuous flow type.

Conclusion:

Drying is one of the most important operation in agro processing industries which consumes large amount of energy. Most of agricultural products are dried at temperature range of 60^0C to 75^0C. Solar energy can be effectively utilized for heating air for this range of temperature. With the use of forced convection drying system uniform and faster drying was achieved.

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