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A Review on Heat Loss Characterization from Solar Cavity Receiver for Concentrating Collector

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***Abstract*—The majority of energy productions from non conventional resources are lost to atmosphere due to onsite equipment inefficiency and losses to waste heat. Waste heat of different degrees could not be found in final products of a certain process. Thermal as well as optical losses affect the performance of a solar thermal cavity receiver used in parabolic concentrating collector system. The convection and radiation losses from cavity receiver to the air within cavity receiver and conduction loss through solid part i.e. cavity receiver body, thermal insulation used behind the tube surface are the constituents of thermal losses. The major constituents of thermal losses in thermal cavity receiver are convection and radiation heat losses as compared to conductive losses. The convection heat loss compared to radiation and conductive heat losses in solar thermal cavity receiver used in solar thermal power system play major role in reducing the thermal efficiency and cost effectiveness of the whole power system. The determination of this convective heat loss from a solar thermal cavity receiver is of great concern to power system designers, researchers due to its direct effect on the thermal efficiency. It is necessary to assess this convective heat loss and subsequently improve the thermal performance of the thermal cavity receiver. A new design of cascaded solar thermal cavity receiver is proposed to reduce convective heat losses using computational and experimental investigations. A comprehensive review and systematic summarization of the review according to research work and progress done in the area of cavity receiver is presented in this review paper which will be beneficial to the design engineer, computer simulation, performance assessment and applications of the solar power system.**

***Keywords*— Cavity receiver, Convection heat loss, Wind effect.**

I. INTRODUCTION

Developing solid engineering design requirements is crucial to the success of any design project. An engineer must spent a lot of time at the beginning of the design process reviewing research, talking to people in the industry, and discussing how their research could be translated into measurable design requirements. In addition to cost requirements, the engineer has to create ambitious but achievable technical requirements. While there are many methods for developing constraints and design requirements, one straightforward method is to simply identify gaps in current solutions.

In India, the key factors to focus on the development of solar applications are abundant solar radiation, clean form of energy, high and increasing cost of fossil fuels day by day and negative emission consequences of fossil fuel consumption along with large requirements for process heat below 250^0C. In addition to its size (inexhaustible source of energy, 1.8 X 10^{11} MW), solar thermal energy has two other factors in its favour all time. First unlike conventional fossil fuels and nuclear power system, it is an environmentally clean source of energy. Second its availability is free and available in adequate quantities in almost all parts of the world where people live.

The energy consumption in India is the fourth biggest after China, USA & Russia. Due to rapid economic expansion, India has one of the world's fastest growing energy markets and is expected to be the second largest contributor to the increase in global energy demand by 2035, accounting for 18% of the rise in global energy consumption. Energy requirement is very serious problem in India. The import of crude oil continues to increase in spite of discoveries of oil and gas off the west coast and the economy paid for it now dominates all other expenditure. Every year the country is spending more than thousand crores for the import of oil. This amount forms a major part of India's import bill. The need for developing energy alternatives is thus evident and hence considerable research on renewable resources, development of work is needed in this direction. One of the promising options for energy crisis, the world facing today is to make more extensive use of renewable sources of free energy derived from the sun. Solar energy is very large, abundant source of energy. The power intercepted by the earth from the sun is approximately 1.8 X 10^{11} MW which is thousands times larger than the present consumption rate on the earth from all conventional energy sources. The inexhaustible solar energy could supply all the present and future energy needs of the world on a continuing basis.

The function of the cavity receiver in the solar-thermal power system is to intercept and absorb all the concentrated solar radiation and convert it to usable energy with the help of energy conversion system. Once it is absorbed, thermal energy is transferred to a heat-transfer fluid, such as air, water, ethyl-glycol, or molten salt, to be stored in different forms and/or used in a power conversion system.

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There are main two types of receiver designs that are found to be used with parabolic solar concentrator systems: external receiver and cavity receivers usually cylindrical in shape. The reflected solar radiation passes through an aperture of a cavity receiver. Once inside the cavity, internal reflections ensure that the majority of the absorbed radiations that has entered the cavity receiver is absorbed on the internal absorbing surface e.g. tube configuration through which working fluid flows. The solar thermal cavity receiver contains a suitable tube configuration through which suitable receiver fluid flows. It is found that the cavity type receiver is most commonly used in large scale solar concentrating projects and commercially available solar concentrators. This is due to fact that heat-loss rate is lower as compared to that of an external receiver. However internal cavity receivers are more expensive than external receivers. Any radiation that is reflected from the absorbed surface or re-radiated from the heated walls inside the cavity receiver is also absorbed internally on the cavity walls resulting in a higher absorptance value of the receiver. This spreading of the solar radiation causes a reduction in the incident flux within the cavity, thus helping to prevent thermal cracking or smelting of the internal walls. Also, because of the design of the cavity receiver, it is easier to insulate to aid in avoiding radiant and convective heat loss to the environment.

II. Literature Review

The literature on convective heat transfer in open cavities mainly involved different shapes like cubical, rectangular and square shaped cavities. Spherical, hemispherical, cylindrical, cylindrical with a conical frustum shaped cavities used for specific applications like solar thermal receivers were also studied. The types of receivers investigated both experimentally and numerically are cubical, rectangular, cylindrical, and hemispherical. Most of studies focus on the convective heat loss mechanism, velocity flow of fluid within cavity receiver and temperature pattern within receivers. Fig. 1 illustrates the main features of a tilted partially open rectangular or cylindrical cavity

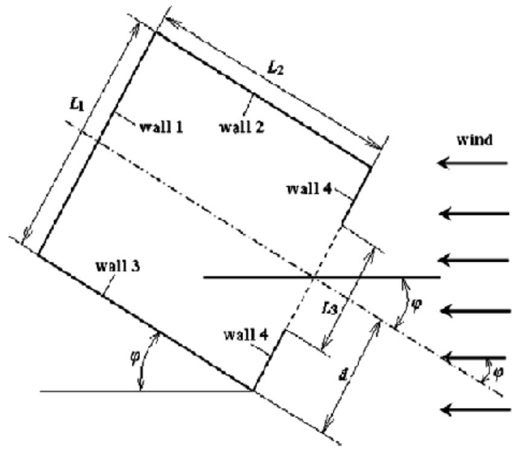

Fig. 1 Main features of a tilted partially

Where as Fig. 2 shows the main features of a typical tilted hemispherical cavity.

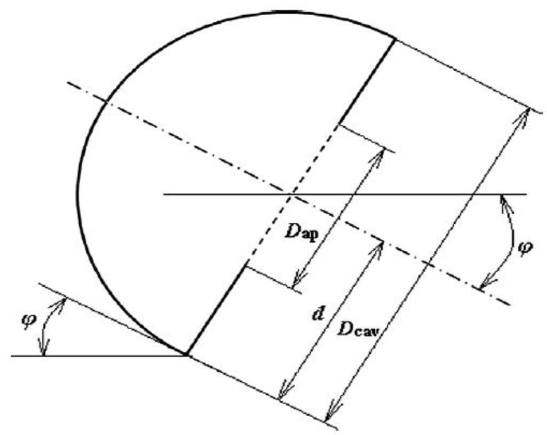

Fig. 2 Main features of tilted open rectangular or cylindrical cavity [16].

A. M. Clausing (1981) studied analytical model(Open) for a large cubical receiver of sizes 1MW receiver & 38 MW receivers with wind effect of 8m/s which enables the estimation of convection heat losses from cavity receivers.Evidence from solar experiments was used to test the hypothesized mechanisms. The analytical results andexperimental evidence indicate that the convective loss from cavity receivers is appreciable.

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The model indicatesthat the influences of the wind on the convective loss at normal operating conditions are minimal. It also shows thatthe internal thermal resistances, i.e. the ability to heat the air inside the cavity, are of greatest importance.Buoyancy induced flows are, on the other hand, very effective in transferring energy across the aperture.Orientation of the aperture was critical.Characteristic vertical height strongly influences buoyancy flow and height of convective zone within cavity. Energy transfer by air through the aperture was mainly due to buoyancy and the wind effect. Buoyancy influence is more dominant in 1 MW receiver. Convective loss varies almost linearly with temp difference. At full power, the power transmission is 40 % less in bottom panel(Convection zone).The Nusselt number correlations obtained in the aforementioned studies have been widely applied for

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III. Convection Heat Loss Mechanism

studied till date.

Table 1.
Type of cavity receivers studied

Sr. No.	Researcher/Author	Year of research	Type of cavity receiver
01	A.M.Clausing	1981	Analytical model(Open) for a large cubical receiver 1 MW receiver 38 MW receiver
02	Koenig and Marvin	1981	Cylindrical cavity receiver
03	Le Quere et al.	1981	Open cubical cavity
04	Penot f	1982	Open square cavity
05	Siebers and Krabel	1984	Partially open cavity
06	Chan Y.L. and Tien C.L.	1985	Shallow open cavity and Shallow open cavity
07	Humphrey JAC and To WM	1986	Isothermal open cavity
08	Yasuaki S. et al.	1988	Hemisphere (bottom surface heated and hemispherical surface cooled)
09	Stine and McDonald	1989	Cylindrical shaped frustum cavity receiver

10	Robert Y. Ma	1993	Cavity receiver
11	Showole and Tarasuk	1993	Isothermal open cavity
12	Angirasa D. et al.	1995	Open square cavity
13	Leibfried and Otjohann	1995	Hemispherical tilted cavity receiver
14	M.M.Elsayed and W.Chakroun	1999	Partially open square cavity
15	O.Polat and E.Bilgen	2002	Inclined open shallow cavity
16	T.Taumoefolau and K.Lovegrove	2002	Electrically heated open cavity solar receiver
17	S.Paitoonsurikam and K.Lovegrove	2003	Electrically heated open cavity solar receiver
18	T.Taumoefolau et al.	2004	Electrically heated open cavity solar receiver
19	Walid Chakroun	2004	Fully open tilted cavity
20	K.C.Yeh et al.	2005	Solar thermal receiver
21	E.Bigen and H.Oztop	2005	Partially open square cavity
22	Charles Newton	2006	Solar cavity receiver
23	GoutamSaha et al.	2007	Fully open square cavity
24	Wilson Terrel Jr. and Ty A. Newell	2007	Open Cavity
25	K.S.Reddy and N.Sendhil Kumar	2007	Modified hemispherical cavity receiver
26	K.S.Reddy and N.Sendhil Kumar	2008	Cavity receiver Semi- cavity receiver Modified cavity receiver
27	M.Prakash et-al	2008	Cylindrical (Solar Receiver)
28	E.Bilgen and A. Muftuoglu	2008	Open square cavity with slots
29	H. Nouanegue et al.	2008	Open cavity
30	Abdullatif Ben-Nakhi et al.	2008	Partially open square cavity
31	Yong Shuai et al.	2008	Six classical cavity geometries
32	A.A.Mohammad et al.	2009	Open ended cavity
33	S. Anil Lal and C.Reji	2009	Open square cavity
34	J.F.Hinojosa and J.Cervantes-de Gortari	2010	Isothermal open cubic cavity
35	M.Prakash et-al	2010	Cylindrical (Solar Receiver)

36	H.Sajjadi et al.	2011	Inclined open cavity
37	Hakan F. Oztop et al.	2011	Partially opened square cavity
38	Shuang-Ying Wu et al.	2011	Solar heat pipe receiver
39	M.Prakash et-al	2012	Cubical, Spherical and hemispherical open cavity.
40	S.K.Natarajan et-al	2012	Trapezoidal cavity receiver
41	Lan Xiao et-al	2012	Fully open cylindrical cavity receiver
42	Matthew Neber and Hohyun Lee	2012	Silicon Carbide cylindrical receiver
43	J.F.Hinojosa	2012	Open tilted cavity receiver
44	Milind S. Patil et al.	2012	Hemispherical solar receiver
45	Dr. Umashankar and Ravi Kumar	2012	Six classical cavity geometries
46	R.D.Jilte et-al	2013	Seven different shaped cavity receivers
47	Fuqing Cui et al.	2013	Hemispherical cavity receiver with glass cover
48	John Pye et al.	2013	Solar cavity receiver
49	Nicolas del pozo et al.	2013	Solar cavity receiver
50	T. Srihari Vikram and K.S.Reddy	2014,2015	Modified hemispherical cavity
51	R.D.Jilte et-al	2014	Five different shaped cavity receivers
52	A.Pina-Ortiz et al.	2014	Open cubic tilted cavity
53	E. Abbasi-Shavazi et-al	2014	Solar cavity receiver
54	Wei Wu et al.	2014	A novel particle receiver
55	M.Montiel-Gonzalez	2015	Solar cubic cavity type receiver

Laminar steady state natural convection in inclined shallow cavities has been numerically studied byO.Polat&E.Bilgen (2002) for Rayleigh number from 10^3 to 10^{10} with cavity aspect ratio between 0.125 to 1. The study was carried out at four different inclinations of 45^0,60^0,75^0&90^0.Volumetric flow rate & heat transfer are increasing functions of the aspect ratio and Rayleigh number.Heat transfer for a given aspect ratio has an asymptotic behavior.Inclination angle of heated plate is an important parameter affecting volumetric flow rate & heat transfer.

The Australian National University (ANU) has been involved with the investigation of solar thermal energy conversion using paraboloidal dish concentrators for many years.

The team was working with a 400 m^2 concentrator fitted with a monotube boiler cavity receiver for superheated steam production and a 20 m^2 concentrator that operates a cavity receiver lined with reactor tubes for ammonia dissociation for energy storage (Johnston *et al*, 2001 and Lovegrove*et al*,2001).An experimental study of natural convection heat loss from a solar concentrator cavity receiver at varying orientation was carried out at ANU by T.Taumoefolau & K .Lovegrove (2002).To better understand the thermal losses from such receivers, a small electrically heated, laboratory simulation of a solar cavity receiver has been constructed to measure losses directly between 350-550^{0}C. The results from this system have then been used in comparison with the predictions obtained from Computational Fluid Dynamics (CFD) calculations.

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Fig.3 presents the results of heat loss measurements using the model receiver operating at a set point temperature of 450^{0}Cwhereas convection loss for three cavity temperatures is compared in Fig. 4.

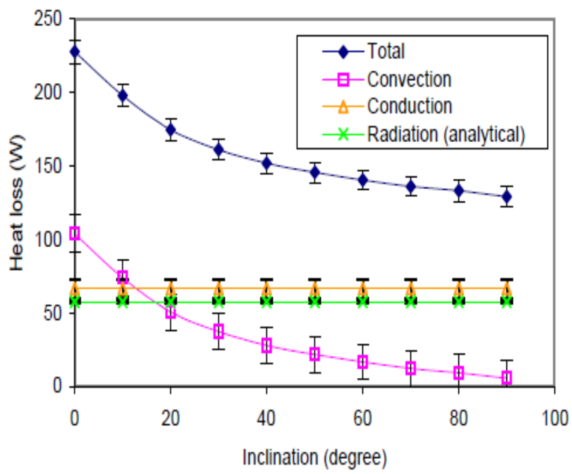

Fig. 3 Experimental heat loss for a cavity temperature of 450^{0}C [49].

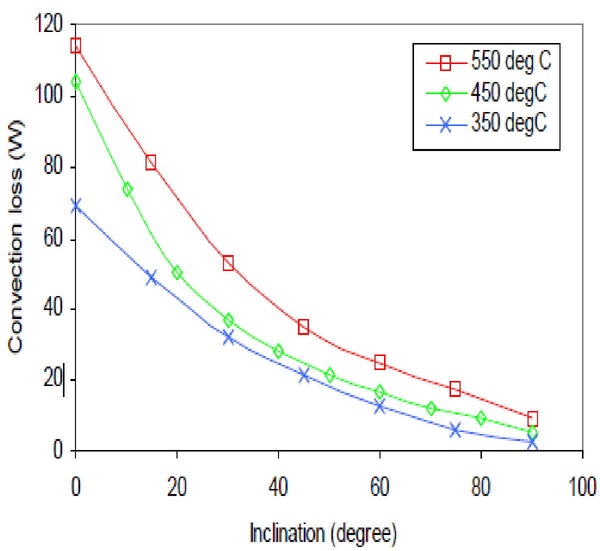

Fig. 4 Convection loss at various cavity temperatures [49].

Paitoonsurikarn & Lovegrove (2002) undertake the numerical investigation of natural convection loss from thermal cavity receivers employed in concentrating solar paraboloidal dish. Three different thermal cavity receiver geometries as shown in Fig. 5 had been considered. One of these was the experimental model receiver for validating the numerical results& the other two were essentially the ones currently used in ANU 20 m^2 and 400 m^2 dishes.

The combined free-forced convection study, i.e. that includes the effect of wind speed and direction onconvection loss, had also been undertaken.

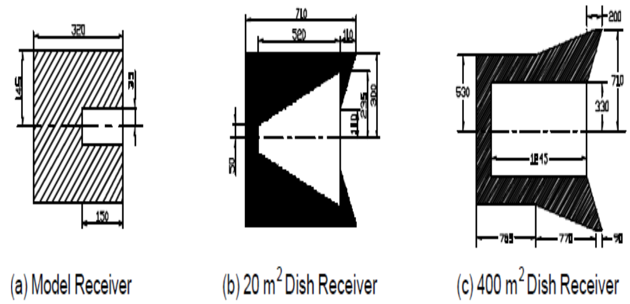

Fig. 5 Three Receiver Systems and Cross Sectional Diagram of All Three Receiver Models [51].

Figures 6 and 7 summarize the most recent results of the combined convection study. In Fig. 6, therelationship of wind speed and convection heat loss for all three receivers with wind parallel to theaperture plane is shown. Surprisingly, it was found that heat loss, was actually reduced below the natural convection value by wind speeds up to about 7 m/s. Fig.6 shows the similar result for a caseof model receiver with wind normal to the aperture plane.

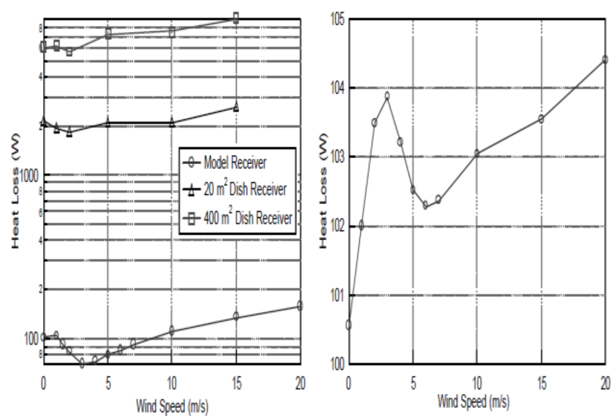

Fig. 6 The Relationship between Wind Speed
Fig. 7 The Relationship between Wind Speed and Heat Loss for All Three Receivers with and Heat Loss for Model Receiver with Wind Parallel to the Aperture Plane [51].

Initially, the sharp increase of heat loss was found up to its local maximum at wind speed of about 3 m/s.After that heat loss decreases to its local minimum at wind speed of about 6 m/s, where it starts to unboundedly increase with increasing wind speed.

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Heat loss is not exactly proportional to the reduced aperture area. was tested at inclinations varying from -90 deg (cavity facing up) to 90 deg (cavity facing straight down), with test temperatures ranging from 450 to 650^{0}C. Ratios of the aperture diameter to cavity diameter of 0.5, 0.6, 0.75, 0.85 and 1.0, were used. An electrically heated experimental simulation of a cavity receiver had been constructed toallow direct measurement of losses under laboratory conditions. The details of the model receiver is shown in Fig. 8.

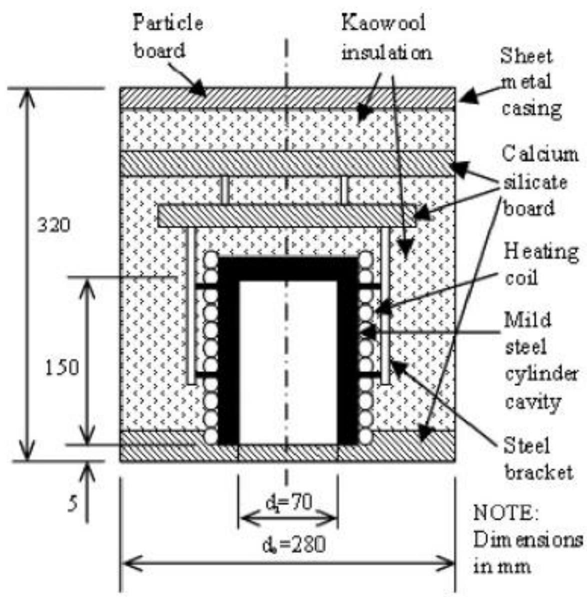
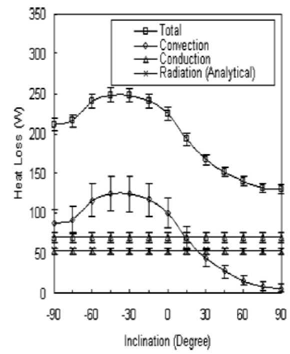


Fig. 8 Cross section sketch of model receiver [39].

Presents the results of heat loss measurements for the model receiver operating at a set point temperature of 450^{0}C. The average experimental cavity temperatures (Tc) were 445^{0}C for the cylindrical section and 420^{0}C for the end plate. Convection loss for three cavity temperatures is compared in Fig. 10. They all show a similar dependence on inclination as that described for the convection loss in Fig. 9. It is also evident that the heat losses increase with higher cavity temperatures throughout all inclinations. -45^0(50.1%)&-90^0(4.8%) of the total heat loss.The convection loss reduces from -45^0 to -90^0.The loss increases with higher cavity temperatures throughout all inclinations.Overall convection loss is higher for larger opening ratio.The inclinations for which maximum convection loss occurs increases as the opening ratio decreases. The maximum & minimum convection loss occurs at E.Bigen & H.Oztop (2005) conducted a numerical on inclined partially open square cavities, which are formed by adiabatic walls and a partial opening.



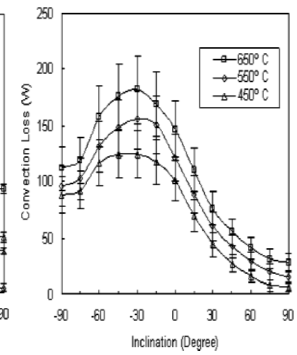


Fig.9 Experimental heat loss with
Fig.10 Convection heat loss from Tc=445° & a fully open cavity [39]

A parametric study was carried out using following parameters: Rayleigh number ranging from 10^3 to 10^6, dimensionless aperture size from 0.25 to 0.75, aperture position at high, center and low, and inclination of the opening from 0^0 (facing upward) to 120^0 (facing 30^0 downward).

It is found that the volume flow rate and Nusselt number are an increasing function of Rayleigh number, aperture size and generally aperture position. Other parameters being constant, Nusselt number is a non-linear function of the inclination angle of cavity. Depending on the engineering thermal application, heat transfer can be maximized or minimized by selecting appropriate parameters, namely aperture size, aperture position and inclination angle at a given operation Rayleigh number.

Studies on combined convection and radiation from hemispherical solar cavities have been reported by Reddy and Sendhil Kumar (2008). A 2D numerical analysis of combined laminar natural convection and surface radiation in the modified cavity receiver of a solar dish was presented. Two separate Nusselt numbers were proposed for both natural convection and surface radiation. The incorporation of the radiation in a modified cavity receiver completely alters the heat loss rate. It was found that the convective loss was significantly influenced by the orientation of the receiver. The convection heat loss was dominated by the radiation heat loss for higher receiver inclination angle (>45˚). The radiation heat loss was considerably influenced by the area ratios. The receiver showed better performance at an area ratio of 8. The model was used to estimate the convection and radiation heat losses from the cavity receiver of solar parabolic dish collector system. The total heat loss from the receiver has been estimated for operating temperatures varying from 300˚C to 700˚C.

A heat transfer and flow simulation was performedby Dr. Umashankar and Ravi Kumar D S (2012) forfour different solar cavity receiver's viz.: cylindrical,conical, dome and spherical receivers at variousreceiver inclinations at constant temperature. Thereceivers are designed such that they have samesurface area and aperture.It was observed that convective heatloss decreases as the inclination changes from 0^0 to 90^0.Among these receivers, the convective heat loss is leastfor conical receiver followed by dome, spherical andcylindrical receivers.

The natural convection occurring from open cavities was analyzed by M.Prakash et al (2012). Three different cavity shapeswere studied namely cubical, spherical and hemispherical geometries having equal heat transfer area.The numerical analysis was performed on three dimensional (3-D) cavity models using the Fluent CFDsoftware. The highest convective loss was observed for the hemispherical open cavity and the lowest for the cubical open cavity for opening ratios of 0.25 and 0.5. The convective loss for all temperature and inclination cases is the least for the opening ratio of 0.25.There was a decrease in the convective loss as the cavity inclinationangle increases. The highest loss is noticed for the 0^0angleand the least for the 90^0. The stagnation zone area is found toincrease with cavity inclination. This leads to the decrease inconvective loss with increase in inclination. This was true for allcavity shapes.

Radiation performance of dish solar concentrator/ cavity receiver system was studied using Monte-Carlo method coupled with optical properties by Yong Shuai et al (2008). Limb darkened sun was given to investigate the influence of sun shape on the flux distribution in the parabolic concentrator. The circumsolar values had little effect on the peak of concentration ratio, but radius of the focal spot increases with the CSR value. The probability model of surface slope error was introduced by the Gaussian distribution. Surfaceslope error broadens the flux distribution and reduces the peak value of the distribution to maintain the energy balance. The directional distribution of sunlight and its effect on the performance of a cavity receiver were performed. All cases examined in different sampling locations of the focal zone show a similar trend. The peak value of the percent directional distribution of radiation flux occurs where the zenith angle θ_P is equal to the rim angle if $\psi_{rim} \leq 45^0$; otherwise, it occurs where the zenith angle is less than the rim angle if $\psi_{rim} > 45^0$. Furthermore, this value increases with the sampling location away from the focus.

The five cavity geometries are evaluated on the uniformity of wall radiation flux; results indicate that cavity geometry has a significant effect on overall flux distribution.Based on the concept of equivalent heat flux, the spherical receiver with relatively good radiation performance provides a starting point for the shape optimization; thus, a desirable shape (upside-down pear) may be achieved with almost uniform distribution. Morestudy was needed to better quantify multi-reflection losses and free and forced convection losses from cavity receivers.

Convective losses from cubical and rectangular opencavities had been extensively studied. The generalassumptions in these investigations are that the cavity wallsare either uniformly heated or one wall is heated and othersare maintained in adiabatic condition. Consequently theresults cannot be directly used for solar cavity receiversused for process heat applications, which are mainly cylindrical in shape and have non-uniform wall temperatures.

Different wall boundary conditionswere studied; all the cavity walls having same wall temperatures, only one wall havingconstant temperature and the remaining walls were kept adiabatic, one wall having constant heat flux and otherwalls are adiabatic, a flow exists in the cavity leading tonon isothermal wall temperatures. Chakroun studied the effect of different wall boundary conditions on the heat transfer from an open cavity. The convection flow patterns and loss mechanismshave been reported. Nusselt number correlations have beenproposed for different cavity shapes and wall boundary conditions.

The important energy loss for the receiver originates from convection and radiation heat transfer to the surroundings. These losses depend on the design of the receiver, whether it is a cavity or external receiver, its heated (or aperture) area, and its operating temperature. Additional factors include the local wind velocity, ambient temperature, and the orientation of the receiver. Studies had been made on the combined radiation, free and forced-convection losses from large surfaces, and tilted cavities. Table 4 is the summary of work done on fully/partially open cubical and rectangular cavities.

Robert Y. Ma (1993) performed the tests to determine the convective heat loss characteristics of acavity receiver for a parabolic dish concentrating solar collector for various tiltangles and wind speeds of 0-24 mph. Natural (no wind) convective heat lossfrom the receiver is the highest for a horizontal receiver orientation andnegligible with the reveler facing straight down.

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Convection from the receiveris substantially increased by the presence of side-on wind for all receiver tiltangles. For head-on wind, convective heat loss with the receiver facing straightdown is approximately the same as that for side-on wind. Overall it was foundthat for wind speeds of 20-24 mph, convective heat loss from the receiver canbe as much as three times that occurring without wind.

The researchers in Centre of Sustainable Energy System, Department of Engineering, Australian National University made great efforts to develop more general correlations for predicting the receiver convection heat loss. Taumoefolau and Lovegrove (2002) as well as Paitoonsurikarn and Lovegrove (2002) experimentally and numerically investigated the natural convection heat losses from a 70 mm cylinder receiver (model cavity receiver) with cavity temperatures ranging from 350^0C to 500^0C. It was reported that the experimental and numerical results obtained were in good agreement qualitatively with those predicted by various correlations proposed by previous researchers.

Lovegrove et al. (2003) have attempted to develop a correlation that can reliably predict natural convection heat losses from cavity receivers employed in solar parabolic dishes at all tilt angles. A correlation was developed using the concept of the ensemble cavity length Ls as the characteristic length to account for the combined effect of the cavity geometrical parameters and the inclination.

Paitoonsurikarn and Lovegrove (2003) undertook the numerical investigation of natural and combined convection heat loss from cavity receivers. A new correlation in the form $Nu = CRa^n f(Pr)$ was developed for prediction of heat transfer coefficients. The ensemble cavity length Ls was modified to include the aperture geometry. Later, they (Paitoonsurikarn et al., 2004) carried out a parametric study of several relevant parameters in natural convection heat loss from open cavity receiver in solar dish application. The previously proposed correlation model in Paitoonsurikarn and Lovegrove (2003) has been modified to take into account the variation of additional parameters. Moreover, a correlation based on the modified Stine and McDonald model was developed. Both models are quite promising in the natural convection heat loss prediction in most cases.Based on the numerical simulation results of three different cavity geometries and the previous works (Paitoonsurikarn and Lovegrove, 2003; Paitoonsurikarn et al., 2004), an improved version of correlationwas presented by Paitoonsurikarn and Lovegrove (2006a).

Taumoefolau et al. (2004) experimentally investigated the natural convection heat loss from an electrically heated model cavity receiver for different inclinations varying in _90–90^0 with temperature ranging from 450 to 650^0C.

It was found that the Clausing model showed overall the closest prediction for both numerical and experimental results with downward-facing angles despite its original use for big scale central receivers. For upward-facing angles, the modified Stine andMcDonald model showed the closest agreement to the experimental results. The inclination, for which maximum convection heat loss occurs, increases as the opening ratio decreases, which was also observed by Leibfried and Ortjohann (1995).

Most recently, an experimental and numerical study of the steady state convective losses occurring from a downward facing cylindrical cavity receiver of length 0.5 m, internal diameter of 0.3 m and a wind skirt diameter of 0.5 m was carried out by M. Prakash et al (2008).The effects of fluid inlet temperature, receiver inclination angle and external wind on the total thermal loss and the convective losses were studied experimentally as well as numerically for a downward facing cavity receiver made up of helical coil tube having cavity diameter less than the depth as well as the aperture diameter. The highest total and convective losses were obtained for the head-on wind condition at 0^0inclination of the receiver. The losses were higher than the side-on wind convective loss. The no-wind convective loss at 0^0inclination is greater than that due to 1 m/s and 3 m/s side-on wind as the side-on wind presumably prevents the hot air from flowing out of the cavity. At 3 m/s wind speed, the total and convective losses are independent of wind direction for all inclination except 0^0receiver inclination. The effect of inclination on losses due to the side-on wind condition was very small when compared to the no-wind and head-on wind conditions. Table 6 & 7 represent the correlations obtained based on cylindrical and hemispherical receivers.

IV. CONCLUSION

The thermal cavity receiver is an important component of solar thermal power system. The convection loss in solar thermal cavity receiver significantly reduces the performance of solar thermal power system. It is necessary to estimate the convective heat loss with considerable accuracy

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