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Enhancement of Solar Salt Production by Using Solar Thermal Energy Systems

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Abstract

At present, salt is being extracted from seawater and/ or brine by solar evaporation of impounded water in ponds. Evaporation rate is dependent on sunshine intensity and angle during daytime and sun's traverse across the sky. It means a non-uniform evaporation of the brine and slowing down of the condensation and crystallization of salt at a lesser efficiency of the whole process. To make up this, installation of solar thermal energy systems is given a thought which would at least elevate the temperature of brine to be stored in the ponds. Such systems are simply an assembly of parabolic reflector with a coaxial pipe. This pipe is connected to pipe meander immersed within saltern's feeder channel. The circulating water inside the pipe delivers the heat, received from the parabolic reflector, to the feeder channel water which elevates the brine water temperature. In fact, it provides a mean to heat the brine before it is to be stored in the ponds. Therefore, a faster evaporation could be expected. In this conceptual note, solar energy system coupled with a heat exchanger is discussed as a viable facility for enhancing the salt production in Thoothukudi region by improving the evaporation rate. The heat and mass transfer behavior of the system is artificially modified. The added heat increases the pond solution layer temperature, thereby increasing the evaporation rate and the sea salt production rate.

Key words: brine water, solar salt pan, parabolic reflector, solar energy system

Introduction

Salt is generally produced from seawater and/ or brine by solar evaporation of impounded water in ponds or otherwise called saltpans (saltern). Salt is being harvested from evaporation pans along coasts of India, in particular, of Gujarat, Odisha and Tamil Nadu. The process is simple; seawater and/ or brine are allowed to evaporate by sun's insolation. However, each saltern has its own layout of ponds into reservoirs, condensers and crystallizers (Lakshmanan, 2010). See Figs. 1 and 2 for process elements and layout of a functioning saltern. Each of these three forms a progressive stage in the salt production i.e. it is used to enhance the density of water. The density of raw seawater or brine available for salt production dictates the number and areal extent in individual cases. Density of source water is measured in terms of Baume (Be) which is a measure of total salt concentration in water and is obtained using a hydrometer. The range of density of source water is from 6 to 20 Be. Lower the initial density of feeding saline water longer is the duration for salt crystallization and harvesting and in turn it reduces the returns. So, several attempts have been made to minimize the gestation period for salt. Among them one is systematic layout of ponds and the transfer of water in cycles from reservoir through condenser and through crystallizer. In that case, density of raw water increases from 6 in reservoir to 20 in crystallizer through condenser with an intermediate value.

Principally, evaporation leads to growth of salt crystals in supersaturated saline water. Therefore, salt production depends on solar evaporation. However, evaporation rate is dependent on sunshine intensity and angle during daytime and sun's traverse across the sky. It means a non-uniform evaporation of the brine and slowing down of the condensation and crystallization of salt at a lesser efficiency of the whole process. This industry sustains chiefly on solar (renewable) energy. Only for pumping of brine, electricity is used.

Its production rate and/ or schedule is controlled by local weather conditions; i.e., wind and sunshine. On the contrary, rain hampers production and dampens the stock, too. During seasonal winds, a better evaporation is observed followed by high productivity. As winds not only help drive away overcast shadowy evaporative moisture from above the pans but also supply minute dust particles as nuclei for salt growth.

Salt production enhancement attempts

Lakshmanan (2010) also tried, in his own saltern, a microbiological method of increasing salt production by introducing an alga, *Dunaliella* that absorbs heat and thereby elevates the temperature of the pond water resulting in faster evaporation.

Modeling studies through simulation have given insight into the improvement of production from evaporative ponds (Manganaro and Schwartz, 1985). Diaz et al., (2013) proposed raising of feedwater temperature through solar energy systems.

The present work also proposes one such additional installation along the bund of feeder water channel. In principle, it is a heat transfer method.

Design of heat transfer system

It requires arrangement of a coil of pipe with circulating heat conducting liquid with its top portion exposed to concentrated solar irradiation and the bottom ends submerged within the brine waters of feeder channel. Water of the exposed part of the coil gets heated up from sunshine and when it is allowed to circulate through coil, heat is transferred to feeder channel water by conduction elevating the temperature of raw water before it is fed into ponds for evaporation cycle. Figure 2 illustrates such an arrangement with a facility for focusing of sunlight onto the top part of the coil.

Maximising the receipt of sun's energy

In photovoltaic systems sun's energy is obtained using silicon flat panels which require vast land area. But, here in salt manufacturing heat energy is to be used and hence a suitable structure is necessary to heat secondary fluid. For this purpose, a conduit pipe is fitted coaxially at the focus of a long parabolic reflector. Further geographic orientation of this reflector also counts, considerably, due to sun's apparent east to west movement across the sky. This necessitates the orientation of the reflector along north-south direction that allows higher incidence of solar insolation (Diaz et al., 2013).

Fluid circulator

Figure 3 is the design of an apparatus consisting of pipe and liquid to be used for heat exchange the pipe is bent into wave form as it provides enough time for the liquid's heat to be exchanged with the channel water that surrounds it. The choice of the liquid that is to be used for circulation range from isopropane to salt water. Considering the safety and nonpolluting situations ordinary water may be used. Retention of heat will be much better if brine is used, but scaling of interior of the pipe is the imminent danger and hence pure water may be input and accordingly provisions may be given for both inlet and outlet.

Mode of heat transfer

Fig. 4 schematically illustrates the mode of heat transfer that occurs in the proposed system of solar thermal energy. Radiative heat raises the temperature of the pipe. By conduction, pipe heats internally flowing liquid; liquid maintains heat by convection; at the channel end of the pipe liquid's heat is conducted to the brine surrounding the pipe. This warmed brine is streamed into pans for condensation and evaporation leading to the crystallization of salts.

Installation

Parabolic reflector will be installed along the brine feeder channel and on top of the bund. The heat exchanger coiled-pipe structure is erected between parabolic reflector and the channel that feeds brine to condenser ponds. Parabolic reflector should be installed in such direction not to obstruct the wind. It will act as the heat source for the fluid contained in the heat exchanger. The proposed heat exchanger will be comprised of a collection of pipes that assist heat transfer from the working fluid to the salt water. These pipes would be slightly submerged under the surface of the water since the temperature of pond solution layer dictates the evaporation rate of water as presented by Manganaro and Schwartz (1985).

Parabolic reflectors

Parabolic reflectors are made up of a polished stainless steel, longitudinally bent, capable of reflecting the sunlight maximum. To receive the heat energy a horizontal pipe (black coloured) is erected at the focal distance of reflector, coaxially. By this fixture solar radiation is concentrated by reflection onto the horizontal pipe which heats the fluid inside the pipe. The two open ends of the pipe are mounted with the parallel ends of horizontally laid coil submerged under the feeder channel of raw brine. Of course, arrangements are necessary to fill and empty this heat exchanger pipe system. They are light structures that provide temperatures in the hundreds of degrees Celsius at low costs (Kalogirou, 2009). Kalogirou recommends a glass cover around the black tube with a vacuum seal to reduce convective heat loss.

Heat Exchangers

Heat exchanger is a meandering pipe structure with working fluid that circulates wthin the pipe. Meandering shape provides longer path and time for dissipation heat inot the surrounding feeder raw brine (Cengel, 2003). It maximizes the heat transfer from working fluid to raw brine.

Scope and limitations

It burdens the business by capital investment in establishing solar energy system. Additional pumping installation and power expenses make saltpan owners to have a second thought.

Conclusion

In this conceptual note, solar energy system coupled with a heat exchanger is discussed as a viable facility for enhancing the salt production in Thoothukudi region by improving the evaporation rate. The heat and mass transfer behavior of the system is artificially modified. The added heat increases the pond solution layer temperature, thereby increasing the evaporation rate and the sea salt production rate.

Reservations may prevail, as to the implementation of such parabolic reflectors, among the real salt pan operators, considering the establishment investment expenses. However, if it is viewed from a longer time span perspective, the shorter salt crystallization duration would certainly make a better trade off. Primarily in this conceptual note a 'why-not' situation is discussed as it is a new proposal-in-concept.

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Fig. 1 Process elements in a salt pan operation

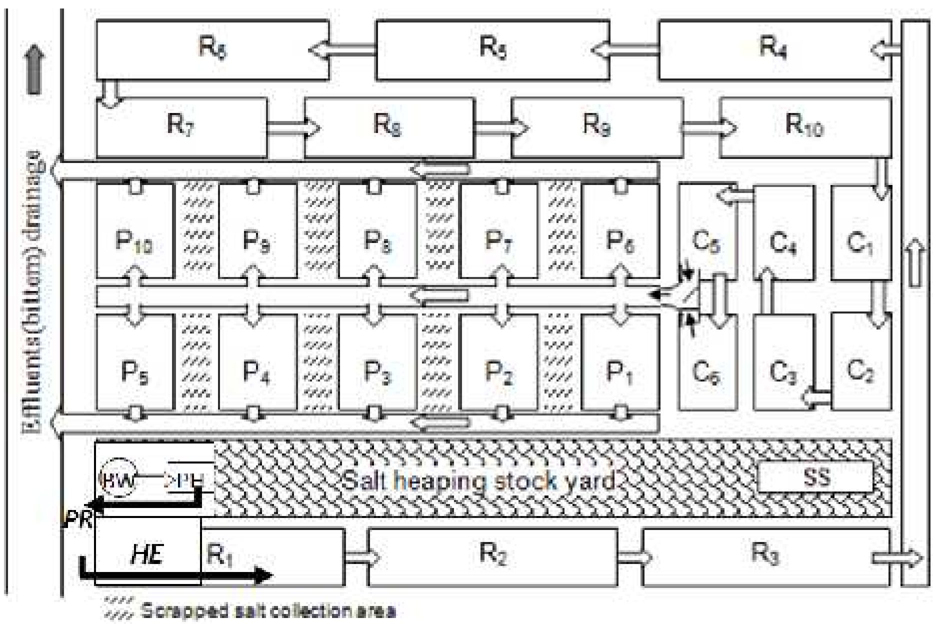

Fig. 2 Schematic of salt manufacturing from solar salt pans (Not to scale)
R_n: n– Reservoir; C_n: n^{th} Condenser; P_n: n^{th} Crystallizer pan; BW: Bore well;
PH: Pump house. SS: Stock shed. Arrows indicate gravitational flow of brine.
Courtesy: M/s Palanithai Salt Works, Thoothukudi. Suggested location of N-S trending parabolic reflector and heat exchanger shown as *PR* and *HE*

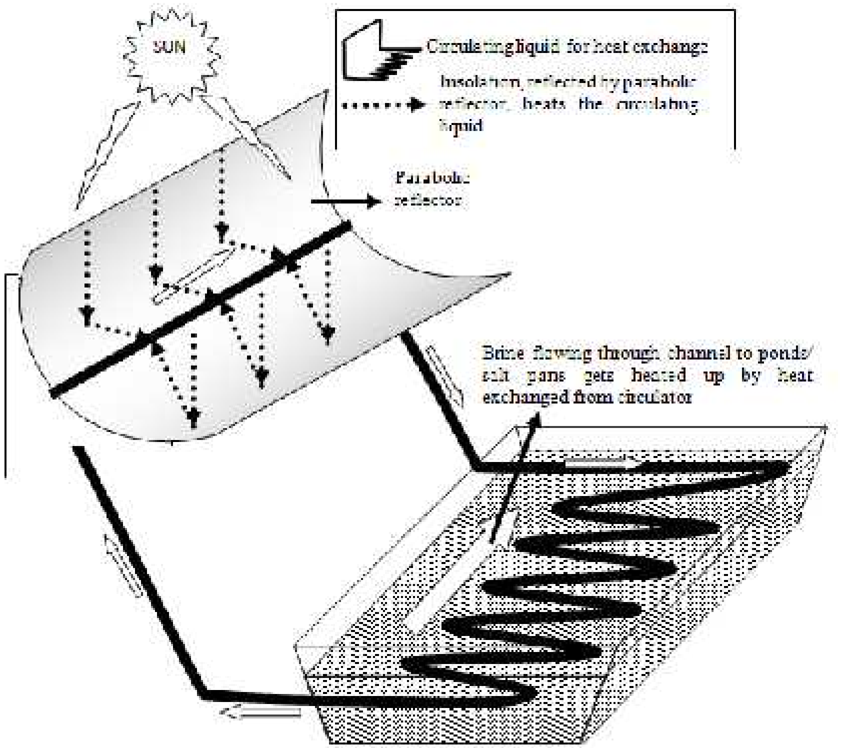

Fig. 3 Warming of brine through heat exchanger arrangement using parabolic reflector (After Diaz et al.,) for speeding up of evaporation

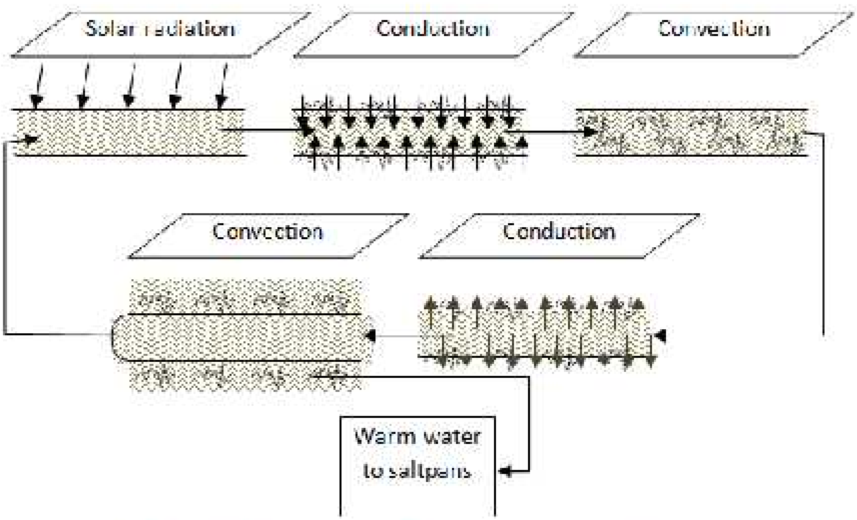

Fig. 4 Modes of heat transfer in solar warming of brine