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Overcoming the Low Efficiency of Box Type Solar Cookers

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Abstract

The solar cooking is not so popular in India owing to the reason of prolonged cooking time of conventional solar cookers. The conventional solar cookers work on the principle of green house effect. Here the incident rays fall on the top of the lid which is usually painted with black. The delay can be attributed mainly to the air gap in the top portion of the utensil between the lid and the food. Convection loss also delays the cooking process. This paper suggests a cost effective Fresnel reflective concentrator to concentrate the solar beam to the bottom of the utensil.

Keywords: Convection Loss, Fresnel Reflector, Green House Effect

1. The Conventional Solar Cooking

The solar cooking is not yet familiar to many parts of India. It has lost charm in many places where it has been introduced, as it takes few hours to cook. Box type solar cookers are widely sold in India. MNRE also recommends some manufacturers for box type solar cookers. The cost is also not affordable to rural Indian and the pay back period is high. The delay in cooking time forces the user to limit his food to a narrow band of varieties. Pressure cooking or frying is not possiblige in this box type cooking. The manufacturing cost is high due to the insulation provided to prevent convective heat loss. On the other hand the parabolic concentrators are a little bit complicated in design and requires comparatively sophisticated machinary to manufacture. Concentrating cookers occupy larger area.

2. Indian Scenario

2.1 Bio Mass Fuels

As per UNICEF report 2011, 80% of rural India still uses fire wood and other bio mass for cooking. Apart from economic view, it has a health issue behind it. Green fuels require popularity in most of the rural areas. Generally the solar cookers used in many parts are box type. The ease of its use and comparatively low cost makes it popular among all types of solar cookers. But, it takes a lot of time to cook in a box type solar cooker. It is suitable where time is insignificant comparing to the cost of conventional fuel. Overcoming this disadvantage can boost up the usage of solar cookers in rural as well as in urban India.

2.2 The Design of Box Type Solar Cooker

The box type solar cooker works on the principle of greenhouse effect. The incident solar rays which have a short wavelength of 0.5 μm are easily pass through the glass top of the cooker and get trapped in the black inner of the cooker. The black body of the vessel and the inner walls of the cooker re emits the absorbed solar heat in the form of longer wave length infra-red rays in the range of 7 to 10 μm do not easily pass through the glass covering. It is absorbed by the glass and reemitted. 50% of it is emitted out of the glass and the remaining reflected inside the cooker. The slow heating up of the inner space cooks the food.

- The incident heat falling on the black lid has to cross the air gap and then reach the water to heat it up. The thermal conductivity of air is 0.026 W/mK. Even if the water gets evaporated the space will be filled by steam. Steam has a thermal conductivity of 0.025 W/mK. It takes 2 to 3 hours to cook a meal. If the incident rays are made to fall on the food directly the delay can be reduced.

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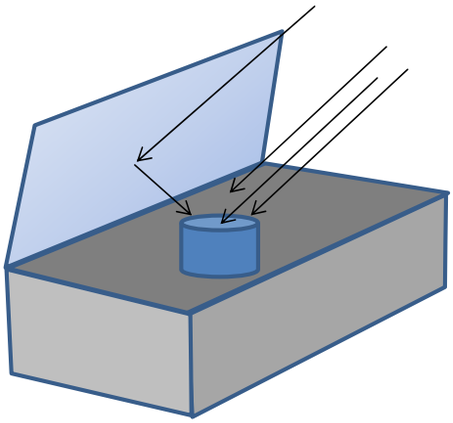
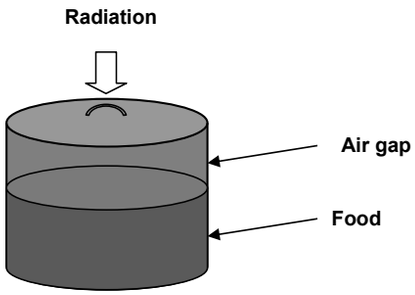
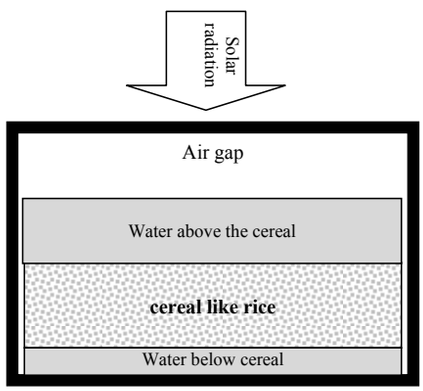




Indian foods are boiled in water. Most of the cookers have one single reflector to enhance the heating.

- Further the walls of the cooker have to be made of insulating material which adds up the cost.
- To be specially made with black coating to absorb maximum radiation.
- Box type cooking has a limitation of cooking food by steam boiling. No variants are possible.

Let us consider an aluminium vessel of thickness t_{al} and thickness of water below the foodstuff be t_{wb} and thickness of water above food stuff as t_{wa} and thickness of air above water level be $t_{a,}$



The resistances of the layers being,

$$R_{Al} = \rho_{Al}A/t_{Al}$$
$$R_{Air} = \rho_{Air}A/t_{Air}$$
$$R_{water} = \rho_{water}A/t_{water}$$

The resistance from top lid = $(\rho_{Al}t_{Al} + \rho_{Air}t_{Air} + \rho_{water}t_{water1})/A$

When the heat is supplied from bottom of the vessel, the resistance encountered would be,

$$= (\rho_{Al}t_{Al} + \rho_{water}t_{water1})/A$$

Again the second term would be insignificant as t_{water1} is negligible.

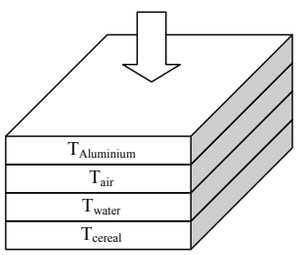
3. Concentrating Type Cookers

Since the insolation intensity is only in the range of 0.5 – 1.0 kW/m^2, solar concentrators are required for practical l utilization. Parabolic concentrators are used to focus the solar radiation. Most of the time they are not required to track the Sun. It works efficiently when the Sun is overhead and less efficiently otherwise. This compromise makes it economical to design. To overcome the effect of slant rays of solar radiation, the incident area is made larger.

3.1 Disadvantage of Concentrating Type Solar Cookers

- Unlike the box type cookers here the vessel is kept at the focal point which is not covered. Convection losses are significant in this type. To overcome this, the incident area has to be made large enough.
- Parabolic concentrators require mounting with a strong base which increases the cost of the concentrator.
- Further it requires special machinery to make a parabolic concentrator otherwise it has to be shipped from a faraway manufacturing unit.

Prolonged exposure to sunlight may affect the vision. Care must be taken to avoid peeping into the reflector.



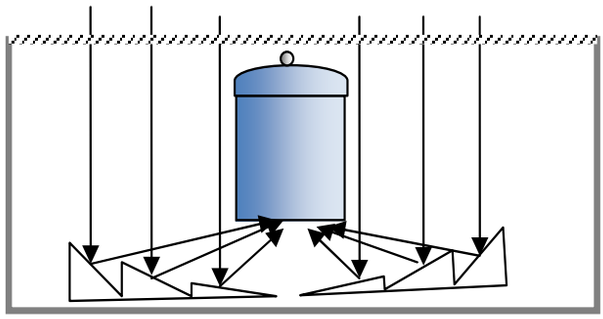
In general a sunglass is a must. Rural people may ignore using sunglasses.

3.2 Reflector to Focus from Bottom

- The parabolic reflector has a pointed focus. Pointed focus is not desirable to cooking. It may scorch the food or make the food not evenly cooked. The discrete pieces of the mirrors enable to decide the focal area such that it is distributed to a size suitable to the bottom area of the Indian cookware.
- This enables evenly distributed heat to the base so that the food is cooked uniformly.

3.3 Some Common Mistakes

- A joint research on healthy cooking fuel options for India carried out by TERI and AIIMS during 2009–10 with funding support from UNICEF. India derives the bulk of its cooking energy needs from solid fuels, such as firewood and cattle dung. In contrast, economically developed countries, such as the USA, UK, Italy, Denmark, and others use cleaner cooking fuels. 80% of rural homes in India - continue to use biomass - firewood, crop residue or cow dung - as their primary cooking fuel1. Urban India, on the other hand, opts for cleaner and convenient cooking fuels. Liquefied petroleum gas (LPG), marketed in portable cylinders lights the fire in over 59% of urban Indian kitchens. Many more are using cleaner fuel each year, thereby moving away from kerosene stoves and firewood or cow-dung-fuelled chulhas.



4. Fresnel Type Reflector

Fresnel type of reflectors has been in use for generating steam in axially running tubes. This replaces the parabolic type concentrators. This paper proposes a design that concentrates the solar radiation to an area less than 300 cm^2, which is suitable to a base of conventional Indian cookware. Parabolic concentrators focus the radiation either axially or to point. A smooth curve instead of steps can bring the focus to a concentrated point. But this application is more suitable for industrial use such as specimen heating of metals.

5. References

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