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DESIGN AND ANALYSIS OF A TWO-STAGE ADSORPTION AIR CHILLER

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ABSTRACT

The objective of this article is to design and build a bio-friendly air-conditioner, by using adsorption method in the presence of 15% of calcium carbide in water. Aluminum sheet metals are used to form three identical tunnels, to pass the air for processing. Exhaust heat generated from the dairy sterilizing unit process is reutilized, for cooling the environment through this equipment. This equipment is designed, and the analysis is carried out to quantify the COP, SCP, and cooling power. Heat exchangers are designed; its Performance Parameters are quantified and correlated with the conventional designs. It is observed that the new adsorption chiller can produce the coefficient of performance of chiller as 1.068; the Specific cooling power of 10.66 (W/Kg); and the Cooling power of 4.2 KW. This equipment needs 0 to 15 minutes to reach the desired cool breeze (24˚c) from the existing room temperature (29˚c).

Keywords:

 Adsorption Chiller, Cooling Equipment

1. INTRODUCTION:

Air Conditioning by non-conventional method evolved due to environmental regulations in Montreal protocol in 1987, Kyoto Protocol in 1997, and European Commission Regulation 2037/2000. These regulations decided to reduce the contribution of CFC, HCFC, and HFC-134a and to mitigate its effects in the depletion of ozone layer, global warming [1]. Amidst the total energy generation, eighty percent of energy is generated from fossil fuels. It helps the majority of legislative initiative to address towards the energy saving and use of renewable energy [2]. Eighty-five percent of the European population is working in cities, and it increases the scope of advanced solar cooling in European cities.

It can help to save the energy in the range of thirty to fifty Mtoe and it reduces the energy saving up to eight percent of total consumption [3].

2. LITERATURE REVIEW:

2.1 AUTOMOBILE AIR COOLING

The potential utility of adsorption air conditioners in the automobile is identified and validated by a virtual model test [4]. Adsorption air cooling helps to reduce the use of ozone-depleting substances such as CFC, HCFC. They are quiet, durable and inexpensive to maintain it. Working pair utilized was palm-derived activated carbon with methane and the cycle time of twenty minutes with an average chilled air of 22.6 degree Celsius. While the cooling coil temperature operates in the range of 9.5 to 14.7 degree Celsius, the Coefficient of performance and specific cooling power are 0.19 and 396.6 W/Kg [1].

An adsorption air conditioner was developed to cool the passenger cabin of a bus, by extracting the waste heat from the diesel engine. The activated carbon and ammonia are treated as the original working pair with the Coefficient of performance (COP) and cooling power of 0.16 and 2.58 KW. In the second stage, activated carbon is compressed to a small density of 900 Kilogram per cubic metre and then it is mixed with an additional adsorbent [5]. Another attempt to develop an adsorption air conditioner for locomotive driver cabin was made by using a working pair of Zeolite and water. It extracts the exhaust heat, and it generates the cooling power of 3.0 to 4.2 kW and Coefficient of performance (COP) of 0.18 to 0.21 [6]. An empirical test was conducted for the application of air conditioner in the electric vehicles, and it is observed that air conditioning by compression technology is having high supremacy than the adsorption air conditioner with Coefficient of performance (COP) of 0.28 which uses Zeolite and water as working pair[7]. An experiment of the intermittent cooling system was developed with Zeolite-13X, water as working pair and finned double tube heat exchanger as the absorber. It extracts the exhaust heat from the diesel engine with Coefficient of performance (COP) of 0.38 and Specific Cooling power (SCP) as 25.7 W/Kg [8].

2.2 SOLAR REFRIGERATION

Adsorption refrigeration was carried out by silica gel-water as working pair driven by waste heat and it operates closer to ambient temperature [9]. In a cold storage system, an adsorption principle was adopted with Zeolite and water as working pair with the Coefficient of performance (COP) of 0.18 to 0.21 and cooling power of 3.0 to 4.2 KW [10]. Dual power source refrigerator is developed by combined solar thermoelectric adsorption air cooler with activated carbon-methanol as working pair [11]. An effort was made to develop a refrigerator operates on the multi-stage adsorption method, which was several times larger than the conventional type and it is highly impossible to fit in the passenger cabin of automobile [12]. Because of sizing and cooling capacity limitations, no working prototype has been feasible to be fit in the automobiles [13]. Analysis was made on the energy efficiency and economic feasibility of solar refrigeration used in ice making and cold production [14].

A solar ice maker was developed with the cooling power of 4 to 7 Kilogram per square meter and with the Coefficient of performance (COP) of 0.2 to 0.6 [15]. Usually solar cooling plants are used for refrigeration; nevertheless, it has the feasibility to couple with traditional solar plants for producing warm water for industrial and sanitary use for heating [16]. Many solar collectors are used for cooling in European countries and since 2007 more than 100's are used for cooling [17]. To reduce the impact of fluctuating intensity of solar radiation, the working temperature of the working fluid gets reduced and it is obtained by flat plate collectors or thermal effluents [18]. Another design of adsorption refrigerator was developed with three stage adsorption cycles and it works with an optimum

temperature of 90 degree Celsius [19]. Wang et al. developed a refrigerator, which operates within a range of -40 to +65 degree Celsius, which extracts heat from the low-level thermal source [20].

A seasonal cold storage indoors is developed with solar collectors, which operates only on broad daylight [21]. In a unique design of solar power absorption refrigeration system (SPAR), solar energy can be absorbed and stored as a chemical potential of the working fluid [22]. To improve the performance of solar air conditioner, a heat pump source, and flat plate collectors are added in which latter one as a replacement to vacuum tube collectors [23]. A solar refrigerator was developed by a team to process beef and pork in the food processing industries which can reduce the energy utility bill of 12000 pounds per year and it operates with the Coefficient of Performance (COP) of 1.15 [24]. Based on the environmental regulations, researchers from agriculture field started developing bio-friendly threshers [25].

3. DESIGN OF AN ABSORPTION CHILLER

3.1 EQUIPMENT USED

- Aluminum metal of grade 3003-H14 with the dimensions of 0.5 X 610 mm,
- 0.5 HP Self-Priming Motor,
- Bronze joints,
- Rivets, 10" Tin Cutter
- Two Exhaust fans,
- Miscellaneous (Burettes, Conical flasks, Calcium Carbides, Burette holders, Thermometers, Funnels, Cotton adhesive tapes 2", Rubber sheet black (1mm) -1.5 Kg, Rubber corks, Copper tubes, wire mesh, wire heating coil.)[26].

3.2 DESIGN DATA

Aluminium foils are rolled into four tunnels [Refer Fig(1)] with three similar sizes and one with dissimilar. Copper tubes (15mm) are used to construct exchange tubes.
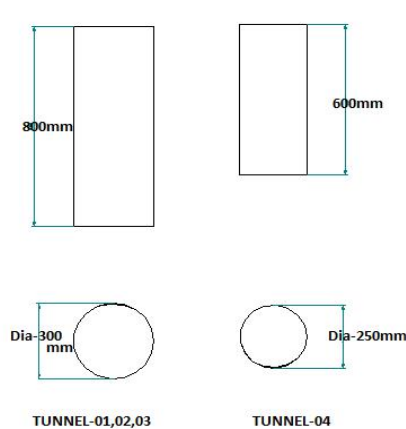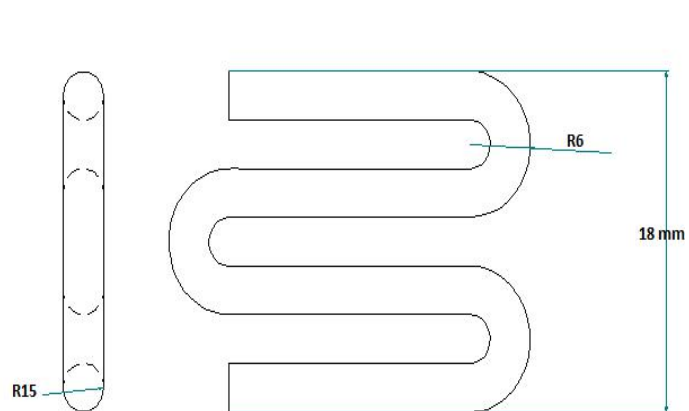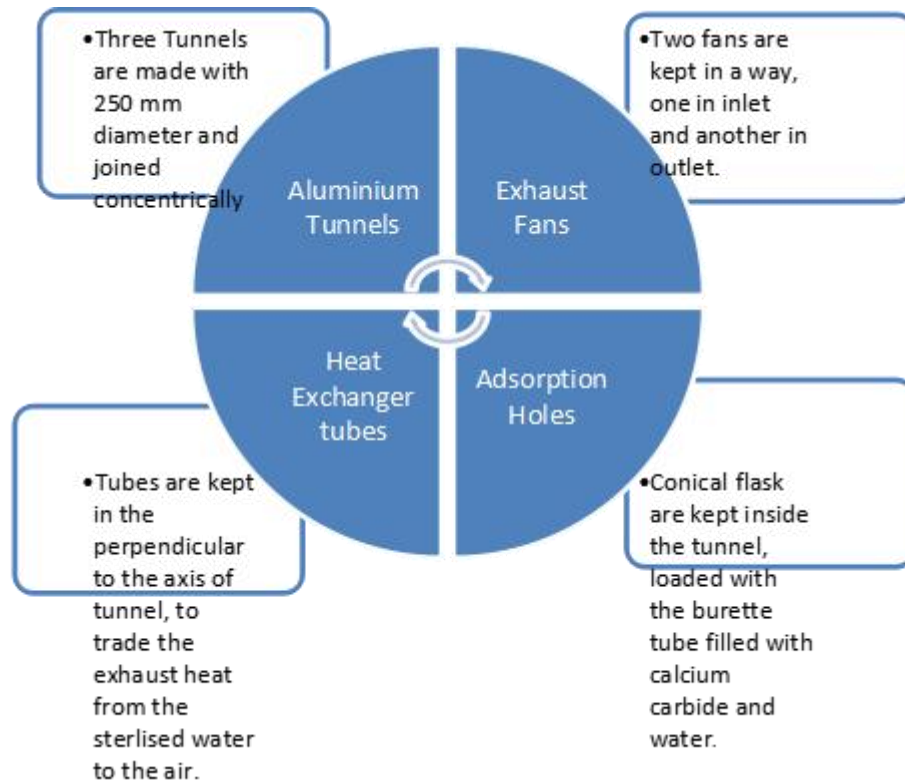

Figure 1: Tunnel Sizes [26]

Figure 2: Heat Exchanger Design [26]

3.3 ASSEMBLY STEPS [26]:

3.4 TESTIMONIALS

Figure 3 Heat exchanger tubes design [26]   **Figure 4** Project Display [26]

4. ANALYSIS:

TABLE 1 Comparative Study of various adsorption designs.

SNO	INVESTI - GATORS	HEAT SOURCE	WORKING PAIRS	COP	SCP (W/Kg)	Cooling Power (Kw)
1.	Present Study	Exhaust heat	Calcium carbide + Water	1.068	10.66	4.2
2.	Leo sing lim[1]	Exhaust heat	Activated Carbon + Methanol	0.19	396.6	0.635
3.	Aceves [7]	Electric heater	Zeolite/Water	0.28	--	--
4.	Zhang [13]	Exhaust heat	Zeolite 13X + water	0.38	25.7	--
5.	Wang et al [5]	Exhaust Heat	Activated Carbon + ammonia	0.16	--	2.58
6.	Lu et al [6]	Exhaust heat	Zeolite/Water	0.18-0.21	--	3 to 4.2

4.1 FORMULAE

- COP (Coefficient of Performance) = $\{(T_c)/(T_H-T_c)\}=\{(24+273.15)/[(29+273.15)-(24+273.15)]\}$ = 1.068

Specific Cooling Power (SCP) = $(Q_{ev})/(T_{cy}.M_{ac})$

Where Q_{ev} = Desired Room temperature after it pass through the evaporator.

T_{cy}=Cycle Time

M_{ac}= Mass of the adsorbed component

- SCP = $\{(24)/(15*0.15)\}$ =10.66 W/Kg

4.2 CALCULATIONS

Heat generation Amount by the customer machine=Q (Unknown)

Circulating fluid   = water

Circulating fluid mass flow rate (Q_m) = $(\varrho *Q_v)/60$ Kg/sec

Circulating Fluid (density) ϱ = 1 Kg/dm^3

Circulating Fluid (volume) flow rate (Q_v) = 10 dm^3/min

Circulating fluid specific heat capacity (C) =4.2*10^3 J/Kg/k

Circulating Fluid Outlet temp(t_1)= 29˚c= 302.15K

Circulating fluid Inlet temperature (t_2) = 24 ˚c= 297.15K

Circulating fluid return temperature (Δt) =5 ˚c=5K

Conversion factor : Minutes to seconds =60 S/minutes

- $Q= q_m *C*(T_2-T_1)$

- $Q= \{(\varrho *Q_v * \Delta t)/60\}$ =3.5 Kw

- Cooling capacity = Consider the safety factor of 20%

  = 3500 X 1.2

  = 4200 W = 4.2 Kw

TABLE 2 Experiment Data [26]

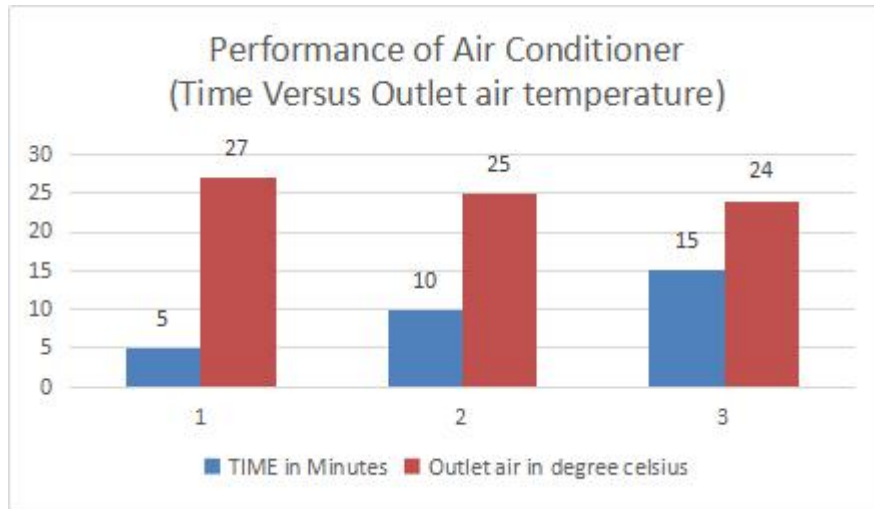| SNO	TIME (MINUTES)	INLET AIR(ºc)	OUTLET AIR(ºc)	STEAM TEMP (ºc)	COLD WATER TEMP (ºc)
1.	05	29	27	95	19
2.	10	29	25	96	18
3.	15	29	24	98	17

5.GRAPHS:

Figure 5: Adsorbing air conditioner Performance
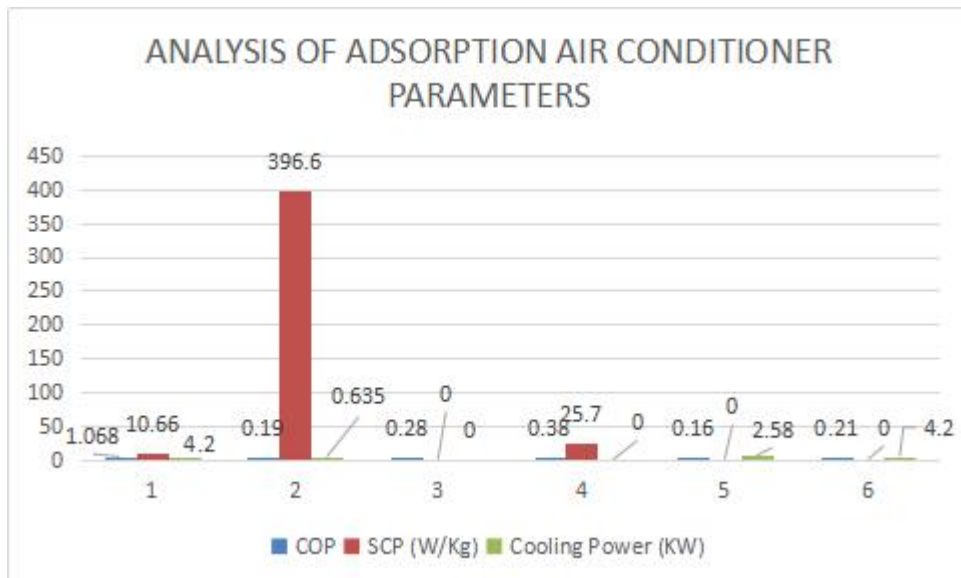

Figure 6: Plot for the Table-1 Values

6. RESULTS AND CONCLUSION:

The Graph-1 results, shown that decline in the outlet air temperature are directly proportional to operation time. It starts with 27 degree Celsius at the end of the 5th minute, and it progresses to 24 degree Celsius at the end of the 15th minute. The Graph-2 infers that the present study is executed with 10.66 W/Kg for the specific cooling power which is inferior to two designs of five, but it has the better performance in the cooling power. Thus, the adsorption air conditioner, have the ability to subside the heat waves without harming the ozone layer or by emitting poisonous gases. It complies with the environmental regulations made in the Montreal protocol in 1987, Kyoto Protocol in 1997, and European Commission Regulation 2037/2000. There are a lot of scopes to improve the COP, SCP, the Cooling power of adsorption air conditioner however without adding the size of the equipment.

APPENDIX:

- COP: Coefficient of Performance
- SCP: Specific Cooling Power
- HP: Horse Power
- VAC: Voltage of Alternate Current
- ˚C: Degree Celcius
- CFC – Chlorofluorocarbon
- HCFC –Hydro Chlorofluorocarbon.

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