

Feasibility Study of Sustainable Sweat Evaporative Fridge in Jorhat(26.75⁰n,94.22⁰e),Assam

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Abstract— This paper presents the feasibility study of sustainable sweat evaporative fridge in Jorhat, Assam. The first experiment was done on solar powered eco-fridge. The results obtained after one month observation indicated that the solar powered eco-fridge is not effective in Jorhat .The difference in atmospheric and inner temperature obtained was only about 2-3⁰ C. The factors affecting the performance were Relative humidity, Air temperature, Surface area of evaporation, Air movement. Amongst these the controllable factors are surface area of evaporation and air movement. Considering these factors the model was modified accordingly to bring about forced evaporation. The results indicated that there was a drop of temperature to 2-3⁰C above wet bulb temperature. Further in the third model the air was dried using silica gel to drop the wet bulb temperature inside the container. With this arrangement a temperature drop upto and also sometimes below the wet bulb temperature was achieved.

Keywords— sustainable sweat evaporative fridge, solar eco fridge, latent heat of vaporization, relative humidity, silica gel induced drying.

I. INTRODUCTION

Sweat evaporation occurs from the surface of a liquid into a gaseous phase that is not saturated with the evaporating substance. The amount of heat that is needed to evaporate the liquid is drawn partly from the air and evaporating surface. Thus the surface becomes cooler.

Evaporative cooling occurs at the surface. The heat needed to change phase is drawn from the surface and thus it can be used to cool without using much energy like common refrigerators.

II. LITERATURE REVIEW

Traditional evaporative cooling devices like Zeer pot, Traditional Matka have been around for many years.

In Nigeria Mr. Mohammad Bah Abba [1] designed a pot within a pot fridge. The fridge consists of two pots made of clay, one pot is within the other. The space between the pots is filled with sand and water is poured in it. When the water evaporates it takes the heat from the pot surfaces and thus lowers the temperature.

Emily Cummins [2] has developed a way of using the sun's power to help poor communities in Africa. Emily designed

a solar eco fridge modifying the traditional Zeer pot. Her fridge is quiet efficient in African countries.

Sreejith.K, [3] an Assistant Professor of Jyothi Engineering College, Kerela modified Emilys' Solar fridge and found that the model works at that environment.

III. NEED FOR SUSTAINABLE FRIDGE

Vapour compression refrigeration is most widely used method in common refrigerators. Here, the refrigerant is used as medium which absorbs and removes heat from the body and subsequently rejects that elsewhere. But it has many drawbacks

- 1) The compressor uses large power .Therefore energy is wasted and the efficiency is low.
- 2) Cost is high. Because of this the common people cannot afford a refrigerator.
- 3) Inflammability is another cause of disadvantage. The gas is highly inflammable and may cause accident.
- 4) Sometimes there may be leakage of vapour. This may cause depletion of ozone layer.

So, the need is to come up with an alternative-a sustainable fridge for developing areas like Assam . Fridge is one of the important household appliance nowadays for the common people. The main advantages of evaporative are-

- 1) Estimated cost of operation is low.
- 2) Power consumption is limited to the fan only, as there is no compressor.
- 3) The refrigerant is water unlike CFC, ammonia.
- 4) Ease of maintenance

IV. EXPERIMENTAL SETUP

A. Emily Cummins fridge reconstruction

The first experiment was done on Emilys' solar powered eco-fridge (Fig 1). The fridge is made up of two containers one within the other. Outer cylinder made of any material (wood/plastic) with holes drilled in the side. Inner cylinder is made of Aluminium and has no holes so that the contents remain dry. The gap between inner and outer cylinder is filled with a material such as sand, soil that can soak water. In hot weather the sun rays heats this wet material and the water evaporates. As the sand is held against inner cylinder wall heat is removed from the inner chamber by evaporation

process. Re soaking material with water will keep the fridge working (Fig 2).



Fig. 1 First Experimental Model

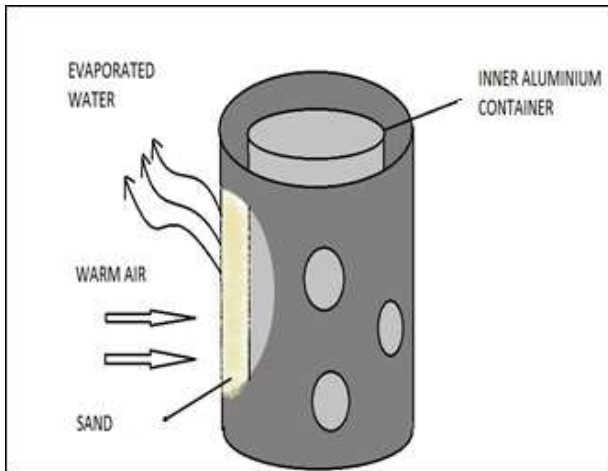


Fig.2 Sectional view of Solar Fridge

B. Observations

The apparatus is placed under various conditions like direct sunlight, shade and the variations of temperature inside the inner cylinder and outer temperature were noted down. Readings were taken for one month in September. From the readings it is seen that the solar powered eco-fridge is not that effective in Jorhat (26.75°N, 94.22°E), Assam due to the high relative humidity. The evaporation rate is not sufficient. The temperature difference obtained was only about 2-3°C. So the project needs to be modified and bring about forced evaporation.

C. Construction of Second Model (Modification of the First Model)

Major practical problems were Relative humidity, Air temperature, Surface area of evaporation and Air movement. Considering these factors the model was modified accordingly.

To increase the rate of evaporation certain modifications were made.

- 1) Fins are added to increase surface area of evaporation. After fin addition total surface area increased to 5534.4 cm² from 2006 cm² initial surface area.
- 2) The sand/clay mixture was removed since soil is not good conductor and may reduce the amount of cooling. The cylinder was then covered with coarse cloth like blanket which can soak the water and is in contact with the inner cylinder. Thus the latent heat of evaporation is directly taken from the inner container.
- 3) In order to increase the air flow, an exhaust fan was fitted to the outer container at the top (Fig 3). This was done to create suction and to decrease the pressure inside. Thus air will rush into the container through the holes.
- 4) A number of suction holes were made at the bottom part of the outer container for air to enter inside it (Fig 3).

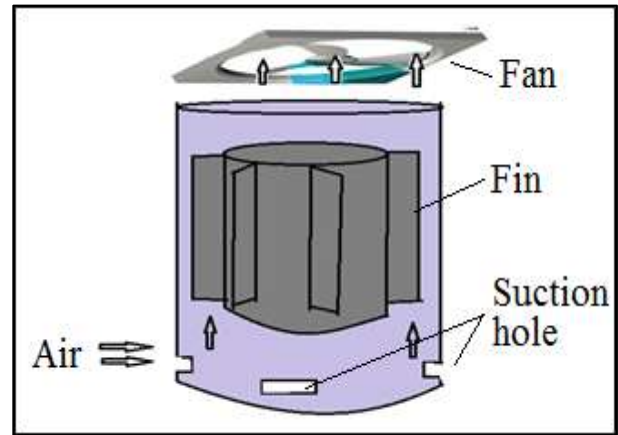


Fig. 3 Sustainable Sweat Evaporative Fridge



Fig. 4 Sustainable Sweat Evaporative Fridge

D. Observations of Second Model

The performance evaluation of the modified model was done in the month of February for about 20 days. The model was kept in shade after soaking in water and the ambient atmospheric temperature was noted. Then the fan was switched on and kept running for about 60 min. the subsequent inner container temperature and the wet bulb temperature of the atmosphere were noted down. The readings indicated a drop of temperature in the range of 8-9⁰ C. The experiment was done during February when the relative humidity was lower. So the wet bulb temperature was also low.

The total air flow was measured with anemometer and found to be 167.5×10^{-4} kg/s at STP.

During the initial testing of the second model, a certain phenomenon similar to *Coanda effect (Fig 5) was observed. The moist air coming out of the fan urges to enter the container again through the bottom holes, because of the convex body of the upper container. This may reduce the rate of evaporation. So modification is needed to eliminate this effect.



Fig. 5 Suction of Moist Air .

*Coanda effect – when a moving fluid comes in contact with a curved surface, it tends to stick to the curvature of the surface rather than moving in straight line.



Fig. 6 : Drift of air to Bottom

Also a secondary suction as shown in Fig 7 was observed at the top of the container.

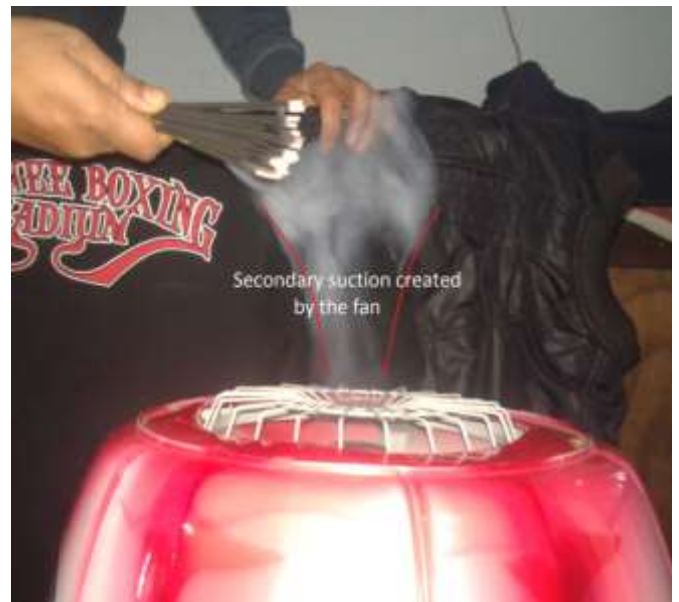


Fig. 7 Secondary Suction of moist air .

Possible Causes:

- 1) Contour of the upper surface creates an air current from fan exhaust to inlet holes.
- 2) Moist exhaust air being heavier than surrounding air comes to bottom.
- 3) Exhaust flow pattern of the air from the fan is swirling in nature, which causes a low pressure zone at the center, this establishes a secondary suction to the fan minimizing airflow through the system.

D. Construction of Third Model (Modification of the second Model)

The second model had certain drawbacks like the secondary suction. Moreover the exhaust air following the contour of the convex surface of the container to the bottom was again entering through the bottom holes thus creating a vortex. Thus the moist air was circulated again and again and so the evaporation rate was affected upto some extent. so the model was remodified.

The exhaust fan was enclosed within a container and fitted at the top of the bucket. This eliminated the vortex motion of the moist air. But the secondary suction is still there. Moreover in order to make the incoming air through the bottom holes dry reusable drying agent such as silica gel were used. This is referred to as silica gel induced drying (Fig 8 and Fig 9). This would drop the wet bulb temperature inside the container so that there would be further scope of cooling. So accordingly a round bowl was designed with two layers of thermocol where the silica gel layers were spread so that there is sufficient contact of the incoming air with the silica gel. The silica gel is made reusable by keeping it under sunlight to dry.

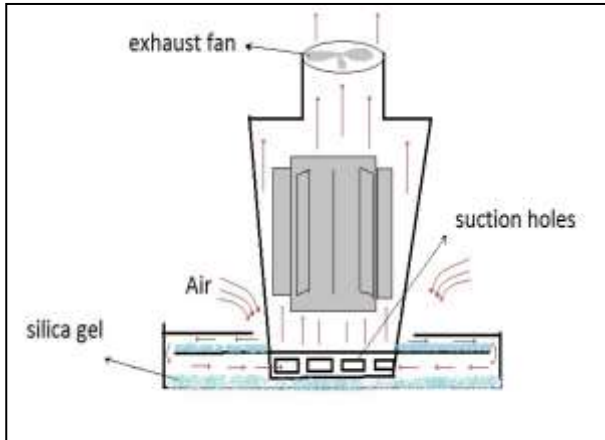


Fig. 8: Third model of sweat evaporative fridge



Fig 9: Third model of sweat evaporative fridge

F. Regeneration of silica gel

The silica gel used is self-indicating. Initially its colour is blue. After absorbing moisture it turns into violet. It can be regenerated by heating or keeping under the sun. but for better results a small flat plate solar heater (Fig 10) was constructed of thermocol for its regeneration.

It consists of a black coloured aluminium plate insulated by placing over a plywood with thermocol at the base and side. The silica gel was spread in the plate and covered with a glass and kept under the sun. The plate gets heated upto 80°C. The silica gel gets regenerated after about 120 min.



Fig. 10 Solar heater regenerating silica gel

V. RESULTS AND DISCUSSIONS

Readings of Emily Cummins model were taken for the month of September. From the readings in Table 1 (Annexure), it is seen that the solar powered eco-fridge is not that effective in Jorhat (26.75°N, 94.22°E), Assam due to the high relative humidity. The evaporation rate is not sufficient. The temperature difference obtained was only about 2-3°C. So the model was modified.

The various temperature readings for the second model were plotted as shown in Fig 12. It is seen that the inner temperature drops about 8-9°C. The experiment was done during February when the relative humidity is lower than summer. So the wet bulb temperature was low. But there was still a difference of about 2°C between the wet bulb temperature and inner container temperatures.

The readings of the third model were taken in March-April by keeping the fridge inside room and running it for about 60 min. from Fig 13 it is seen that there is significant drop of temperature compared to the outer atmospheric temperature. The silica gel was regenerated after use by heating it in a solar heater.

A. Performance of Drying Section

It is seen from table III that 350 gm of silica gel with a drying area of about $1550 \times 10^{-4} \text{ m}^2$ dropped the wet bulb temperature inside the container about 1°C .

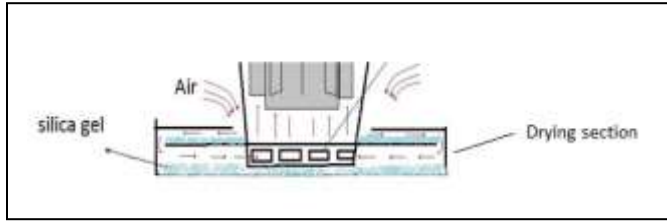


Fig. 11 Drying section of third model

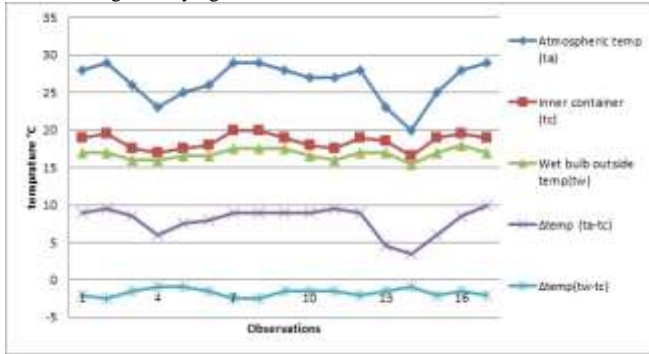


Fig. 12 Temperature variation graph of second model

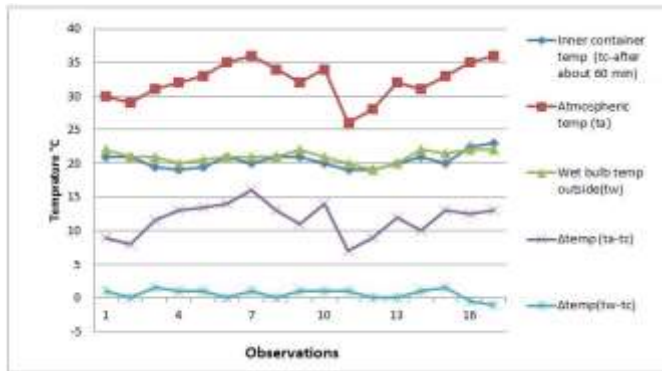


Fig 13. Temperature variation graph of third model

Another performance measure of evaporative cooling system is the approach temperature which is the difference in temperature between the obtained temperature (inner container temperature) and the entering-air wet bulb temperature (t_w-t_c). For the first and second model approach temperature is about 2 to 3°C . for the third model the approach temperature is zero and in some points also negative.

For Calculating Co-efficient of Performance (COP) , 1 ltr of water was cooled in the second and third model simultaneously for 15 min. The average temperature differences obtained from Table III (Annexure) were 7.58°C for second

model and 11.7°C for third model. The power (P) of the exhaust fan used in both the model is 45 watt.

$$\text{COP} = \frac{mC\Delta T}{P_t}$$

where, m= mass of water

Cp= Specific heat of water

ΔT = average change in the temperature of inner container

$$\text{COP}_{(\text{second model})} = 0.74$$

$$\text{COP}_{(\text{third model})} = 1.14$$

VI. CONCLUSION

The sustainable sweat evaporative fridge with drying section is successful in bringing the temperature of the container below or upto the wet bulb temperature. The drop in temperature is about $12-13^{\circ}\text{C}$. In areas with lower humidity the temperature drop in the fridge will be even more. Medicines, vaccines, cold drinks etc. can be kept at a temperature quiet lower than the ambient temperature. Vegetables can be stored for longer duration. The fridge will find wide application in Rural/Urban areas amongst lower income groups.

REFERENCES

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ANNEXURE

TABLE I.

OBSERVATIONS OF FIRST MODEL

Date	Time	Inner Temp (°C)	Outer Temp (°C)	Wet Bulb Temp (°C)
7 SEP	1.40 PM	29	32	27
	5.14 PM	28	30	
8 SEP	1.35 PM	31.5	33	28.5
	4.20 PM	30	32	
9 SEP	11.30 AM	29	30	26
	1.35 PM	27	31	
10 SEP	2.30 PM	28.5	31	26.5
	5.30 PM	29	30	
11 SEP	11.30 AM	32	33	27
	4.30 PM	30	32	
12 SEP	1.40 PM	27	29	27.5
	5.50 PM	27	28	
14 SEP	10.30 AM	28.5	30	26.5
	4.00 PM	27	30.5	
15 SEP	12.10 PM	30	32	28
	4.30 PM	30	31.5	
16 SEP	10.15 AM	26.5	27	25
	3.30 PM	27	29	
17 SEP	11.30 AM	29	30	27
	4.40 PM	29.5	31	
18 SEP	10.45 AM	28	29	27
	5.50 PM	28	30	
19 SEP	12.30 AM	28.5	32	26
	4.00 PM	27	31.5	
22 SEP	12.10 PM	29	30	27.5
	4.30 PM	29	31	
23 SEP	10.15 AM	27.5	27	26
	3.30 PM	27	28	
24 SEP	11.30 AM	30	31	29
	4.30 PM	31	34	
25 SEP	10.40 AM	28.5	30	26
	4.15 PM	28	29	
26 SEP	1.35 PM	32	33	27
	4.25 PM	31	33	
27 SEP	11.30 AM	29	30	26.5
	1.50 PM	27	30.5	
28 SEP	1.30 PM	32	34	27
	5.30 PM	30	32	
29 SEP	11.30 AM	28.5	29	25.5
	4.30 PM	28	29	

TABLE II.

OBSERVATIONS OF SECOND MODEL

Date	Temperature Readings (°C)				
	Atmospheric Temp (ta) °C	Inner Containr temp (tc- after about 60 min) °C	Wet Bulb outside Temp (tw) °C	ΔTemp (ta-tc) °C	ΔTemp (tw-tc) °C
1-Feb	28	19	17	9	-2
2-Feb	29	19.5	17	9.5	-2.5
3-Feb	26	17.5	16	8.5	-1.5
5-Feb	23	17	16	6	-1
6-Feb	25	17.5	16.5	7.5	-1
7-Feb	26	18	16.5	8	-1.5
8-Feb	29	20	17.5	9	-2.5
9-Feb	29	20	17.5	9	-2.5
10-Feb	28	19	17.5	9	-1.5
11-Feb	27	18	16.5	9	-1.5
12-Feb	27	17.5	16	9.5	-1.5
13-Feb	28	19	17	9	-2
14-Feb	23	18.5	17	4.5	-1.5
16-Feb	20	16.5	15.5	3.5	-1
18-Feb	25	19	17	6	-2
20-Feb	28	19.5	18	8.5	-1.5
21-Feb	29	19	17	10	-2

TABLE III

DATA COLLECTED FROM EXPERIMENTAL SETUP SECOND AND THIRD MODEL SIMULTANEOUSLY

Date	Temperature readings (⁰ C)						
	Atmospheric temp (t _a) ⁰ C	Inner Container Temp of Third Model(t _c) (after about 60 min) ⁰ C	Inner Container Temp of Second Model(t _n) (after about 60 min) ⁰ C	Wet bulb temp outside(t _w) ⁰ C	Δtemp (t _a -t _c) For 3 rd Model ⁰ C	Δtemp (t _a -t _c) For 2 nd Model ⁰ C	Δtemp (t _w -t _c) For 3 rd Model ⁰ C
27-Mar	30	21	25	22	9	5	1
28-Mar	29	21	23	21	8	6	0
29-Mar	31	19.5	25	21	11.5	6	1.5
30-Mar	32	19	23	20	13	9	1
31-Mar	33	19.5	24	20.5	13.5	9	1
1-Apr	35	21	26	21	14	9	0
2-Apr	36	20	25	21	16	11	1
3-Apr	34	21	25.5	21	13	8.5	0
4-Apr	32	21	26	22	11	6	1
5-Apr	34	20	25.5	21	14	8.5	1
6-Apr	26	19	22	20	7	4	1
7-Apr	28	19	23	19	9	5	0
8-Apr	32	20	24	20	12	8	0
9-Apr	31	21	25	22	10	6	1
10-Apr	33	20	25	21.5	13	8	1.5
11-Apr	35	22.5	26	22	12.5	9	-0.5
12-Apr	36	23	25	22	13		-1