

PROPOSED SOLAR DRYING SYSTEMS FOR CREPE RUBBER DRYING

S Siriwardena

INTRODUCTION

Natural Rubber (NR) production is an important contributor to the Sri Lankan economy. In 2008, Sri Lanka produced 129,243 MT of natural raw rubber of which 21,043 MT was in the form of Crepe Rubber (CR). Sri Lanka has the reputation for manufacture of the purest CR in the world. This grade is mainly for the export market and has earned more than 6,000 million rupees as foreign exchange revenue in 2009 (Anon, 2009). The rest of the rubber namely Ribbed Smoked Sheets (RSS), Centrifuged Latex (CL) and the small amount of Technically Specified Rubber (TSR) were mainly consumed locally for the manufacture of local and export market oriented products.

Manufacture of CR involves three main processing steps. They are field latex coagulation, milling and drying. Drying of CR is carried out conventionally in warm air chambers known as drying towers. A drying tower is primarily a three storied building in which hot water radiators are installed on the ground floor. CR laces are hung in the top floors. Firewood fed external boiler produces hot water circulated through the radiators, warming the air inside the drying tower. The warm air is then carried upward by natural convection and removes the moisture of the laces.

Work done by Tharmalingam *et al.* (1977) shows that the drying process of CR has two main regimes namely, constant and falling rate periods. During the constant rate period, surface moisture is removed from the surface of the material being dried. Internal moisture is first migrated to the surface and then evaporated at the surface during the falling rate period. Table 1 summarizes the drying characteristics of CR.

Table 1. *Drying characteristics of crepe rubber*

Factor	Value
Initial moisture content (% , wb)	7 - 12, 20*
Drying temperature (°C)	34
Critical moisture content (% ,wb)	3
Drying period (days)	3- 5
Falling rate period (% of total drying period)	> 85
Final moisture content (% wb)	0.02

Source: *Tharamalingam *et al.* (1977), Seneviratne (1995)

According to Tharamalingam *et al.* (1977) the initial moisture content of CR was 7-12% (wb). Another estimation by Seneviratne (1995) further increases this value to 20% (wb). This variation may be due to the varying milling conditions and thickness of crepe rubber laces.

It was established that CR requires a maximum of 34°C drying temperature, beyond which, rubber laces get adversely affected (Seneviratne & Sarathkumara, 2003). This drying temperature is only a few degrees (4-9 °C) above the local ambient temperature. Therefore, the drying process is a low temperature drying process and results no defects. Drying operation requires a drying period of three days to achieve complete dryness of laces. It should be noted that during the drying period, drying process is considerably interrupted for loading and unloading operations while the doors and windows of the heated drying chamber are left open. This practice definitely reduces drying efficiency and wasting the valuable energy (Walpita *et al.*, 1984). They estimated that the drying efficiency of these drying towers is as low as 13%.

Rubber wood, which is the main source of energy for the CR drying process has now become a very expensive and scarce source of energy due to its value as a quality timber, after chemical treatment (Walpita *et al.*, 1984; Mohd & Sopian, 1991). Treated Rubber wood has an expanding international market and burning of it results in a loss of another source of foreign revenue (Karunaratne, 1993). In the face of this scenario, it is of vital importance of looking into alternative energy sources for this low temperature drying process of CR. The growing concern on the environmental pollution caused by firewood fed heating systems has further intensified the necessity of finding an alternative, reliable, cheap and environmentally friendly drying system for CR.

Solar energy for drying of rubber

The use of solar energy has been identified as a viable alternative energy source for this application (Jolly, 1987). Many different solar crop-drying systems have been developed and used for drying of many different agricultural crops in the world. Sri Lanka has not so far used solar energy for drying rubber, though sun drying is carried out on a smaller scale for drying of sheet rubber.

Jolly (1987) has reported that the existing drying towers could be partitioned easily and then each compartment can be used independently to accommodate the daily crop. Therefore, the drying operation could be commenced in the morning and carried out continuously without interruption. Solar energy could then be used in the drying operation easily as the drying process is not interrupted. The intention of this article is therefore to discuss few potential and appropriate solar drying systems for drying of CR. Finally, a brief comparison of practical considerations relating to this drying system is presented.

Possible solar dryers

Solar air heaters

A solar air heating system converts incident solar radiation into thermal energy, which is carried out by air flowing through the system to the point where the drying operation takes place. There are two basic types of solar air heating systems. Flat plate collectors use both direct and diffuse radiation and do not require tracking the sun, while in concentric air collectors concentric, an optical device is installed between the sun and the energy absorbing surface. This system uses only direct radiation. The optical device needs to track the sun. The optical surface focuses the direct radiation exposed on its surface to its absorbing surface. Therefore, concentrating collectors produce high temperatures than the flat plate collectors. As in most of the agricultural crop drying processes, CR drying process also requires a very low temperature. Therefore, flat plate air collectors would be suitable for CR drying.

Figure 1 shows the important components of a flat plate solar air collector which consists of collector box holding the solar energy absorbing unit, a black solar energy absorbing surface to absorb solar radiation and converts it to thermal energy, cover material transparent to solar radiation over the solar radiation absorber surface which assist in reducing convection and radiation losses to the atmosphere and air conduits which carry the heat absorbed to the drying chamber, where the drying operation is carried out.

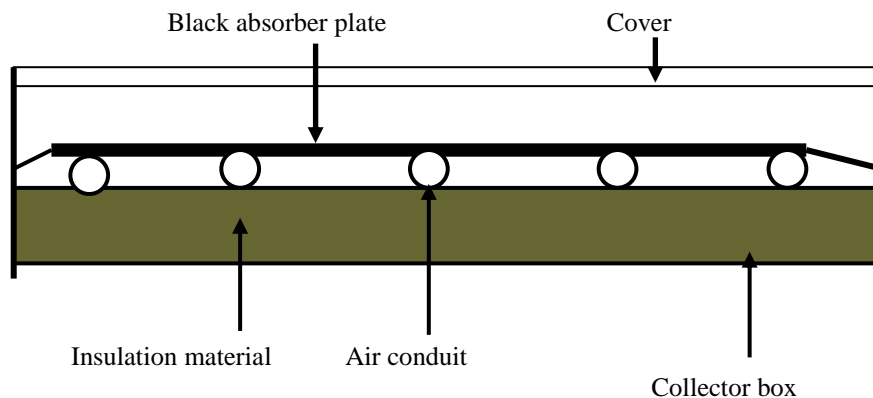


Fig. 1. Cross section of a basic flat-plate solar air collector

Basic energy balance equation for a collector of this type is given below.

$$Q_u = A_c[S - U_L(T_{pm} - T_a)]$$

Where,

Q_u	=	Useful energy gain rate in watts (J/s)
A_c	=	Collector area

S	= Solar radiation absorbed by a collector per unit area expressed in W/m^2
U_L	= Heat loss coefficient expressed in W/m^2K
T_{pm}	= Absorber plate temperature in K
T_a	= Ambient temperature in K

As per the basic equation, the collector area could be adjusted to achieve the required energy demand. Also it shows that energy released to the load is not consistent and depend on the available solar radiation and the absorbing efficiency of the absorber material. Heat loss coefficient should be minimized to avoid thermal energy losses from the collector to the environment by conduction, convection and infrared radiation. Therefore, collector configuration plays an important role in the energy harnessing process.

Galvanized iron sheets are the widely used as absorber plate material for solar air heaters, but possesses a high susceptibility to corrosion and poor thermal conductivity. The corrosion problem is less important when selecting an absorber material for air heaters. Whiller (1964) has pointed out that adequate heat transfer can be achieved irrespective of the absorber for solar air heaters. Low conductivity materials require a greater area of absorber for equivalent heat transfer, and the low cost of galvanized iron sheet would compensate for the extra cost of material. Considering all these factors, galvanized iron sheet would be an appropriate material for the absorber plate of the air heaters to be used in this application. According to Whiller (1964), for air heating applications for small temperature rises, no significant improvement of collector efficiency can be achieved by using selective surfaces. Ordinary black paint has been used in low grade temperature drying applications. Therefore, a black paint having absorbance and remittance 0.95 and 0.9, respectively is considered to be adequate to harness heat.

An auxiliary energy storage unit is also necessary in conjunction with the solar air heating system to meet the continuous energy supply to the load (drying chamber). Figure 2 shows the schematic block diagram of a basic solar air heating system with a pebble bed storage unit and an auxiliary heating unit. When excess energy is available, it is added to pebble bed storage unit. Alternatively, a separate flat plate air collector can also be used to provide energy to the storage unit. When solar energy supplied from both the solar collector and storage is inadequate to meet the load, an auxiliary heater has to be used to meet the total energy demand.

The various modes of operation could be achieved by using appropriate damper positioning. In this system configuration, it is possible to by pass both the collector and storage unit when auxiliary alone is being used to provide heat to the load.

A similar system as above has been previously used and the performance of a flat plate collector has been determined at the Rubber Research Institute of Sri Lanka (RRISL) for drying of CR (Walpita *et al.*, 1984). However, the system had no solar energy storage unit or an auxiliary heating unit. Construction had flat plate air

collectors using black painted galvanized iron sheets as a flat absorber plate. The experimental results show that more than 10 degrees of temperature difference between inlet and outlet temperature could be achieved at air mass flow rate of 46.5 kg/m²h and 52 kg/in²h. This temperature difference was achieved for seven hours during the day and the outlet temperature was well above the optimum drying temperature of CR. However, the same temperature rise could not be achieved at the drying tower, situated few meters away because of heat losses in the ducting system. In this system, the distance between the solar air heater panel and the drying chamber into which heated air needs to be diverted was about 30 m. However, this result indicates potential use of solar energy in crepe drying. In fact, this was the only preliminary work carried on solar drying of CR using solar collectors.

Therefore, properly designed solar air heating system with a couple of solar energy storage unit and auxiliary heater could be a potential heating system for drying of CR.

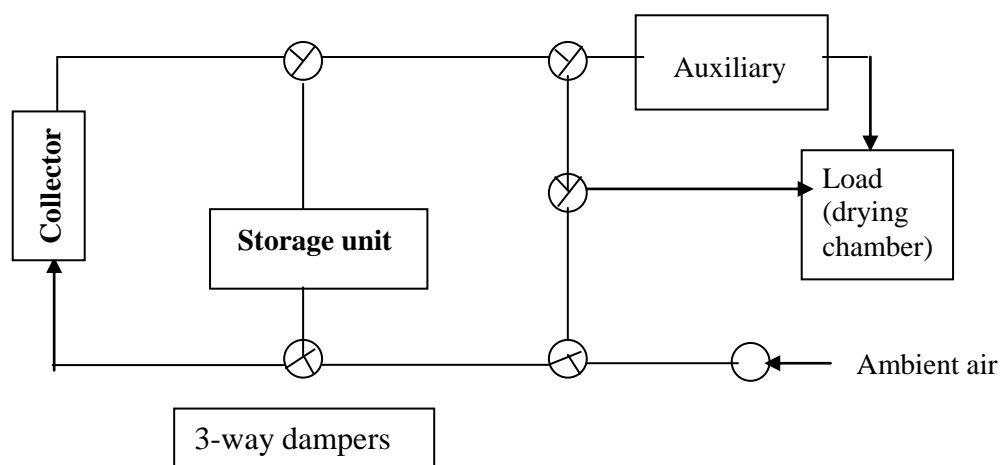


Fig. 2. Simple schematic block diagram of solar air heater/rock bed system

Roof integrated solar air heater and storage

Use of the galvanized steel roof of a building as the solar radiation absorber plate has been reported by Trim & Kamau (1984) and Wai *et al.* (1991). For example, the drier used by Philip (1964) for drying coffee looks very attractive for CR drying. Absorber plate of the solar collector was the part of the roof of a coffee processing building. The roof was constructed with a 75 mm deep air passage between the roofing sheet and ceiling. The air was passed through this passage, and then this warmed air was further heated to the desired temperature by an electric heater. It has been further recommended that utilization of the entire roof of the building as an absorber plate would give better results.

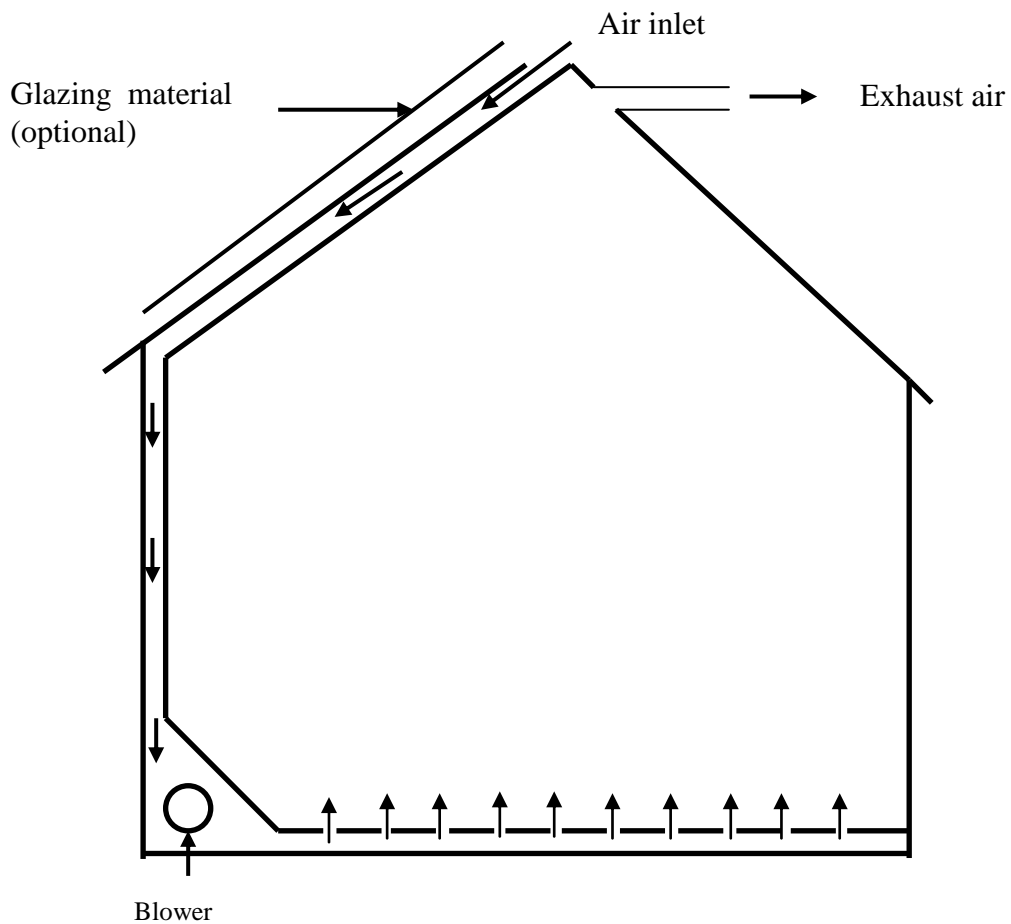


Fig. 3. Cross section of a roof integrated solar dryer

This concept could be very easily adopted in existing rubber drying towers where the roofing material is galvanized iron sheets. The roof of the building could be converted to a built-in solar radiation absorber. Since rubber-processing factories are situated adjacent to the drying towers, and have very large roofing areas, the factory roof can be used, if the area of drying tower roof is not sufficient. This system reduces the cost of a conventional flat plate collector. However, the ceiling should be properly insulated and this would incur some expenditure. The use of a glazing is not practical in term of cost and complexity. Glass and plastics are the two possible alternatives for a glazing. Installation of a glazing over the roof will increase the construction as well as material costs. However, since an extended collector area is available, an unglazed collector would be adequate to meet the energy requirement.

Configuration of whole drying system is similar to the system explained earlier except the replacement of solar air heater, which could be constructed using the roof. In this structure, roofing material which is galvanized steel absorbs the solar radiation and a part of the absorbed energy is transferred to the moving air underneath the sheets. A detailed description of a possible “roof collector” is discussed below.

A duct system is formed under the roofing material parallel to the corrugation. The heated air collected from roof sections enters the main duct which runs along the apex of the roof and directed towards vertically at one end. At the bottom end of the vertical duct, heated air enters a horizontal perforated duct system, and the air is uniformly distributed above the ground floor at a suitable height. An electrically driven fan which forces the air through the duct system needs to be located at the bottom end of the vertical duct. A disadvantage of this system is that orientation and the slope of the air heaters cannot be changed to harness maximum amount of solar energy as it is determined by the existing roof.

Greenhouse type drier

A greenhouse is a structure with transparent roof and walls through which solar radiation is transmitted. The major components of this system are a modified/altered greenhouse, an auxiliary heating unit, heat storage unit and a fan. Components such as the structure, the materials for drying, and the floor of the greenhouse absorb the radiant energy. The temperature of the air inside the greenhouse increases due to conduction, radiation and convective heat transfer from all the inside surfaces. When required, an auxiliary heater should also be used to supplement the radiant energy or provide total heat requirement when no stored solar energy is available or it is inadequate.

Ghosh (1973) developed a glass roof greenhouse type drier with a natural gas heating unit as a backup energy source. Fuller *et al.* (1990) has tested a cost effective polythene greenhouse type drier for large scale drying of grapes. A green house type dryer experimented at RRISL, for drying of sheets has reached a temperature above 42°C during the daytime. Therefore, this type of dryer would be a viable alternative for crepe rubber, if carried out under controlled conditions. Further, a temperature control mechanism is still required, if this system is going to be utilized. An auxiliary energy source is required during the night to meet the energy requirement.

Heat storage

Solar drying of CR may be feasible, if the stored solar energy or an auxiliary energy source is available to carry out continuous drying when the solar radiation is absent. Water, rocks and phase change materials (PCM) can be used to store solar energy, collected by a solar air heater. If water or PCM is used, they should be packed in small containers, to allow the solar heated air to travel around those containers and transfer its heat to the medium. This will increase the cost of the storage unit and operational complexity. The use of PCM has inherent problems such

as contamination and imperfect resolidification, but the advantage of using PCM is that it requires less storage volume.

In contrast, a rock – bed storage is less expensive compared to the water or PCM storage medium. However, it requires a large volume to store the equivalent quantity of energy. This is not a major concern since rubber factories are situated in remote areas where enough space is available. Rock bed storage has the major advantage that it is not necessary to change the heat transfer medium. Heated air from the rock- bed can directly pass into the drying chambers. As such, a rock – bed is selected as the storage medium.

Auxiliary heating unit

An auxiliary air-heating source must be installed for the continuous drying operation during the night time as well as cloudy/rainy daytime hours, if the storage unit cannot provide adequate heat to the system. Existing firewood fed boiler-radiator system or alternatively smoke free, clean, hot air generating unit could be employed for this purpose.

Operational practices

If the solar energy is used for the drying of CR, existing operating practices need to be changed slightly, irrespective of the drying system used. Intermittent interruption of drying process should be completely avoided or should be minimized. This can be achieved by partitioning the existing drying towers to few compartments with a capacity to accommodate only the daily crop in each compartment. It will reduce the actual energy requirement for the drying since considerable heat losses can be avoided by such arrangement. Drying process should be carried out as much as possible during the day time to minimize the drying operation in the night. Temperature control system is essential to make sure that the temperature does not exceed the required drying temperature (34⁰C) to avoid excessive drying of laces.

Practical considerations

Practical implications of each drying system are summarized in Table 2. It should be noted that any heating system has its advantages and disadvantages. A comparison of those factors is summarized below.

Table 2. *Practical considerations of the three drying systems*

	Factor	Air collector	Roof integrated air collector	Greenhouse
1	Availability of collector raw material	Mostly imported	Not imported	Needs to import certain important materials
2	Operational experience	High	Higher	Low
3	Operational complexity	High	High	Simple

	Factor	Air collector	Roof integrated air collector	Greenhouse
4	Availability of technology in manufacturing and maintenance	Locally available	Locally available	Locally available
5	Maintenance	Easy	Easy	Very easy
6	Corrosion damages	Low	Low	Nil
7	Boiling problems	Nil	Nil	Nil
8	Hot fluid leakages	Less serious	Less serious	Nil
9	Detection of leakages	Difficult	Difficult	Difficult
10	Parasitic power requirement	High	High	Lower than other air systems
11	Auxiliary heat requirement	Essential	Essential	Essential
12	Control system of auxiliary heat supply	Necessary	Necessary	Necessary
13	Heat exchanger requirements	Not required Might be required depending on method of auxiliary heat supply	Not required. Might be required depending on method of auxiliary heat supply	Not required. Might be required depending on method of auxiliary heat supply
14	Adoption to the existing system	Needs less modification	Needs less modification	Should be constructed completely
15	Vandalism	Low risk	Low risk	Potentially high risk
16	Life time	Long	Long	Short
17	Operational practice	Slightly different	Slightly different	Different
18	Temperature in the drier chamber	Variations are anticipated	Variations are anticipated	Might be uneven and higher for few hours

Source: Charters & Pryor (1982) & Duffie & Beckman (1991)

CONCLUSIONS

The three systems discussed here could be attempted for the purpose of drying of crepe rubber. The main advantages of the roof integrated system are that its low risk of overheating and low cost of the system. Therefore, the roof integrated system would be more viable than the separate solar air heater system. On the other hand, the greenhouse type drier requires highest energy for the purpose of rubber drying due to its higher heat losses to the environment. Further it has a brief service life since polythene decays with a certain service period of time. If a greenhouse drier is acceptable for crepe rubber drying, the brief life time would be compensated

by its low cost of construction. However, construction of a greenhouse is quicker and easier than the construction of a separate drying chamber. Operation of greenhouse is easier than the other types. These factors favour the use of a greenhouse type drier for crepe rubber drying.

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