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SOLAR AIR HEATER APPLICATIONS IN INDIA

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ABSTRACT

Solar air heaters of many types have been developed in India and their performance studied in detail. The application of these air heaters are limited to a few demonstration projects for food dehydration, and space heating. Some of these case studies are described in this paper. For a few cash crops, the potential of solar air heaters for the drying process has been assessed in detail. Space heating by solar air heaters and their use for natural ventilation has also been discussed and results of a theoretical study presented to make out a case for more intensive research in the fields of solar air heater applications in India.

KEYWORDS

Solar Air Heater; Solar Drying; Space Heating

INTRODUCTION

India is one of the oldest civilisation with kaleidoscopic variety and rich cultural heritage. It has achieved multifaceted socio-economic progress during the last 50 years of independence. Patterns of total energy consumption show that there has been a steady growth in energy demand over six percent and there has been a gradual shift to commercial sources of energy though still 45% of the primary energy is contributed by the biomass. Coal has been and is likely to continue to be the largest primary source of commercial energy in India causing environmental concerns.

The non-conventional source of energy are capable of solving the twin problems of energy supply in a decentralised fashion and simultaneously help in achieving environmental sustainability. Solar thermal as well as photovoltaics are the main components of renewable energy development in India. Under the solar thermal programme, water heating has been the main thrust. However, a few projects involving solar air heaters for space heating and crop drying have been executed.

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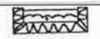
SOLAR AIR HEATERS: DEVELOPMENTS IN INDIA.

A solar air heater is basically a heat exchanger, which intercepts the incident solar radiation, converts it into heat and finally transfers this heat to a working fluid for an end use system (Bansal et al 1984). Basically all solar air heaters can be classified under the categories (i) nonporous absorber and (ii) porous absorber, but the choice of materials, geometry etc. can give a variety of performance of solar air heaters. Gupta and Garg (1967) studied in detail four types of solar air heaters, the performance of which in given in Table 1.

Table 1 A few solar air heaters and their performance parameters (Gupta and Garg 1967).

Collectors	Flow rate ks/m²s	Plate efficiency Factor (F')	Heat Removal Factor (F_R)	Heat Loss Coefficient (W/m^2) U_L
	1.58×10^{-2}	0.96	0.75	10.1
	2.0×10^{-2}	0.94	0.77	10.2
Wire Mesh 	1.93×10^{-2}	0.89	0.73	9.6
	1.22×10^{-2}	0.69	0.52	13.4

Bansal et al (1982) developed collapsible plastic film air heaters using UV stabilised PVC film of nonporous as well as porous absorber type (Fig.1). One hundred percent polyester fibre has been used as a porous absorber allowing maximum absorption of solar radiation and good flow of air yielding good efficiencies (Table 2).

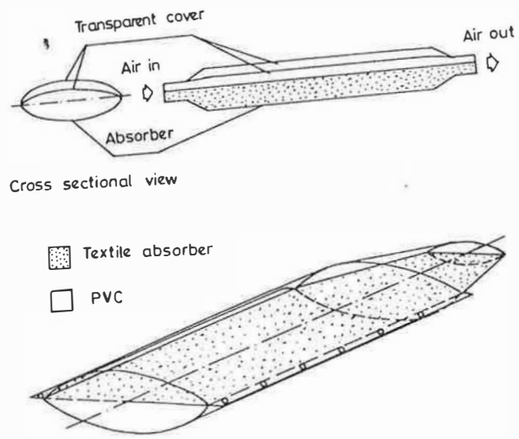


Fig.1 Plastic film solar air heaters of non-porous type (above) and porous type (below)

Table 2 Performance of porous absorber collector with different back insulation (Figures in brackets indicate the incident solar radiation in W/m^2 on the collector surface).

S.No.	Flow rate (m^2/h)	Temperature Rise ^{0}C			Efficiency		
		I	II	III	I	II	III
1	420	23.4 (900)	23.9 (748)	22.8 (732)	0.3991	0.4905	0.4781
2	545	19.4 (836)	18.0 (682)	20.4 (746)	0.4622	0.5257	0.5447
3	654	18.2 (876)	18.4 (800)	19.2 (743)	0.4898	0.5421	0.6090
4	718	17.4 (908)	13.9 (656)	18.8 (752)	0.5029	0.5560	0.6561
5	770	15.9 (855)	13.9 (700)	18.3 (859)	0.5233	0.5588	0.6785

I. 3 cm thick polyethylene.
II. 3 cm thick polyethylene with Aluminium foil above it.
III. 6 cm thick polyethylene.

Solar air heaters find applications in food drying, space heating and natural ventilation which are briefly discussed in this paper

SOLAR DRYING IN INDIA

In this section, we assess the potential of solar drying for a few major crops in India.

Paddy Drying

One of the main crops measured in terms of sowing area as well as the quality is rice.

The most adopted drying method after parboiling is the traditional open sun drying. The moisture content is reduced up to 16%. The layer thickness is kept 2 to 3 cm high. Considering the general disadvantage of open air sun drying, bigger rice mills are using industrial drying process using oil and coal or even the electricity. Another method getting popularity is the use of briquettes made from the rice husk. It is estimated that one tonne of rice husk can save 300 l of oil.

It is understood that the percentage of broken rice is dependent upon the method of drying as well as the temperatures of drying.
Hot air drying with temperatures between 60^{0}C and 80^{0}C, is useful and for that solar air heaters in stand alone mode or in hybrid mode can be employed. In hybrid mode, use of rice husk briquette will make the overall process economical.

Fruit drying

The most important fruit crops in India, however, are Mango, Papaya, Guava, Banana, Apple, Apricot, Oranges, Lemons, Grapes etc. A number of investigations have been made with different fruit products to

conserve them through the drying process. However, only a few of these products offer economic viability.

The price level of most fruits in comparison to vegetables is much higher. The quality of the dried fruits using traditional methods in not acceptable internationally. Also in the domestic market, the dried fruits are very expensive due to losses during drying. A detailed study is required for assessing the economic potential for solar dried fruits in the Indian market as well as for the export purposes. The solar dryers which have been used for fruit drying so far are a transparent plastic foil covered cupboard tent dryer (Bhardwaj 1990, Fazal ur Rahman 1986, 1988, Kalra and Bhardwaj 1980, Rahman 1981 & Reddy 1988).

Timber Drying

The solar kilns are employed to season timber for handicrafts, ammunition boxes, furniture, doors and windows. The feedback obtained was satisfactory and the economics are very attractive.

A comparative solar kiln drying and open air drying experiment on 25 mm thick green planks showed that during winter the first took 28 days while the latter 65 days to achieve 12% moisture content. Similarly, 75 x 100 mm framing took 55 days to 18% m.c. in open sun during summer but only 26 days in solar kiln. Solar drying thus reduced drying times by about 40-50%.
Drying in steam heated kilns at medium temperatures (40-65 ^{0}C) takes 8-12 days for planking and 16-26 days for framing that has to be partially pre-air-dried for economical kiln seasoning. Experiments have shown that solar kiln drying seldom takes more than 1.5-2 times the estimated drying times of identical timber in the heated kilns.

Drying of Cash Crops

Some of the cash crops like Tea, Coffee, Spices, Cardamom and Cashew are major foreign exchange earners. Use of solar air heaters for drying process in the production of these cash crops can provide an impulse to the solar energy programme in the country. Potential of a few major cash corps is discussed in the following:

The thermal and electrical energy consumption for tea processing are shown in Table 6. It is apparent that drying consumes the highest fraction of energy. As mentioned earlier, coal is the main source or energy in the north eastern estates and firewood is predominantly used in southern states.

Table 6 Average thermal and electrical energy consumption in tea processing.

Process Stage	Energy Consumption			
	CTC		Orthodox	
	thermal kWh/kg	electric kWh/kg	thermal kWh/kg	electric kWh/kg
Withering	0.70	0.11	1.08	0.14
Drying	3.80	0.04	3.30	0.04
Others (1)	-	0.45	-	0.40
Total	4.50 (2)	0.60 (3)	4.38	0.58

Since the temperature levels for tea processing are around 100^{0}C, solar technologies in hybrid mode can be used for withering and drying. In a project located in the Nilgri's mountain in south India, a flat plat solar air heater preheats the air before conventional heating by a furnace. A total of 212 m^2 solar collector area is integrated into the southern sloping roof. The system is in operation since the year 1992. It is

estimated that during the period between April 1992 to December 1994 (2.75 years), the fuel consumption is reduced by 199 tons of coal equivalent. The payback periods are estimated between 3 to 4 years.

Chilles. Chillies can be dried by using different solar air heater/dryers depending upon the quantity. Since there are no strict conditions of temperature or air flow in chilly drying, one can use simple dryers, like a tent dryer or a tunnel dryer.

Pepper. Pepper growing regions in India lie essentially in warm-humid coastal regions of Kerala. During the earlier harvesting period of March and April, the weather conditions for solar drying are good. The second harvesting period of August-September is however characterized by bad weather conditions. In the early harvest period therefore, simple tent type of dryers are ideal. Pepper is not a critical product in the drying process. Controlled solar drying results not only in a better quality but also in reduced losses.

Cardamom. The green cardamoms are a high quality product which needs drying in three phases at temperatuns 40, 50 and 55°C. The quality of the product is very much effected by the temperature and relative humidity of the drying air, particularly during the first phase. The process of using solar heated air has to be done in a hybrid mode. It is found that it was possible to reduce the wood consumption by 1 5 kg/kg of dried cardamom by using solar air heaters. (Pellizoni et al, 1985)

SPACE HEATING

Space heating is required in high mountain regions in the North and North-Eastern Himalayas during the winter periods Natural convection based solar air heaters, known as thermosyphon air panels have been employed for space heating in Leh (Fig. 2). It is found that the TAP worked with an overall efficiency of 32.5% and it is able to collect 2.3 kWh of energy per m^2 per day on an average basis

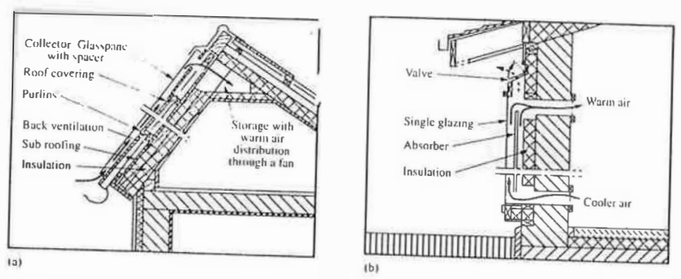


Fig 2. (a) Thermosyphon air panel installed on the rod
(b) Thermosyphon air panel installed on the wall

Large scale experimentation with solar air heaters for space heating has not been undertaken in India so far

SOLAR INDUCED VENTILATION

An innovative way of using a solar air heater is to induce ventilation as shown in Fig. 4

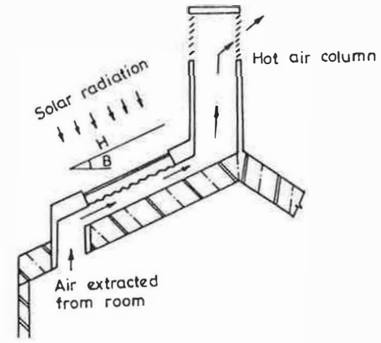


Fig. 3. Natural veneration through a roof integrated solar air heater.

A study by Mathur (1994) shows that is possible to generate mass flow rates of the order of 150 to 200 m^3/h with only $1m^2$ of collector area for an incident solar radiation of 800 W/m^2.

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