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A Review on liquid desiccant Regeneration in air-conditioning system

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Abstract : This paper overviews liquid desiccant Applications, abstract operation, and experimental analysis of conventional desiccant and mongrel systems used with vapor contraction Regeneration systems. This review provides information about colorful parameters which affect the performance, i.e. COP, of the system. Liquid desiccant air Conditioning(LDAC) systems have significant energy savings ranging between 20 to 30 above conventional air Conditioning systems. Liquid desiccant Conditioning systems use low- grade energy sources that are sustainable and terrain friendly. dehumidification is a veritably important variable that helps in maintaining the comfort position in hot as well as sticky condition of terrain. Desiccant dehumidification system is promising indispensable technologies that help in reducing power consumption. Then different parameters and variables are delved , similar as inflow rates of desiccant and air, it's temperature, attention, and moisture that can affect the performance of dehumidification and Regeneration along with COP of the system. Mix desiccants give the stylish performance along with inflow control of both air and desiccant.

***IndexTerms* - Liquid desiccant, air Conditioning, dehumidification, performance parameters, Regeneration of desiccant**

I. INTRODUCTION

In present world, cargo of heating, ventilation and air Conditioning(HVAC) is rise 6.2 per time is estimated(6). For Mortal thermal comfort the energy use is nearer to 50 of the structure total energy consumed(5). Also refrigerant use in air Conditioning is responsible for adding the ozone reduction and global warming. For overcome this difficulties desiccant Conditioning systems are considered as system of controlling humidity content in out-of-door process air. The main factors of liquid desiccant Conditioning system are heat exchanger, regenerator, dehumidifier, pump, heater & cooler.

Applications of liquid desiccant

1. Banking and snack food result
2. Bulk handling results
3. Delicacy and sugar results
4. Chemical and cold storehouse results
5. Dairy results
6. Film and glass results
7. Hospital results
8. Plastic results

Graces of liquid desiccant Conditioning system over solid desiccant are as follows

1. Conditioning as well as dehumidification can be achieved using an liquid desiccant system compare to overheating of dry air brume.
2. humidity carrying capacity of liquid desiccants is high.
3. Desiccant Regeneration temperature is low for liquid desiccant.
4. Energy storehouse is possible in LDAC system because it's possible to store concentrated desiccant in tanks.

II. BASIC SYSTEMS OF LIQUID DESICCANT AIR CONDITIONING SYSTEMS(LDACS)

As shown in Figure 1(5) simple LDAC system containing regenerator and dehumidifier. humidity from the out-of-door process air at entry is removed in the dehumidifier or in absorber unit, where the water vapor from the process air is absorbed by liquid desiccant. As a result of difference in vapor pressure bone can achieve mass transfer. In coming process heat is liberated during condensation of water. Also heat exchange takes place because of mixing

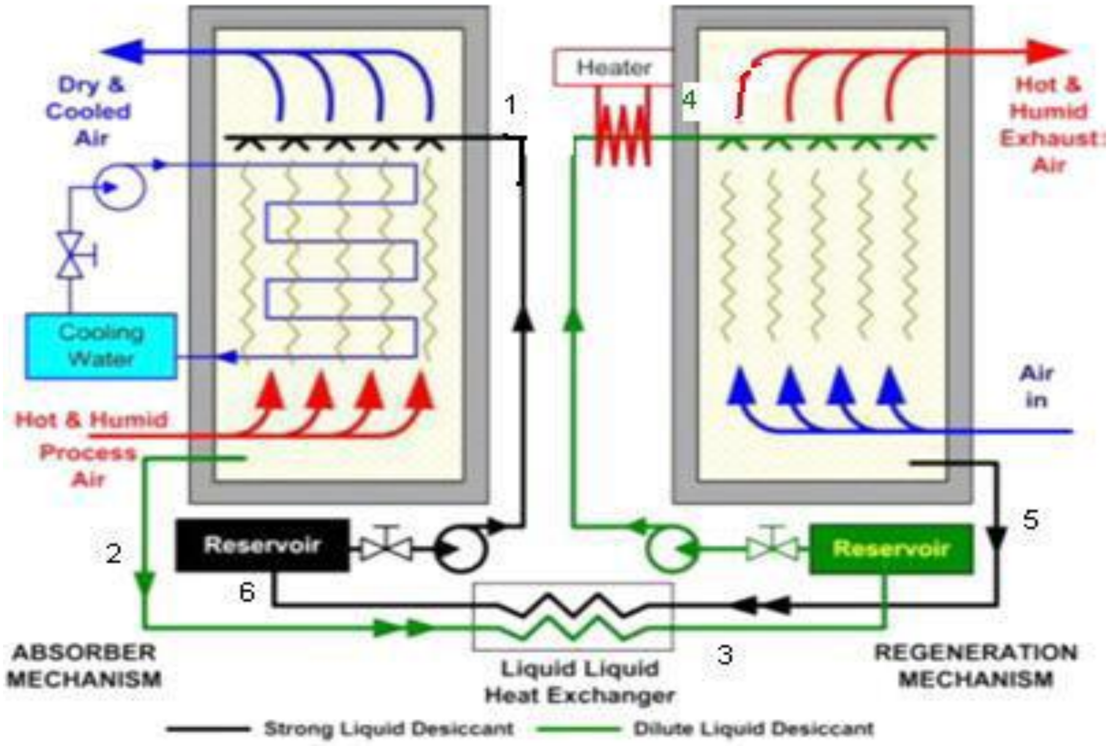

Figure 1: Schematic of liquid desiccant air Conditioning system [5]

Fig shows the at different pressure, humidity will be present in desiccant result or to show that desiccant absorb humidity or desorbs. The different processes are as follows

1- 2 dehumidification process During this process the desiccant absorbs the humidity from incoming air. This is done by direct contact to air which is come to atmosphere.

2- 3 Preheating process This process in done in a heat exchanger by transfer heat between weak desiccants to strong desiccant.

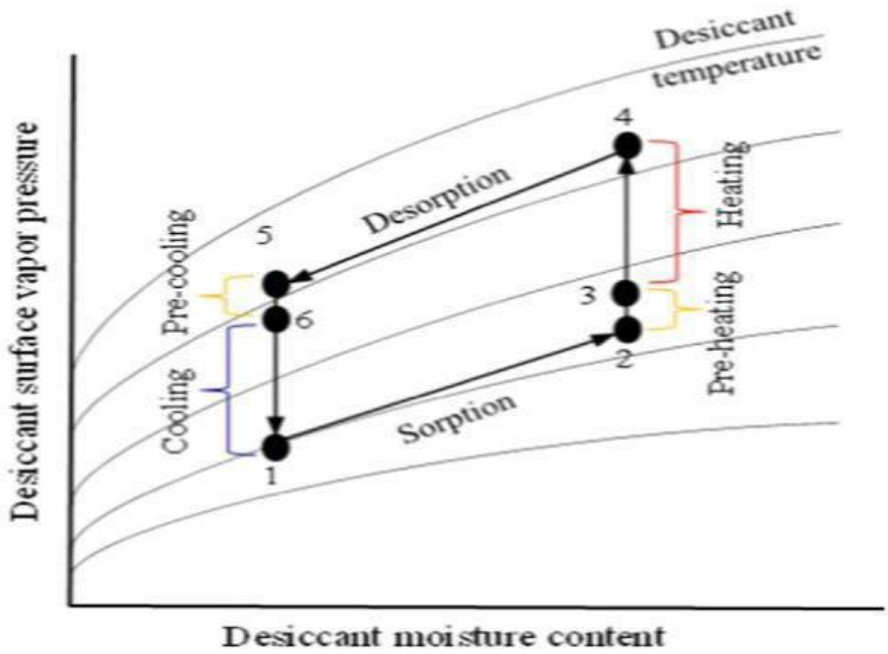

Figure 2 Diagram of desiccant vapor pressure to moisture content [3]

3- 4 Heating process This process is done in heater. This process is done because of increase the temperature of desiccant at a certain limit before it enters the regenerator section.

4- 5 Regeneration process- In this process, desiccant desorbs humidity to the air. This is done by contact between the air and desiccant.

5- 6 Pre Conditioning process- This process is done in heat exchanger by transferring heat to strong desiccant to weak desiccant

6- 1 Conditioning process- This process is done in cooler. This process is done because of drop the temperature of desiccant to a certain limit before in passes to dehumidifier section.

In dehumidifier section, desiccant is scattered on top portion of dehumidifier and the air bay is from nethermost portion of dehumidifier. Desiccant absorbs humidity from process air and also this adulterated result is being stored in bottom portion of dehumidifier.

From that adulterated result is passing through heat exchanger to heater and also to regenerator unit. In regenerator unit the dilute desiccant result removed the humidity to state and this wettish air is removed to atmosphere. In heat exchanger heat transfer takes place between hot to cold or cold to hot desiccant.

III. DIRECT CONTACT TYPE DEHUMIDIFIER OR REGENERATOR

In direct contact dehumidifier- regenerator system, water vapor and heat exchange takes place between the aqueducts of desiccant and air. There are colorful designs for direct contact dehumidifier- regenerator system like packed bed type, spray palace and falling film type.

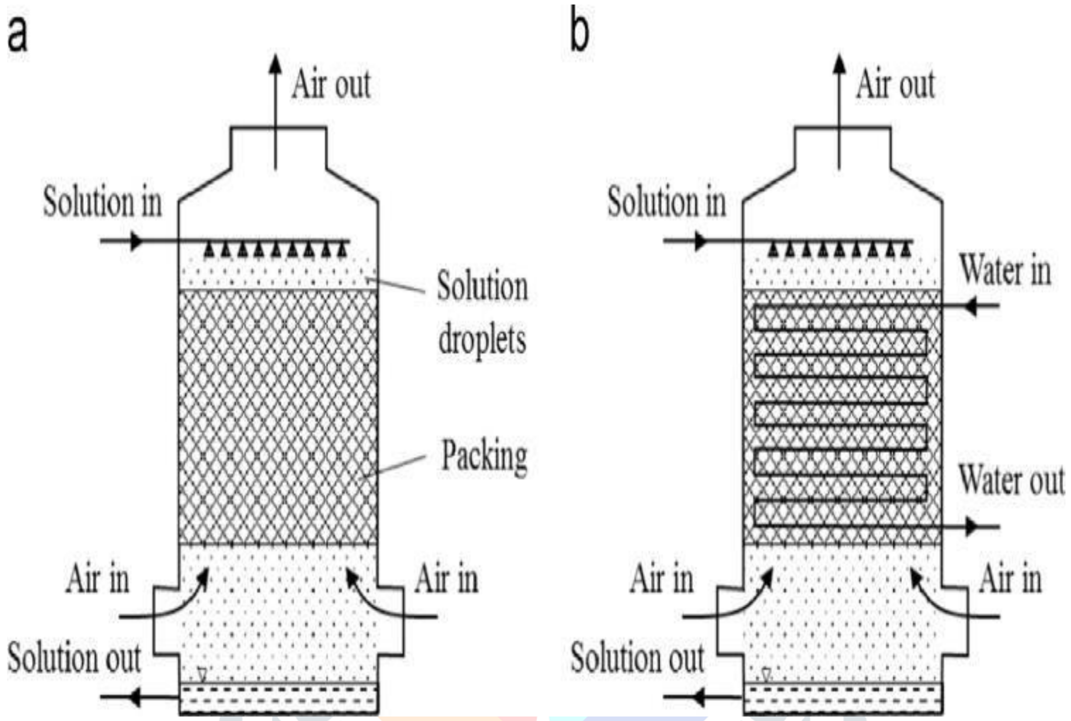

Figure 3: (a) Adiabatic packed bed and (b) Iso-thermal packed bed[3]

Packed bed Desiccant result is scattered with the help of snoot of any other scattering medium from top of packed bed. also desiccant comes into the direct contact of air. The reaching dehumidifier and regenerator may be of two type, Adiabatic or Isothermal or Internally cooled/ heated type as shown in figure 3.(3)In an adiabatic packed bed, Figure 3(a)(3), as desiccant pass through dehumidifier- regenerator set, its temperature varies because of heat exchange with air sluice and phase change. Because of this reason humidity junking or addition takes place. In internally hotted cooled " isothermal " packed bed, shown in Figure 3(b)(3), Water is used as third fluid for nonstop heating/ Conditioning of result. So results' temperature remains nearly constant and it has better mass transfer compared to adiabatic type.

IV. CONCEPTUAL STUDY OF LDAC SYSTEM

Grossman(1) did an expansive review on solar Conditioning and solar air Conditioning system. Different styles have been compared similar as liquid desiccant, immersion cycle, solid desiccant, ejector Conditioning system, heat machine driven VCRS with different refrigerants. In an open type liquid desiccant system, the authors considered four processes dehumidification, sensible Conditioning, evaporative Conditioning, and liquid desiccant systems. Liquid desiccant can be $CaCl_2$, ethylene glycol, LiBr, LiCL. As per experimenters, Lithium and Calcium grounded desiccants are strong and weak independently. For a veritably low relative moisture position one can used LiBr or LiCl.

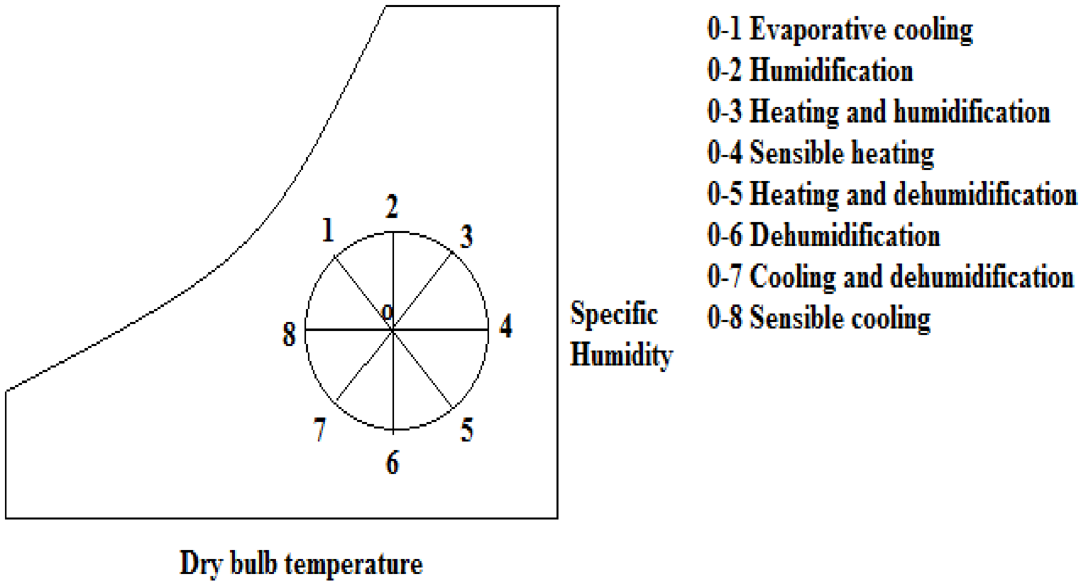

Figure 4 Processes on psychrometric chart

(1) Glycol is illustration of veritably mild desiccant. When anyone is using organic desiccant also desiccant condensation is must because during the Regeneration process, there's evaporation of desiccant.
(2) Review of desiccant Conditioning system. He shows design advance in liquid desiccant system like computer modeling and mongrel system that combine with vapor contraction system. In advancement of technologies the use of solar energy for Regeneration during day time and druthers are used for night Regeneration.
(3) Carry over problem reduced by circular contact design like liquid to air membrane energy exchanger. For better performance combination of LDAC and dew point evaporative cooler used.
(4) Performance evaluation of colorful fusions of liquid desiccants to get better performance. Admixture of different liquid desiccants can give better dehumidification effectiveness and lower energy consumption as well as lower material cost. They got enhancement in COP for colorful cases in rage of 18 to27.5. They've colorful group of admixture,
Group 1 pure LiBr
Group 2 is 43 LiBr and4.8 CaCl2
Group 3 is 41 LiBr and 9 CaCl2,
Group 4 is 39 LiBr and 13 CaCl2,
Group 5 is37.5 LiBr and16.7 CaCl2.
Group 5 gives good results in dehumidification effectiveness as18.5 advanced as compare to Group 1
M.Mujahid (5) did a review on liquid desiccant material and dehumidifiers. They showed liquid desiccants have high humidity immersion capacity,non-corrosive, andnon-volatile in nature. LiCl and CaCl2 admixture are veritably cost effective. Stability of LiCl is loftiest among all and has veritably low vapor pressure. To remove carry- over problem, innernally cooled dehumidifier, rotary type dehumidifier and liquid – air membrane exchanger were proposed. Also, the authors have proposed the operation of a high adiabatic inflow rate in order to ameliorate the wettability of the face. Wettability of face allow the air to come in a contact with liquid desiccant in proper manner and it provides further commerce time to desiccant and air which results in high humidity junking.
M.Mujahid (6) showed that in hot and sticky climate, evaporative Conditioning isn't so effective, so author proposed LDAS in combination with evaporative Conditioning. Conventional VCRS system is substantially designed to work with idle heat cargo. This system is good only for sensible heat rate advanced than0.75. circular evaporative Conditioning and direct sinking Conditioning were suggested to ameliorate latent and sensible heat cargo junking.
V.Desai (7) has study about introductory process of LDAC system. There are numerous challenges faced while the system design like which type of material used, carryover & comity. He conclude that for LDAC system aluminum & COP is preferable material.
Y.Yin (8) had shown that to remove carry- over loss, internally heated regenerators can be used and they set up to be more promising than adiabatic regenerator with lower inflow rate. X.Xie (9) did experimental analysis and developed fine model for LD systems including both sensible and idle heat loads. girding air temperature29.1°C to33.6°C and moisture rate13.7 to19.7g/kg. Supply air temperature23.6 °C to24.2 °C and moisture rate is7.4 to8.6 g/ kg. COP of the system is1.3 to1.8. As shows in above data, they considered Conditioning and dehumidification process. They compare the +ir fine model with their results. rather of VCRS if we used LD system driven by water than it saves the energy up to 30, got COP as 4.5.

V.EXPERIMENTAL INVESTIGATION OF LDAC SYSTEM

M. Bassuoni (10) has done experimental analysis with vapor contraction Regeneration cycle with liquid desiccant system. Combination of both of these systems increase 54 COP than conventional VCRS with reheating. Energy consumption saved up to 46.
M.Ali(11) explains integrated cold-blooded cycle between desiccant systems with vapor contraction system. The result shows that thermal COP drop around 35 to 25 than VCRS system. Then desiccant wheel was used along with VCRS.

C.Lin(12) explain veritably important conception of entrancy dispersion. When humidity transfer from one medium to another, there is actuality of resistance appertained as humidity transfer resistance(MTR). They alsoco-relate MTR and its performance. To reduce humidity transfer resistance, it's suggested to do pre Conditioning.
W. Cole (13) thermal storehouse applied for combined heat and power system, solar thermal power station. The result shows that if the thermal energy storehouse is duly designed, increases system effectiveness, inflexibility, reduce energy consumption, emigration & outfit cost.
X. Song(14) explains demand of inner air quality. Energy consumption of colorful accoutrements for domestic and Artificial is given over then. As shown in below figure, maximum quantum of energy consumed by HVAC. Liquid desiccants can be alternate result to conventional technology

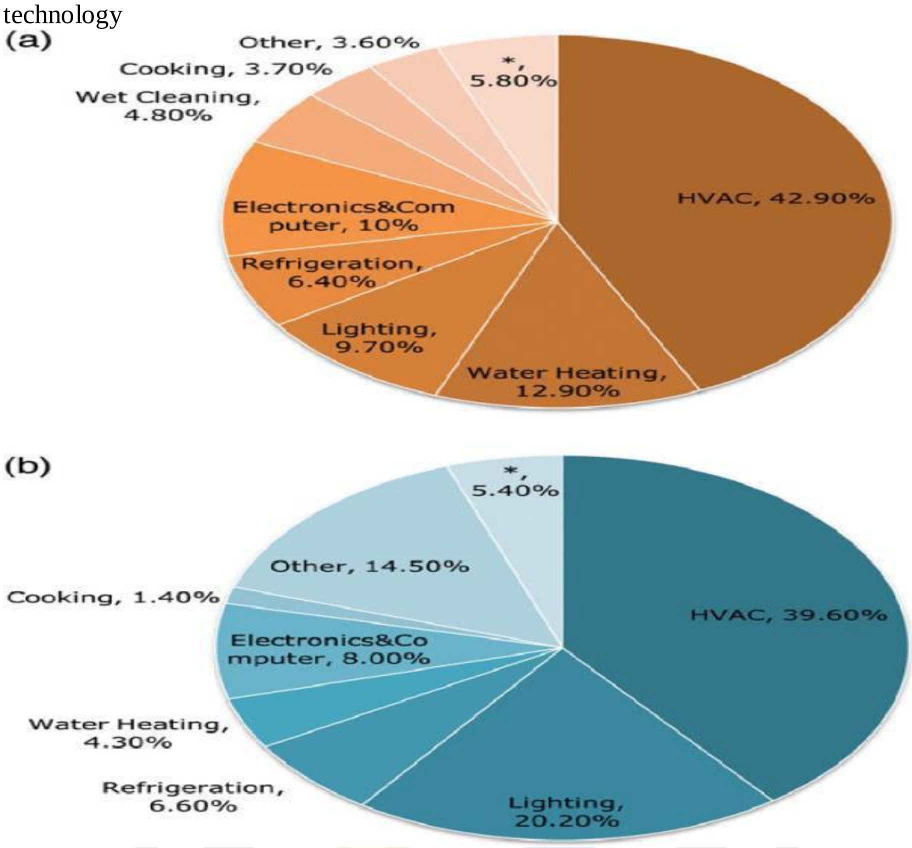

Figure 5: (a) Energy consumption in domestic purpose (b) Energy consumption in Industrial application [14]

Y. R. Qi (15) shows that energy consumption of conventional Regeneration can be reduce by adding collector area and give Conditioning coil to dehumidifier increase the rate of dehumidification. It can save 11- 35 of energy
consumption during colorful cargo condition.
S.Huang(16) has done trials oncross-flow system for air inflow and desiccant inflow. On perpendicular face, water Subcaste was formed. On that water subcaste, air inflow over it. The inflow condition of air was hydro- stoutly and thermally completely developed inflow. subsequently governing equations were applied to the system. confirmation of Sherwood number and nusselt number were done by experimental result analysis for completely developed inflow condition. 2- 3 divagation they got because of experimental query.
Park(17) explains empirical analysis for vaticination of dehumidification effectiveness. LiCl used as liquid desiccant in the system.33.3 m3/ min was inflow rate and they attained colorful value of dehumidification effectiveness at different operating condition, validate this model with current was model.
N. Fumo(18) shows that while considering regenration process, liquid desiccant is more profitable than solid type. Humidification as well as Regeneration rate depend upon inflow rate and temperature of both i.e. liquid desiccant and air. To get desire experimental result, Oberg model has been used.
Kessling(19) it's the stylish way to store dissipated energy in the desiccant itself. A new dehumidification is designed in which a micro scale inflow of liquid desiccant result was made. dehumidification of air5.5 g/ kg and Storehouse capacity 700 MJ/ m3 would be gain.
X.Lui(20) experimentally shows that desiccant Conditioning is far better than air Conditioning for better dehumidification effectiveness. It was suggested to put one further heat exchanger for further heat recovery also proposed to put one further spray section. When air processor ran by heat pump, system's COP becomes 5. COP becomes1.19 when water driven processor is used. This system can save 20- 30 energy. To get good humidification(regenerative), desiccant can be hotted.
G.Angrisani(21) the performance of the LDAC system depends upon moisture rate, Regeneration and outof-door air temperature, and flow rate of air.When Regeneration temperature increase thermal performance of the system reduces or vice versa. The thermal COP is0.9 &1.28 was gain with regenerative temperature is equal to 55 °C & 85 °C.
L.Yinglin(22) has done work on performance analysis of combination of VCR and LDAC sytems. The result shows that by small difference of attention of1.5 loss of Conditioning capacity exceeds 10.
K.Keniar(23) proposed theoretical model which gives nearer result to the experimental result with solar Regeneration. It was observed that 10 of relative moisture drop inner air quality.

VI. EXPERIMENTAL INVESTIGATION OF HYBRID DESICCANT CONDITIONING SYSTEM

K.Gommed(24) proposed the solar powered desiccant system. This is for taking idle cargo only and there's separate heat pump for sensible cargo. moisture of air supplied to conditioned space depends substantially on inflow rate of result also temperature and inflow rate of heating/ Conditioning water. Certain condition is bandied for optimum affair.

K.Gommed(25) analyses the performance of element theoretically and give real- time data of heat as well as mass transfer factor or measure for system having dehumidification capacity of about 16 KW(average). The data analysis indicates that thermal COP of about0.8 having plastic losses on the order of 10.

D.Salimized(26) in this review paper, estimate Conditioning water storehouse for that TRNSYS simulation is use to measure the optimal operating condition of the sinking Conditioning palace. Also the TRNSYS simulation is use to measure the performance of the Conditioning water storehouse. Result shows that Conditioning water storehouse system consuming lower energy and increase the performance of the system up to 16 also ameliorate Conditioning rate about 6.

S.Bergero(27) the mongrel system is used to achieving advanced COP by using heat pump. Advantage of the heat pump is that it operates at the advanced evaporation temperature than conventional system. operation of heat pump increases COP of the system and also the thermal effectiveness of the condenser andevaporator.Result shows that by using the heat pump energy saving increase up to 50.

I.Karonaki(28) by using untoward current inflow between desiccant and air to make high dehumidification mass rate, lower mass inflow rate of air, lower desiccant and Conditioning water temperature. For the same bay condition LiCl moisture rate is dropped to 31 and the LiBr moisture rate is reduced to 12. This results indicate that LiBr is less effective than LiCl.Along with Regeneration temperature and coolant temperature, performance of system affected by inflow rate of air, desiccant and coolant. By considering energy balance equation in steady state condition,

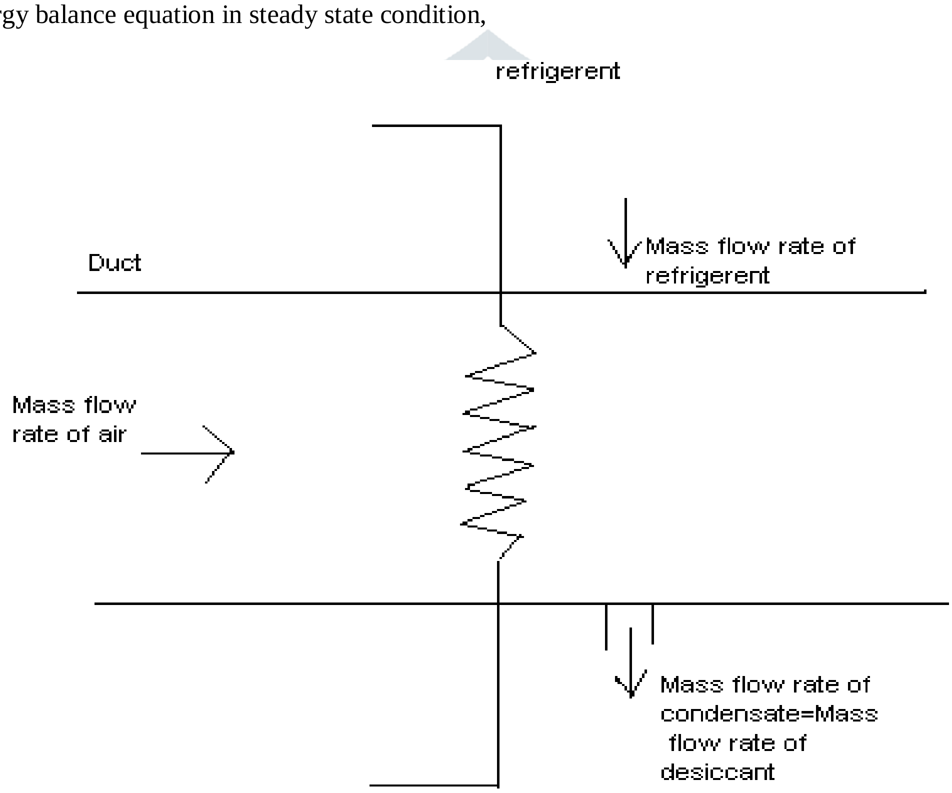

Figure 6: Fluid flow direction (air, desiccant and coolant)

following equation can be derived.

$m_{air}\ Cp_{air}\ T_{air,in} + m_{ref}\ h_{ref,in} = m_{air}\ Cp_{air}\ T_{air,out} + m_{ref}\ h_{ref,out} + m_{desiccant}\ hfg$

$m_{air}\ Cp_{air}\ (T_{air,in} - T_{air,out}) + m_{ref}(h_{ref,in} - h_{ref,out}) = m_{desiccnt}\ hfg$

$h_{ref,in}$ = enthalpy of refrigerant into the system

$h_{ref,out}$ = enthalpy of refrigerant out of the system

H_{fg} = heat of vaporization

RE = refrigeration effect=$(h_{ref,in} - h_{ref,out})$

ΔTa = temperature drop in air

$m_{air}\ Cp_{air}\ \Delta Ta - m_{ref}\ RE = m_{desiccant}\ hfg$

$M_{desiccant} = \frac{maircpair\Delta Ta - ref\ RE}{hfg}$

By considering energy balance equation in steady state condition, following equation can be derived.

VII. CONCLUSIONS

The following conclusions of can be made from the review of recent advance technology LDAC for both system as well as outfit.

- Desiccant reduces moisture of air and temperature is reduced by other factors.
- Effectiveness of Regeneration and dehumidification process depends on the effect of variable similar as air temperature, air and desiccant inflow rates, moisture, desiccant attention and temperature.
- LDAC system save 20 to 30 energy in comparison with conventional AC system.

● The COP of cold-blooded desiccant system has changed according to climate. The COP of the mongrel desiccant system is 36 and 28 lower than the COP of VCS in hot dry or sticky condition.
● A attention of strong result increases, specific humidity junking rate and COP will increase.
●Thermal performance of mongrel Conditioning system reduces when temperature of Regeneration
increase is useful for adding Conditioning effect handed by the desiccant Conditioning system.
● The COP of mixed desiccant i.e. LiBr – CaCl2 – water can bettered to 18 and27.9 also the pure water system independently.
● utmost design suitable good heat transfer effectiveness attained respectable pressure drop 80 effectiveness.
● The mass inflow rate of air to desiccant result varies in range of0.15 to0.25.
● By adding the inflow rates of desiccant and air both result, the system COP as well as humidity junking rate are increased.

PARAMETERS:
C.C. - Conditioning Capacity
AC - Air conditioning
LDAS - Liquid desiccant air Conditioning system
LD - Liquid Desiccant
VCR - Vapor Compression Refrigeration
SMR - Specific moisture removal rate
DCS - Desiccant Conditioning system
DW - Desiccant wheel
ILADAC - Internally cooled liquid desiccant air conditioning system
ALDAC - Adiabatic liquid desiccant air conditioning system
TES - Thermal energy storage
RSHF - Room sensible heat factor
HVAC - Heating, ventilation & air conditioning
LiBr -Lithium Bromide
LiCl - Lithium Chloride
CaCl2 - Calcium Chloride
SHR - Sensible heat ratio
ε - Effectiveness

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