Studies on Semi-Cylindrical Solar Tunnel Dryer for Drying Di-basic Calcium Phosphate

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ABSTRACT

A walk in type semi-cylindrical poly house for drying Di- basic Calcium Phosphate for 1.5 tons capacity per batch has been commissioned at the M/s Phosphate India Pvt. Limited, Udaipur. In this paper the results of year round thermal performance of collector of semi-cylindrical solar tunnel dryer has been presented. The performance of the dryer during drying Di- basic Calcium Phosphate has been analyzed through no load and full load test.

Keywords: Solar Tunnel Dryer (STD), Di-basic Calcium Phosphate (DCP), Ultra-Violet (UV), India.

1. INTRODUCTION

Solar drying is a continuous process where moisture content, air and product temperature change simultaneously along with the two basic inputs to the system i.e. the solar insolation and the ambient temperature. The drying rate is affected by ambient climatic conditions. This includes: temperature, relative humidity, sunshine hours, available solar insolation, wind velocity, frequency and duration of rain showers during the drying period.

Open sun drying of various industrial and agricultural products is being practiced since age. Open sun drying is slow and expose the produce to various losses and deterioration in quality. A number of industries have, therefore, accepted mechanical drying of the produce. Fuel wood, petroleum fuel, coal or electricity is used for air heating in the mechanical dryers. Solar air dryers have great potential for replacement of industrial scale drying of industrial and agricultural products. Besides, effecting saving of precious fossil fuel, fuel wood or electricity, the solar drying may also be cost effective.

M/s Phosphate India Pvt. Limited, Udaipur produces feed grade Di-basic Calcium Phosphate in their plant using rock phosphate as the prime raw material. The initial moisture content of the Di-basic Calcium Phosphate is about 38-40 percent and this is to be reduced to around 10 percent for further usages (Rathore, 2004). Presently mechanical methods are used for drying the material. It consists tray drying system which equipped with a 5.6 kW blower, a 7.5 kW suction motor and 3.7 kW hammer mill. The air is heated to a temperature of around 60^0C in diesel fired hot air generator. Its drying is costly, time consuming and labour intensive

Looking to the power requirement and high cost of existing mechanical dryer, a solar tunnel dryer has been design and commissioned at the factory site.

A solar tunnel dryer is a tunnel like framed structural covered with Ultra-Violet (UV)-stabilized polythene sheet, where agricultural and industrial products such as Di-basic Calcium Phosphate($CaHPO_4.2H_2O$) could be dried under at least partially control environment and which is large enough to permit a person to load and unload the material to be dried. Di-basic Calcium Phosphate is odorless, tasteless, white powder mineral based inorganic compound widely used for supplementing phosphorous and calcium to animals along with feed. It is also used in pharmaceutical grade and dentifrice grade.

The microclimatic variations have been studied inside a solar tunnel dryer under hot and cold climatic conditions throughout the year. Which include the measurement of the natural rise of temperature, due to reduced air movement and green house effect, which helps to maintain the desirable thermal conditions for drying and relative humidity inside the tunnel dryer.

2. DESIGN OF THE SOLAR TUNNEL DRYER

In the study a solar tunnel dryer of 1.5 tons capacity was designed and developed for drying Di-basic Calcium Phosphate at 40 percent moisture content to 10 percent moisture content. The design parameters were decided on the basis of amount of moisture removed per day, specific gravity of material and flow rate required for removing moisture in stipulated time. According by specification of solar tunnel dryer including length and width of tunnel, number and height of chimney required and area of north wall required for boosting required temperature were calculated.

Low cost materials possessing high rigidity, long life and superior thermal characteristics have been used for construction. The metallic frame structure of the tunnel dryer has been covered with UV stabilized semi-transparent polythene sheet of 200-micron thickness. A gradient of $5\text{-}7^0$ has been provided along the length of the tunnel to induce natural convection airflow. Cement concrete floor has been painted black for better absorption of solar radiation. Five cm thick glass wool insulation has been provided to reduce heat loss through the floor. It is based on the theoretical calculation for critical insulation thickness for this dryer.

The orientation of solar tunnel dryer is in east-west direction. The structural components of solar tunnel drier include Hoops foundation, floor, UV stabilized polythene film and drying trays. The dimensions and other design parameters of the solar tunnel dryer are presented in table 1.The schematic illustration of the solar tunnel drier is given in Fig.1.

Table 1. The dimensions and other design parameters of the solar tunnel dryer

Parameter	Specifications
Length of solar tunnel dryer	21.0 m
Diameter of solar tunnel dryer	3.75 m
Ceiling Height	2.0 m
Floor area of solar tunnel dryer	78.75 m^2
Area of semi-cylindrical shape of solar tunnel dryer	134.74 m^2

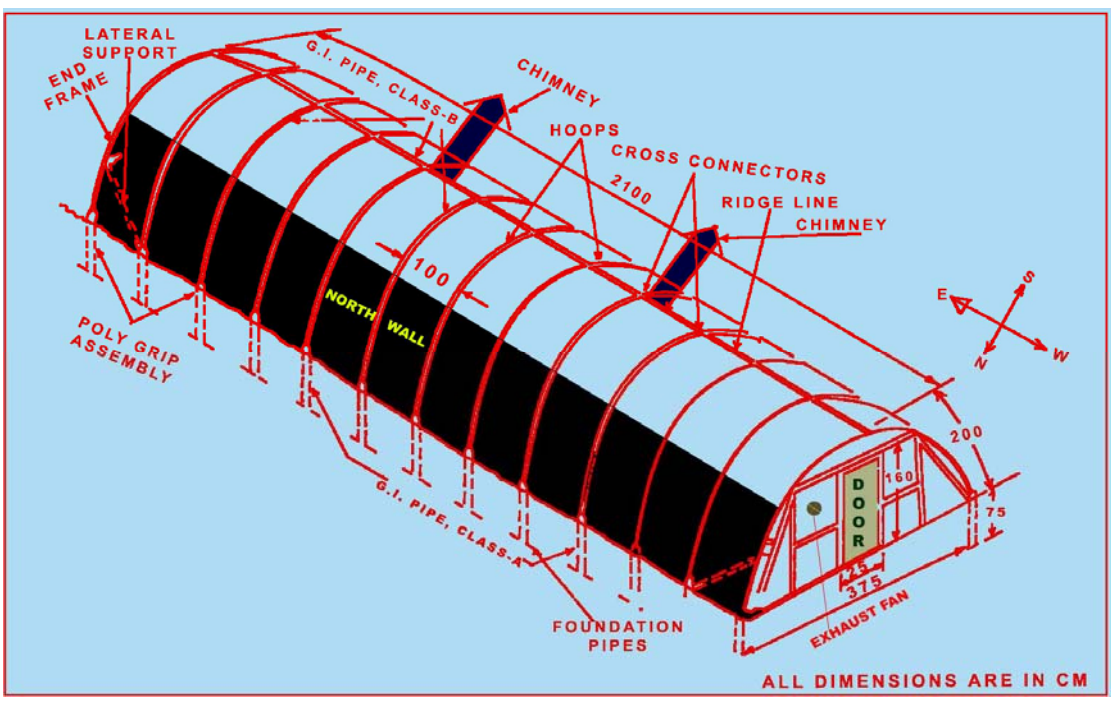

Figure 1. Line diagram of solar tunnel dryer

3. EXPERIMENTAL SET-UP

The performance of the dryer was evaluated by conducting tests at no-load and by loading with Di-basic Calcium Phosphate, by measuring the following parameters: (a) radiation incident on the dryer, (b) air temperatures at various locations in the dryer and (c) Moisture content variation.

To measure the temperature of air at various locations of the dryer, three sensors inside and one sensor outside the solar tunnel dryer were kept for recording. Sensors number first, second and third were kept inside the solar tunnel dryer at mid bottom point, at 1 m above mid bottom point and at north wall respectively and sensor number zero was kept outside the solar tunnel dryer. All temperature data were registered at an interval of half an hour by a data logger. The solar insolation measured by solar insolometer. Keeping view the each months for winter and summer season the January and June months were adopted for conducting the experiments. Drying tests were started at 8:00 hours and stopped at 17:00 hours in the month of January and while in the month of June tests were started at 8:00 hours and stopped at 18:00 hours. Under full load condition Di-basic Calcium Phosphate was spread in 4 cm thick layer in trays. Total ten trolleys having equally distributed 24 trays of size 80 cm × 40 cm in each trolley were provided to accommodate 1.5 ton of material at a time in each batch. Each tray carries approximate 6.25 kg material.

4. PERFORMANCE ANALYSIS

The performance of a dryer depends on the duration of drying and the quality of the end product, besides factors such as collector performance and drying temperature. Elaborate testing of the solar tunnel dryer was carried out under no load and full load conditions during month of June and January for drying Di-basic Calcium Phosphate at the factory level.

4.1 No Load Testing

No load testing was conducted with a view of find out temperature profile, relative humidity and air flow rate at different places in solar tunnel dryer. The testing on no load was done for consecutive days in the month of January and June respectively. As shown in Fig.2 it was observed that the maximum temperature attended inside the tunnel was 47.4^{0} C at 15:00 hrs while the minimum inside temperature was 12.5^{0} C at 8:00 hrs in the month of January. Corresponding, the maximum ambient temperature was 26.6^{0} C at 15:00 hrs while minimum ambient temperature was 11.6 ^{0}C at 8: 00 hrs. It was also observed that the maximum and minimum solar insulation in this month was 906 W/m^2 at 13:00 hrs and 64 W/m^2 at 17:00 hrs respectively.

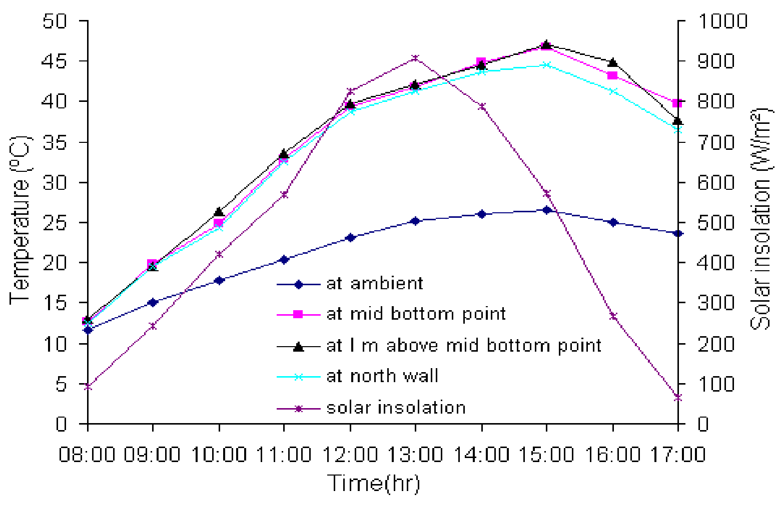

Figure 2. Temperature variations at different places in solar tunnel dryer and ambient with time at no load in the month of January

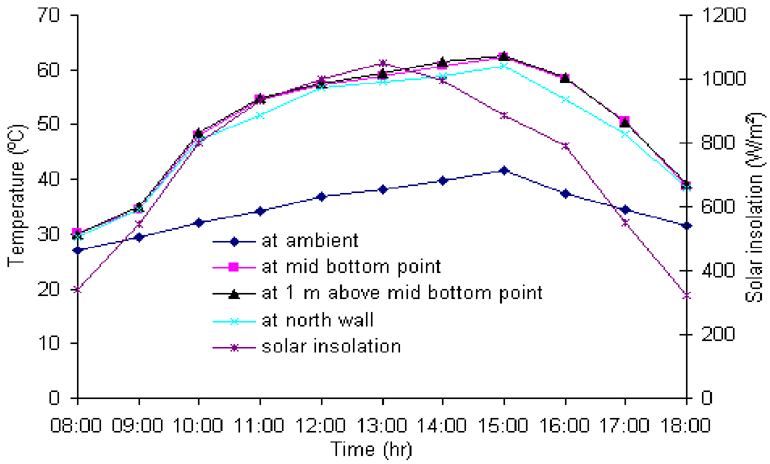

Figure 3. Temperature variations at different places in solar tunnel dryer and ambient with time at no load in the month of June

As shown in Fig.3 it was observed that the maximum temperature attended inside the tunnel was 63.1^0 C at 15:00 hrs while the minimum inside temperature was 29.4^0 C at 8:00 hrs in the month of June. Corresponding, the maximum ambient temperature was 41.6^0 C at 15:00 hrs while minimum ambient temperature was 27.1 ^{0}C at 8: 00 hrs. It was also observed that the maximum and minimum solar insulation in this month was 1052 W/m^2 at 13:00 hrs and 320 W/m^2 at 18:00 hrs respectively.

It has been observed that increase the temperature inside the solar tunnel dryer as compared to corresponding ambient temperature to a level of 21.5^{0}C and 20.8^{0}C respectively in the month of June and January respectively.

4.2 Full Load Testing

Full load testing of solar tunnel dryer was done for evaluating the performance in actual loaded condition. Di-basic Calcium Phosphate with 40% initial moisture content was taken for study and loaded in the trays of solar tunnel dryer. Wet Di-basic Calcium Phosphate is spread in thin layer of approximately 4 cm thickness in the trays of 40× 80 cm size. Twenty four trays are loaded on to a trolley. Ten trolley containing 1.5 ton material are moved into the tunnel dryer in the morning. Inside view of solar tunnel dryer under full load condition is given in Fig. 4.

Figure 4. Inside view of solar tunnel dryer under full load condition

The testing on full load was done for consecutive days in month of January and June respectively. As shown in Fig. 5 that maximum temperature inside the solar tunnel dryer was 46.1^{0}C at 15:00 hrs while the minimum temperature inside the solar tunnel dryer was 13^{0}C at 8:00 hrs in typical day in the month of January against the maximum and minimum ambient temperature of 26.3^{0}C and 12^{0}C respectively.

It was also observed that the maximum and minimum ambient solar insolation in this month was 901 W/m^2 at 13:00 hrs and 68 W/m^2 at 17:00 hrs respectively. As shown in Fig. 6 it was observed that the maximum temperature attended inside the tunnel was 60.0^0 C at 15:00 hrs while the minimum inside temperature was 30.1^0 C at 8:00 hrs in typical day in month of June.

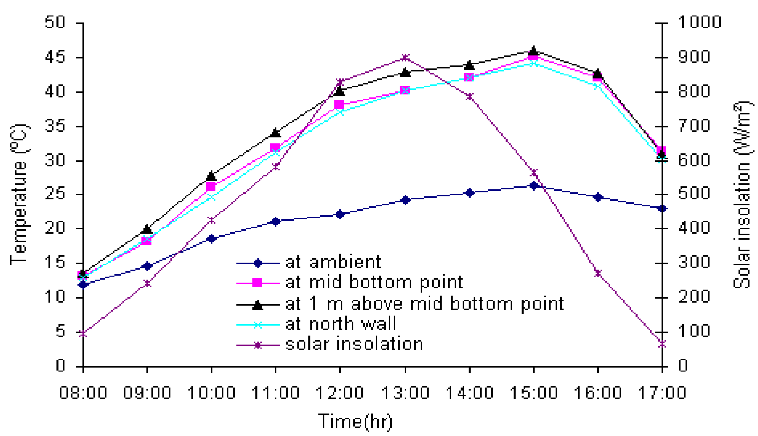

Figure 5. Temperature variations at different places in solar tunnel dryer and ambient with time at full load in the month of January

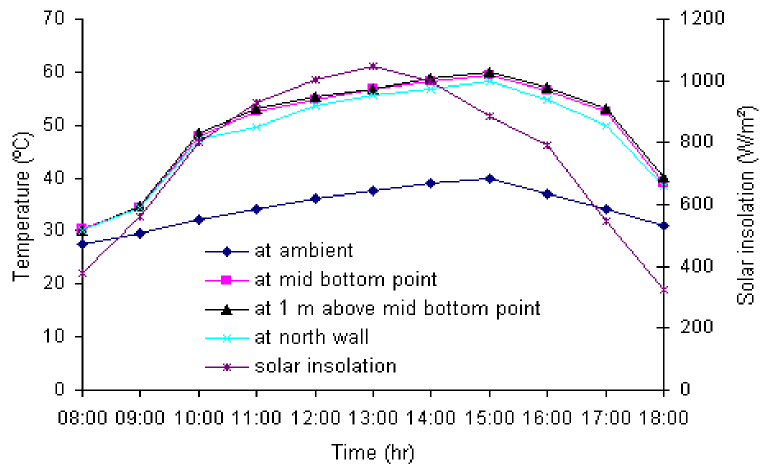

Figure 6. Temperature variations at different places in solar tunnel dryer and ambient with time at full load in the month of June

Corresponding, the maximum ambient temperature was 40.0^{0} C at 15:00 hrs while minimum ambient temperature was 27.6 ^{0}C at 8: 00 hrs. It was also observed that the maximum and minimum solar insulation in this month was 1049 W/m^2 at 13:00 hrs and 323 W/m^2 at 18:00 hrs respectively.

4.3 Moisture Content Variation

As shown in Fig. 7 that moisture content was reduced from 62.87 percent on dry basis to 55.42 percent on dry basis during first two hours of drying in typical day of month of January. It was further reduced to 10.62 percent at the end of the trial.

The variation of moisture content is shown in Fig. 8 for a typical day of month of June. It was observed that the moisture content was reduced from 64.5 percent on dry basis to 11.4 percent dry basis.

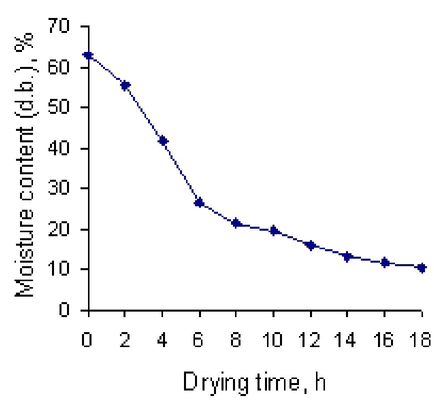

Figure 7. Relationship between moisture reduction and drying time in solar tunnel dryer, in the month of January

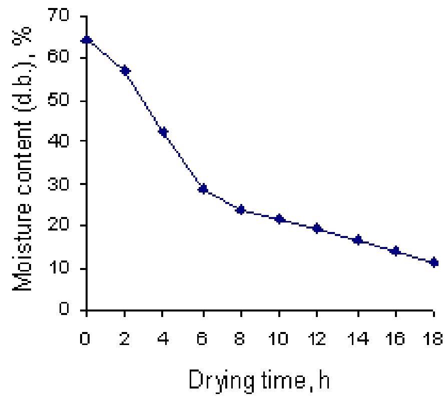

Figure 8. Relationship between moisture reduction and drying time in solar tunnel dryer, in the month of June

5. CONCLUSIONS

In all air temperature in the solar tunnel dryer was higher than outside by 15-20^{0}C during sunshine hours and the moisture content of approximately 1.5 tons of wet Di-basic calcium phosphate loaded in the dryer in one batch was reduced from an initial value of 38-40% to around 10-12% in 18 hrs or 16 hrs depending upon solar insolation.

6. ACKNOWLEDGEMENTS

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