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Feasibility Analysis of Regeneration of Silica Gel Used in Dehumidification Process of Air Conditioning by the Condenser Waste Heat of Air Conditioner

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ABSTRACT: The conventional air conditioning systems rely on electrical power to drive the cooling cycle. Another important factor for indoor comfort is the humidity control for which the conventional air conditioning system needs a lot of energy. Due to this high power consumption, supply of fresh air is restricted which results in poor indoor air quality. Thus, desiccant cooling serves to be a perfect supplement to the conventional air conditioning system as it reduces the energy consumption by removing the latent load on the cooling coil beforehand with the use desiccant rather than by cooling. So, in this paper, to address the importance of improved IAQ by humidity control and reduction in energy consumption, a dehumidifier has been designed consisting of silica gel as desiccant material which is very cost effective and can be reused by regenerating it to certain temperature. It has been found that a relative amount of heat has been released by the condenser of the air conditioner which is always wasted. Thus, an experimental analysis was performed to observe whether the waste heat released from the condenser of the air conditioner is sufficient enough to regenerate the silica gels fully for its reuse which has been saturated with moisture after dehumidification. From the experimental result, the waste heat temperature from the condenser was found 64^0C and the saturated silica gels have been regenerated completely by heating them for 4 hours with this temperature.

KEY WORDS: Desiccant dehumidification, Indoor air quality, Energy saving, Waste heat, Silica gel

I.INTRODUCTION

The main purpose of an air conditioning system is to provide conditions for human thermal comfort and to maintain indoor air quality. In summer, ventilation, solar heat gain and moisture generation by the occupants and components raise the temperature and humidity of the conditioned space and so the demand for cooling is increasing for comfortable conditions specially in the urban areas, which have led to a significant increase in per capita energy demand and thus total energy consumption in the last few decades. It has been found through many researches that the energy used by conventional air conditioning system to provide human thermal comfort condition is about 50% of building total energy consumption in the form of electrical energy [10]. Air conditioning system today account for 15% of the total energy consumption of the world.

The fast depletion of conventional energy resources and increasing demand of human comfort conditions is becoming a major global problem [10]. Most of the air conditioning systems in use are vapour compression based systems which uses refrigerants like CFC, HCFC and HFC which are one of the main sources of ozone layer depletion. These coolants are used to cool the water in the evaporator and over the period they leak into the atmosphere and react with the ozone layer. Again, these air conditioning systems run by electricity and for its regeneration fossil fuels are utilized which results in the emission of CO_2 which is a greenhouse gas into the atmosphere. A large amount of greenhouse gases are emitted due to burning of conventional energy resources. Thus the use of air conditioning system plays a major role in the emission of these gases which causes depletion of the ozone layer and other environmental issues [10].

The main concern while designing a building is to counterbalance thermal comfort, indoor air quality and energy usage for which a vapour compression based air conditioning system has to maintain two types of load- sensible load and latent load. A conventional VCS system removes moisture from the process air by cooling the air below the dew point temperature with the help of coolants and removing the air by condensation. The cold and the dry air after cooling must always be reheated from that temperature to supply temperature to meet the required indoor conditions. This process of simultaneous heating and cooling leads to a considerable amount of energy waste which reduces the performance of the system further. In addition to that, the supply of fresh air is always restricted in such systems in order to save energy which affects the indoor air quality to some extent as the interior space sustains damp condition that promotes the growth of mould and can be a source of several health problems.

Thus, if this moisture can be handled separately by some other means beforehand then the power consumption will be reduced and indoor air quality will also be improved to a great extent. In such situations, desiccant cooling has gained its importance as it is an energy efficient, environment friendly and healthy means of air dehumidification system [8]. These systems significantly reduce the operating cost when powered by free energy sources such as solar energy and waste heat. In this paper, an experimental setup in which a dehumidifier is installed and investigated and an effort has been made to utilize the waste heat from the condenser of the air conditioner to regenerate the desiccant material. The main aim of this paper is to analyse the feasibility of regeneration of silica gel by using this waste heat.

II. DESICCANT COOLING

Desiccants are hygroscopic substances capable of releasing or adsorbing moisture from the surrounding environment due to the vapour pressure difference between the surrounding air and desiccant surface. When the vapour pressure of the desiccant surface is less than that of the surrounding air, dehumidification occurs and continues until it reaches equilibrium with the surrounding air [5]. Moreover, these desiccants regenerated by driving out the moisture that has been taken up during the adsorption phase ensuring that it is dried enough to adsorb moisture again [5]. This regeneration is done by heating the desiccant material with a variety of thermal energy sources which include solar energy, waste heat, natural gas heating etc. desiccants can be classified as solid desiccant and liquid desiccant based on which desiccant system can be categorized as – solid desiccant system and liquid desiccant system. Some commonly used solid desiccants include silica gel, alumina, molecular sieves etc. whereas liquid desiccants comprise lithium chloride, lithium bromide, calcium chloride etc. In this paper, the desiccant used was solid desiccant i.e. silica gel.

III. SILICA GEL

Fig 3.1: Silica gel particles

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Silica gel is a granular and amorphous form of silica manufactured from sodium silicate and sulphuric acid and consists of mainly partially hydrated silicon dioxide. Silica gel has many grades and each grade are of different sizes. It has a surface area of 0.6-0.8 km^2/kg with average internal porosity 38-48%, bulk density of 700-820 kg/m^3, average pore diameter 2-5 nm, heat of adsorption 2800 kJ/kg and adsorption capacity of about 0.35-0.50 kg of water/kg of dry air. These small pores become filled with liquid by capillary condensation at high humidity and the total amount of adsorbed depends on the volume of the small pores and the surface area.

As compared to molecular sieves, silica gel has good pore volume although water is held most strongly by molecular sieves and is cheaper. Silica gel may be either non indicating or self indicating in nature. It is referred as non indicating because it remains physically unchanged when moisture is adsorbed but self indicating gels are moisture sensitive and changes colour as moisture is adsorbed thus giving a visual indication of the activity level of the silica gel.

IV. CONSTRUCTION AND WORKING

The experimental setup is a rectangular duct of galvanized iron sheet of 88.9 cm width consisting of three adjustable plates made of steel net in which the solid desiccant (silica gel) are filled with and these plates are 15.24 cm apart from each other. An exhaust fan of capacity 720 m^3/min is fitted at one end of the duct which is required to suck the atmospheric air and the other end of the duct is fitted at the condenser of the air conditioner. The whole setup is placed in a wooden stand at a height of 129.54 cm from the ground and the set up is insulated with kini foam from all sides so that the exhaust heat of the condenser is fully utilized. The atmospheric air is sucked by the exhaust fan and when the air is passed through these plates which are placed parallel to each other, the moisture present in the atmosphere is adsorbed by the silica gel and will continue its adsorption until it gets exhausted which means that the silica gels are fully saturated. As the silica gels have the capacity of regeneration, they can be reused by drying. The condenser of the air conditioner releases a relative amount of heat which is utilized for drying the wet silica gel. The moisture adsorption capacity and the regeneration capacity of the silica gel can be obtained by taking the readings of the weight of silica gel of each plate in some time intervals. These readings are taken in summer condition to visualize the variation of adsorption and regeneration.

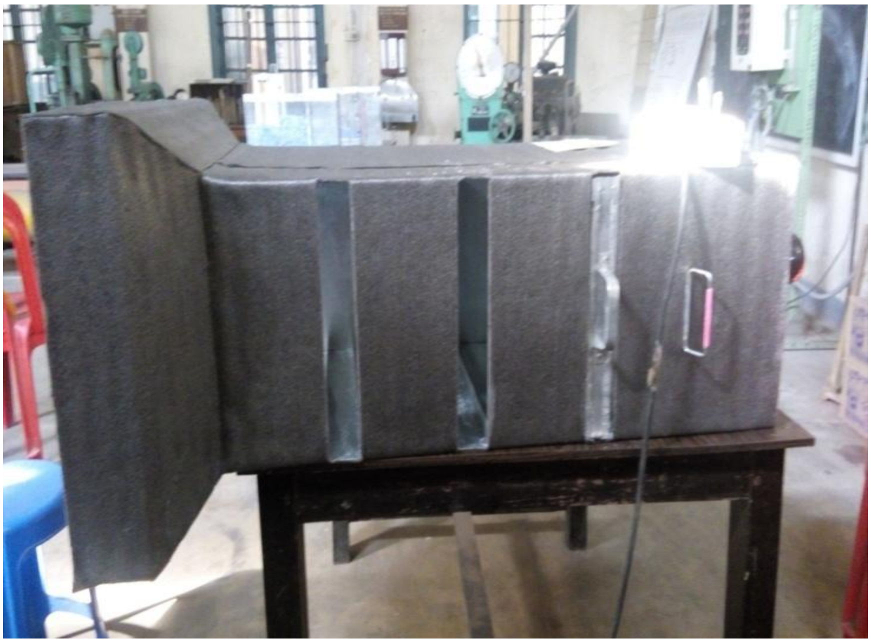

Fig 4.1: Side view of the duct

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Fig 4.2: Front view of the duct

Fig 4.3: Exhaust fan

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Fig 4.4: Plate consisting of silica gel

Specification of the air conditioner:

- Design : Window type Electrolux air conditioner with 100% copper tubing
- Capacity : It is of 1.5 TR and has 5100 watts of cooling capacity
- Dimensions : 660 × 780 × 472 mm
- Air circulation : 850 cubic metre per hour(cmh)
-

V. OBSERVATION AND PRESENTATION OF THE RESULTS

Day 1 (MORNING)

Dry bulb temperature of ambient air = 34^0C
Wet bulb temperature of ambient air = 26.2^0C, Relative humidity = 54%
Dry bulb temperature of dehumidified air = 34.4^0C
Wet bulb temperature of dehumidified air = 25.5^0C, Relative humidity = 50.2%

Day 1 (NOON)

Dry bulb temperature of ambient air = 34.6^0C
Wet bulb temperature of ambient air = 27^0C
Waste heat temperature (dry bulb) = 62.2^0C
Relative humidity = 57%

Day 2 (morning)

Dry bulb temperature of ambient air = 36.1^0C
Wet bulb temperature of ambient air = 27.9^0C
Waste heat temperature (dry bulb) = 64^0C
Relative humidity = 55%

Day 2 (noon)

Dry bulb temperature of ambient air = 36.2^0C
Wet bulb temperature of ambient air = 25.7^0C, Relative humidity = 45%
Dry bulb temperature of dehumidified air = 36.4^0C
Wet bulb temperature of dehumidified air = 24.4^0C, Relative humidity = 38%

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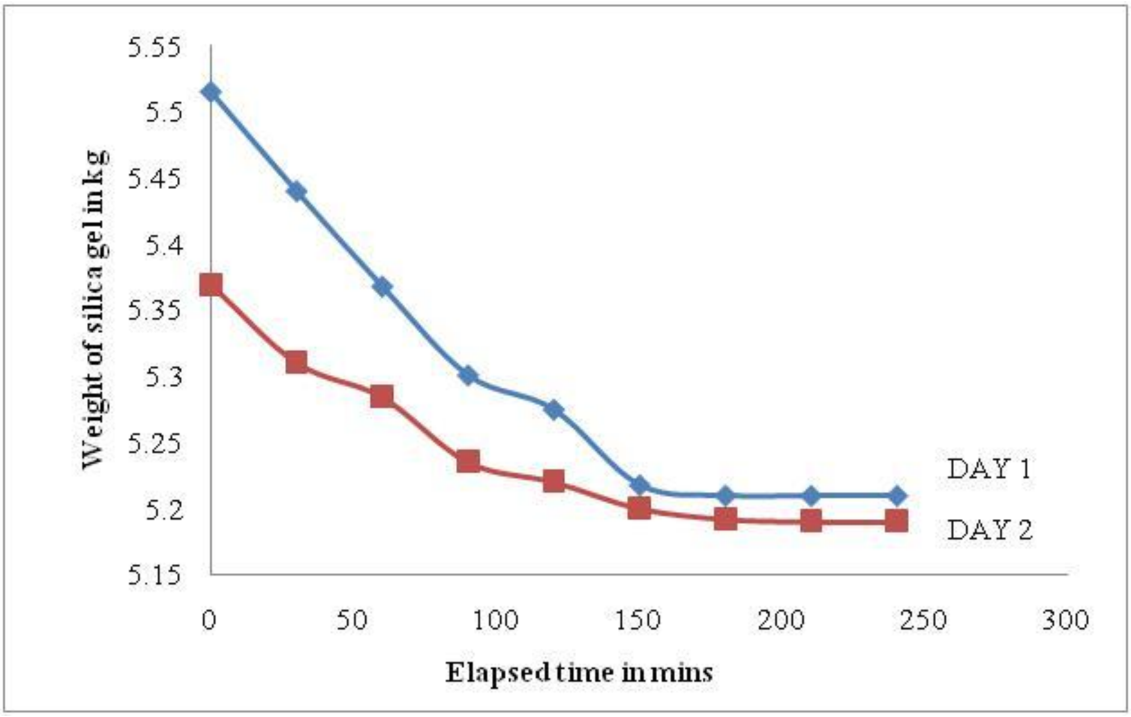

Fig 5.1: Variation in weight of silica gel vs. time interval during regeneration of silica gel

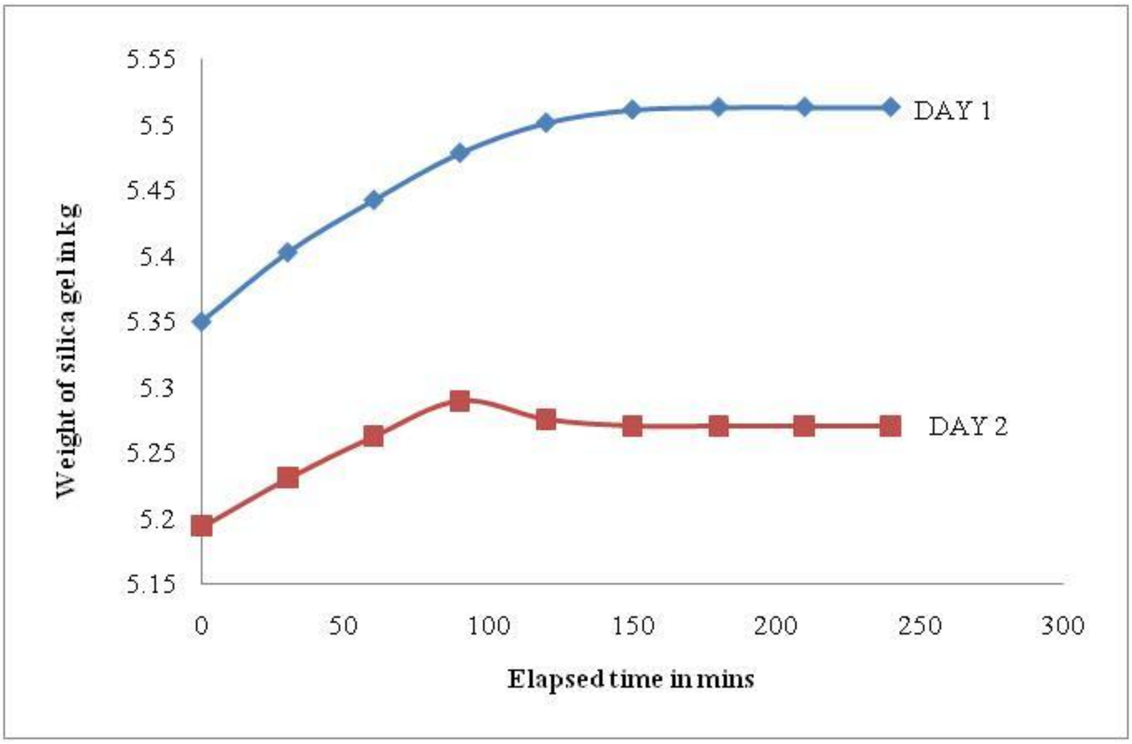

Fig 5.2: Variation in weight of silica gel vs. time interval during adsorption of silica gel

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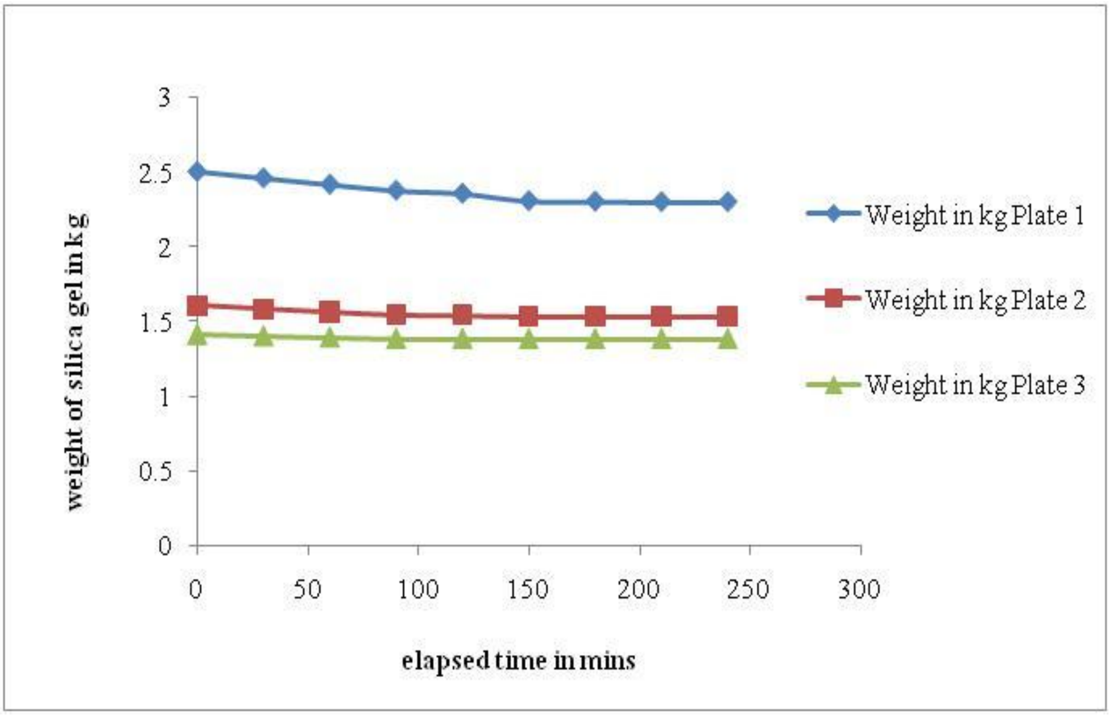

Fig 5.3: Variation in weight of silica gel vs. time on regeneration in each plate on day 1

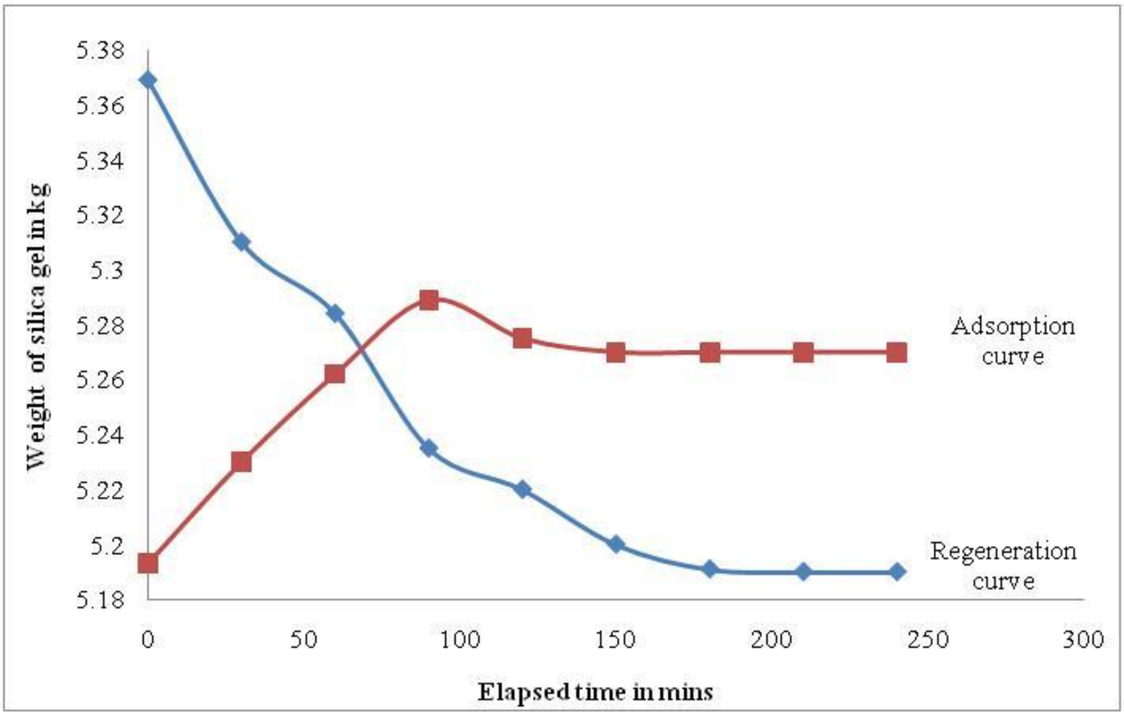

Fig 5.4: Variation in weight of silica gel vs. time interval on day 1

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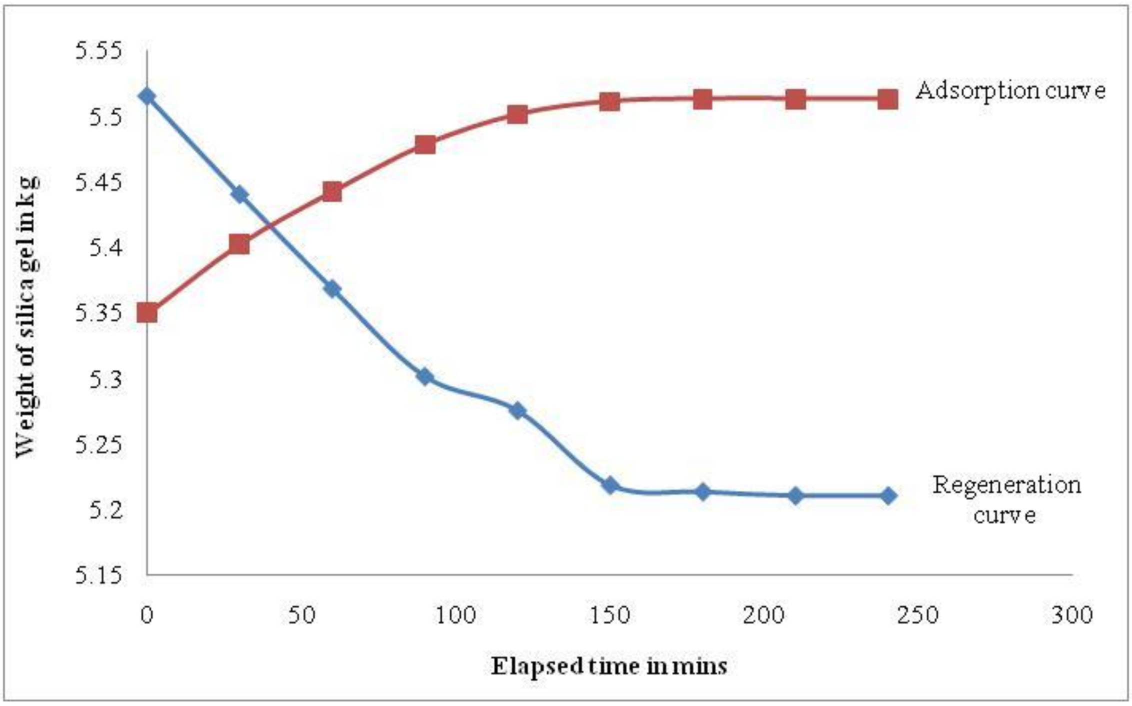

Fig 5.5: Variation in weight of silica gel vs. time interval on day 2

VI. DISCUSSION OF THE ANALYSIS

The four graphs represent the regeneration process and adsorption process in summer in the month of July. The experiment was performed for several days in different ambient conditions and from the analysis the maximum condenser waste heat temperature range was found to be 62^0C-64^0C and this heat is allowed to dry up the silica gel. From the above analysis, it is observed that the he silica gel has gradually decreased and finally became constant after a period of 4 hours. B y the end, the silica gel is completely regenerated and is capable of adsorbing moisture again. In the third graph, the variation in the weight of silica gel in each plate is represented and it is seen that the regeneration is more in the first plate than the other two plates. This is because the whole surface area of the first plate is exposed to the heat and the air pressure is also greater and then gradually decreases in the other two plates and is found least in the third plate. Similarly, a gradual increase in weight of silica gel is also seen from the adsorption curve and has attained a constant state after 3-4 hours which means that the silica gel is saturated with water vapour and is unable to adsorb further. Thus, the above analysis shows the feasibility of the condenser waste heat for removal of moisture from the solid desiccant.

VII. CONCLUSION

This study shows the solid desiccant, i.e., the silica gel can be regenerated by using 64^0C of heated air from the condenser of the air conditioner. The experiment was basically done to control humidity and to test the feasibility of the condenser waste heat from air conditioner for the removal of moisture from the solid desiccant i.e. the silica gel. Thus, it can be concluded that the exhaust heat from the condenser of air conditioner is reasonable to regenerate the desiccant material used which will make the system run at low operating cost.

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