SOLAR PONDS

WHAT IS A SOLAR POND

- **A solar pond is a body of water that collects and stores solar energy. Solar energy will warm a body of water (that is exposed to the sun), but the water loses its heat unless some method is used to trap it. Water warmed by the sun expands and rises as it becomes less dense. Once it reaches the surface, the water loses its heat to the airthrough convection, or evaporates, taking heat with it. The colder water, which is heavier, moves down to replace the warm water, creating a natural convective circulation that mixes the water and dissipates the heat. The design of solar ponds reduces either convection or evaporation in order to store the heat collected by the pond. They can operate in almost any climate .**

- **A solar pond can store solar heat much more efficiently than a body of water of the same size because the salinity gradient prevents convection currents. Solar radiation entering the pond penetrates through to the lower layer, which contains concentrated salt solution. The temperature in this layer rises since the heat it absorbs from the sunlight is unable to move upwards to the surface by convection. Solar heat is thus stored in the lower layer of the pond .**

WORKING PRINCIPLE

- **The solar pond works on a very simple principle. It is well-known that water or air is heated they become lighter and rise upward. Similarly, in an ordinary pond, the sun’s rays heat the water and the heated water from within the pond rises and reaches the top but loses the heat into the atmosphere. The net result is that the pond water remains at the atmospheric temperature. The solar pond restricts this tendency by dissolving salt in the bottom layer of the pond making it too heavy to rise .**

Most people know that fluids such as water and air rise when heated. Solar ponds stop this process when large quantities of salt are dissolved in the hot bottom layer of the pond, making it too dense to rise to the surface and cool.

Solar Ponds consist of three main layers. The top layer is cold and has little salt content. The bottom layer is hot, 70-100°C (160-212°F), and very salty.

Separating these two layers is the important gradient zone. Here salt content increases with depth as shown by the drawing. Water in the gradient can't rise because the water above it has less salt content and is therefore lighter. Similarly, water can't fall because the water below it has a higher salt content and is heavier. Thus the stable gradient zone can act as a transparent insulator, permitting sunlight to be trapped in the hot bottom layer, from which useful heat is withdrawn.

In this simplified description, no attempt is made to describe the hydrodynamic phenomena which influence zone and interface stability, salt and heat transport, and other complex behavior.

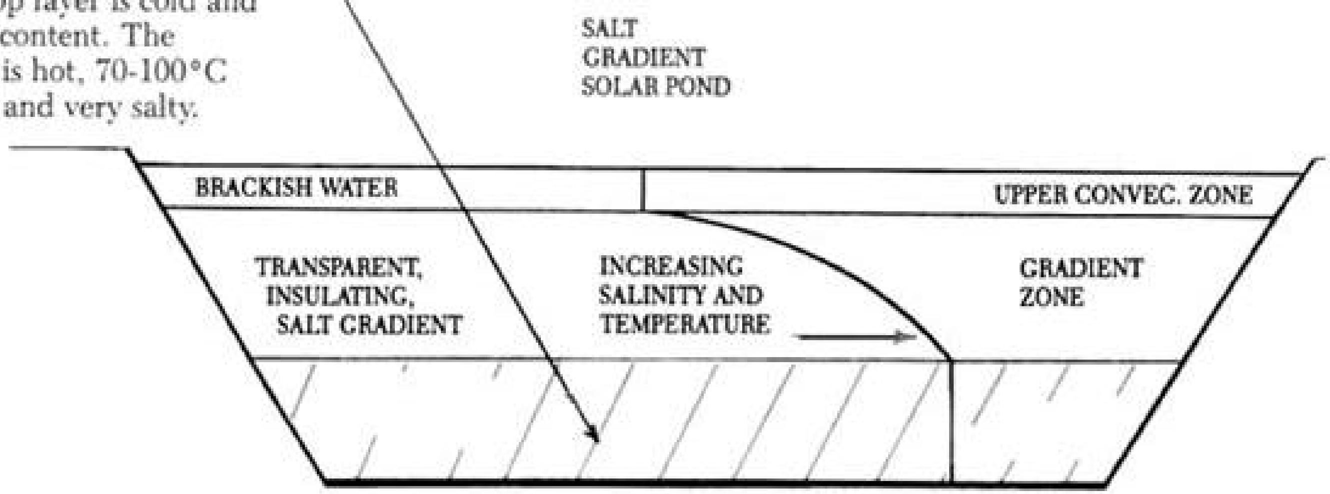
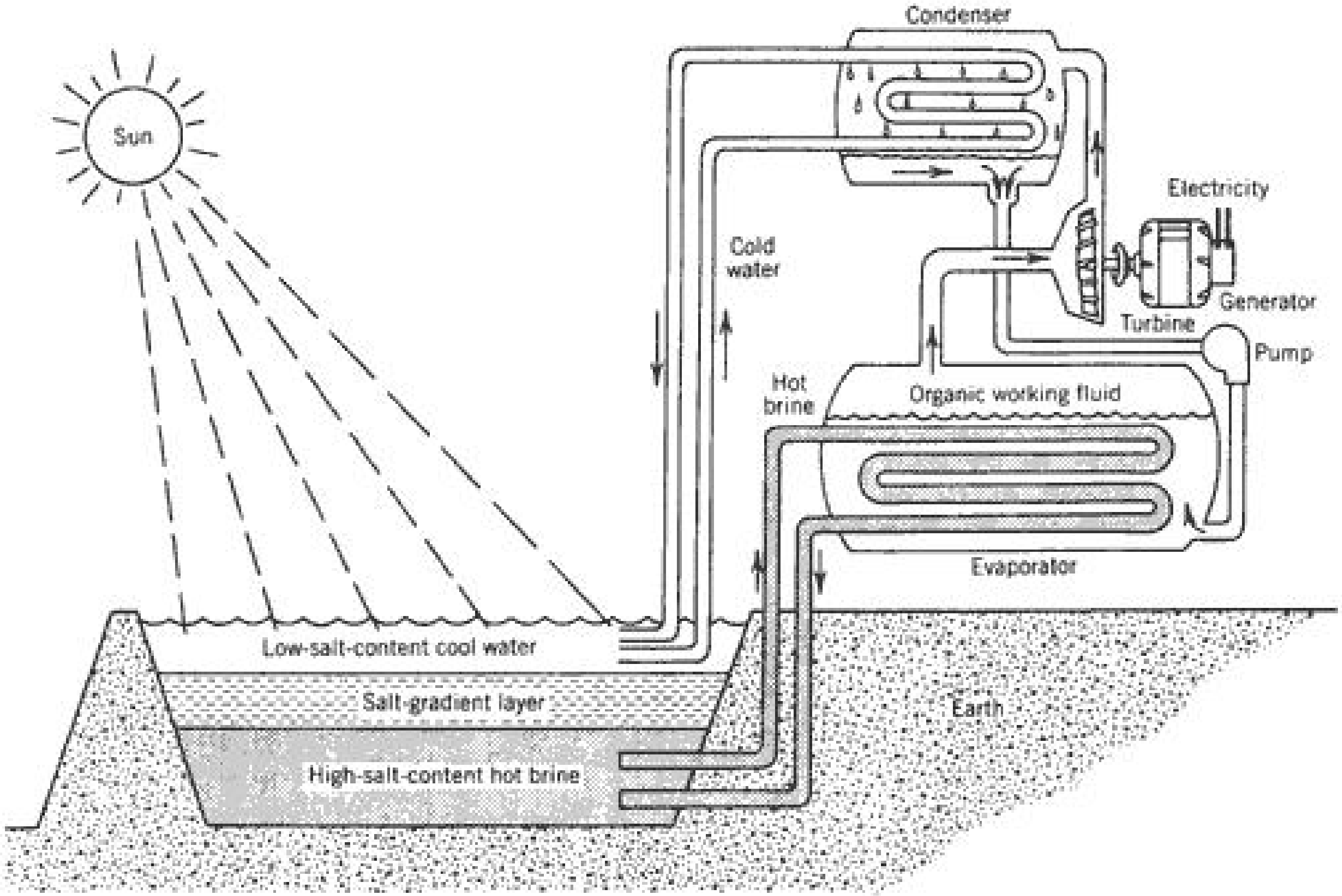


Fig. 1 Shematic View Of A Solar Pond


Condenser
Sun
Electricity
Cold
water
Generator
Turbine
Pump
Hot
brine
Organic working fluid
Evaporator
Low-salt-content cool water
Salt-gradient layer
Earth
High-salt-content hot brine

- **A solar pond is an artificially constructed water pond in which significant temperature rises are caused in the lower regions by preventing the occurrence of convection currents. The more specific terms salt-gradient solar pond or non-convecting solar pond are also used. The solar pond, which is actually a large area solar collector is a simple technology that uses water- a pond between one to four metres deep as a working material for three main functions [6].**
- A salt-gradient solar pond can provide heat at temperatures in excess of 90ºC (194ºF). Such a pond provides built-in thermal storage of such large volume that heat can be collected in the summer and stored for use during the winter. Pioneering work on salt-gradient solar ponds has been done in Israel.

- **Collection of radiant energy and its conversion into heat (upto 95° C)**

- **Storage of heat**

- **Transport of thermal energy out of the system**

- **The solar pond possesses a thermal storage capacity spanning the seasons. The surface area of the pond affects the amount of solar energy it can collect. The bottom of the pond is generally lined with a durable plastic liner made from material such as black polythene and hypalon reinforced with nylon mesh. This dark surface at the bottom of the pond increases the absorption of solar radiation. Salts like magnesium chloride, sodium chloride or sodium nitrate are dissolved in the water, the concentration being densest at the bottom (20% to 30%) and gradually decreasing to almost zero at the top. Typically, a salt gradient solar pond consists of three zones [6].**

- **An upper convective zone of clear fresh water that acts as solar collector/receiver and which is relatively the most shallow in depth and is generally close to ambient temperature,**
- **A gradient which serves as the non-convective zone which is much thicker and occupies more than half the depth of the pond. Salt concentration and temperature increase with depth,**
- **A lower convective zone with the densest salt concentration, serving as the heat storage zone. Almost as thick as the middle non-convective zone, salt concentration and temperatures are nearly constant in this zone [6].**

TYPES OF SOLAR PONDS

There are two main categories of solar ponds:

- **Nonconvecting ponds, which reduce heat loss by preventing convection from occurring within the pond;**
- **Convecting ponds, which reduce heat loss by hindering evaporation with a cover over the surface of the pond .**

CONVECTING SOLAR PONDS

- **A well-researched example of a convecting pond is the shallow solar pond. This pond consists of pure water enclosed in a large bag that allows convection but hinders evaporation. The bag has a blackened bottom, has foam insulation below, and two types of glazing (sheets of plastic or glass) on top. The sun heats the water in the bag during the day. At night the hot water is pumped into a large heat storage tank to minimize heat loss. Excessive heat loss when pumping the hot water to the storage tank has limited the development of shallow solar ponds .**

- **Another type of convecting pond is the deep, saltless pond. This convecting pond differs from shallow solar ponds only in that the water need not be pumped in and out of storage. Double-glazing covers deep saltless ponds. At night, or when solar energy is not available, placing insulation on top of the glazing reduces heat loss [3].**

NONCONVECTING SOLAR PONDS

- **There are two main types of nonconvecting ponds: salt gradient ponds and membrane ponds. A salt gradient pond has three distinct layers of brine (a mixture of salt and water) of varying concentrations. Because the density of the brine increases with salt concentration, the most concentrated layer forms at the bottom. The least concentrated layer is at the surface. The salts commonly used are sodium chloride and magnesium chloride. A dark-colored material usually butyl rubber lines the pond. The dark lining enhances absorption of the sun's radiation and prevents the salt from contaminating the surrounding soil and groundwater .**

- **As sunlight enters the pond, the water and the lining absorb the solar radiation. As a result, the water near the bottom of the pond becomes warm up to 93.3°C. Although all of the layers store some heat, the bottom layer stores the most. Even when it becomes warm, the bottom layer remains denser than the upper layers, thus inhibiting convection. Pumping the brine through an external heat exchanger or an evaporator removes the heat from this bottom layer. Another method of heat removal is to extract heat with a heat transfer fluid as it is pumped through a heat exchanger placed on the bottom of the pond .**

- **Another type of nonconvecting pond, the membrane pond, inhibits convection by physically separating the layers with thin transparent membranes. As with salt gradient ponds, heat is removed from the bottom layer .**

Salt Gradient Solar Pond

APPLICATIONS

- **Salt production (for enhanced evaporation or purification of salt, that is production of 'vacuum quality' salt)**
- **Aquaculture, using saline or fresh water (to grow, for example, fish or brine shrimp)**
- **Dairy industry (for example, to preheat feed water to boilers)**
- **Fruit and vegetable canning industry**
- **Fruit and vegetable drying (for example, vine fruit drying)**
- **Grain industry (for grain drying)**
- **Water supply (for desalination).**

- **Process heat :Studies have indicated that there is excellent scope for process heat applications (i.e. water heated to 80 to 90° C.), when a large quantity of hot water is required, such as textile processing and dairy industries. Hot air for industrial uses such as drying agricultural produce, timber, fish and chemicals and space heating are other possible applications .**
- **Desalination :Drinking water is a chronic problem for many villages in India. In remote coastal villages where seawater is available, solar ponds can provide a cost-effective solution to the potable drinking water problem.**
- **Refrigeration : Refrigeration applications have a tremendous scope in a tropical country like India. Perishable products like agricultural produce and life saving drugs like vaccines can be preserved for long stretches of time in cold storage using solar pond technology in conjunction with ammonia based absorption refrigeration system.**

EXAMPLES OF SOLAR PONDS

- **BHUJ SOLAR POND**
- **El PASO SOLAR POND**
- **PYRAMID HILL SOLAR POND**

BHUJ SOLAR POND

- **The 6000-square-metre solar pond in Bhuj, the first large-scale pond in industrial environment to cater to actual user demand, supplied totally about 15 million litres of hot water to the dairy at an average temperature of 75°C between September 1993 and April 1995 [8]. In figure 3 you can see the Bhuj solar pond.**
- **It was the first experiment in India, which successfully demonstrated the use of a solar pond to supply heat to an actual industrial user. But, sadly, the Bhuj solar pond, constructed by the Tata Energy Research Institute (TERI), today lies in disuse for want of financial support and government policy to help this eco-friendly technology grow .**

The Bhuj Solar Pond

- **The Bhuj solar pond was conceived as a research and development project of TERI, which took over nine years to establish, to demonstrate the feasibility of using a salt gradient pond for industrial heating .**
- **The solar pond is 100 m long and 60 m wide and has a depth of 3.5 m. The pond was then filled with water and 4000 tonnes of common salt was dissolved in it to make dense brine .**

EL PASO SOLAR POND

- **The El Paso Solar Pond project is a research, development, and demonstration project initiated by the University of Texas at El Paso in 1983. It has operated since May 1986 and has successfully shown that process heat, electricity, and fresh water can be produced in the southwestern United States using solar pond technology .**
- **Over 90 graduate and undergraduate students have been involved in the project, performing tasks ranging from construction to applied research. In addition, numerous students have done projects related to the pond, gaining valuable experience in equipment design and construction, lab techniques, problem solving, instrumentation, and documentation**

El Paso Solar Pon

Closer View of El Paso Solar Pond [10].

- **The solar pond provides a unique opportunity to do research in such areas as double diffusive convection, wind/wave interaction, flow in stratified fluids, and computer modeling. In addition, the state of the art equipment on site provides an excellent opportunity for energy efficiency studies, cost analysis, system studies, heat exchanger .**

PYRAMID HILL SOLAR POND

- **A consortium of RMIT University, Geo-Eng Australia Pty Ltd and Pyramid Salt Pty Ltd has completed a project using a 3000 square metre solar pond located at the Pyramid Hill salt works in northern Victoria to capture and store solar energy using pond water which can reach up to 80°C.**

The Pyramid Hill Solar Pond

- **Pyramid Salt will use the pond's heat not only in its commercial salt production but also for aquaculture, specifically producing brine shrimps for stock feed. It is planned in a subsequent stage of the project to generate electricity using the heat stored in the solar pond, thus making this local industry more energy self-sufficient.**
- **At the local level this will be a significant boost in an area with high unemployment and a depressed economy .**

ADVANTAGES AND DISADVANTAGES

- **Low investment costs per installed collection area.**
- **Thermal storage is incorporated into the collector and is of very low cost.**
- **Diffuse radiation (cloudy days) is fully used.**
- **Very large surfaces can be built thus large scale energy generation is possible.**
- **Expensive cleaning of large collector surfaces in dusty areas is avoided .**
- **Solar ponds can only be economically constructed if there is an abundance of inexpensive salt, flat land, and easy access to water. Environmental factors are also important. An example is preventing soil contamination from the brine in a solar pond. For these reasons, and because of the current availability of cheap fossil fuels, solar pond development has been limited.**

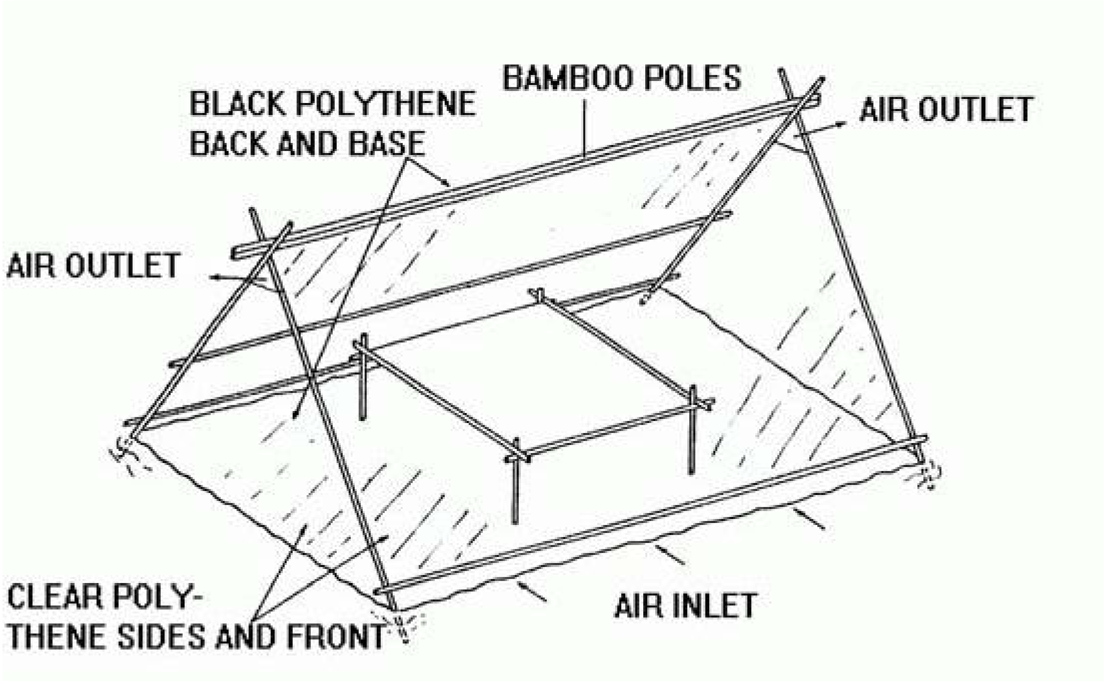
- **Solar ponds can be effectively used as replacements in industries that use fossil fuel to generate thermal energy. Solar ponds can be used for process heating, refrigeration, water desalination, production of magnesium chloride, bromine recovery from bittern, enhancement of salt yield in salt farms. It will be the future energy source.**

Solar Dryer

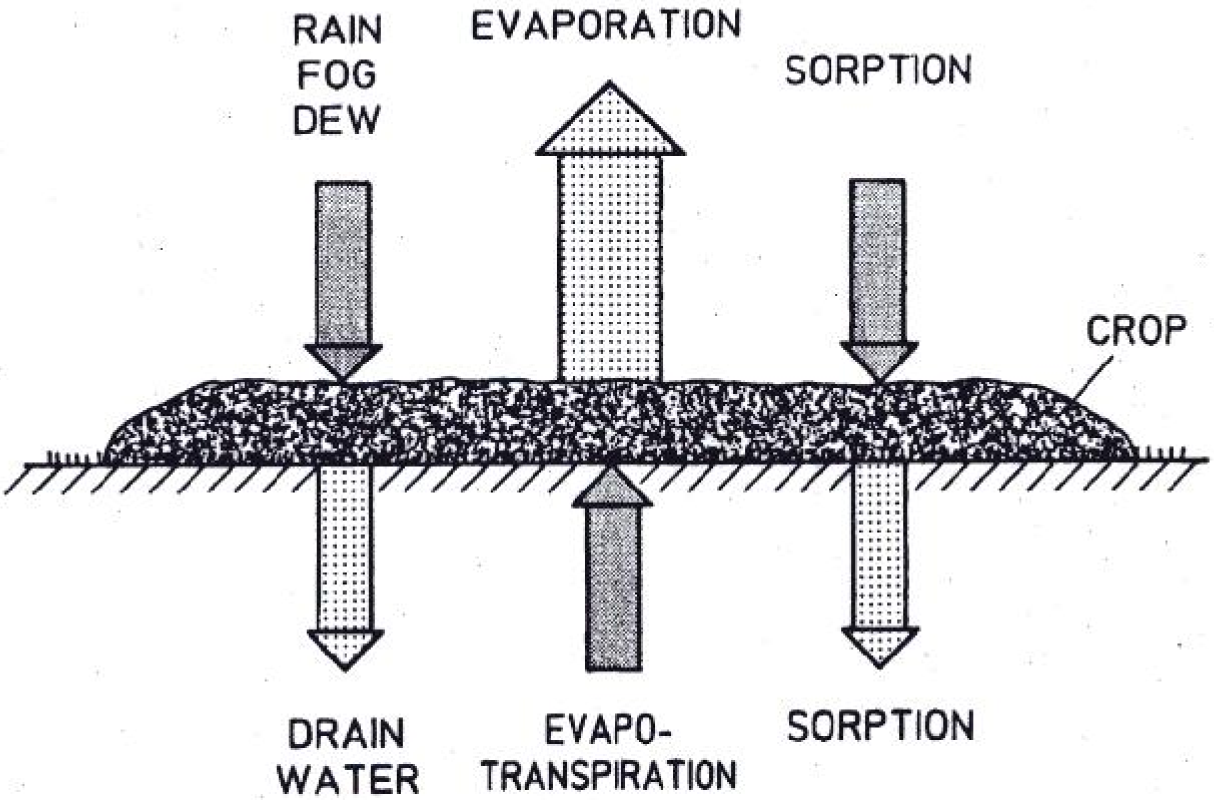
Solar Drying

- In India, Only 2-3 % of agricultural produce is being processed. Reduction of post harvest losses is inevitable.
- According to FAO reports, Crop loss accounts about 5-10 % (Paddy alone during Harvesting and Marketing : 30-50%),Fruits and vegetables is about 10 to 30 %, Pulses 8-10 %,)
- Food and agricultural Commodities loss is about 20-50%.
- Drying process alone can reduce post harvest loss of 2-3 %.
- Uniform drying and quality of product is essential for better marketability.
- Reduction of fossil fuel usage and dependence of conventional power for drying process.
- Utilization of renewable energy is essential to reduce GHG emissions.
- Effective drying mechanism is needed for the hour for enhancing value of agro-produce.
- Our country is blessed with abundant solar energy available for more than 250 days in a year.

Tent dryers


BAMBOO POLES
BLACK POLYTHENE
BACK AND BASE
AIR OUTLET
AIR OUTLET
CLEAR POLY-
THENE SIDES AND FRONT
AIR INLET

Solar tunnel dryer


RAIN
FOG
DEW
EVAPORATION
SORPTION
CROP
DRAIN
WATER
EVAPO-
TRANSPIRATION
SORPTION

Products	Temp °C	Initial moisture content %	Desired moisture content%	Drying Time (Days)	
				Open Sun Drying	Solar dryer
COCONUT	65	55	6 - 7	7-10	3-4
ARECANUT	70	70	12-14	6	3
COCOA	60	79.6	7.5-8.5	14	6
CHILLY	40-45	80	10	4-5	2

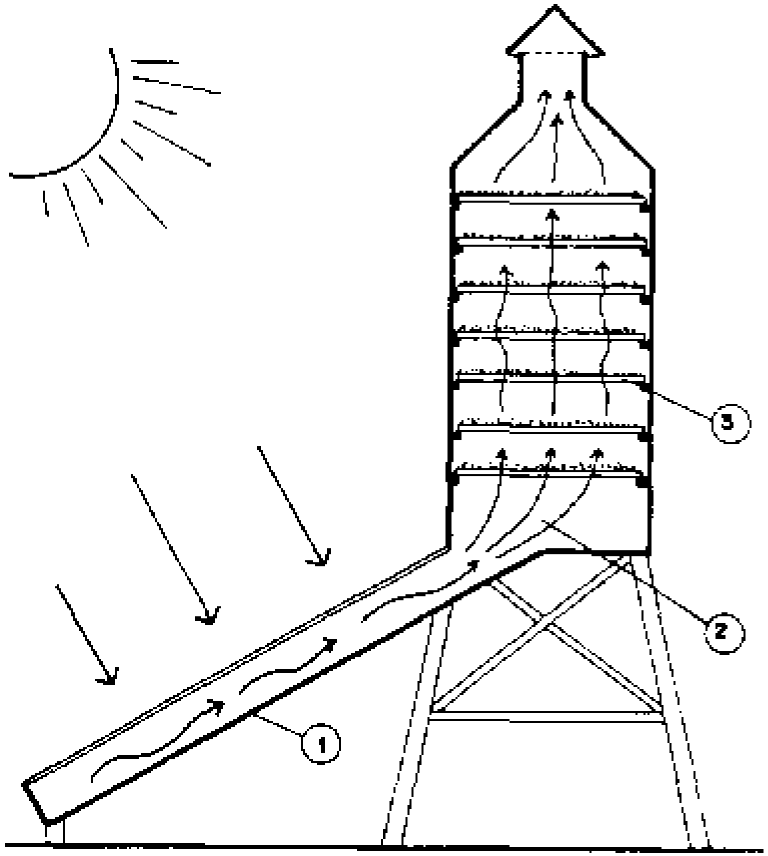
- Conventional method of drying is to spread the material in a thin layer on ground and let it exposed to the sun. Such a method has various disadvantages like,
- Accumulation of dust and harms due to insects
- Wastage of material due to birds
- Non uniform drying due to varying intensity of sun
- Larger area required for drying

All these difficulties are removed by using solar drier. There are two types of solar driers.

- **Natural convection solar drier**
- F**orced convection solar dryer (Hot air system):**

- For drying high moisture paddy the solar drier can be used. The different components of the drier are air heater, air ducts and blower and grain drying chamber. The flat plate collector used for heating the air has an efficiency of 60% and rise in ambient air temperature is 13^{o}C. Freshly harvested paddy can be dried and it may take about 7-8 hours to bring the moisture content from 30% to 16% (d.b.).

- Solar drier consists of air heater, blower drying chamber, air distribution system and thermal storage system. The heated air is blown to drying chamber by blowers of the centrifugal type to handle large quantity of air.



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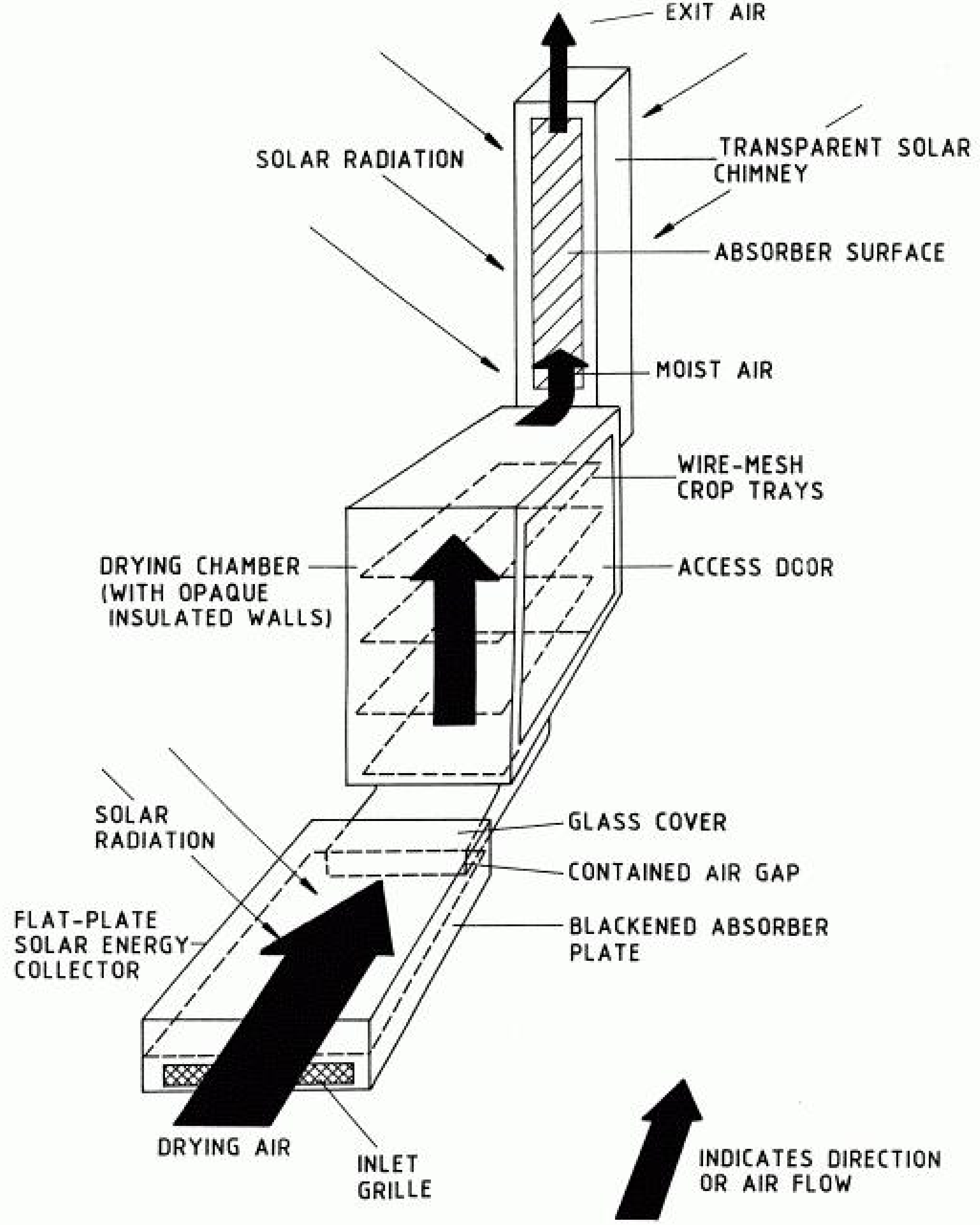
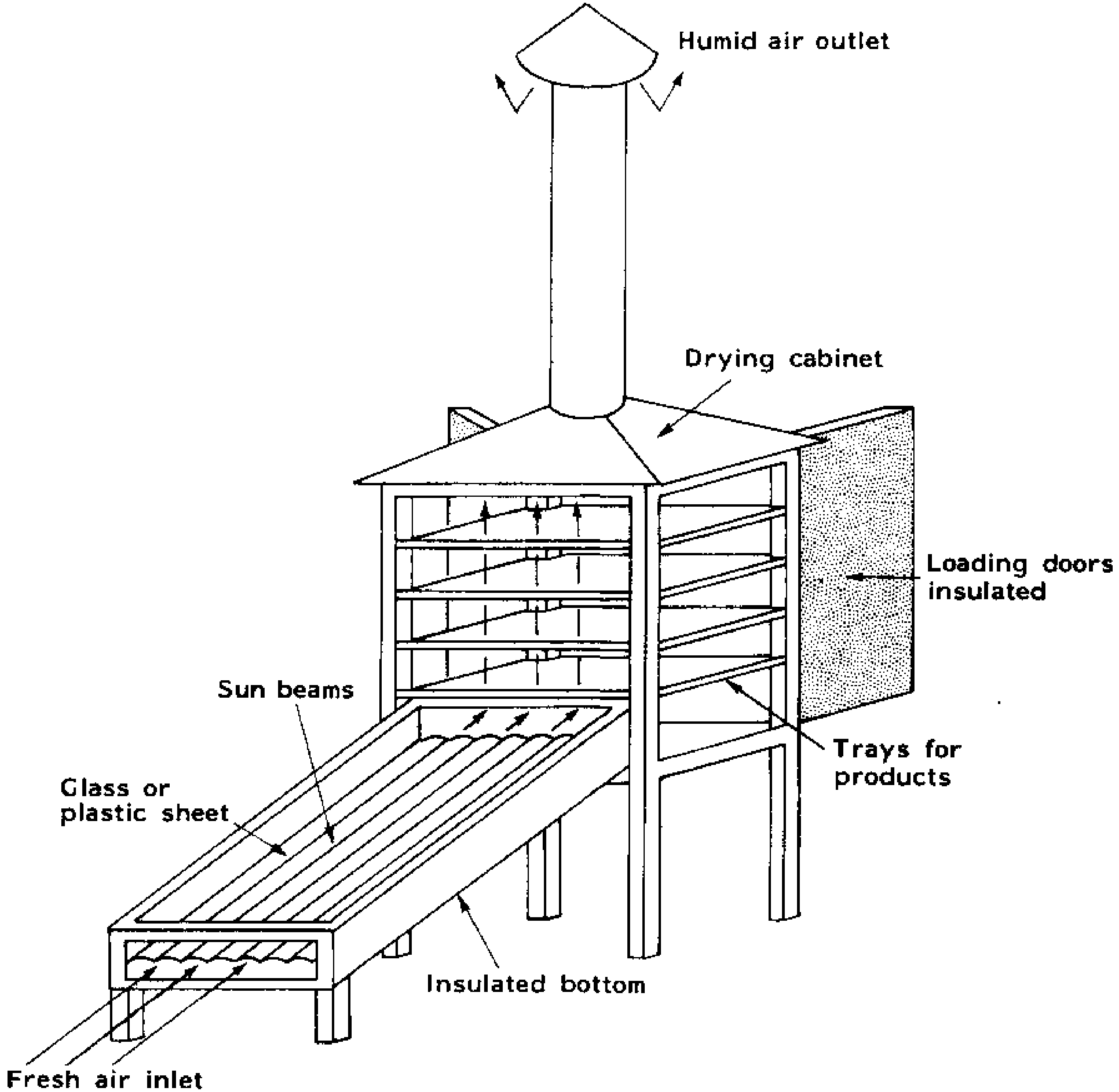
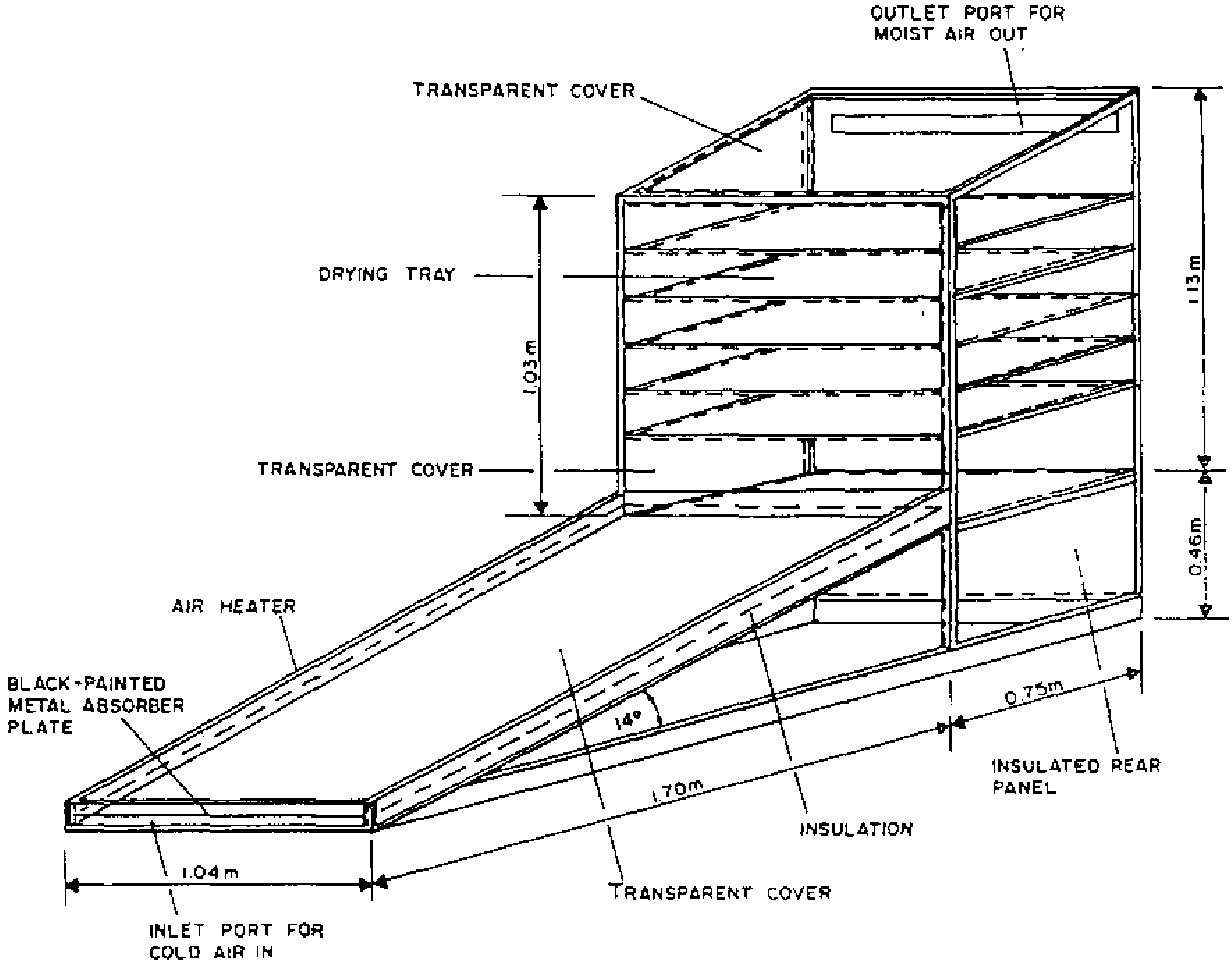
2
3


EXIT AIR
SOLAR RADIATION
TRANSPARENT SOLAR CHIMNEY
ABSORBER SURFACE
MOIST AIR
WIRE-MESH CROP TRAYS
DRYING CHAMBER (WITH OPAQUE INSULATED WALLS)
ACCESS DOOR
SOLAR RADIATION
GLASS COVER
CONTAINED AIR GAP
FLAT-PLATE SOLAR ENERGY COLLECTOR
BLACKENED ABSORBER PLATE
DRYING AIR
INLET GRILLE
INDICATES DIRECTION OR AIR FLOW


Humid air outlet
Drying cabinet
Loading doors
insulated
Sun beams
Trays for
products
Glass or
plastic sheet
Insulated bottom
Fresh air inlet



OUTLET PORT FOR
MOIST AIR OUT
TRANSPARENT COVER
DRYING TRAY
1.03 m
1.13 m
TRANSPARENT COVER
0.46m
AIR HEATER
BLACK-PAINTED
METAL ABSORBER
PLATE
14°
0.75m
INSULATED REAR
PANEL
1.70m
INSULATION
1.04 m
TRANSPARENT COVER
INLET PORT FOR
COLD AIR IN