ISSN 2250-3153

Energy Conservation through Roof Surface Evaporative Cooling for Air Conditioning System

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Abstract- Day by day the demand of energy is rising tremendously, but there is lack in supply. So there is no option for proper and efficient utilization and conservation of energy. In this paper the main stress is given on energy conservation by using technique of Roof surface evaporative cooling for Air-conditioning system. The target of saving and conserving energy up to 15 to 22% but in this case we achieved our goal of energy saving up to 13% by adopting RSEC technique.

Keywords- Appliance load, Cooling load, DCS Room, Evaporative cooling, Energy conservation, Thermal transmittance (U), Vfds

I. INTRODUCTION

Energy is a basic requirement for the existence and development of human life, primarily; the commercial sources such as fossil fuels (coal, oil and natural gas), hydroelectric power and nuclear power provide the energy needs of a country. The fear of release of radioactivity into the atmosphere in the event of an accident or from nuclear waste has forced people to reconsider the use of nuclear power. In view of these problems associated with conventional energy sources, the focus is now shifting to conservation of energy.

In a commercial building, the cooling load can be saved by about 26% in a hot and dry climate (like Jodhpur) by adopting appropriate design considerations and operation strategies. Simple design procedures such as orientation, shading, insulation, etc. can be easily incorporated in any building, leading to substantial benefits from the point of view of comfort and energy saving.

In some climates, simple techniques alone may not be adequate for achieving ideal comfort conditions. In such cases, advanced features such as wind tower, roof pond, Trombe wall, etc. may be used. Even in conditioned buildings, where mechanical devices are used to create a comfortable environment, the use of passive methods would help reduce the energy consumption (i.e. [1])

Technique of Roof surface evaporative cooling is used for reducing cooling load on air-conditioning system ultimately this technique serves purpose of energy conservation.

I. What is Roof Surface Evaporative Cooling (RSEC)

In a tropical country like India, the solar radiation incident on roofs is very high in summer, leading to overheating of rooms below them. Roof surfaces can be effectively and inexpensively cooled by spraying water over suitable water-retentive materials (e.g. gunny bags) spread over the roof surface(i.e.[1]).As the water evaporates, it draws most of the required latent heat from the surface, thus lowering its temperature and reducing heat gain. Besides, evaporation also cools the air above the roof. The cool air slides down and enters the living space through infiltration and ventilation, providing additional cooling. This is an example of the passive indirect evaporative cooling technique. (i.e. [1])

II. Procedure for Installing a Roof Surface Evaporative Cooling System:

Suitable waterproofing treatment of the roof should be done. The roof must be covered with water absorptive and retentive materials such as gunny bags, brick ballast, sintered fly-ash, coconut husk or coir matting. On account of their porosity, these materials when wet, behave like a free water surface for evaporation. The durability of such materials is rather good, but they have to be treated for fire safety.

During peak summer, the quantity of water needed is approximately 10 kg / day / m^2 of roof area. (i.e. [1])

The roof must be kept wet throughout the day using a water sprayer. The sprayer can be manually operated or controlled by an automatic moisture-sensing device. The sprayer usually works at low water pressure which can be achieved either by a water head of the storage tank on the roof, or by a small water pump.

III. Effectiveness of RSEC Depends on Ambient air temperature and humidity. Intensity of solar radiation. Wetness of the roof surface Roof type.

The effect of evaporation increases when the air humidity is low and the air temperature as well as the intensity of solar radiation falling on the roof surface is high. A uniform and constant wetting of the roof surface is essential for continuous evaporation. It should be noted that the roof needs to be adequately treated with water proofing material.

The evaporation of water causes cooling of the roof surface. This sets up a temperature gradient between the inside air and outside roof surface, resulting in loss of heat from the inside to outside. Thus, heat transfer through the roof is the dominant aspect in the overall performance of RSEC, Higher the rate of heat transfer, more effective is the RSEC. Consequently the

RSEC system is most effective when the roof has a high thermal transmittance (U). (i.e. [1]).

A Case Study of-Shree Renuka Energy Ltd
(30MW Co –Generation Project at Ichalkaranji.)

Here, RSCE technique is used to reduce cooling load of DCS room (Distributed control system). In this Co-gen.Plant we have DCS room of 19.8 Mtr.Long x 7.8Mtr.Width and 3.06Mtr Ht. having Terrace area-151Sq.Mtr. (e.g.Fig.1)

For this size room heat load calculations done as follows:

Under the steady state approach the heat balance for room air can be written as (i.e. [2]).

Q total = Qc + Qs+Qi+Qv – (1)

Now, Total heat conduction through each side wall +door +Glazing +Roof + Hard Board.

Qc Total =17.475 W

Total solar heat gain through wall

Qs = 10.422 W

Internal heat gain due to -Artificial light + Occupants + Appliance load.

In this case considering appliance load the major heat emitting source is VFD's (Variable Frequency Drive) used for various drives such as ID,FD,SA fan and Boiler feed pump.

Qi Total = 82,219 W

Now Heat flow rate due to Ventilation

Qv = 12,096 W

Now putting all calculated values in above eq'. - (1)

We get Q Total =1, 22,212 W = 122 kW.

For this DC's Room we have terrace area Total = 151 Sq.Mtr

For using RSEC technique for this area.

Total Gunny Bag Req. = 196 Nos

Also during peak summer the quantity of water required for sprinkling on terrace is Q water =1510 Ltr/ Day (Theoretical)
Q water = 800 Ltr/ Day (Actual).

Table I: List of Equipment's and Material Required for RSEC.

Item Name	Qty.	Cost in Rs.
Monoblock pump	01 Nos	1575.00
Drip Irrigation pipe with clips	65 mtr	730.00
Four – Arm Sprinkler with stand	01 Nos	230.00
1 ph Energy meter Range - 10-40 amp	01 Nos	1400.00
3 ph CT Meter Range – 200/5	01 Nos	3378.00
Gunny Bags (1100 x 700 mm)	196 Nos	3920.00
Ø 1" M.S. Pipe +Fabrication	06 Mtr.	590.00
Soft Pipes for water connections	13 mtr.	223.00
Plastic Barrel	01 Nos.	500.00
Miscellaneous Item		150.00
Total = Rs. - 12,696.00		

II. Experimental Set Up

Selection Criterion for Water Spray System

During our project work on Roof Surface evaporative cooling, the system adopted for this project such as sprinkler & drip pipe system. While selecting this it become a problem some, since total Area where we going to carry out experiments divided into two parts.

Part One – Plain Area of 51M^2 (out of 151 M^2)

Such area is open; there is no any restriction for using a water sprinkler system. There is no any steam line. So use of water sprinkler proved efficient way of spraying water on Gunny Bags. (e.g.Fig.3)

Part Two – Area of 100M^2 (Under steam pressure reducing station.)

This area is creating a headache to choose a water sprinkling system. Since near to this area main live steam line of 510^{0}c leading to main T.G. set so use of water sprinkler create a

horrible problem of steam joint leakage, so use of water sprinkler is out of use.

To overcome this problem we use here irrigation drip pipe systems for providing better wetness to Gunny bags.

The use of drip system proved a highly efficient & better way to overcome this problem. (e.g.Fig.2)

Necessary Measurements Recorded

During project – important parameters measured and recorded on hourly basis.

I) **During - with R.S.E.C. effect.**

- Measurement of Ambient temperature both dry and wet.
- Measurement of relative humidity.
- Measurement of DCS room temperature.
- Measurement of terrace slab temperature.
- Measurement of DCS room ceiling temperature.
- Water evaporation rate during day hours.
- Electrical Measurements
- Energy consumption by air conditioning
- Energy machine – for 24 hrs and day hrs. (8 hrs)
- Consumption by monobloc pump set during day hrs.

II) **During - without R.S.E.C. effect**

- Measurement of Ambient temperature both dry and wet.
- Measurement of relative humidity.
- Measurement of DCS room temperature.
- Measurement of terrace slab temperature.
- Measurement of DCS room ceiling temperature.
- Electrical Measurements -Energy consumption by air conditioning machine – for 24 hrs and day hrs. (8 hrs) For this Measurement, we used 3 Phase Energy Meter (CT Meter, Range-200/5)
- Energy Consumption by monoblock pump- For this Measurement, we used 1 Phase Energy Meter (1Ph.Meter, Range-10-40Amp)

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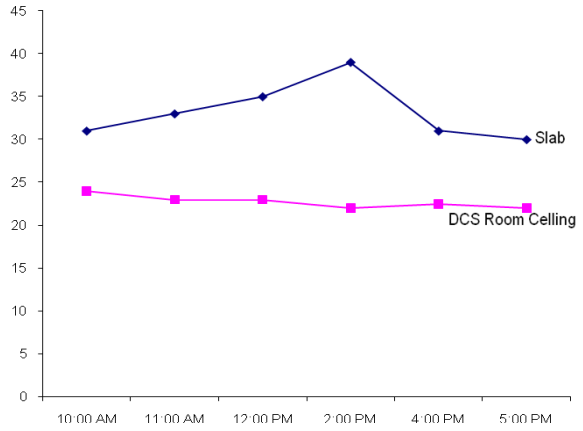
Fig 1: Entire view of DCS Room.

Fig 2: Drip irrigation pipes placed on roof top

Fig 3: Water Sprinkler used for plain area.

Following graph shows temperature behaviour with and without RSEC effct.(Temp.recorded during Day time from 8.0 AM to 05 PM)



(Temp ^{0}C Vs Time Hr.)

Fig 4: Shows temperature behavior with RSEC effect

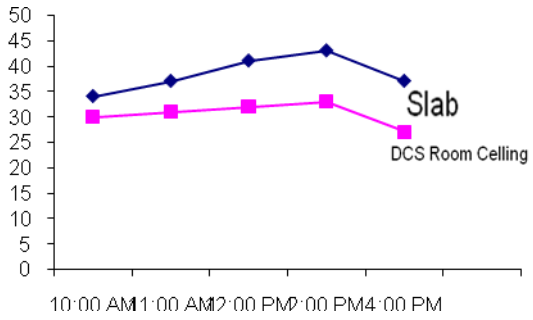


Fig. 5: Shows temperature behavior without RSEC effect.

III. Records of Temperatures

Temperature parameters were recorded carefully as per time schedule. The following observations were recorded.

Table II

Details	With RSEC	Without RSEC
Ambient temp.	44˚C	44˚C
Terrace slab temp	35˚C	42˚C
DCS Room ceiling temp.	23˚C	31˚C
DCS Room temp.	24˚C	25˚C
Energy consumed by A/C Machine	2,303 kWh (08 hrs.)	2.649 kWh (08 hrs.)

IV. Energy Saving Calculation

From observation sheets, we have following readings of energy consumption by A/C Machine &small pump.

Table III

Power Consumption (in kWh)

With RSEC Effect			Without RSEC Effect	
Day	Power Consumption by A/C 8Hrs.	Power Consumption by Monoblock Pump	Day	Power Consumption by A/C 8Hr
7/5/10	2,360	0.7	19/5/10	2,740
8/5/10	2,250	0.7	20/5/10	2,680
9/5/10	2,200	0.7	21/5/10	2,770
13/5/10	2,280	0.7	22/5/10	2,650
14/5/10	2,300	0.9	23/5/10	2,590
15/5/10	2,360	0.7	28/5/10	2,580
17/5/10	2,370	0.7	29/5/10	2,530
Avg.	2,303	0.72	Avg.	2,649

(Above Data collected from observation sheets.)

Energy consumed by A/C machine with RSEC effect =2,303 kWh /Day (08 Hrs.)

Also, Energy consumed by A/C machine without RSEC effect =2,649 kWh /Day (08 Hrs.)

Difference =2,649-2303
=346 kWh /08 Hrs.

Therefore, Net saving of Energy =346 kWh /08 Hrs. i.e. per day

% of saving of energy = 13.06 % per day

Assuming 150 Days of working Season (The RSEC system is more effective in the month of March, April, May& June.)

Then, Total Saving =346x150

Total Saving = 51,900 kWh /Season

Now such an energy consumed may be purchased from State Electricity Board at a Rate of Rs.8.10 per kWh

Total Saving =51,900 x 8.10

Total Saving =Rs. 4, 20,390 per Season

Now, investment done for achieving RSEC effect are shown in table no. I

1. It is presumed that gunny bags will be required fresh every year. Rests of the items are assumed to have a life of 3 years.
   Hence cost of items from table I per year = Rs. 6845/-
2. Cost of Electricity consumed by small pump
   (i.e. [4]) =1kWh/Day x8.10x150 =Rs.1215
3. Sprinkling water required-800 lit. /Day
   (Water charges as per Jeevan Pradhikaran Agency-Rs.10.20/1000 Ltr.)
   Hence, Cost of Sprinkling Water (i.e. [3]) =8.16x150= Rs.1224

Hence, after deducting the expenses incurred for implementing RSEC effect, the above costs from 1), 2), and 3) are deducted from total saving.

Net saving = Total saving – (expenses 1+2+3)
= Rs. 4, 20,390 – (Rs. 6845 +1215 +1224)
= Rs. 4, 11, 106/- per season

Net saving = Rs. 4, 11, 106/- per season

V. CONCLUSION

Historically sugar industry has been slow in its development and in adopting technology. However, in the recent past power shortage & other economical issues have forced technocrats and industry to use more efficient energy conservation system and cost reduction systems. The above paper highlights some efforts towards this direction.

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