Overview Of Liquid Desiccant Based Indirect Evaporative Cooling System

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Abstract— Liquid desiccant indirect evaporative cooling system consists of dehumidifier, regenerator, evaporative cooling unit and liquid desiccant. This system become alternative for convectional mechanical vapor compression system, because it reduces the consumption of electrical energy and avoids emission of harmful gases i.e. it is cost effective as well as environment friendly. Liquid desiccant absorb moisture from air in dehumidifier unit. Often solar energy is used to produce thermal energy and this thermal energy is used for regeneration of liquid desiccant in a regenerator. Further indirect evaporator is used for sensible cooling of a dehumidified air. In this paper, a review of dehumidifiers, regenerators, indirect evaporative coolers and also integrated liquid desiccant system with indirect evaporative coolers are studied. Also system configurations, modes of operations are presented. This review designates that liquid desiccant indirect evaporative cooling technology can provide human comfort in hot and humid climatic conditions.

Index Terms—Dehumidifier, Indirect evaporative cooler, Liquid desiccant, Regenerator

1 INTRODUCTION

Due to the speedy buildout and temperature rise in recent years, the amount of air-conditioned constructions and their energy consumption are increasing significantly everywhere the globe. Building sector accounts four-hundredth of the world's primary energy and to blame for concerning one third of worldwide carbon dioxide emission [1]. Conventional cooling technologies using refrigerant typically want lot of energy and lead peak masses that end in negative impact on the surroundings. In order to supply human comfort condition, the cooling necessities shouldn't be mentioned in terms of sensible cooling capacity solely however latent cooling ought to even be included particularly for warm and humid outside conditions. Developing and promoting environmental friendly systems emerges as an imperative want because energy and environmental problems have to be compelled to be treated globally. To satisfy the cooling load necessities, liquid desiccant evaporative cooling system is one such helpful and optimistic system. This system consists of liquid desiccant dehumidifier unit and indirect evaporative cooling unit. Driving the fans pumping and regenerating desiccant throughout the regeneration process is the only energy used in this technique. The energy may be provided from any low grade thermal energy supply like solar, exhaust or waste heat etc. A comparison between totally different cooling techniques is bestowed in Table 1 [2]. In hot and humid climatic conditions simple evaporative cooling isn't helpful but an indirect evaporative cooling system are often utilized in co-occurrence with the liquid desiccant dehumidification system The dehumidification system used first to get rid of moisture load and latter an indirect evaporative system controls sensible load. The notable feature of the system is to control the moisture load and sensible load separately avoiding wasteful cooling and heating. The intention of this study is to present a literature review of liquid desiccant evaporative cooling system.

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Table 1[2]

Parameter	Mechanical vapour compression	Evaporative cooling	Desiccant based evaporative cooling
Cost of operation	High	Low	Low
Input energy resource	electricity, natural gas, vapour	Low grade energy	Low grade energy e.g. solar energy, waste heat etc.
Latent load control	Average	Low	Accurate
System installment	Average	Average	Slightly complicate
Emission of green house gases	High	Low	Low
Cooling medium	Refrigerants	Water	Water

2 Research study on Dehumidifiers

Humidit features a important impact on indoor environments. High indoor humidness ends up in uncomfortable and unhealthy surroundings And liquid desiccant has ability to absorb water vapour from surrounding air, therefore liquid desiccant dehumidification system is popularly used The main attraction of the system is no mechanical compressors are required in the cooling process and no use of chlorofluorocarbons.

The system consists of dehumidifier, regenerator, cooling and heating units [3]. Typically desiccant spread from the highest of the packed bed and flows over a packing during this it comes in direct contact with air stream. Adiabatic or internally cooled/heated packed bed dehumidifiers/regenerators are mostly used. Pradeep Bansal et al. [4], by using CaCl2 as a desiccant compared structured packed bed adiabatic and internally cooled dehumidifier. It was found that maximum effectiveness between 0.55 and 0.706 with concurrently cooling and without cooling it was 0.38 to 0.55, i.e effectiveness of internally cooled packed bed dehumidifier is larger than adiabatic ones. Yonggao Yin et al. [5] by using LiCl as desiccant studied internally cooled plate fin heat exchanger for dehumidification. The results suggested that plate fin heat exchanger had good cooling performance for the desiccant also low desiccant temperature cause more mass transfer. Improved dehumidification performance can be obtained using simultaneous internal cooling dehumidifier. Yonggao Yin et al. [6], by using LiCl as liquid desiccant investigated internally cooled dehumidifier and heated regenerator. The study shows that internally heated regenerator will avoid dehumidification risk which might happen in adiabatic one, and additionally it might provide higher regeneration potency that the adiabatic one. The internally cooled dehumidifier may also give higher dehumidification performance examination with adiabatic one, but its profit would be not nearly as good as internally heated regenerator. The commonly used liquid desiccants are inorganic salts like lithium chloride (LiCl), lithium bromide (LiBr) and calcium chloride (CaCl2). LiCl and LiBr are strong desiccants than CaCl2. A therotical model was proposed by I.P. Koronaki et al. [7] under the same operating condition for a small counter flow adiabatic dehumidifier. LiCl has the best efficiency, can reduce humidity ratio by 10% compared to LiBr 8% and CaCl2 6%. . For cross flow liquid desiccant dehumidifier C. G. Moon et al. [8], developed new empirical correlation by experimenting dehumidifier with CaCl2 as liquid desiccant. It was found that air flow rate, air humidity ratio, air temperature, solution flow rate and solution concentration affects performance of dehumidifier system. Moisture removal increases with solution flow rate but stand at higher desiccant flow rate, moisture removal rate decreases as desiccant solution temperature increases but moisture removal rate increases with increasing desiccant solution concentration also with increasing air humidity ratio and air flow rate moisture removal rate increases. For cross flow air dehumidifier with CaCl2 as desiccant material M.M. Bassuoni [9] suggested a simple analytical method. Good accuracy has been found between analytical solution and experimentation carried out by C.G. Moon [8]. P. Gandhidasan.[10] predicted pressure drop with liquid desiccant as a calcium chloride for four different random packing and three different structural packing materials.. The study indicates that Raschig ring material from the random packing material gives the highest irrigated pressure drop. And in structural packaging material sheet type gives lower irrigated pressure drop compared to gauze type packing. As compared to random packing material structural packaging material has the lower pressure drop and higher capacity. For liquid desiccant dehumidification system Sanjeev Jain et al. [11] used CaCl2 and LiCl as a liquid desiccant. Results of experiment did using calcium chloride shows that the moisture removal rate in dehumidifier depends on the ambient humidity and the equilibrium humidity of the desiccant. The dehumidifier used in this experiment was indirect contact type to prevent carryover and therefore effectiveness of dehumidifier was varying between 0.25 and 0.44. Regenerator had direct contact type and its effectiveness vary between 0.07 and 0.80. Outcomes of experiment did using lithium chloride shows that due to a lower value of equilibrium humidity of lithium chloride compared to calcium chloride, performance of dehumidification was increased in dehumidifier. Effectiveness of dehumidifier was mostly unaltered by any change in concentration of lithium chloride at concentration value of 0.45. Liquid desiccant packed bed regenerator was studied by X.H. Liu et al. [12]. It was found that For the hot air driven regenerator counter flow arrangement had the poorest mass transfer performance and parallel flow had best performance at the same condition. Counter flow arrangement had the beat mass transfer performance and parallel flow had poorest performance for the hot air driven regenerator. Heat removal rate was higher in hot desiccant driven regenerator therefore heat should be used to heat liquid desiccant instead of air.

3 Research study on Regenerators

The solution becomes diluted when it come out from dehumidifier as effect of absorbing moisture from air stream. The concentration of liquid desiccant decreases as moisture content increases because of this regeneration of liquid desiccant is required. And regeneration can achieved in regenerator by using low grade heat sources, such as industrial waste heat , solar energy with temperature between 60℃-100℃. By using LiCl as a desiccant regeneration in packed bed is proposed by P. Gandhidasan [13] with two heating method, with method **A** the desiccant is heated in heat exchanger by hot water and with method **B** the desiccant is heated by conventional energy sources. In method **A** it was found that higher inlet temperature of fluid increases the rate of evaporation and in method **B** it was found that water evaporation rate increases with heat input and as scavenging air flow rate increases regeneration rate decreases. CaCl2 as a liquid desiccant, regenerator with solar air pre-treatment was analysed by Donggen Peng and Xiaosong Zhang [14]. The study designated that as solution concentration will increase seventieth, regeneration potency improves 45.7% and storage capability extends 44% as effective solution proportion declines from 100% to 62%. Storage capacity and effective solution proportion indicates energy consumed for concentration of unit volume diluted liquid and mass ratio of liquid entering into the dehumidifier among the total regenerated liquid. The less effective solution proportion denotes the more flow rate of liquid needed in air pretreatment unit. Liquid desiccant regenerator by using CaCl2 was studied by A. E. Kabeel and M. M. Bassuoni [15]. The results indicated that humidity ratio change of scavenging air and exit solution concentration decreases with the increase of the inlet air humidity ratio. As scavenging air temperature increased, ability of desorption process is increased causing air to become more wet and in turn strong desiccant solution. Plate type heat exchanger was analysed by Tae Hyun Kim [16] for a liquid desiccant. In this experiment 40% liquid solution LiCl with fluorescent substance is used for wettability test also internal cooling is adopted. The results shows that as mass flow rate of desiccant increases, liquid desiccant wettability increases and the regeneration rate increases. And For 1mm groove pitch, wettability of heat exchanger surface was highest. Regenerator with CaCl2 is as a liquid desiccant was examined by A.S. Alosaimy and Ahmed M. Hamed [17] by using solar water heater coupled. The experimental results demonstrated that solar water heater can be used to regenerate CaCl2 from 30% to 50%. And it shows good agreement between the experimental outputs and theoretical outputs. Structured packed regenerator studied by Esam Elsarrag.[18] using triethylene glycol as a liquid desiccant. For a minimum carryover of triethylene glycol cellulose rigid media pad with packaging arrangement was used. The study indicates that with increase in air flow rate evaporation rate increased and humidity effectiveness decreased. With increase in desiccant concentration, evaporation rate decreases, because increase in desiccant concentration reduces driving force of mass transfer. In humid climate regeneration requires higher solution temperature as compared to dry climates. Absorber and regenerator of packed type studied by Nelson Fumo and D. Y. Goswami.[19] using aqueous lithium chloride desiccant. With increase in air humidity ratio, water condensation rate increases. Dehumidifier gives lower condensation rate for higher desiccant temperature. If the temperature of air greatly higher than desiccant temperature it resulting in reduction of mass transfer due to the desiccant temperature increases. With the air flow rate and air temperature small decrease in humidity effectiveness and with increase in desiccant flow rate small increase in humidity effectiveness was found. For the regenerator it was found that, water evaporation rate increases as with increase in air flow rate. Increase in desiccant temperature evaporation rate increases. For higher desiccant concentration, evaporation rate decreases. Using lithium chloride, regenerator of packed bed type studied by Min-Hwi Kim et al. [20]. Model was developed based on open literature and experimental data. For the analysis simple first order polynomial regression model was used. And this model can be used for finding most favourable regeneration temperature or desiccant flow rate in liquid desiccant system. This model approved well with experimental data and other models. Solar regenerator using liquid desiccant as calcium chloride was studied by S. Alizadeh and W. Y. Saman [21]. For variation in mass flow rate different numbers of spray nozzles was used. Experimental result shows that as the air mass flow rate increases, water evaporation from diluted solution increases. Water loss rate decreases as the solution mass flow rate increases. And regenerator thermal performance impacted by solar isolation during regeneration. The experimental results show general concurrence with results of the test executed by alternative investigators and truthful agreement with model prediction.

4 Research study on Indirect Evaporative Coolers

The principle of evaporative cooling is water evaporation for heat absorption. In direct type evaporative cooling supply air is direct contact with water causing reduction in temperature of product air but also vapour is added into air produces humid air. To solve this difficulty indirect evaporative coolers are used. For hot and humid climates, indirect evaporative cooler gives better cooling performance since air is cooled without adding any moisture. In this system there are two cross air passes, supply side i.e. dry which reject the heat and wet side for pre-cooling ambient air with water as refrigerant which absorbs the heat. And water is sprayed over this wet channel for evaporation cooling purpose. Indirect evaporator cooler with parallel and counter flow type was studied by Chengqin Ren and Hongxing Yang [22]. The results showed that the product air flows in counter current direction to the water film gives the better performance. By reducing mass flow rate of spray water and by improving wettability, performance of indirect evaporator cooler can be upgrades. Also analytical results found good agreement with numerical results. Modified effectiveness – NTU method was proposed by Zhijun Liu et al. [23] for indirect evaporator heat exchangers. And For calculating overall heat transfer rate two different types of method explained. Selected evaporators with the Maisotnesko cycle was analysed by Sergey Anisimov et al. [24].In this analysis, based on modified effectiveness-NTU method with accurate assumptions and heat and mass transfer process inside M-cycle heat exchanger the mathematical model was proposed. It was found that for cross-flow M-cycle heat and mass exchanger temperature effectiveness is comparable to the counter flow M-cycle heat and mass exchangers, whereas its specific cooling capability is higher and construction is simpler to style, thus cross flow M-cycle heat and mass exchanger appears to be the foremost affordable unit for business functions. Modelling and performance analysis of cross flow heat exchanger type indirect evaporative cooling system is performed by Paolo Liberati et al. [25]. By using indirect evaporator cooler it was found that vital energy saving in the majority the investigated conditions. Also water with low flow rate increases cooling capacity strongly. Cross flow M-cycle heat exchanger was studied numerically by Changhong Zhan et al. [26]. The results specified that cross flow M-cycle indirect evaporative cooler can achieve cooling effectiveness higher than conventional cross flow heat exchanger. Also channel length and height additionally impose vital impact to system performance. Woo Ham and Jae-Weon Jeong.[27] was studied parametric study on dew point indirect evaporative cooler and dew point evaporative heat exchanger and simulation result shows that when dehumidified air temperature increases effectiveness in decreased for both dew point indirect evaporative cooler and dew point evaporative heat exchanger. Effectiveness of dew point indirect evaporative cooler was smallest also conditioned air temperature was lowest when dehumidified air dew point temperature is low. Supply air temperature for both cases was similar when the supply air flow is high. And for low flow supply air, temperature of supply sir of dew point evaporative cooling is higher than dew point indirect evaporative cooler. Performance of dew point indirect evaporative cooler and dew point evaporative heat exchanger were same when wet channel air flow varies and this is because of a humidity ratio for dehumidified air and return air is similar. For indirect evaporative air cooler, Gh. Heidarinejad and M. Bozorgmehr [28] found that mass flow rate ratios of primary and secondary air flows and spacing between the plates of dry and wet channel were key parameter for cooling performance. The highest cooling performance was found for counter configuration .Cooling effiency decreases with increases in ratio of primary and secondary air flow. Also increase in space between plates of dry and wet channel reduces cooling efficiency. For thermal comfort in buildings M. Jradi and S. Riffat. [29] Investigated indirect evaporative cross flow cooling system. Numerical model was developed by using Matlab. The numerical model was used to perform parametric study and the outcomes of a study shows that as the intake air temperature increases wet bulb and dew point effectiveness increases. Wet bulb effectiveness and dew point effectiveness decreases as the intake air velocity increases. Supply air temperature was directly proportional to channel height and wet bulb effectiveness and dew point effectiveness were decreased with increased in the channel gap. Supply air temperature increases as the supply air to intake air ratio increases. Performance of indirect evaporative cooler studied by, A.E. Kabeel and Mohamed Abdelgaied. [30]. Five configurations with internal baffles in dry channel were proposed for better configuration. For the change in inlet air condition and with increase in the number of baffles the outlet cooling temperature decreases more for internal baffle configuration compared to non baffle configuration. Dew point evaporative cooling system was studied by influencing of inlet air condition and influencing inlet air velocity by B. Riangvilaikul and S. Kumar. [31]. Simulation and experimental study were conducted for two cases first one was by influencing of inlet air condition and second one was by influencing inlet air velocity. It was found that inlet air humidity had a great impact on outlet air condition. Outlet air temperature increases with increase in inlet air temperature and humidity. When the intake air velocity is reduced the outlet temperature was decreased. But for the same inlet air velocity with higher humidity it gives notably increase in outlet air temperature. Static and dynamic studies were conducted by B. Riangvilaikul and S. Kumar. [32] For dew point evaporative cooling system. Static studies were done by keeping constant inlet conditions and dynamic studies were done by varying inlet conditions. It was found in static studies that lower outlet air temperature can be obtained for lower inlet temperature and lower humidity. Higher wet bulb effectiveness was obtained for lower intake air humidity ratio. When the intake air velocity increased, both wet bulb and dew point effectiveness values decreased. The results of dynamic studies indicates that outlet temperature not vary too much throughout the day. And outlet air temperature decreases slightly when ambient air humidity was low in the evening. For counter-flow configuration of dew point evaporative cooler, improved mathematical model was presented by J. Lin et al. [33]. It was found that water evaporation rate proceed towards minimum value at 0.2m and 0.3m from the entrance. For working air ratio more than 0.5 and for channel 1enght greater than 1.8 and height less than 5mm, wet bulb effectiveness was always greater than 1.

5 Research study on Liquid Desiccant Evaporative Cooling System

The Liquid desiccant indirect evaporative cooling system is an ideal alternative system for conventional vapour compression systems. In which latent heat is take care by dehumidifier system and indirect evaporative cooler take care for sensible cooling. By using lithium bromide aqueous solution W.Z. Gao et al. [34] investigated M-cycle indirect evaporative cooling system. The experimental results shows that, dehumidification can increase with increasing inlet air flow rate and humidity ratio but lessens cooling capacity of M-cycle indirect evaporative cooler. With increasing desiccant flow rate and inlet concentration, moisture removal rate in dehumidifier and cooling capacity of M-cycle indirect evaporative cooler increases. By using solid and liquid desiccant Min-Hwi Kim et al [35] studied evaporative cooling. The desiccant system installed at two sides, one at primary air side of indirect evaporative cooler for reducing humidity and other at scavenging air side for to enhance its effectiveness. It is found that desiccant system which was located upstream i.e at primary air side consumes 76-85% less energy than downstream side. It was also designated that liquid desiccant system saves 21-50% primary energy than solid one. Mahmut Sami Buker et al. [36] investigated building integrated photovoltaic roof collector with liquid desiccant indirect evaporative cooling with potassium formate as a desiccant. A cost effective easy to make polyethylene heat exchanger loop was used beneath PV panels for regeneration of a liquid desiccant and the regeneration temperature need to be at around 60-70℃. It was found that average temperature drop across the dehumidifier and cooler unit is around 4.5℃ and 7.5℃ also average relative humidity drop across dehumidifier unit was found 25.7%. From power efficiency data indicated that the PV module can improve power energy performance by 10.7%. Indirect evaporative cooling system with liquid desiccant was theoretically studied by X. Cui et al. [37]. The study examines the impact of key parameters such as ratio air flow rate ratio, dimensionless channel length, and the intake air condition. The results show that, in heat and mass exchanger unit working air acts as cooling source. One of the influential parameter in controlling the cooling effectiveness is working to intake flow ratio rate ratio and when working to intake air flow rate ratio increased from zero to 0.8, temperature of product air significantly decreased. When the length of the liquid desiccant film was about 0.3, dew point effectiveness found to be maximum i.e. 1.1. With increase in channel length of heat and mass exchanger unit, outlet humidity ratio and outlet temperature decreases. A performance of liquid desiccant indirect evaporative cooling system is performed by Xin Cui et al. [38] in which computational model has been developed for performance measurement of heat and mass transfer. The model shows good agreement with experimental data. Simulation results designated that liquid desiccant film length, intake air temperature and intake air humidity ratio impacted on outside temperature and humidity ratio.

Table 2 *Summary of different studies related to indirect evaporative coolers*

Study	System description	Method	System performance
Chengqin Ren, Hongxing Yang[23]	Indirect evaporative cooling with parallel/counter flow configurations	Analytical	Product air flows in counter current direction to the water film gives the better performance
Zhijun Liu et al. [24]	Indirect evaporative heat exchangers	Analytical	Model using modified effectiveness –NTU method for indirect evaporative heat exchangers is presented.
Sergey Anisimov et al. [25]	Maisotsenko cycle	Analytical	Cross flow M-cycle heat and mass exchanger appears to be the foremost affordable unit for business functions.
Paolo Liberati et al [26]	Indirect Evaporative cooling systems	Modelling and Performance	Vital energy saving in the majority the investigated conditions.
Changhong Zhan et al[27]	M-cycle cross-flow heat exchanger	Analytical	M-cycle indirect evaporative cooler can achieve cooling effectiveness higher than conventional cross flow heat exchanger

Table 3 *Summary of different studies related to dehumidifiers, regenerators and liquid desiccant indirect evaporative cooling system.*

Study	System description	Method	Desiccant	System performance
Bansal et al.[4]	Adiabatic and an internally cooled structured packed-bed dehumidifier	Experimental	CaCl2	Effectiveness of internally cooled packed bed dehumidifier is higher than adiabatic.
Yin et al.[5]	Internally cooled/heated dehumidifier/regenerator	Experimental	Licl	Simultaneous internal cooling dehumidifier can offer better dehumidification performance.
Yin et al.[6]	Internally cooled/heated dehumidifier/regenerator	Analytical	LiCl	Internally heated regenerator will avoid dehumidification risk which might happen in adiabatic one.
Koronaki et al.[7]	Analysis of a counter flow adiabatic dehumidifier	Analytical	Licl	LiCl has the best efficiency, can reduce by 10% humidity ratio compared to LiBr 8% and CaCl2 6%.
Kabeel and Bassuoni [16]	Regenerator supported with scavenging air heat exchanger	Theoretical	CaCl2	As scavenging air temperature increased, ability of desorption process is increased causing air to become more wet and in turn strong desiccant solution.
Kim [17]	Regeneration on the surface of a plate-type heat exchanger	Experiment	LiCl	Mass flow rate of desiccant increases, wettability of liquid desiccant intensified and the regeneration rate and mass transfer
Alosaimy and Hamed [18]	Solar water heater for regeneration	Theoretical and Experimental	CaCl2	Solar water heater can be used to regenerate CaCl2 from 30% to 50%.
Goswami [20]	Packed tower absorber and regenerator	Experiment	LiCl	Water evaporation rate increases with increase in air flow rate and desiccant temperature.
Gao et al.[34]	Maisotesenko – Cycle	Experimental	LiBr	With increasing desiccant flow rate and inlet concentration, moisture removal rate in dehumidifier and cooling capacity of M-cycle indirect evaporative cooler increases
Kim et al.[35]	Evaporative cooling system assisted with outside air	Experimental	Licl, LiBr, CaCl2,TEG	Desiccant system which was located upstream consumes 76-85% less energy than downstream side.
Mahmut Sami Buker et al.[36]	Building integrated indirect evaporative cooling system	Experimental	HCOOK	It was found that average temperature drop across the dehumidifier and cooler unit is around 4.5°C and 7.5°C

6 Conclusion

In this paper, the work done by different researchers on liquid desiccant dehumidifiers, regenerators, indirect evaporative coolers and combined liquid desiccant indirect evaporative cooling system has been summarized.

- The commonly used liquid desiccants are inorganic salts like lithium chloride (LiCl), lithium bromide (LiBr) and calcium chloride (CaCl2).
- Adiabatic or internally cooled/heated packed bed dehumidifiers/regenerators are mostly used.
- Effectiveness of internally cooled packed bed dehumidifier is higher than adiabatic ones because low desiccant temperature cause more mass transfer.
- Regeneration can achieved in regenerator by using low grade heat sources, such as industrial waste heat , solar energy with temperature between 60°C-100 °C.
- Internally heated regenerator will avoid dehumidification risk which might happen in adiabatic one, and additionally it might provide higher regeneration potency that the adiabatic one. The internally cooled dehumidifier may also give higher dehumidification performance examination with adiabatic one, but its profit would be not nearly as good as internally heated regenerator.
- Solar water heater can be used to regenerate CaCl2 from 30% to 50%.
- In indirect evaporative cooler, process air is sensibly cooled because process air is not directly interacting with cooling fluid can be used even in hot and humid climates.
- In hot and wet weather conditions, indirect evaporative cooling system becomes less economical underneath these conditions an indirect evaporative cooling system may be operated in combination with

liquid desiccant dehumidifier system with high potency.

- Product air flows in counter current direction to the water film gives the better performance in indirect evaporative coolers.
- For cross-flow M-cycle heat and mass exchanger temperature effectiveness is comparable to the counter flow M-cycle heat and mass exchangers, whereas its specific cooling capability is higher and construction is simpler to style, thus cross flow M-cycle heat and mass exchanger appears to be the foremost affordable unit for business functions.
- By using indirect evaporator cooler it was found that vital energy saving in the majority summer conditions.
- Indirect evaporative cooler can give better performance by using internal baffles in dry channel.
- Cross flow M-cycle indirect evaporative cooler can achieve cooling effectiveness higher than conventional cross flow heat exchanger.
- The liquid desiccant indirect evaporative cooling system is an ideal alternative system for conventional vapour compression systems. In which latent heat is take care by dehumidifier system and indirect evaporative cooler take care for sensible cooling.

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