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# Experimental Analysis of Earth Air Tunnel Heat Exchanger in Series Connection Operating at Transient Conditions Installed at Bikaner

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**ABSTRACT:** The Earth Air Tunnel Heat Exchanger is more economical and effective system to maintain air temperature comfortable to human body with respect to climate conditions. It is producing heating effect in winter and cooling effect in summer as it increases air temperature in winter and decreases air temperature in summer. In this research paper Thermal Performance of Earth Air Tunnel Heat Exchanger in Series Connection Operating at Transient Conditions installed at Bikaner was analyzed experimentally in the month of July & August over 8 days of period. Experimental setup of Earth Air Tunnel Heat Exchanger in Series Connection is installed at Mechanical Engineering Department Government Engineering College Bikaner having mild steel pipe of 45.67ft length, 40mm inner diameter and 3mm thickness placed at a depth of 11ft. The Average Air Temperature Difference for 8 working days was found as 11 °C, 12.13 °C, 13.26 °C, 14.52 °C, 15.65 °C & 16.87 °C corresponds to inlet air velocities 10m/s, 14m/s, 18m/s, 22m/s, 26m/s & 30m/s respectively. The Maximum Air Temperature Difference for 8 working days was found as 18.1 °C, 19.2 °C, 20.1 °C, 20.7 °C, 21.7 °C & 22.9 °C corresponds to inlet air velocities 10m/s, 14m/s, 18m/s, 22m/s, 26m/s & 30m/s respectively. The Minimum Air Temperature Difference for 8 working days was found as 5.2 °C, 5.9 °C, 7.2 °C, 8.1 °C, 9.1 °C & 10.1 °C corresponds to inlet air velocities 10m/s, 14m/s, 18m/s, 22m/s, 26m/s & 30m/s respectively.

**KEYWORDS:** Earth Air Tunnel Heat Exchanger, Winter Heating, Summer Cooling, Series Connection, Transient Conditions.

### I. INTRODUCTION

The energy consumption in commercial places like Hospitals, Industries etc. for Winter Heating and Summer Cooling has been increased during the decades. Energy saving is much important point everywhere, particularly in desert climate. The desert climate can be defined as hot & arid and such type of climate exists in a number of areas throughout the world. In India, climate of west Rajasthan is dessert. In general peoples feel comfort zone when the surroundings air temperature is kept between 20 °C to 26 °C and relative humidity or moisture content in the surroundings air is kept between 40% to 60%. Now a days, this is achieved by using Air-Conditioning mostly in the commercial places. Air conditioning system is mostly used for the comfortable summer cooling and winter heating as well as the industrial productions. Modern Air-Conditioning System works on Vapour Compression Refrigeration Cycle in which various refrigerants are used that defects the environment and ozone layer of earth. Due to the Ozone Layer Depletion & Global Warming by using Chlorofluorocarbons (CFCs) and the need to minimize high grade energy consumption various passive techniques are used now a day's introducing new method i.e. Earth Air Tunnel Heat Exchanger. An Earth Air Tunnel Heat Exchanger has one or more buried pipes which are placed under the ground in order to produce cooling effect in summer as well as heating effect in winter comfortable to human body with respect to climate conditions. The

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physics of Earth Air Tunnel Heat Exchanger is very simple: beyond a certain depth of earth, the temperature of ground remains comfortable to human body with respect to environment conditions which is kept constant throughout the year. This ground temperature is known as undisturbed temperature and remains hotter as compared to ambient air temperature in winter session and remains cold as compared to ambient air temperature in summer session. Therefore this is treated as cold or hot sink in summer or winter session respectively. Thus the Earth Air Tunnel Heat Exchanger becomes effective and economical for winter heating and summer cooling to reduction in energy consumption. There is no Global Warming & Ozone Layer Depilation in case of Earth Air Tunnel Heat Exchanger, since it uses fresh air as refrigerant and no Chlorofluorocarbons (CFCs) used in this as refrigerant. Several Researchers have described that the Earth Air Tunnel Heat Exchanger installed in a building is an effective and economical passive energy system for summer cooling and winter heating. The Thermal Performance of Earth Air Tunnel Heat Exchanger is dependent upon inlet air velocity, geometry of buried pipe, pipe material, climate conditions and mostly on soil thermo-physical properties.

## II. EXPERIMENTAL SETUP & METHODOLOGY

### 2.1 Description of Experimental Setup:-

Earth Air Tunnel Heat Exchanger in Series Connection has been installed at Mechanical Engineering Department Government Engineering College Bikaner Rajasthan India 334004 (28.0229°N, 73.3119°E). Since Soil temperature beyond 3 to 4 meters depth is kept constant[1]. Therefore the system was placed at a depth of 11ft. Mild steel pipes were used in the Earth Air Tunnel Heat Exchanger in Series Connection because of its lower cost, strength and durability. The total length of mild steel pipe was taken as 45.67ft. The Inner Diameter and Thickness of mild steel pipe were taken as 40mm and 3mm respectively. The Geometry of Earth Air Tunnel Heat Exchanger in Series Connection is Shown in Fig. 1.



Fig. 1. Geometry of EATHE in Series Connection (a) ANSYS Geometry (b) Installation of Setup (c) EATHE in Series Connection

### 2.2 Instruments Used:-

- i. The air temperature was measured by Digital Thermometer + 2-K-Type Thermocouples.
- ii. The air velocity was measured by Digital Vane Probe Type Anemometer.
- iii. Ambient air is forced through the buried Earth Air Tunnel Heat Exchanger in Series Connection pipe with the help of Cheston Air Blower of 550 Watt having six variable speeds regulator.

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### 2.3 Experimental Methodology:-

The experimental analysis was performed on the Earth Air Tunnel Heat Exchanger in Series Connection System in the month of July and August over 8 days of period operating at Transient Conditions which is installed at Mechanical Engineering Department Government Engineering College Bikaner. Experiments were carried out in the month of July and August from 9A.M. to 1P.M. i.e. I-Session & from 3P.M. to 6P.M. i.e. II-Session. Reading was taken every after one hour interval of time. Thus the readings were taken at time 9A.M., 10A.M., 11A.M., 12P.M., 1P.M. & 3P.M., 4P.M., 5P.M. and 6P.M. The system is kept shutdown from 6P.M. to 9A.M. (15 hours) for soil regeneration. The ambient air is forced through the buried pipe of system with the help of Cheston Air Blower of 550 Watt having speed regulator at different inlet air velocities (10m/s, 14m/s, 18m/s, 22m/s, 26m/s & 30m/s). The Ambient Air Temperature, Inlet Air Temperature & Outlet Air Temperature were measured by using Digital Thermometer + 2-K-Type Thermocouples. The Air Velocity is measured by Digital Vane Probe Type Anemometer.

### 2.4 Calculation of Experimental Results:-

Using experimental results, Temperature Difference ( $\Delta T$ ) was calculated for different inlet air velocities. Also Average Temperature Difference was to be calculated for different inlet air velocities.

- Temperature Difference ( $\Delta T$ ) is given by following equation:

$$\Delta T = T_1 - T_2 \quad (1)$$

- Average Temperature Difference ( $\Delta T_{avg}$ ) is calculated by following equation:

$$\Delta T_{avg} = \frac{\sum_{i=1}^{72} \Delta T}{72} \quad (2)$$

- Where  $T_1$  &  $T_2$  are Inlet & Outlet Air Temperature respectively.

## III. EXPERIMENTAL RESULTS & DISCUSSIONS

Inlet Air Velocity ( $V_1$ ) (m/s)	Minimum Inlet Air Temperature ( $T_{1min.}$ ) (°C)	Average Inlet Air Temperature ( $T_{1avg.}$ ) (°C)	Maximum Inlet Air Temperature ( $T_{1max.}$ ) (°C)
10	36.5	43.91	50
14	38.2	44.77	50.5
18	39.8	45.66	51.2
22	41.5	46.67	51.9
26	43.3	47.56	52.7
30	44.2	48.5	53.8

Table 3.1 Inlet Air Temperature Corresponds to Inlet Air Velocity

Inlet Air Velocity ( $V_1$ ) (m/s)	Minimum Outlet Air Temperature ( $T_{2min.}$ ) (°C)	Average Outlet Air Temperature ( $T_{2avg.}$ ) (°C)	Maximum Outlet Air Temperature ( $T_{2max.}$ ) (°C)
10	36.5	43.91	50
14	38.2	44.77	50.5
18	39.8	45.66	51.2
22	41.5	46.67	51.9
26	43.3	47.56	52.7
30	44.2	48.5	53.8

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Table 3.2 Outlet Air Temperature Corresponds to Inlet Air Velocity

Inlet Air Velocity (V <sub>i</sub> ) (m/s)	Minimum Air Temperature Difference ( $\Delta T_{\min.}$ ) (°C)	Average Air Temperature Difference ( $\Delta T_{\text{avg.}}$ ) (°C)	Maximum Air Temperature Difference ( $\Delta T_{\max.}$ ) (°C)
10	5.2	11	18.1
14	5.9	12.13	19.2
18	7.2	13.26	20.1
22	8.1	14.52	20.7
26	9.1	15.65	21.7
30	10.1	16.87	22.9

Table 3.3 Air Temperature Difference Corresponds to Inlet Air Velocity

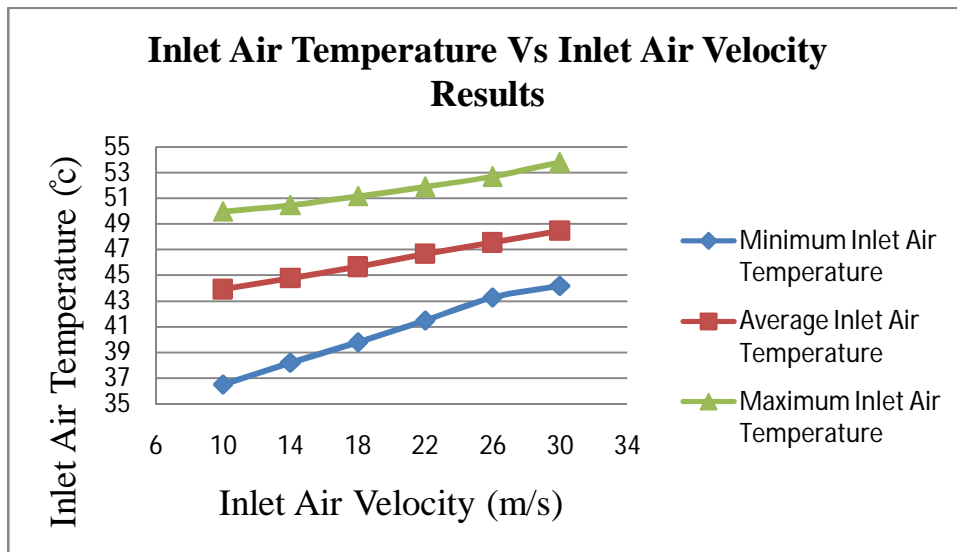


Fig. 2. Inlet Air Temperature Vs Inlet Air Velocity

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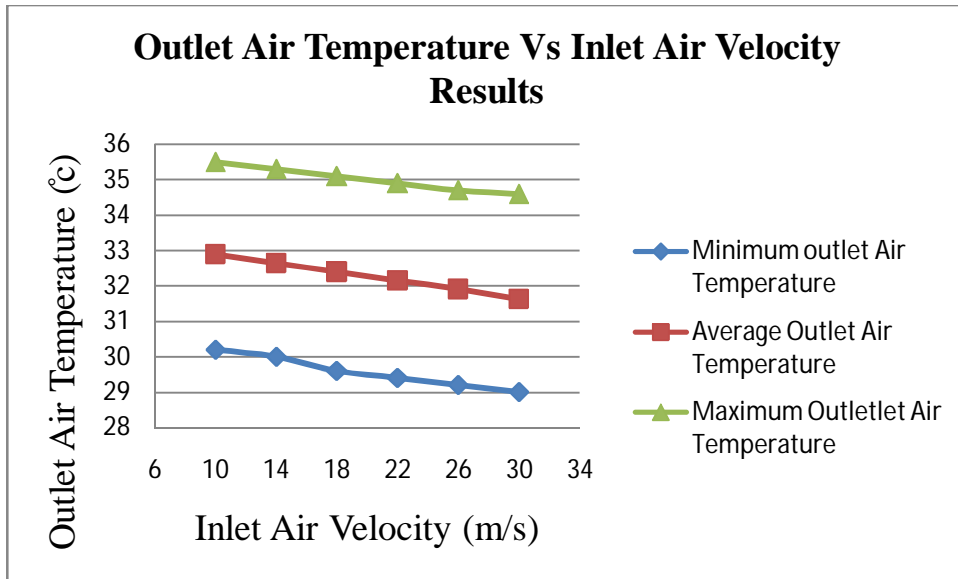


Fig. 3. Outlet Air Temperature Vs Inlet Air Velocity

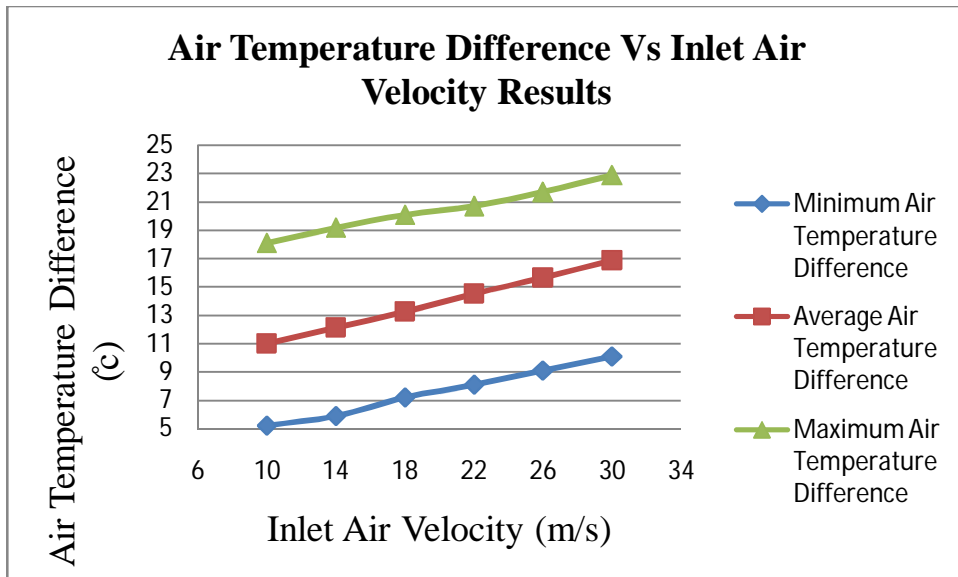


Fig. 4. Air Temperature Difference Vs Inlet Air Velocity

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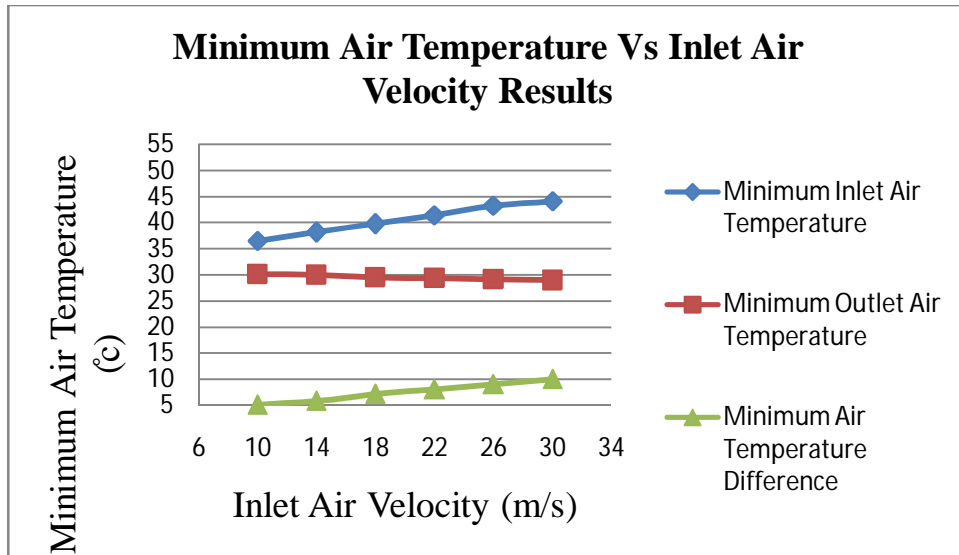


Fig. 5. Minimum Air Temperature Vs Inlet Air Velocity

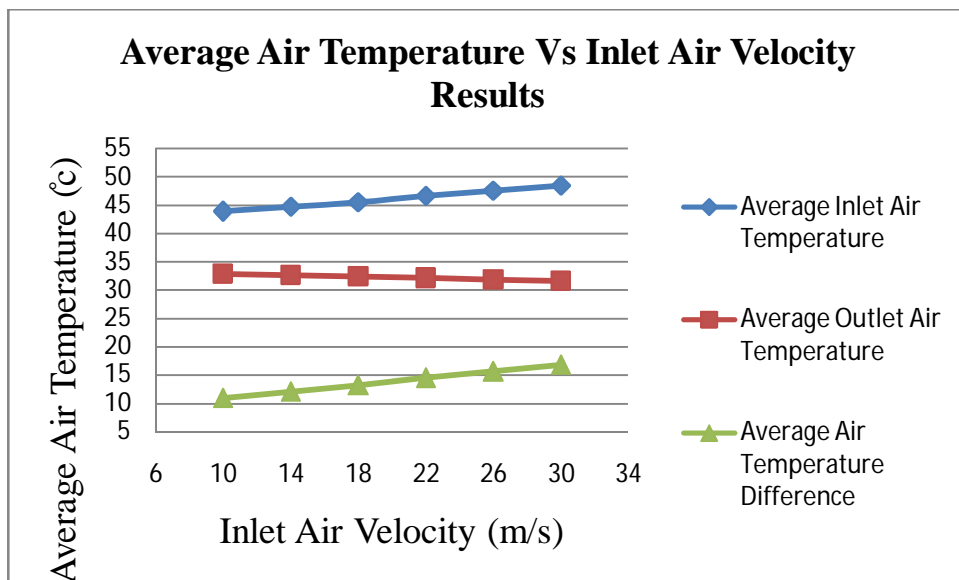


Fig. 6. Average Air Temperature Vs Inlet Air Velocity

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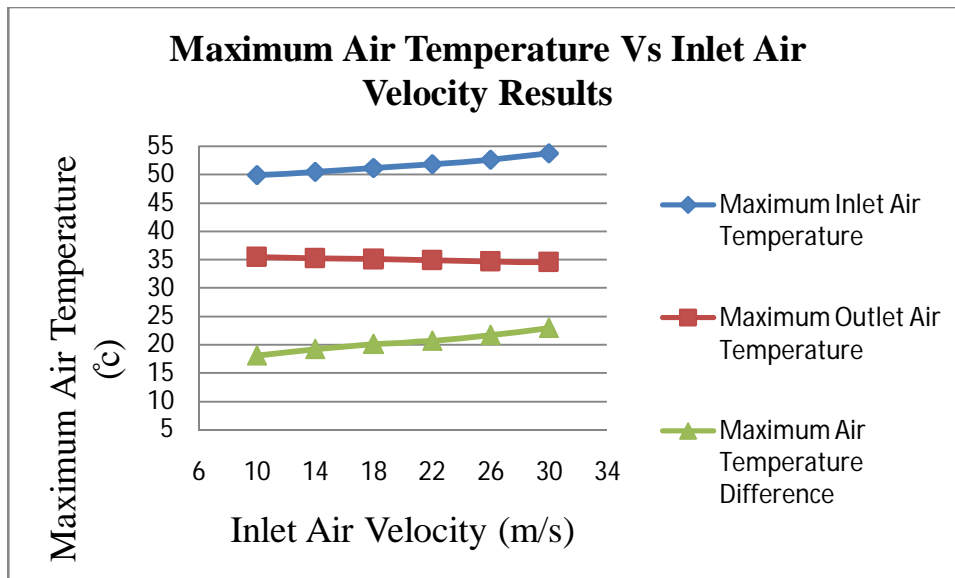


Fig. 7. Maximum Air Temperature Vs Inlet Air Velocity

- Maximum Inlet Air Temperature was found as 50.0°C, 50.5°C, 51.2°C, 51.9°C, 52.7°C & 53.8°C corresponds to Inlet Air Velocity 10m/s, 14m/s, 18m/s, 22m/s, 26m/s & 30m/s respectively for 8 working days, which is shown that inlet air temperature increases with respect to air velocity.
- Minimum Inlet Air Temperature was found as 36.5°C, 38.2°C, 39.8°C, 41.5°C, 43.3°C & 44.2°C corresponds to Inlet Air Velocity 10m/s, 14m/s, 18m/s, 22m/s, 26m/s & 30m/s respectively for 8 working days, which is shown that inlet air temperature increases with respect to air velocity.
- Average Inlet Air Temperature was found as 43.91°C, 44.77°C, 45.66°C, 46.67°C, 47.56°C & 48.5°C corresponds to Inlet Air Velocity 10m/s, 14m/s, 18m/s, 22m/s, 26m/s & 30m/s respectively for 8 working days, which is shown that inlet air temperature increases with respect to air velocity.
- Maximum Outlet Air Temperature was found as 35.5°C, 35.3°C, 35.1°C, 34.9°C, 34.7°C & 34.6°C corresponds to Inlet Air Velocity 10m/s, 14m/s, 18m/s, 22m/s, 26m/s & 30m/s respectively for 8 working days, which is shown that outlet air temperature decreases with respect to air velocity.
- Minimum Outlet Air Temperature was found as 30.2°C, 30°C, 29.6°C, 29.4°C, 29.2°C & 29°C corresponds to Inlet Air Velocity 10m/s, 14m/s, 18m/s, 22m/s, 26m/s & 30m/s respectively for 8 working days, which is shown that outlet air temperature decreases with respect to air velocity.
- Average Outlet Air Temperature was found as 32.9°C, 32.64°C, 32.4°C, 32.15°C, 31.91°C & 31.63°C corresponds to Inlet Air Velocity 10m/s, 14m/s, 18m/s, 22m/s, 26m/s & 30m/s respectively for 8 working days, which is shown that outlet air temperature decreases with respect to air velocity.
- Since air travels 11ft depth inside the buried pipes of the system when it is coming outside the system from the ground so outlet air temperature decreases with respect to air velocity, as we know that earth ground temperature in the upward direction increases with height and earth ground temperature at a depth of 4ft is more than earth ground temperature at a depth of 11ft. So Air at higher velocity travels 11ft depth quickly as compared to air at lower velocity and time contact for heat transfer decreases. So outlet air temperature decreases with respect to air velocity.



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- Maximum Air Temperature Difference was found as 18.1 °C, 19.2 °C, 20.1 °C, 20.7 °C, 21.7 °C & 22.9 °C corresponds to Inlet Air Velocity 10m/s, 14m/s, 18m/s, 22m/s, 26m/s & 30m/s respectively for 8 working days, which is shown that air temperature difference increases with respect to air velocity.
- Minimum Air Temperature Difference was found as 5.2 °C, 5.9 °C, 7.2 °C, 8.1 °C, 9.1 °C & 10.1 °C corresponds to Inlet Air Velocity 10m/s, 14m/s, 18m/s, 22m/s, 26m/s & 30m/s respectively for 8 working days, which is shown that air temperature difference increases with respect to air velocity.
- Average Air Temperature Difference was found as 11 °C, 12.13 °C, 13.26 °C, 14.52 °C, 15.65 °C & 16.87 °C corresponds to Inlet Air Velocity 10m/s, 14m/s, 18m/s, 22m/s, 26m/s & 30m/s respectively for 8 working days, which is shown that air temperature difference increases with respect to air velocity.

## IV. CONCLUSIONS

The Thermal Performance of Earth Air Tunnel Heat Exchanger in Series Connection was analysed experimentally, which concludes various points: Earth Air Tunnel Heat Exchanger in Series Connection requires less space for installation as compare to Simple Earth Air Tunnel Heat Exchanger. Maximum Air Temperature Difference was found as 18.1 °C, 19.2 °C, 20.1 °C, 20.7 °C, 21.7 °C & 22.9 °C corresponds to Inlet Air Velocities 10m/s, 14m/s, 18m/s, 22m/s, 26m/s & 30m/s respectively for 8 working days. Minimum Air Temperature Difference was found as 5.2 °C, 5.9 °C, 7.2 °C, 8.1 °C, 9.1 °C & 10.1 °C corresponds to Inlet Air Velocities 10m/s, 14m/s, 18m/s, 22m/s, 26m/s & 30m/s respectively for 8 working days. Average Air Temperature Difference was found as 11 °C, 12.13 °C, 13.26 °C, 14.52 °C, 15.65 °C & 16.87 °C corresponds to Inlet Air Velocities 10m/s, 14m/s, 18m/s, 22m/s, 26m/s & 30m/s respectively for 8 working days.

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