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DESIGN AND DEVELOPMENT OF ICE POWERED AIR CONDITIONER

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Abstract - *Air-conditioners (AC's) have the largest share in the energy-consuming equipment in residential, administrative, commercial, and industrial buildings in various countries. The more energy consumed higher the cost of electricity bills. In countries like India, where AC's are mostly used in the summer or in the afternoon time (12 PM to 6 PM) due to higher surrounding temperatures. For producing comfort, the consumers operate their air conditioner units during the daytime that will increase peak demand, so fulfilling peak demands required more electricity that increases CO_2, SO_2, and NO_X emissions from the peak power plants. Therefore, it is preferable to cut the daytime peak demand and reduce carbon emission from the power plants and also make the air conditioner unit an energy storage device instead of the energy-consuming device. As a simple but innovative solution regarding power consumption by AC's and carbon emission through peak power plants "Ice Powered Air Conditioner" can be a better option with a cost-saving function.*

***Key Words*: Air Conditioners, Power Consumption, Peak Demand, Peak Power Plants, Emission, Ice Thermal Storage, Thermal Energy Storage, Ice Energy**

1. INTRODUCTION

According to "The Economic Times", the electricity demand in Gujarat has risen drastically because more people are switching on their AC units to get comfort in summer. The elevated temperatures on Tuesday increased the peak power demand up to 15,050 MW, the highest demand recorded in March for Gujarat.

On 19 May 2016, the demand for electricity reaches the highest and it was recorded at 15,142 MW. It is the second-highest peak demand recorded. The major cause of the surge in demand is residential and commercial consumers switched on their ACs and coolers for relief from extreme heat.

TSSPDCL (Telangana State Southern Power Distribution Company Limited) has reported that the electricity supply during peak winter months, December and January, are 41% less than the May and June summer season.

The TSSPDCL provides on an average nearly 65000 MW per day during the hot days in summer. This is reduced to 38000 MW and even less at the peak of winters.

As indicated by the article published in June 2018 "Down to Earth Magazine", Delhi's electricity demand has recorded its highest demand, climbing to a new peak of 6,934 MW, which was 6 percent above the last year's figure.

Although Delhi's electricity demand has surpassed the 2017 record four times since June 1, it has not been the hottest day in the summer. The previous record was 6,526 MW on June 6, 2017, which was a warmer day than June 8, 2018.

As per an analysis by the Center for Science and Environment (CSE) released in June 2018, there is a connection between the electricity demand, the surge in usage of ACs, the deficiency of centralized rules for the use of ACs, and the soaring temperature of summer result in the huge demand for electricity in Delhi.

The ice powered air conditioner is working on the concept of ice thermal storage that activates a refrigeration system that produces and store thermal energy employing ice or chilled water during the night when energy demand is low, additionally, this stored energy can be utilized to provide conditioned air to the room of the house.

1.1 Objectives

(1) To Reduce the Power Consumption and inturn Electricity Bill.
(2) Less Peak Demand = Less CO_2, NO_X, and SO_2 Emissions.
(3) Energy Conservation and Environmental Friendliness.
(4) Maintain the Low Temperature by Energy of Ice.

1.2 Methodology

"Ice Powered Air Conditioner" is based on the 'Ice Thermal Storage' in which cold heat of ice is transferred inside the indoor unit for air conditioning purposes.

Main components of ice powered air conditioner:

(1) Insulated Ice Storage Drum
(2) VCR System for Ice Making
(3) Three Fluid Heat Exchanger (Combination of Two Copper Coils)
(4) Glycol Pump
(5) Indoor Unit

Also, there are three kinds of fluids are used:

(1) Refrigerant (R134a)
(2) Ethylene Glycol (Antifreeze Liquid)
(3) Water (Phase Change Medium)

The working principle of ice powered air conditioner is based on two cycles:

(1) Refrigeration Cycle for Ice-making at Night-time
(2) Air Conditioning Cycle at Daytime

(1) Refrigeration Cycle for Ice-making at Night-time

There are four main components of a vapour compression refrigeration system, compressor, condenser, expansion device, and evaporator.

Here a capillary tube is used as an expansion device and copper coil-1 as an evaporator.

At night time, an insulated ice storage drum is used which is filled with water and contains two kinds of copper coils, copper coil-1, and copper coil-2.

The refrigerant R134a is used in the VCR system and first, it is passing through the compressor. The compressor compresses the refrigerant and after the pressure and temperature of that refrigerant increases and the refrigerant comes in the form of superheated vapour. Now, the refrigerant is coming inside the air-cooled condenser and it condenses inside it and comes in the form of saturated liquid.

After this, the refrigerant is expanded in the capillary tube, and suddenly decreasing pressure causes a decrease in temperature. Then refrigerant becomes cold and it is circulating inside copper coil-1 and it takes the heat from the water and freezes the water. It requires 7 hours for freezing the water and making the ice.

(2) Air Conditioning Cycle at Daytime

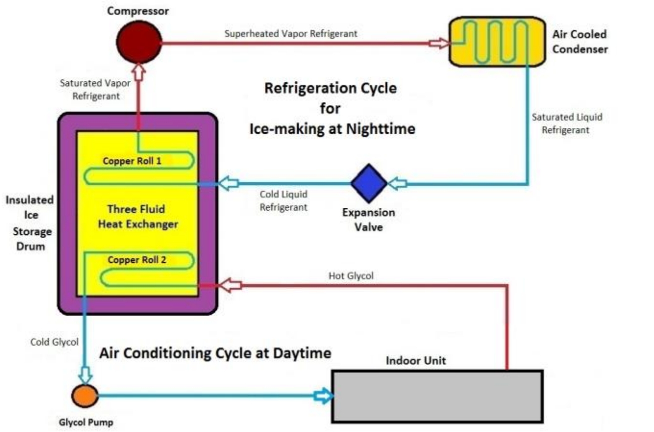
In the daytime, for air conditioning, we have main three components, indoor unit, glycol pump, and copper coil-2.

Now, we already have made the ice at night-time, and copper coil-2 is also submerged inside the ice.

Ethylene glycol is used as a coolant for exchanging the cold heat from ice to an indoor unit and a glycol pump is required that circulates the ethylene glycol through the indoor unit and copper coil-2 (inside the ice storage drum).

First, the ethylene glycol circulates inside the ice and it takes cold heat from ice and becomes cold, and then cold glycol is circulated inside the indoor unit evaporator by glycol pump.

When the cold glycol is flowing inside the indoor unit evaporator, then it takes the hot heat from the indoor air and reduces the temperature of the indoor air. We operate the air conditioner for 2 hours in the daytime.



Schematic Diagram of Ice Powered Air Conditioner

2. EXPERIMENTAL SETUP

2.1 Components of Ice Powered Air Conditioner

(1) Compressor

(2) Condenser

(3) Condenser Fan

(4) Capillary Tube

(5) Insulated Ice Storage Drum

(6) Glycol Pump

(7) Indoor Unit

(8) Three Fluid Heat Exchanger

2.2 Assembly of the Components

2.3 Actual Appearance of Ice Powered Air Conditioner

2.4 Observation Readings of Ice Storage Drum

Day	Temp. of Water (Tw)	Time	Temp. of Ice/Water mixture (Tiw)	Time	Reduction in Temp. of Water (ΔT = Tw - Tiw)
1	33 °C	11:00 AM	1.8 °C	5:00 PM	31.2 °C
2	34 °C	12:00 PM	1.8 °C	6:00 PM	32.2 °C
3	31 °C	9:30 AM	0.1 °C	4:00 PM	30.9 °C
4	33.7 °C	9:30 AM	0.2 °C	5:30 PM	33.5 °C

2.5 Observation Readings of Indoor Unit

Day	Temp. of Room (Tr)	Time	Temp. of Air at the inlet of Indoor Unit (Ti)	Temp. of Air at the outlet of Indoor Unit (To)	Reduction in Temp. of Indoor Air (ΔT = Ti - To)
1	37.8 °C	5:00 PM	37.8 °C	30.1 °C	7.7 °C
2	39 °C	6:00 PM	39 °C	30.1 °C	8.9 °C
3	38 °C	4:00 PM	38 °C	28.6 °C	9.4 °C
4	38.3 °C	5:30 PM	38.3 °C	29 °C	9.3 °C

2.6 Temperature Profile of Ice Powered Air Conditioner

Sr. No.	Fluid	Location	Temperature (°C)
1	Refrigerant R134a	Compressor Outlet	65.3
2	Refrigerant R134a	Condenser Inlet	65.3
3	Refrigerant R134a	Condenser Outlet	45.2
4	Refrigerant R134a	Capillary Tube Inlet	45.2
5	Refrigerant R134a	Capillary Tube Outlet	-21.3
6	Refrigerant R134a	Ice Storage Drum Inlet	-21.3
7	Refrigerant R134a	Ice Storage Drum Outlet	-15.7
8	Refrigerant R134a	Compressor Inlet	-15.7
9	Ice/Water Mixture	Ice Storage Drum	-2.4
10	Ethylene Glycol	Ice Storage Drum Outlet	2

11	Ethylene Glycol	Indoor Unit Inlet	2
12	Ethylene Glycol	Indoor Unit Outlet	9
13	Ethylene Glycol	Ice Storage Drum Inlet	9
14	Indoor Air	Indoor Unit Inlet	37 to 39
15	Indoor Air	Indoor Unit Outlet	28 to 30

3. RESULTS

3.1 Calculation of Power Consumption

(1) Normal Air Conditioner:

Cooling Capacity = 1 Ton (12000 BTU/h)
EER = 12.25 BTU/W

Power Consumption = 12000 / 12.25
= 980 W

Considering cut off function of compressor, during which consumption decreased by 10%
= 980 x 0.9
= 882 W

Power Consumption for 1 Hour = 882 W

Note: Compressor = 705.6 W (80 %)
Other Parts = 176.4 W (20 %)

Now, if we use for 2 hours, then power consumption will be:
= 882 x 2
= 1764 W (for 2 hours)

(2) Ice Powered Air Conditioner:

Cooling Capacity = 1 Ton (12000 BTU/h)

EER = Cooling Capacity(BTU/h) / Power Consumption(W/h)
= 12000 / 782
= 15.35 BTU/W

The below table represents the input power of each component of the ice-powered air conditioner. The voltage and ampere of each component are measured by multimeter, and after the help of equation (Power = Voltage x Ampere), we determined the input power.

Sr. No.	Parts	V	A	Input Power (W) P = V x A
1	Compressor	220	0.736	162
2	Condenser Fan	220	0.180	40
3	Glycol Pump	12	3.2	39
4	Indoor Unit Blower	220	0.160	35
5	Indoor Unit LED light	3	0.333	1

(1) Power Consumption in Air Conditioning Mode:

Note: Glycol Pump = 39 W
Indoor Unit Blower = 35 W
Indoor Unit LED light = 1 W

= 39 + 35 + 1
= 75 W

Power Consumption for 1 Hour = 75 W

Now, if we use for 2 hours, then power consumption will be:
= 75 x 2
= 150 W

(2) Power Consumption in Ice Making Mode:

Note: Compressor = 162 W
Condenser Fan = 40 W

= 162 + 40
= 202 W

Power Consumption for 1 Hour = 202 W

Now, we need 7 hours for ice making process, then power consumption will be:
= 202 x 7
= 1414 W

(3) Total Power Consumption:

= Daytime (Air conditioning mode for 2 hours) + Nighttime (Ice making mode for 7 hours)
= 150 + 1414
= 1564 W (for 2 hours)

3.2 Calculation of Coefficient of Performance (COP)

(1) Normal Air Conditioner:

COP = Cooling Capacity(W/h) / Power Consumption(W/h)
= 3517 / 980
= 3.588

(1) Ice Powered Air Conditioner:

COP = Cooling Capacity(W/h) / Power Consumption(W/h)
= 3517 / 782
= 4.497

3.3 Calculation of Energy Efficiency Ratio (EER)

(1) Normal Air Conditioner:

EER = Cooling Capacity(BTU/h) / Power Consumption(W/h)
= 12000 / 980
= 12.244

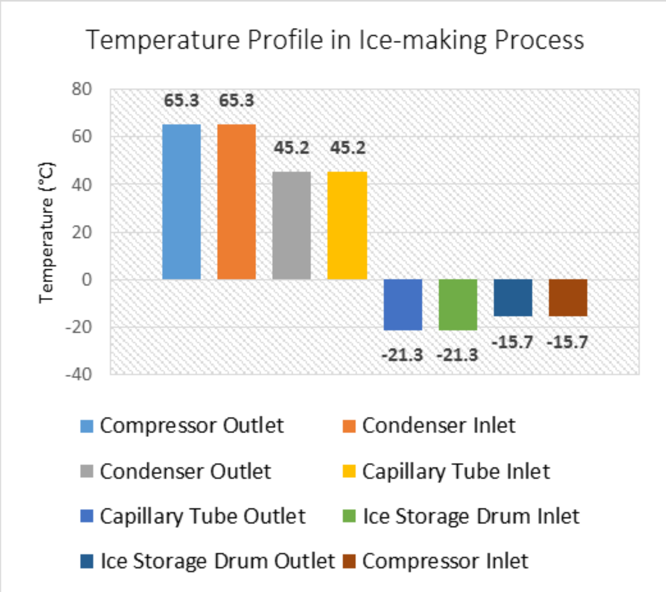
(2) Ice Powered Air Conditioner:

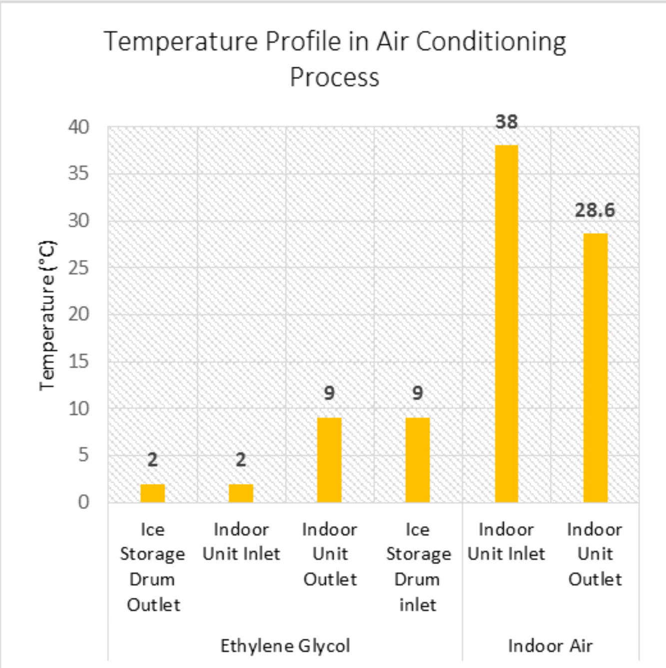
EER = Cooling Capacity(BTU/h) / Power Consumption(W/h)
= 12000 / 782
= 15.345

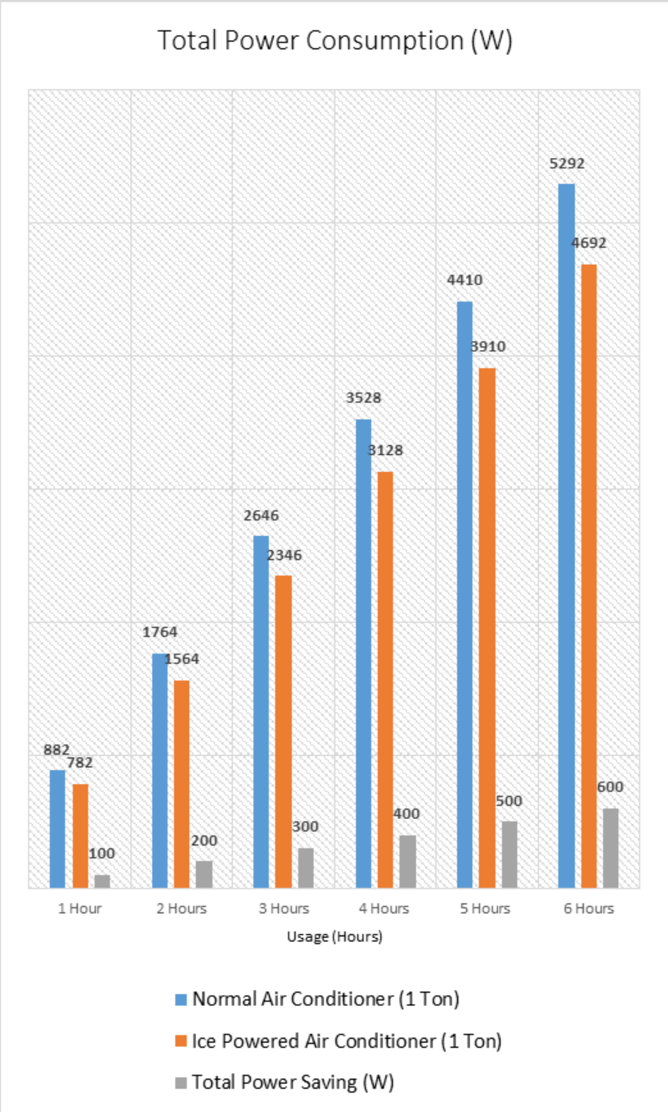
3.4 Power Ratings

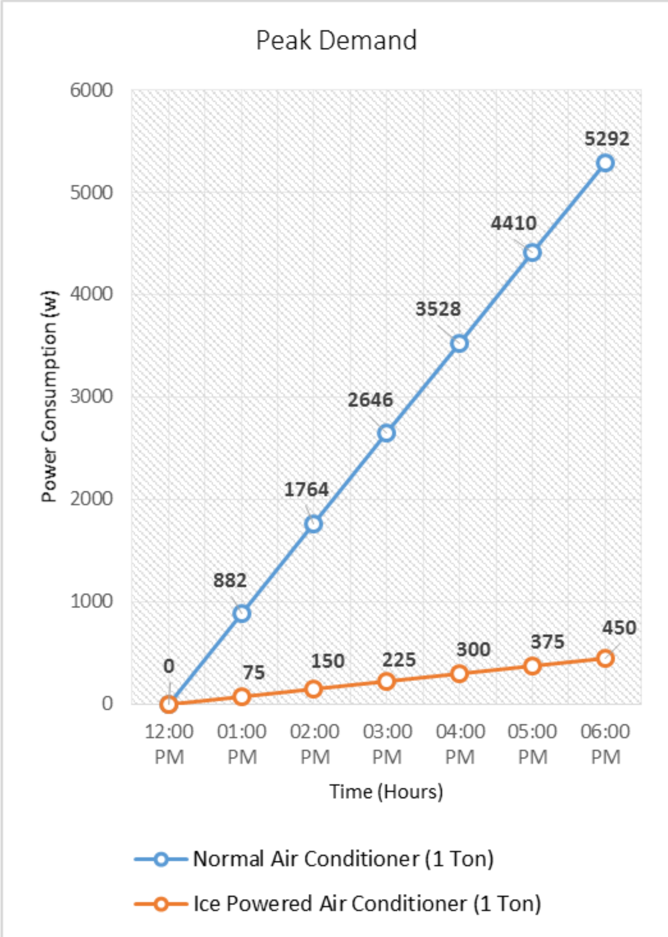
Sr. No.	Parts		Normal AC 1 TR	Ice Powered AC 1 TR	
				Ice making Process (Night time)	Air Condi. Process (Day time)
		Usage	2 Hours	7 Hours	2 Hours
		Power Rating	W		
1	Compressor		1411.2	1134	-
2	Condenser Fan Motor		140	280	-
3	Indoor Unit Blower		70	-	70
4	Glycol Pump		-	-	78
5	Others		142.8	-	2
	SUM. (+)	=	**1764**	**1414**	**150**
	TOTAL	=	**1764**	**1564**	

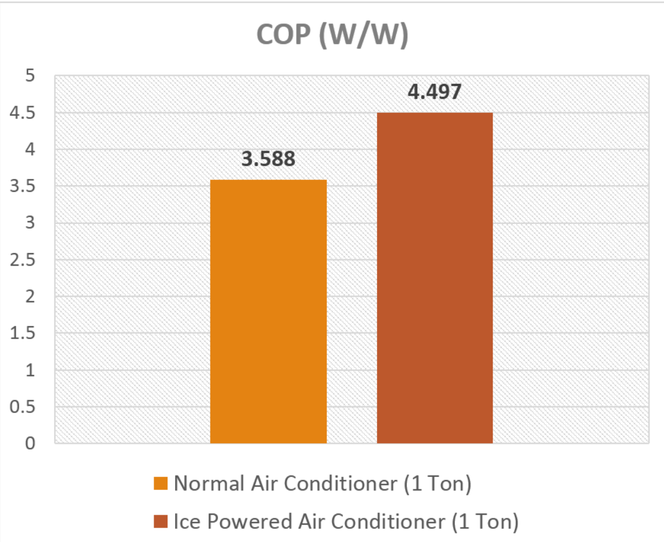
4. CONCLUSIONS

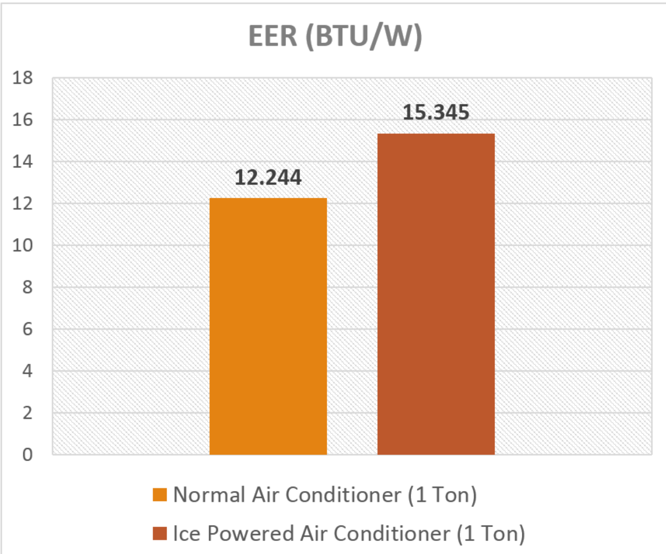





Total Power Consumption (W)
882
782
100
1764
1564
200
2646
2346
300
3528
3128
400
4410
3910
500
5292
4692
600
1 Hour
2 Hours
3 Hours
4 Hours
5 Hours
6 Hours
Usage (Hours)
Normal Air Conditioner (1 Ton)
Ice Powered Air Conditioner (1 Ton)
Total Power Saving (W)


Peak Demand
6000
5000
4000
3000
2000
1000
0
Power Consumption (w)
0
882
1764
2646
3528
4410
5292
75
150
225
300
375
450
12:00 PM
01:00 PM
02:00 PM
03:00 PM
04:00 PM
05:00 PM
06:00 PM
Time (Hours)
Normal Air Conditioner (1 Ton)
Ice Powered Air Conditioner (1 Ton)


COP (W/W)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
3.588
4.497
Normal Air Conditioner (1 Ton)
Ice Powered Air Conditioner (1 Ton)


EER (BTU/W)
18
16
14
12
10
8
6
4
2
0
12.244
15.345
Normal Air Conditioner (1 Ton)
Ice Powered Air Conditioner (1 Ton)

- The observation readings of the ice storage drum are taken during afternoon time when the atmosphere is hot and the temperature is too high around 37 °C to 39 °C, after that, we got impressive results. If we can take the readings in the nighttime when the atmosphere is cold and the temperature is around 30 °C, then the results will be very impressive.

- As per the power rating comparison, a Normal air conditioner of 1 TR cooling capacity which consumes 1764 W in 2 hours, and Ice powered air conditioner of 1 TR cooling capacity which consumes 1564 W in 2 hours and saves 200 W.

- The COP of ice powered air conditioner is 4.497 and the EER of ice powered air conditioner is 15.345.

- Ice-powered air conditioner saves overall power consumption by up to 100 W per hour (11%) and saves power consumption during peak demand by up to 807 W per hour (91%).

- Ice powered air conditioner reduces the temperature of indoor air by up to 10 °C and produces a comfortable temperature of 25 °C to 27 °C inside the room.

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