AN EVAPORATIVE HEATER USING SOLAR ENERGY

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INTRODUCTION:

The necessity to maintain thermal comfort conditions inside a built up environment has been emphasized by several authors [1-3]. Human body generates heat by the process of metabolism and it dissipates heat to its surroundings in order to maintain a nearly constant temperature for proper functioning of its inner organs. Various factors such as level of activity and clothing, temperature, humidity and speed of the surrounding air, and the temperature and distances of the surrounding surfaces determine the rate of heat dissipation from the human body. So, we may need a cooling device during the summers to avoid high room air temperature and humidity. Krishan Kant [4] has studied the possibility to achieve thermal comfort in summers by evaporative process. During winters, when the temperature and humidity of room air are low, a major portion of heat generated by human body (through metabolism) is dissipated by convection, radiation and evaporation of sweat from the skin. An excessively high rate of the heat dissipation leads to discomfort.

ABSTRACT

A simple evaporative heater using solar energy is proposed. It consists of a flat plate collector coupled with an evaporator. When the device is installed, with the receiver plate held in a vertical plane facing sun, its temperature rises. The heat entering the plate is transferred to the layer of water that falls along the back surface of the plate. The heated water is brought in direct contact with air and hence the enthalpy of air rises. This warm and humid air is supplied to a room to achieve thermal comfort during winters when the temperature and humidity of room air are below their comfortable values. The heater and the room are modeled by using computer simulations. Results are obtained for a typical room in a multistory building for the months of January in Delhi and Srinagar.

Key words **:** Thermal Comfort, Heating and humidification, Solar collector

Andersen, Franck, Nordstrom and others [5-7] have described the necessity to maintain proper level of humidity of room air during winters. Breathing dry air is a potential health hazard which can cause such respiratory ailments as asthma, bronchitis, sinusitis, and nosebleeds, or general dehydration since body fluids are depleted during respiration. Skin moisture evaporation can cause skin irritations. Low relative humidity causes ocular discomfort and eye itching. Irritative effects, such as static electricity which causes mild shocks when metal is touched, are common when the air moisture is low. According to ASHRAE Standard 55-1992 the level of relative humidity of room air should not be lower than 30%.

In cold and dry climates the temperature and humidity of room air fall below their thermal comfort values. Under such conditions, if an ordinary heater is used, the room air temperature increases but its relative humidity decreases and the resulting thermal condition may be uncomfortable as discussed by Krishan Kant and S.C. Mullick [8]. It was suggested in that paper that an evaporative heater can be used to increase both temperature and humidity of the room air and achieve thermal comfort. The results were illustrated through a case study for cold and dry climate of Srinagar and composite climate of Delhi in the month of January.

In the present paper a simple evaporative heater using solar energy is proposed. It consists of a rectangular flat plate collector (C) with an evaporator, (E), attached at the back of the absorber plate as shown in Fig. 1. The sides of the collector are properly insulated in order to minimize losses. The absorber plate is made of corrugated mild steel with its front surface painted black to improve absorptance for solar radiations. The

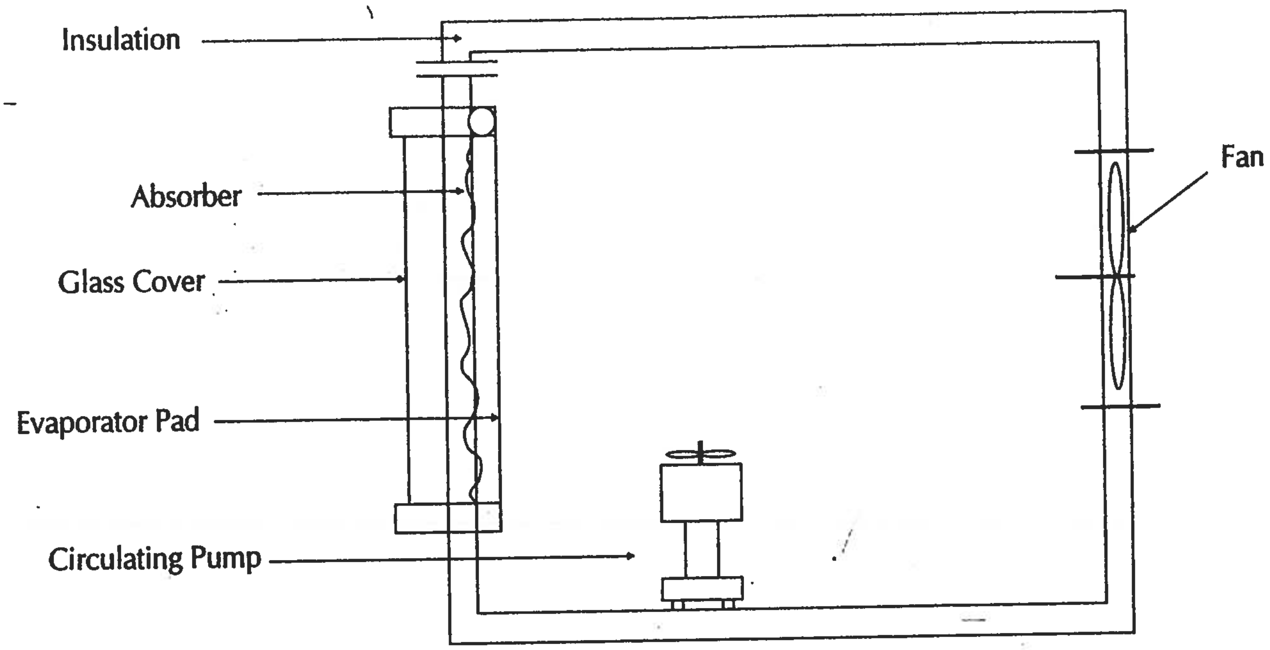


Fig. 1 The proposed evaporative heater

evaporator consists of a pad (P) which is similar to those used in desert coolers. There is an arrangement to re-circulate water through the pad after it gets heated while coming in contact with the absorber plate. Also, there is an arrangement to vary the area of the evaporator directly exposed to air. The air in direct contact with warm water gets saturated with water vapour at the temperature of the warm water. The condition of the air coming out of the evaporative device will depend on the temperature and humidity of saturated air at the interface and also the bypass factor. Thus we have

$$T_{SUP} = XT_A + (1-X)T_W$$

and

$$W_{SUP} = XW_A + (1-X)W_W$$

where

X = Bypass factor

T_A = Temperature of ambient air

W = Specific humidity of ambient air

T_W = Temperature of saturated air at the interface

W_w = Specific humidity of saturated air at the interface

T_{SUP} = Temperature of the supply air

W_{SUP} = Specific humidity of supply air

The performance of the evaporative heater is studied in this paper through a case study. It is assumed that the heater described above is fixed in a window in the south wall of a typical, thermally efficient room in a multistorey building. The room is 4m × 4m × 3m high consisting of insulated walls, ceilings and floor has been chosen as a repetitive unit in a multi-storey building. The walls consist of 101.6 mm concrete with 50.8 mm insulation and 12.7 mm finish. The U value of the structure is 0.693 W/m^2 K and its weight is 260 kg/m^2. It is assumed that the room has one 1.m × 1.m window in the south-facing exterior wall; all other walls and floor are interior partitions. Absorptance of exterior surface to solar radiation is 0.8 and reflectance of inner surface is 0.7. It is assumed that the room is occupied by two persons doing light work. It is also assumed that the radiative energy due to lights, equipment etc is 140W and the capacitance of room air and furnishings is 150 kJ/°C. The walls are modeled using the ASHRAE transfer function approach and simulations were carried out with a computer program, TRNSYS [9], for computing the hourly values of room air temperature and humidity. Transfer function coefficients are taken directly from the data file, ASHRAE.COF, provided with TRNSYS.

WEATHER DATA

For the present study, weather data for the months of December and January in Delhi, has been taken from the Handbook by Mani [10]. The handbook provides mean hourly values of solar radiation, ambient air temperature, relative humidity and wind speed based on a ten years' data.

Several authors have developed thermal indices, which take into account the combined effect of these factors.

Watt [11] has suggested Extended Comfort Zones (ECZ) which take into account the dry-bulb temperature (tdb), relative humidity (rh) and velocity (V) of air. According to the ECZ, relative humidity up to 80% and dry-bulb temperature depending on rh and V are acceptable. Its right- boundary line passes through the points (26.7 °C, 80% rh) and (31.1°C, 20% rh); whereas the left-boundary passes through the points (22.7 °C, 80% rh) and (23.3°C, 20% rh). The ECZ conditions are plotted in figure 2. The lines of 30% and 60% RH which are relevant for cold and dry conditions according to the ASHRAE Standards are also shown in the figure.

The temperature and humidity of air are not uniformly distributed in the room. Detailed distribution models have been suggested by scientists such as Chen et al [12]. The air in the occupied zone (which is at a lower height of the room) is cooler and drier than the air in the upper zone. The effect of non uniformity of temperature and humidity can be reduced by providing higher temperature and humidity of the supply air.

When the ambient air is brought in direct contact with warm water, its temperature and humidity rise. In the present study, it is assumed that the temperature of warm water is 20 °C for Delhi and 40°C for Srinagar and supply air flow rate is sufficient to provide one air change per hour for both cases (which is also the minimum fresh air requirement) for the room. The air in direct contact with warm water gets saturated with water vapour at the temperature of the warm water. The effects of the evaporative heating and humidification process in the month of January in Delhi (composite climate) and Srinagar (dry and cold climatic) have been examined.

RESULTS AND DISCUSSIONS

The effect of evaporative heating and humidification is shown in figures 2 & 3. Figure 2 shows the hourly values of temperature and humidity of room air in the month of January in Delhi. The supply air flow rate is 1 ac/h, the BPF is 80% and collector area is 0.5 m2. The temperature of warm water is 20 °C. With this combination, the room air condition is seen to be within the ECZ. In case of Srinagar the required collector area is 2 m2, supply air flow rate is 1 ac/h, the temperature of warm water is 40 °C and the BPF is 80%. The resulting room air conditions are shown in figure 3. The results are also plotted in Fig. 4 which clearly shows that room air conditions are brought in to the comfort zone described above. Figs. 5 and 6 depict the hourly values of solar energy available at the collector of the device in the month of January in Delhi and Srinagar respectively. The amounts of heat utilized are also shown in these figures.

CONCLUSION

A solar collector can be installed in the south window of a room to obtain thermal energy for heating water. The heated water can be brought in direct contact with room air to raise its temperature and humidity and provide thermal comfort in a room under cold and dry ambient air conditions.

Nomenclature

ACH number of air changes (ac/h)

BPF bypass factor (%)

DBT dry bulb temperature (°C)

WBT wet bulb temperature (°C)

RH relative humidity (%)

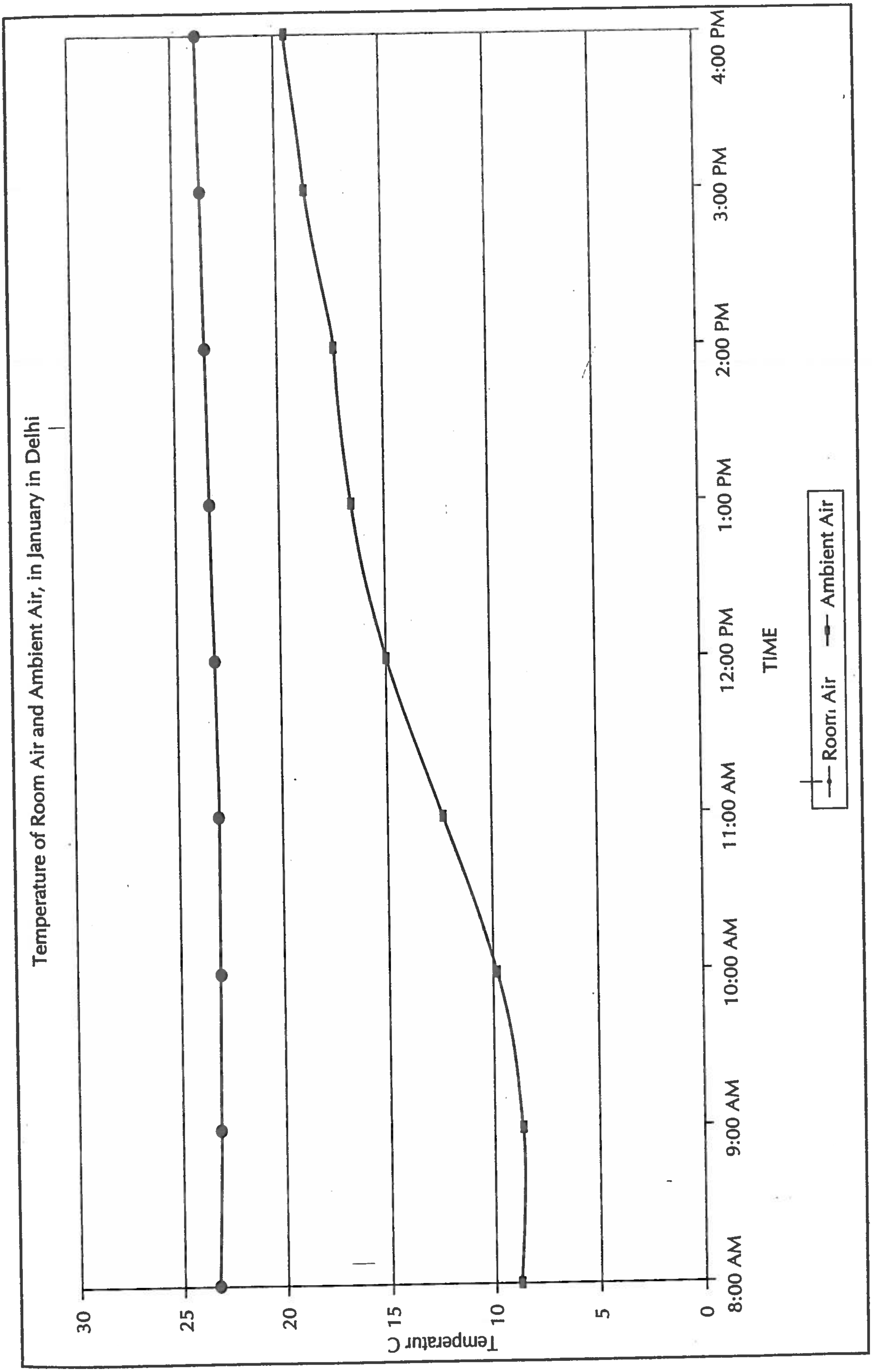

Temperature of Room Air and Ambient Air, in January in Delhi
30
25
20
15
10
5
0
Temperatur C
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
TIME
Room Air
Ambient Air

Fig. 2 (a)

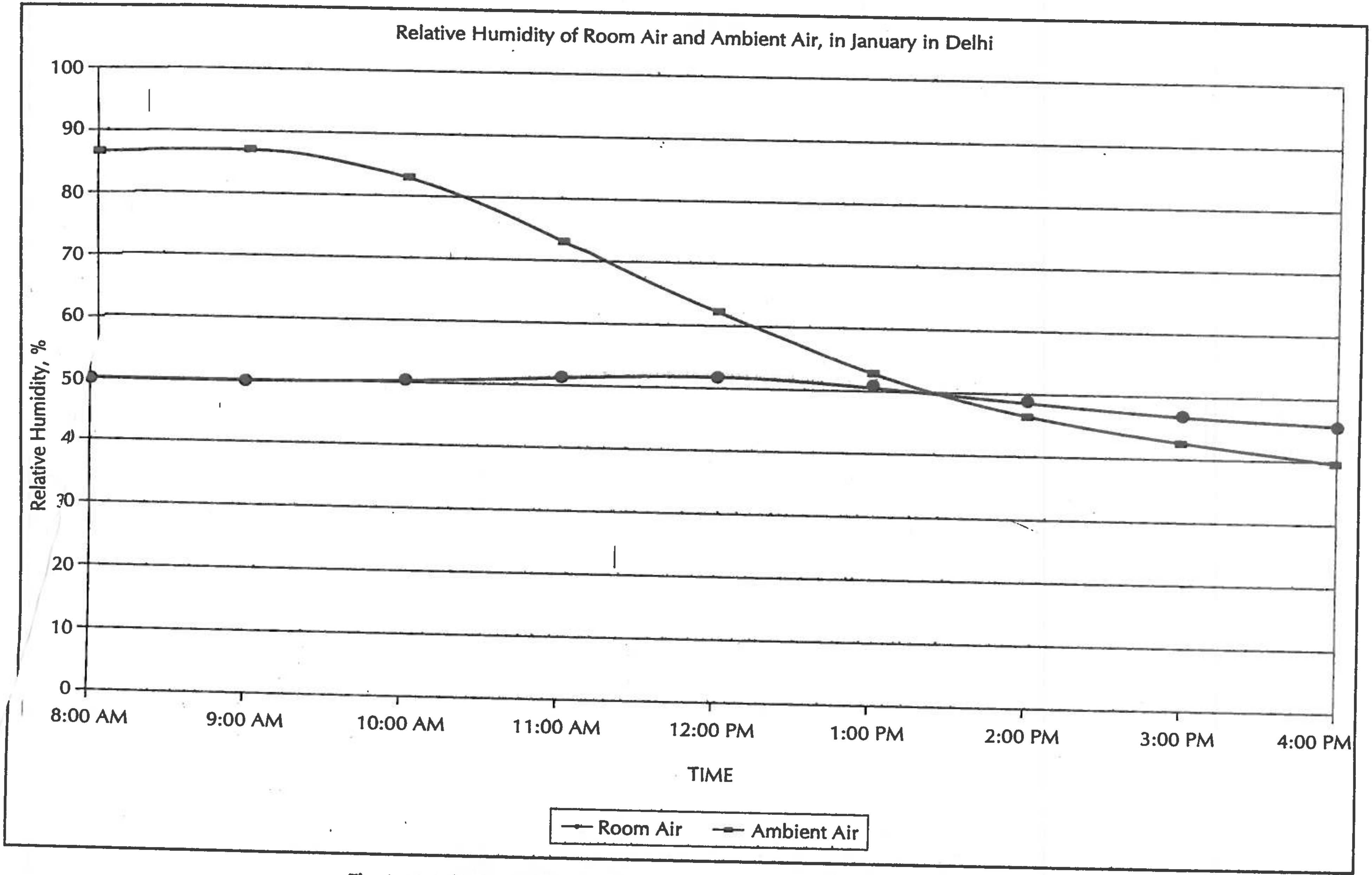


Fig. 2 (a) Relative humidity of room air and ambient air in January in Delhi

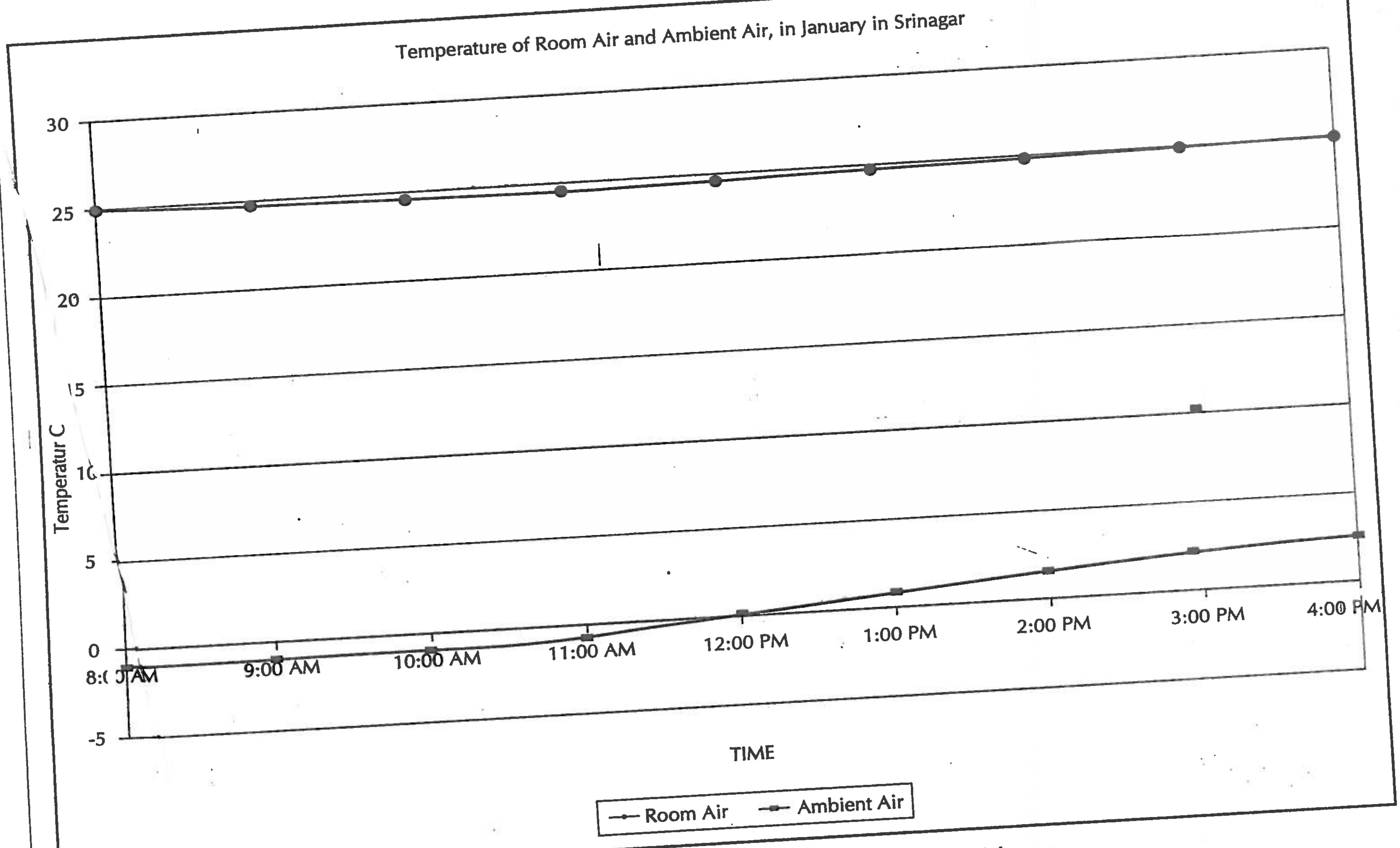


Fig. 3 (a) Temperature of room air and ambient air in January in Srinagar

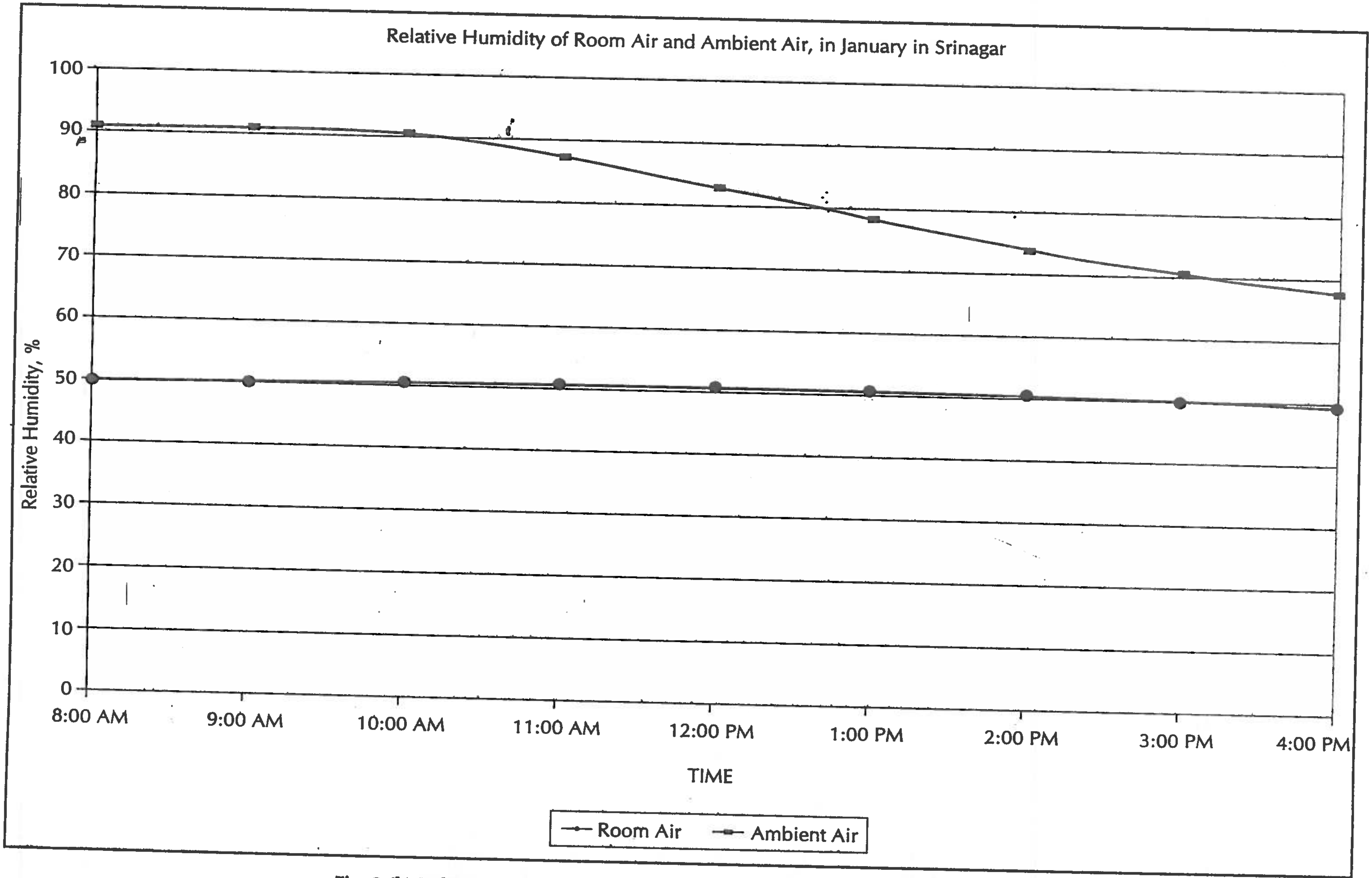


Fig. 3 (b) Relative humidity of room air and ambient air in January in Srinagar

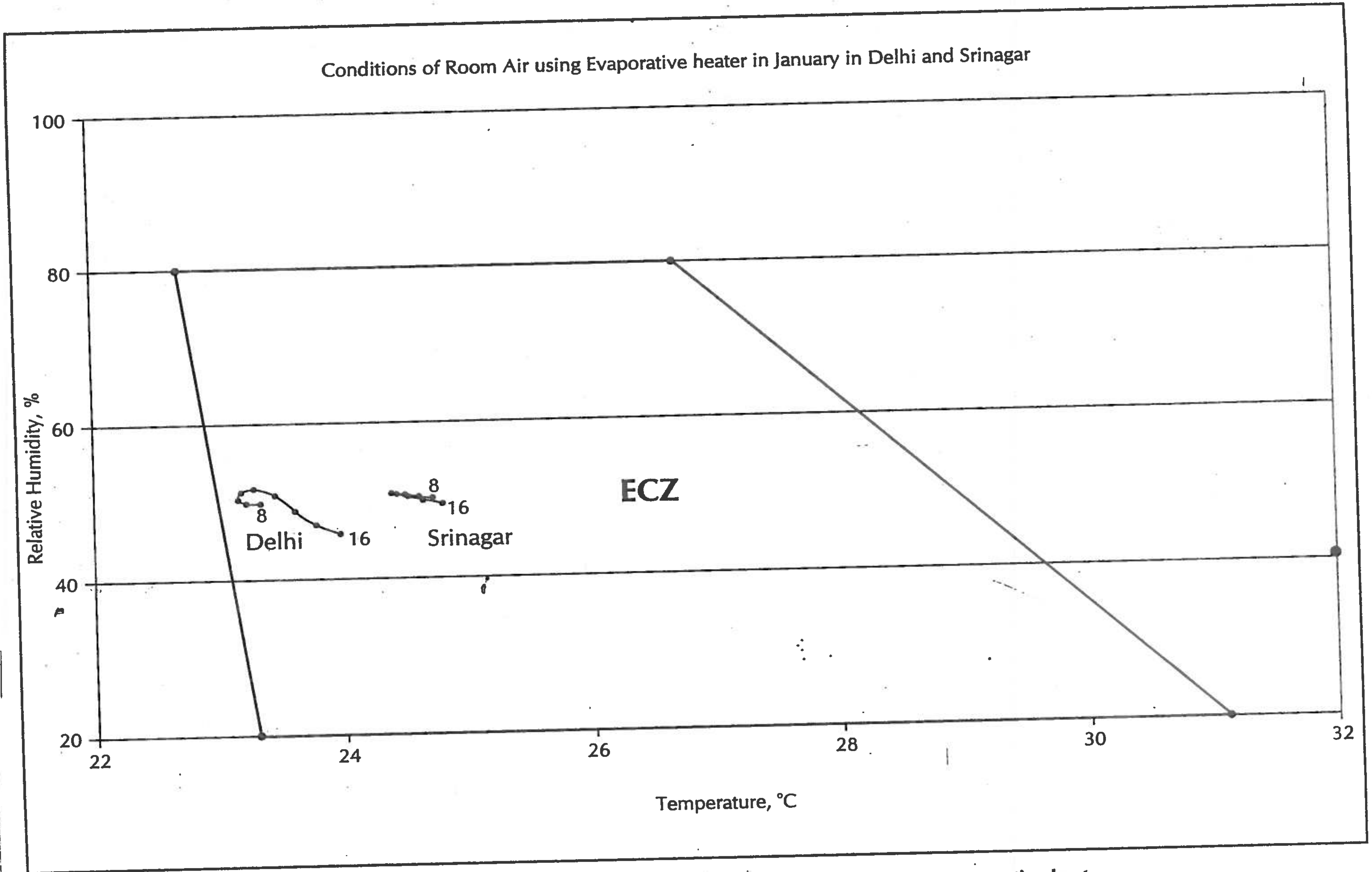


Fig. 4. Hourly values of temperature and humidity of air in a room using evaporative heater

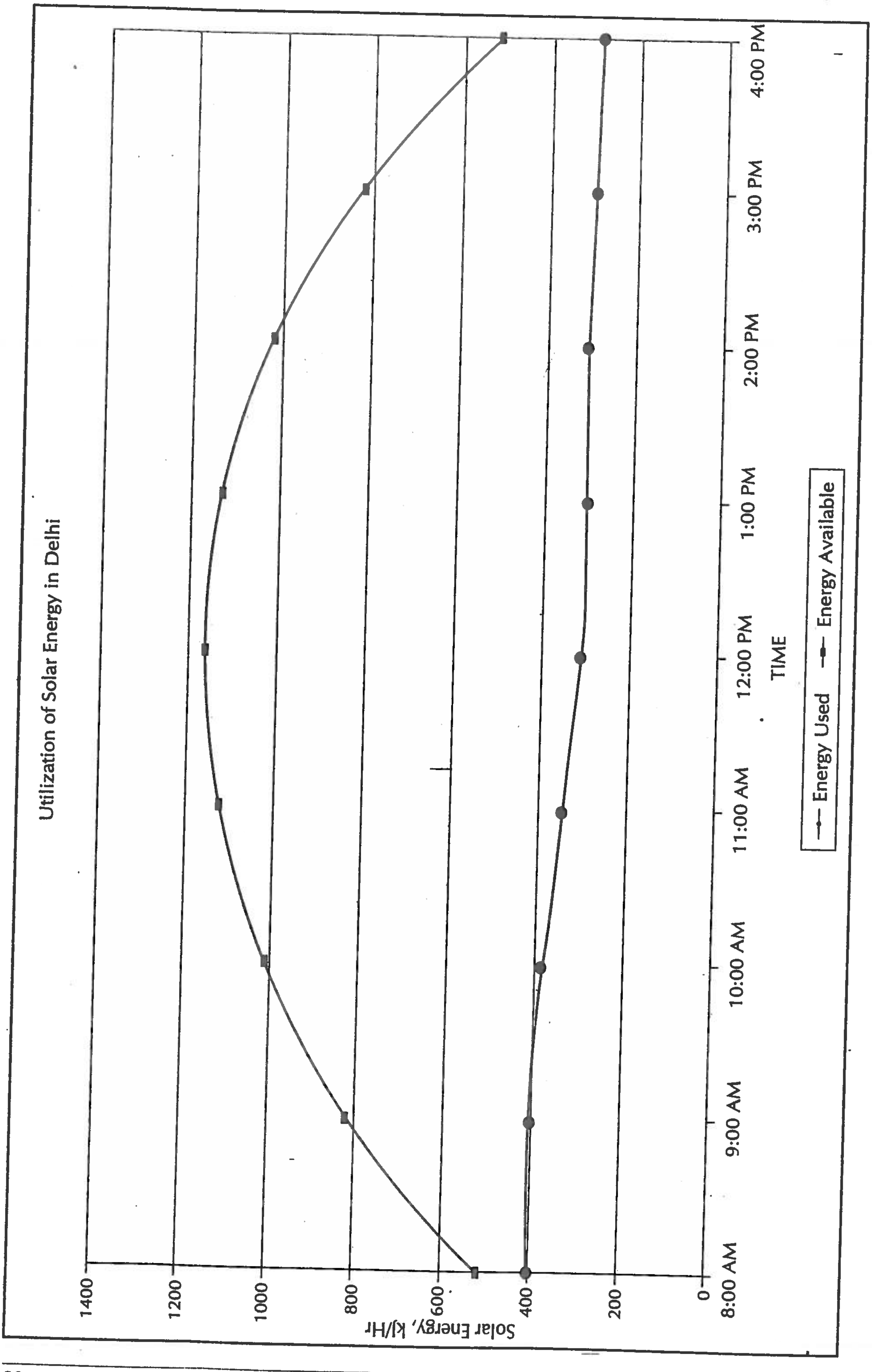
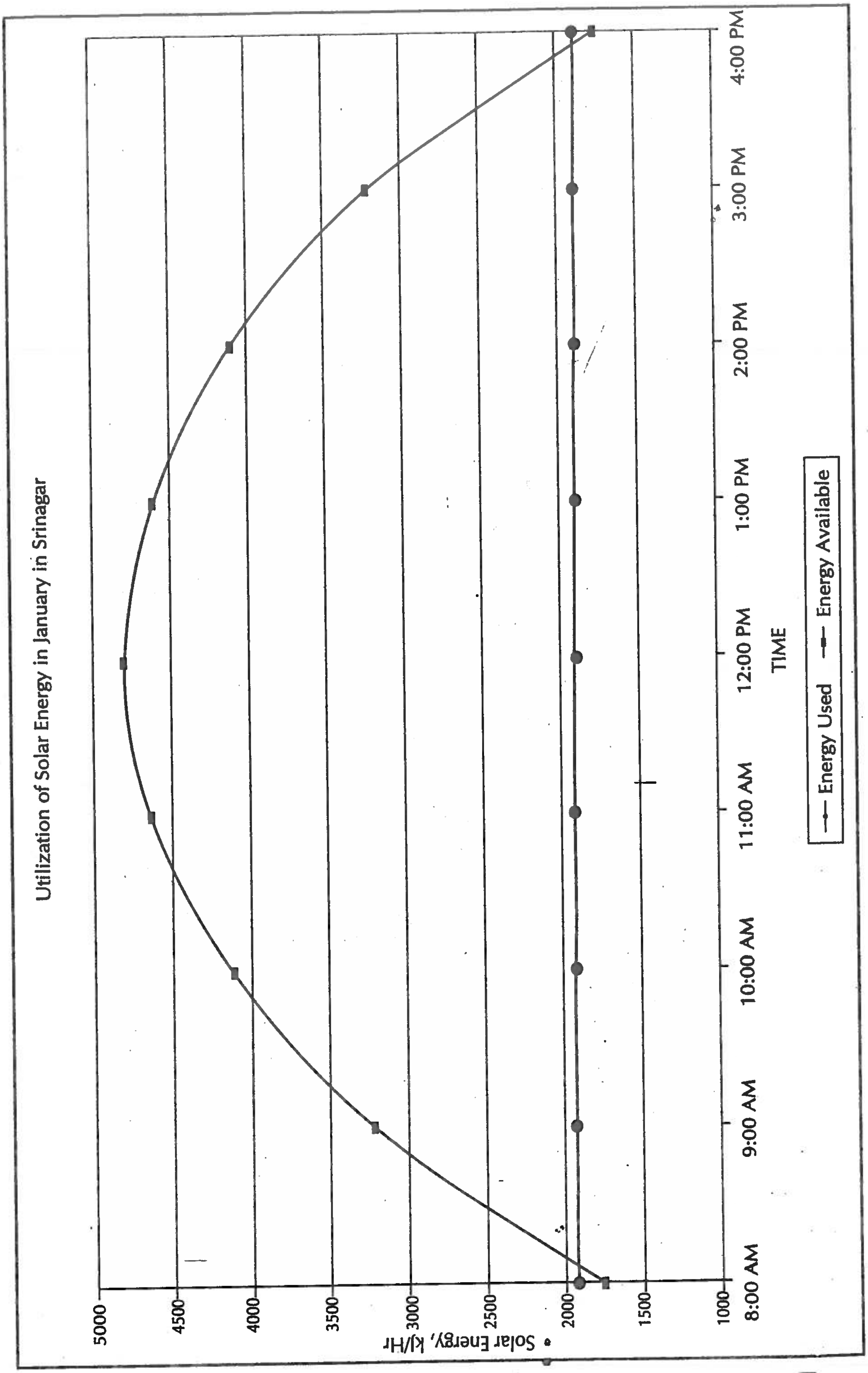

Utilization of Solar Energy in Delhi
Solar Energy, kJ/Hr
0
200
400
600
800
1000
1200
1400
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
TIME
Energy Used
Energy Available

Fig. 5



Utilization of Solar Energy in January in Srinagar
Solar Energy, kJ/Hr
5000
4500
4000
3500
3000
2500
2000
1500
1000
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
TIME
Energy Used
Energy Available

Fig. 6

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