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Thermal Behavior and Exergy Analysis of a Salinity Gradient Solar Pond

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ABSTRACT

The solar pond is considered the most reliable and economic solar systems. The collecting and storing of the solar energy is in one system. Solar pond is an artificially constructed pond in which significant temperature rises are caused to occur in the lower regions by preventing convection. To prevent convection, salt water is used in the pond. Those ponds are called "salt gradient solar pond". Present many salt gradient solar ponds varying in size from a few hundred to a few thousand square meters of surface area have been built in a number of countries. Nowadays, mini solar ponds are also being constructed for various thermal applications. This paper gives an overview of a Thermal behavior and Exergy analysis of the salt gradient solar pond and describes the losses of upper convective zone, non-convective zone and lower convective zone is used.

Keywords: Salinity Gradient Solar Pond, Exergy, Thermal Behavior and Mini Solar Pond

I. INTRODUCTION

The Natural water solar ponds was observed and reported first time by Kalecsinsky in the Medve Lake in Transylvania in 1902. Solar ponds have been suggested to be simple and economical in terms of collecting and storing energy on a large scale. There are two types of solar ponds depending on the convecting behaviors and the non- convecting solar ponds [3]. Solar pond is an artificially constructed pond in which significant temperature rises are caused to occur in the lower regions by preventing convection. To prevent convection, salt water is used in the pond. Those ponds are called "salt gradient solar pond". The Salinity Gradient Solar Pond consists of Three zones [7]. The surface layer is called Upper Convective zone (UCZ), The Upper Convecting Zone (UCZ) which has the least cost, salinity, temperature, and is close to ambient temperature, below the UCZ is called the Non convective zone (NCZ) or salinity gradient zone, The Non-Convecting Zone (NCZ) which is located between the upper and the lower zones of the pond. Since the temperature and salinity increase with depth, this layer is not homogeneous. If the salinity gradient is large enough, the NCZ inhabits a convection phenomenon even when the lower zone is hotter. The layer below salinity-gradient zone is called storage zone. The Lower Convecting Zone (LCZ), which is a homogenous layer and has a relatively high salinity and high temperature. Heat is stored in this zone and can be exchanged in or out of the pond. As the LCZ's depth increases, the heat capacity increases and the temperature variation decreases. The thickness of storage zone is normally around one or two meters, the surface zone is around 0.3 meters and the overall pond should be around two or more meters [4].

If the solar ponds have suitable gradient of salt concentration at the storage zone and clear fresh water at surface zone. Therefore, the solar energy would be absorbed and collected by the storage zone, which salt water will not rise when it has been heated due to the salt water is heavier than the fresh water on the surface zone. Then the surface zone acts as an insulating blanket and temperature at the storage zone could reach up to 90°C [5]. This temperature is high enough to generate a vapour cycle engine to generate the electricity.

Solar Ponds are used for different applications [6]. Process Heat, Solar ponds can be used for heating purposes in many ways such as Process Industries, Domestic & Commercial Heating Systems in colder countries, Thermal Electricity desalination. Solar Ponds can play an efficient role in providing clean drinking water refrigeration.

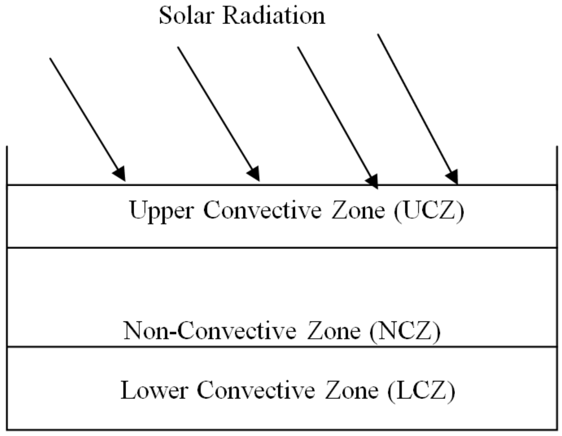

Figure 1 : Schematic view of a solar pond

II. METHODS AND MATERIAL

A. Thermal Analysis of a Salinty Gradient Solar Pond

The solar pond depends on the amount of its thermal energy storage, and on the construction costs plus maintenance expenses. Therefore, an accurate analysis of its thermal behavior will be needed. The thermal performance of a solar pond is a function of solar irradiation, heat losses from the sides to the surroundings and from the LCZ towards the upper layers, ultimate storage capacity, and the effectiveness of the heat exchanger system. All the characteristics of different zones of a solar pond may vary during the time; and for a perfect analysis, the mass and energy balance equations should be solved simultaneously [8].

The thermal energy balance for a large solar pond was first investigated by Weinberger (1964). He had neglected the thicknesses of the upper and lower convective zones and solved the energy equation analytically, by a superposition method. Rabl and Nielsen (1975) developed the one-zone model of Weinberger into a two-zone pond. In their model, the thickness of the UCZ had been analyzed. Analytical methods are useful for simple studies, however, when the boundary conditions are complex, or the variations of thermo physical parameters are to be considered, numerical models should be utilized. There have been several attempts for the numerical solution of energy equation in the literature. For example, Hull (1980), Hawlader and Brinkworth (1981), and Rubin et al. (1984) have applied a finite difference method, while Jayadev and Henderson (1979), and Panahi et al. (1983) have used a finite element technique.

The Thermal behavior can be described by developing a Mathematical model for the solar pond zones, and it starts applying the energy balance principles for a body of water as shown in figure.

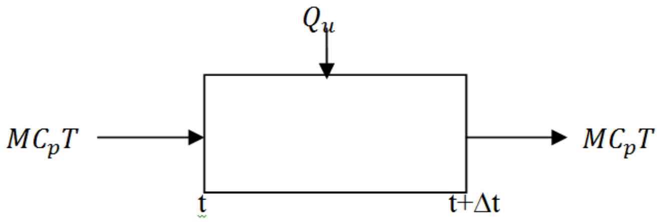

Figure 2 : Heat balance of volume

From the figure,

$$[MC_pT]_t - [MCpT]_{t+\Delta t} - [\Delta t]Q_u = 0 \qquad (2.1)$$

Where

Qu: the useful heat.
t: Operating time.
M: mass of water.
Cp: water heat capacity .

Dividing the above Eq.1 by Δt we get:

$$[MC_pT]_t - [MC_pT]_{t+\Delta t} - (\Delta t)Q_u = 0$$

$$\frac{[MC_pT]_t - [MC_pT]_{t+\Delta t}}{\Delta t} - Qu = 0 \qquad (2.2)$$

Applying the limits both sides, we get

$$\lim_{\Delta t \to 0} \frac{[MC_pT]_t - [MC_pT]_{t+\Delta t}}{\Delta t} - Qu = 0 \qquad (2.3)$$

$$MCp\left(\frac{dT}{dt}\right) - Q_u = 0 \qquad (2.4)$$

Thus, the above equation represents the gained heat from the solar radiation (into the salinity gradient solar pond) minus the heat loss from the pond. The use of a one-dimensional model is widely adopted because salinity gradient solar ponds are usually constructed on large scales with large surface area.

2.1. Upper Layer Heat Losses

Heat losses from the Upper layer surface of a salinity gradient solar pond, affect the performance of a solar pond. The heat losses may occur through convection, conduction, radiation and evaporation processes. Although the solar pond is a source of heat, it is found that the surface temperature is usually cooler than the ambient temperature [8]. Alhussieni found that, generally speaking, the surface temperatures are at least (as a minimum) 5% less than the atmospheric ones [9]. Hence, assuming that the upper surface temperature is equal to the ambient air temperature may lead to avoidable errors.

The input and output heat values passing through the upper zone of a solar pond as shown as in Figure 2, and they can be mathematically represented by the Equation 4. The net heat in the surface layer is thermally fed by the solar irradiation and the conducted heat from the lower zones.

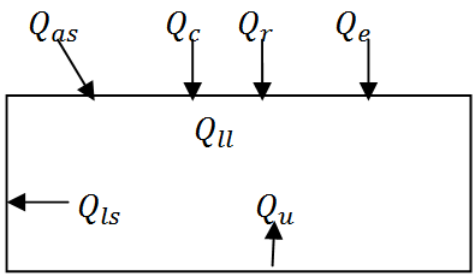

Figure 3 : Heat balance in the upper zone

$$Q_{net} = Q_{as} + Q_{ll} - Q_{ls} - Q_c - Q_r - Q_e \qquad (2.1.1)$$

where:

Q_{as} : absorbed heat from solar radiation in the upper zone.
Q_{ls}: heat loss from the sides.
Q_{ll}: heat gained from the lower layers.
Q_c : heat loss by convection.
Q_r: heat loss by radiation.
Q_e: heat loss by evaporation.

2.2. Convection Heat Loss:

The Convection heat loss may be depend on the wind speed and the temperature difference between the atmosphere and the water surface.

It may be expressed as follows;

$$Q_c = h_c A_{ucz}(T_{ucz} - T_{amb.}) \qquad (2.2.1)$$

where:

hc : convection heat transfer coefficient.
Au : upper layer surface area
Tu : upper layer temperature
Ta : ambient air temperature

From Several equations have been derived for obtaining the convection heat transfer coefficient. Atkinson [10] suggested the relation below for estimating hc:

$$h_c = 0.255\ f(\upsilon_z)$$

where $f(\upsilon_z)$ is the wind speed as a function of wind speed measurement height (z).

Considering the ambient air pressure with wind speed, the above equation may be written as;

$$h_c = 0.0041\ (\upsilon\ P_a)$$

Where,

υ = wind speed
P_a = Ambient air pressure

A common correlation for calculating the convective heat transfer coefficient was given by McAdams[11],

$$h_c = 5.7 + 3.8\ (\upsilon) \qquad (2.2.2)$$

The above Equation can be used for predict both free and forced (mixed) convection heat transfer on flat collectors [12] and it is also validated experimentally [13], thus, it used in many research works.

2.3. Radiation Heat Loss:

The heat transfer between the upper zone and the sky (because of the radiation *Qr*) is a function of the ambient and water surface temperatures and the upper zone area. Thus, the radiation heat loss equation may be written as:

$$Q_r = \sigma \varepsilon_s A_{ucz}\left[[T_{ucz}]^4 - \left[T_{sky}\right]^4\right] \qquad (2.3.1)$$

where:
σ: Boltzman-Stefan constant .
ε: emissivity of the water surface.
A_{ucz}: upper layer area (m2).
T_{ucz}: the upper layer temperature (K)

T_{sky} : the sky temperature (K)
The sky temperature value may be determined by using several equations, such as Swinbank's formula [14]:

$$T_{sky} = 0.0552\ (T_a)^{1.5} \qquad (2.3.2)$$

where T_a is the ambient temperature (K).

Evaporation Heat Loss:

The heat loss from the surface of the pond due to the evaporation is considered to be the largest heat loss from the pond [15]. The estimation of the evaporation heat loss is still intensive research [16] and is still not fully understood. It is very difficult to such processes analytically, however, several empirical equations have been proposed to predict the behaviour of this phenomenon, for instance, Sodha and Ali [17] used this formula.

$$Q_e = h_e[C_0(T_{ucz} - T_a) - C_1(1 - \emptyset_h)]$$

where C_0 and C_1 are constants and their values are 2.933 and 39.11505, respectively, and where $\emptyset_h$ is the relative humidity (widely available for each region).

The evaporation heat transfer coefficient (h_e) is a function of wind speed (υ), and can be written by:

$$h_e = 8.88 - (7.82)\ (\upsilon) \qquad (2.3.3)$$

Kishore and Joshi [18] use the next correlation, it includes the wind heat transfer coefficient and the vapour and partial pressure of water.

$$Q_e = \left(\frac{\lambda h_c}{1.6\ c\ _a\ P_{atm.}}\right)(P_u - P_a) \qquad (2.3.4)$$

where:

λ : water evaporation latent heat (kJ/Kg)
C_a : humid heat capacity of air.
P_{atm} : atmospheric pressure (mmHg).
P_u : water vapour pressure as at the upper layer temperature (mmHg).
P_a : water vapour partial pressure in the ambient temperature (mmHg).

2.4. Storage Layer Heat Loss:

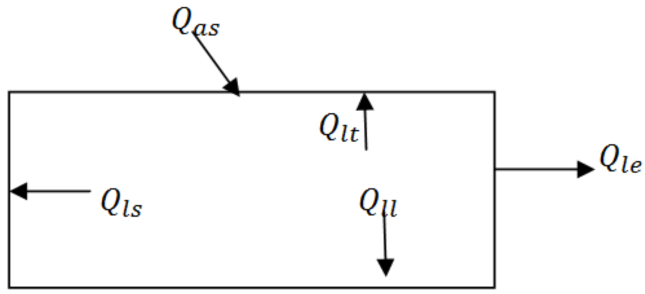

Figure 4 : Heat balance in the storage zone

The heat losses from the storage convecting zone of a solar pond are less, compared than the upper zone heat losses, and the above Figure may describe types of heat losses. Actually, the heat losses in the Storage zone due to conduction heat transfer. Sufficient insulation to the bottom and sides of this layer may improve the solar pond performance significantly. The thickness of the non-convecting zone plays an important role in obstructing the upward heat loss from the lower zone to the surface and thence to the ambient region.
We know that,

$$Q_{net} = Q_{as} - Q_{lt} - Q_{le} - Q_{ll} - Q_{ls} \qquad (2.4.1)$$

Q_{as}: absorbed heat of solar radiation in the storage zone.
Q_{ls} : heat loss from the sides.
Q_{ll}: heat loss from the bottom.
Q_{lt}: heat loss from the top.
Q_{le} : heat loss by heat extraction.

2.5. Sides And Bottom Heat Loss:

The heat loss from the lower layer occurs through the bottom or the sides, depending on the solar pond area, i.e., the bottom heat loss may be greater when the pond area is large but in a small solar pond, the side walls having the major heat loss. Wang and Akbarzadeh [19] studied ground heat loss through wet soil, and they recommended that the pond should be well insulated, particularly when the ground water level is close to the pond bottom. Davis and his group [20] found that unless the bottom of the pond is insulated, almost 20% of the pond insolation may be lost through the ground.

The correlations that are used to describes the ground heat losses may vary according to the simplifications that could be selected; the models can be 1, 2 or 3 dimensions, and could be steady or unsteady states. For a one-dimensional heat conduction unsteady state model, the following relation can be used:

$$\rho_g C_g \left(\frac{\partial T(x,t)}{\partial t}\right) = \frac{K_g\left(\partial^2 T(x,t)\right)}{\partial x^2} \qquad (2.5.1)$$

where:
ρ_g : density of the ground .
C_g : specific heat of the ground .
K_g : thermal conductivity of the ground .
$T_{(x,t)}$: temperature distribution at time (t) and depth

Hull *et al.* [21] carried out several numerical simulations and obtained a semi empirical equation was derived to predict the ground heat loss from the storage zone, as the following:

$$Q_g = \alpha A + \beta P \qquad (2.5.2)$$

where:
α and β are coefficients.
A: pond bottom area (m^2).
P: pond perimetre length (m).

The values of α and β for selected depend on pond configurations.

Table 1: Values of α and β for some pond configurations [22].

Pond shape	**Wall type**	**Wall insulation**	***α* (W/m²)**	***β* (W/m²)**
Circular	Vertical	No	2.22	54.8
Circular	Declined	No	2.20	36.1
Circular	Vertical	Yes*	2.21	40.4
Square	Vertical	No	2.22	53.6

* Insulation thickness = 20cm and thermal conductivity = 0.034 (W/m °C).

2.6 Heat Extraction:

The purpose of Heat extraction is when constructing a solar pond but it is a form of heat loss as it reduces the storage zone temperature. The following equation gives the heat removal from the lower convecting layer.

$$Q_{he} = m_{bf} C_{bc}(T_{bwt} - T_{btt}) \qquad (2.6.1)$$

Where:
m_{bf}: brine mass flow rate .
C_{bc}: brine heat capacit .
T_{bwt}: brine withdrawal temperature.
T_{btt}: brine return temperature.

III. RESULTS AND DISCUSSION

3. Exergy Analysis of a Salinity Gradient Solar Pond:

Exergy analysis permits many of the shortcomings of the energy analysis of solar pond systems, to be overcome, and thus appears to have great potential as a tool for design, analysis, evaluation and performance improvement. An exergy analysis of each zone is presented here.

3.1 Exergy Analysis for UCZ:

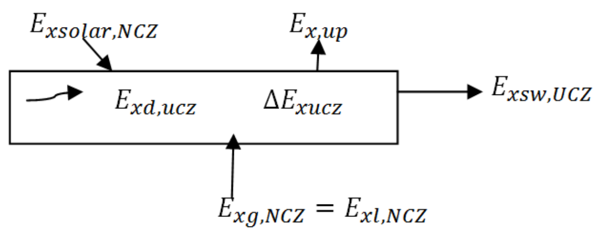

Figure 5 : Exergy and Energy flows in the Upper Convective Zone

Exergy flows in the Upper Convective Zone are illustrated as shown in figure. We can write an exergy balance for the UCZ as follows:

$$E_{xsolar} + E_{xg,ncz} = E_{xr,ucz} + E_{xd,ucz} + E_{xa} + E_{xsw,ucz} \qquad (3.1.1)$$

We know that,

$$E_{xr,ucz} = E_{xti} - E_{xtl}$$

$$= \left(E_{xsolar} + E_{xg,ncz}\right) - \left(E_{xd,ucz} + E_{xa} + E_{xsw,ucz}\right) \qquad (3.1.2)$$

Where E_{xti} is the total energy input to the UCZ and E_{xtl} is the total exergy losses, including exergy destruction.

The exergy of the solar radiation can be expressed, by modifying the expression of Petala (2003), as follows:

$$E_{x,solar} = E_{net}\left[1 - \frac{4T_0}{3T} + \frac{1}{3}\left(\frac{T_0}{T}\right)^4\right] A_{ucz} \qquad (3.1.3)$$

The exergy gained from the NCZ can be expressed as follows:

$$E_{xg,ncz} = m_{NCZ}C_{p,NCZ}[(T_{m,NCZ} - T_{UCZ}) - T_0(\ln\frac{T_{m,NCZ}}{T_{UCZ}})] \quad (3.1.4)$$

Where, E_{net} is the net incident solar radiation reaching the UCZ surface and A_{ucz} net surface area of UCZ, T is the Sun's surface temperature.

And, mass of salty water in the NCZ $(m_{NCZ}) = \rho_{NCZ}.V_{NCZ}$

The exergy destruction in the UCZ can be written as follows:

$$E_{xd,ucz} = T_0(\Delta s_{net}) \quad (3.1.5)$$

Where, Δs_{net} is the entropy change of the UCZ,

$$(\Delta s_{net}) = \Delta s_{system} + \Delta s_{surr.}$$

After substituting each of the entropy change terms, may becomes.

$$E_{xd,ucz} = T_0\left[m_{UCZ}C_{p,UCZ}\ln(\frac{T_{UCZ}}{T_0}) - \left(\frac{Q_{up}}{T_{UCZ}} + \frac{Q_{sw,UCZ}}{T_0}\right) + \left(\frac{Q_{g,NCZ}}{T_{NCZ}} + \frac{Q_{sw,UCZ}}{T_0}\right)\right] \quad (3.1.6)$$

In, addition, we can write the exergy losses to the ambient air through the side wall as follows:

$$E_{xa} = m_{UCZ}\, C_{p,UCZ}\left[(T_{UCZ} - T_a) - T_0\ln\frac{T_{UCZ}}{T_0}\right] \quad (3.1.7)$$

And,

$$E_{xsw,ucz} = m_{UCZ}\, C_{p,sw}\left[[(T_{UCZ} - T_{sw,UCZ})] - T_0\ln\frac{T_{UCZ}}{T_{sw,UCZ}}\right] \quad (3.1.8)$$

Where,

m_{UCZ} = Mass of salty water in the UCZ

$= \rho_{UCZ}.V_{UCZ}$

$C_{p,sw}$ and $C_{p,sw}$ are the respective heats of the UCZ and insulating material. T_a and T_0 are the ambient temperature and reference environment temperature, respectively.

And, T_{UCZ} , and $T_{sw,UCZ}$ denote the average temperatures of the UCZ, the side wall and the NCZ respectively.

We can define the exergy efficiency for the UCZ as the ratio of the "Exergy recovered from the UCZ to the total exergy input to the UCZ.

$$\eta_{UCZ} = \frac{E_{xr,ucz}}{E_{xti}} =1-\frac{E_{xd,UCZ}+E_{xa}+E_{xsw,Ucz}}{E_{x,solar}+E_{xg,NCZ}} \quad (3.1.9)$$

3.2 Exergy Analysis of Non Convective Zone (NCZ):

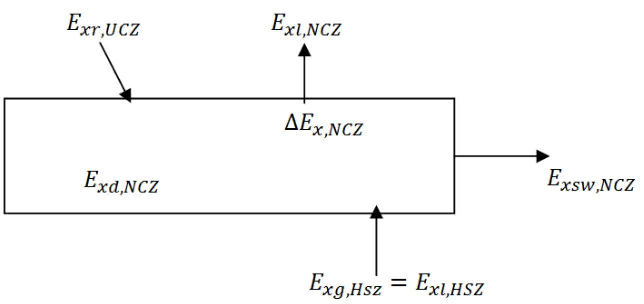

Figure 6 : Energy and Exergy flows in the NCZ of Solar Pond

Exergy flows in the Non Convective Zone are illustrated as shown in figure. We can write an exergy balance for the NCZ as follows:

$$E_{xr,UCZ} + E_{xg,HSZ} = E_{xr,NCZ} + E_{xd,ucz} + E_{xl,NCZ} + E_{xsw,NCZ} \quad (3.2.1)$$

We know that,

$$E_{xr,NCZ} = E_{xti} - E_{xtl}$$

$$= (E_{xr,UCZ} + E_{xg,HSZ}) - (E_{xd,NCZ} + E_{xl,NCZ} + E_{xsw,NCZ}) \quad (3.2.2)$$

Where E_{xti} is the total energy input to the NCZ and E_{xtl} is the total exergy losses, including exergy destruction.

The exergy of the solar radiation can be expressed, by modifying the expression of Petala (2003), as follows:

$$E_{xr,UCZ} = E_{net}\left[1 - \frac{4T_0}{3T} + \frac{1}{3}\left(\frac{T_0}{T}\right)^4\right] A_{NCZ} \quad (3.2.3)$$

The exergy gained from the HSZ can be expressed as follows:

$$E_{xg,HSZ} = m_{HSZ}C_{p,HSZ}[(T_{m,HSZ} - T_{HSZ}) - T_0(\ln\frac{T_{m,HSZ}}{T_{NCZ}})] \quad (3.2.4)$$

Where, E_{net} is the net incident solar radiation reaching the NCZ surface and A_{NCZ} net surface area of NCZ, T is the Sun's surface temperature.

And, mass of salty water in the NCZ $(m_{HSZ}) = \rho_{HSZ}.V_{HSZ}$

The exergy destruction in the NCZ can be written as follows:

$$E_{xd,NCZ} = T_0(\Delta s_{net}) \quad (3.2.5)$$

Where, Δs_{net} is the entropy change of the NCZ,

$$(\Delta s_{net}) = \Delta s_{system} + \Delta s_{surr.}$$

After substituting each of the entropy change terms, may becomes.

$$E_{xd,ucz} = T_0\left[m_{NCZ}C_{p,NCZ}\ln(\frac{T_{NCZ}}{T_0}) - \left(\frac{Q_{up}}{T_{NCZ}} + \frac{Q_{sw,NCZ}}{T_0}\right) + \left(\frac{Q_{g,HSZ}}{T_{HSZ}} + \frac{Q_{sw,NCZ}}{T_0}\right)\right] \quad (3.2.6)$$

In, addition, we can write the exergy losses to the UCZ and through the side wall as follows:

$$E_{xl,NCZ} = m_{NCZ}\, C_{p,NCZ}\left[(T_{NCZ} - T_{UCZ}) - T_0 \ln\frac{T_{NCZ}}{T_0}\right] \quad (3.2.7)$$

And,

$$E_{xsw,NCZ} = m_{NCZ}\, C_{p,sw}\left[[(T_{NCZ} - T_{sw,NCZ})] - T_0 \ln\frac{T_{NCZ}}{T_{sw,NCZ}}\right] \quad (3.2.8)$$

Where,

m_{NCZ} = Mass of salty water in the UCZ

$= \rho_{NCZ}.V_{NCZ}$

$C_{p,ncz}$ and $C_{p,sw}$ are the respective heats of the NCZ and insulating material. T_a and T_0 are the ambient temperature and reference environment temperature, respectively.

And, T_{UCZ} , and $T_{sw,UCZ}$ denote the average temperatures of the NCZ, the side wall and the HSZ respectively.

We can define the exergy efficiency for the Non Convective Zone as the ratio of the "Exergy recovered from the NCZ to the total exergy input to the NCZ.

$$\eta_{UCZ} = \frac{E_{xr,ncz}}{E_{xti}}$$

$$=1- \frac{E_{xd,NCZ}+E_{xl,NCZ}+E_{xsw,NCZ}}{E_{xr,UCZ}+E_{xg,HSZ}} \quad (3.2.9)$$

3.3 Exergy Analysis of Heat Storage Zone (or) Lower Convective Zone:

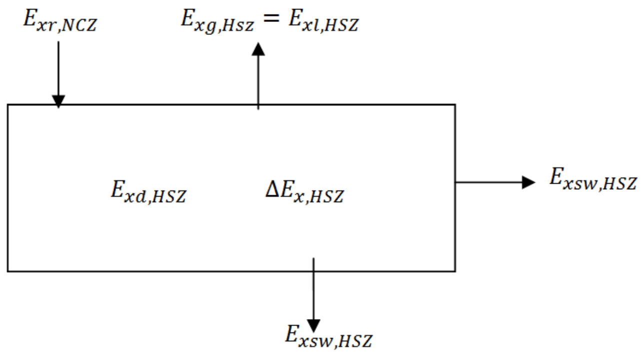

Figure 7 : Energy and Exergy flows in the LCZ of Solar Pond

Exergy flows in the Lower Convective Zone (or) Heat Storage Zone are illustrated as shown in figure. We can write an exergy balance for the HSZ as follows:

$$E_{xr,NCZ} = E_{xl,HSZ} + E_{xd,HSZ} + E_{xsw,HSZ} + E_{xsw,HSZ}$$

$$= E_{xl,HSZ} + E_{xd,HSZ} + 2E_{xsw,HSZ} \quad (3.3.1)$$

The exergy of the solar radiation can be expressed, by modifying the expression of Petala (2003), as follows:

$$E_{xr,NCZ} = E_{net}\left[1 - \frac{4T_0}{3T} + \frac{1}{3}\left(\frac{T_0}{T}\right)^4\right] A_{HSZ} \quad (3.3.2)$$

And, mass of salty water in the NCZ $(m_{HSZ}) = \rho_{HSZ}.V_{HSZ}$

The exergy destruction in the HSZ can be written as follows:

$$E_{xd,HSZ} = T_0(\Delta s_{net}) \quad (3.3.3)$$

Where, Δs_{net} is the entropy change of the HSZ,

$$(\Delta s_{net}) = \Delta s_{system} + \Delta s_{surr.}$$

After substituting each of the entropy change terms, may becomes.

$$E_{xd,HSW} = T_0\left[m_{HSZ}C_{p,HSZ}\ln(\frac{T_{HSZ}}{T_0}) - \left(\frac{Q_{up}}{T_{HSZ}} + \frac{Q_{sw,HSZ}}{T_0}\right) + \left(\frac{Q_{g,HSZ}}{T_{HSZ}} + \frac{Q_{sw,HSZ}}{T_0}\right)\right]$$

$$=T_0\left[m_{HSZ}C_{p,HSZ}\ln(\frac{T_{HSZ}}{T_0}) - \left(\frac{Q_{up}}{T_{HSZ}} - \frac{Q_{g,HSZ}}{T_{HSZ}}\right)\right] \quad (3.3.4)$$

In, addition, we can write the exergy losses to the NCZ and through the side wall as follows:

$$E_{xl,HSZ} = m_{HSZ}\, C_{p,HSZ} \left[(T_{HSZ} - T_{NCZ}) - T_0 \ln \frac{T_{HSZ}}{T_0} \right] \quad (3.3.5)$$

And,

$$E_{xsw,HSZ} = m_{HSZ}\, C_{p,sw} \left[\left[(T_{HSZ} - T_{sw,HSZ}) \right] - T_0 \ln \frac{T_{HSZ}}{T_{sw,HSZ}} \right] \quad (3.3.6)$$

Where,

m_{HSZ} = Mass of salty water in the UCZ

$$= \rho_{HSZ} . V_{HSZ} \quad (3.3.7)$$

$C_{p,HSZ}$ and $C_{p,sw}$ are the respective heats of the HSZ and insulating material. T_a and T_0 are the ambient temperature and reference environment temperature, respectively.

We can define the exergy efficiency for the Non Convective Zone as the ratio of the "Exergy recovered from the HSZ to the total exergy input to the HSZ.

$$\eta_{HSZ} = E_{xr,NCZ} - \left(E_{xl,NCZ} + 2E_{xsw,HSZ} \right) / E_{xr,NCZ} \quad (3.3.8)$$

We construct a solar pond in near to Guntur District, India. The following results are obtained.

Table 1 : Temperature of solar pond at different weather conditions.

S.No	Time (hrs)	Ambient Temperature (^{0}C)	Solar Pond Temperature (^{0}C)
1.	06-07	32	44.68
2.	07-08	34	46.58
3.	08-09	36	48.32
4.	09-10	38	50.42
5.	10-11	40	52.46
6.	11-12	41	53.32
7.	12-01	42	54.86
8.	01-02	43	57.68
9.	02-03	43	55.68
10.	03-04	42	54.76
11.	04-05	41	53.87
12.	05-06	40	52.39

Table I gives the data obtained from the analysis of solar pond, and the results shows that the temperature is a maximum 55.78^{0}C in 01-02 PM, a minimum of 25.15^{0}C in 06-07 AM.

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