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# Experimental Investigation of Adding a Personal Ventilation System as Combined with Hybrid Ventilation System During Isolated Office Rooms

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**ABSTRACT**

Studying the effect of adding a ventilation system consisting of two devices, impinging and personal ventilation, and knowing the extent of their impact on the presence of different thermal loads represented by humans, computers, and light inside a thermally isolated office room by using sandwich panels. In addition, examining the air distribution inside a room also found the required thermal comfort for two people who were represented in the form of the thermal manikin and inside them a heat source close to 80 watts, which is close to the heat emitted by the human being according to the global A share. The most important results that were obtained first when adding the personal ventilation system to the impinging ventilation showed a clear improvement in heat levels close to the thermal manikin at a level of 1.1 meters and above. Second, the homogeneity of temperatures within the space, where the difference between the main source of ventilation (impinging) and the heat at the level of 1.8 meters is relatively small, compared to the use of the impinging ventilation system alone. The aim of the research is to prove the efficiency of such a system within the Iraqi summer weather between march to June month, under the conditions studied during this project, energy savings can be achieved using this strategy. Providing respiratory and thermal comfort inside the air-conditioned space, especially in the people's seating area at 1.1 meters, and achieving two goals of sustainable development (an industry with innovation and clean with affordable energy).

## 1. INTRODUCTION

It is well known that poor ventilation in an office room causes SBS ( Sick Building Syndrome**)**, one of the syndromes that afflict a person as soon as he enters the place for the first time, sometimes some new employees feel that they are uncomfortable in the company or that their respiratory system is getting worse and they feel uncomfortable and during the end of the working hours they return to their normal life without any symptoms, and although this syndrome is not believed by some With its existence or health, it has infected many around the world.

We would like to point out, it is called environmental disease when ventilation is not good in the building or air conditioners are relied on all the time or even because of the inherent dust that contributes to attracting disease, and it was revealed that up to 25% of the newly constructed buildings are unfit of the individual and harm his health because of the air quality inside, which poses a threat to the respiratory system.

Therefore, to enhance human comfort, health and productivity, it is recommended that indoor environments be ventilated at rates higher than the minimum levels stipulated in current standards and guidelines [1]. The ventilation system occupies an important place in the design of buildings, as it is the main factor for the comfort and well-being of its residents, or for the performance of industrial processes inside these buildings [2]. There are some challenges that are formed in the ventilation of the office environment, which raises the calorific value of the place in addition to the intensity of solar radiation, including computers and other devices that carry high thermal loads. Therefore, many studies have appeared with a view to improving the ventilation of offices so that the poor air inside does not cause most diseases and physical discomfort [3]. Efficiency of air exchange is used to refer the action of ventilation and the quality of internal air in ventilation offices. However, it does not pick into account the apportionment of personal in the room and is therefore limited. Revised air exchange efficiency considering occupant distribution in Ventilated Rooms However, for some ventilation types, such as personalized and large space ventilation, the ventilation effect great changes in place on another side, the busy zone is finite to only a definite part of the area. The conventional Efficiency of air exchange weights different zones of the room equally when valuation the ventilation effect. Such treatment may lead to unconscionable results adjusted air exchange efficiency taking into account the distribution of occupants in ventilated rooms. By applying CFD modeling, most researchers have studied airflow in terms of temperature distribution and air movement or in terms of air diffusers [2, 4, 5].

Ng et al. [6] studies of computational fluid dynamics have been widely applied to simulate indoor and outdoor airflow

however, most numerical tests are based on a single factor design at a time. According to the Box-Behnken design method, first- and second-order models were developed based on test conditions using a least-squares method based on a second-order RSM model. The presentation temperature was shown to be the most important design with a 95% dependability term.

Kanaan et al. [7] evaluation the air improvement in spaces conditioned via personalized ventilation and displacement ventilation based on $CO_2$ concentricity levels. The interactivity in the middle of the upward flow of the ascending passenger column, the expiratory flow and the flow of displacement ventilation, and the flow of air intended for transporting carbon dioxide into the space and the inhalation area of the passengers are designed to recorder air quality. The contribution of PV to lower $CO_2$ condensation in inhaling air is calculated by the effectiveness of personal laying open in terms of $CO_2$ condensation in inhaled air also PV air with also without PV. The advanced sample was check it out via comparing sample effects of $CO_2$ condensation with the results were obtained from three-dimensional simulations using business software also with Published empirical data for many PV for distances from the occupant, temperatures and flow rates of PV jets. The performance of PV in conjugation with DV regard to breathing air goodness count on the location with regard to the human face then the PV temperature & air flow rate.

Currently, the devices are widely used in offices, in addition to solar energy conditions, can cause high heat loads in these enclosed spaces. These problems will pose challenges to the ventilation of office buildings [8]. Although the specific factors commitment to ventilation problems are not known, several studies have shown that most diseases and complaints are Due to poor indoor air quality and noticeable physical disturbance [3]. To achieve reasonable indoor conditions of comfort and air quality, both the designers and operators of ventilation systems must be aware of the heat equilibrium in the midst of indoor conditions and the toy body and the factors that involve thermal comfort and disturbance, as well as the concentrations of dirtiness that people can carry and the nature of physical activity [2].

Personal ventilation is a general descriptor of air conditioning registers installed on a desk or workstation that transfers direct delivery of conditioned air to the breathing region of office employees. Photovoltaic systems have the ability to restore occupant comfort by enhancing indoor air quality at the time of usage via increased individual control of air conditioner ports. They may also be able to cut energy use by delivering less conditioned air to the workstation [9]. Personal ventilation has been used for many years to increase the thermal comfort of people in most situations and automobile cabins. Few studies have examined the effectiveness of PV in office buildings [10]. The design of the PV Air-Terminal Device has a significant impact on the efficacy of tailored ventilation [11]. Designing personal ventilation systems with excellent ventilation efficiency and simple implementation is not an easy undertaking. Apart from the effectiveness of ventilation, other factors are also important, such as control strategies, background room air distribution, appearance of air supply devices, occupant activities [12-15]. The ability of personal ventilation systems to promote thermal comfort, the quality of indoor air and the resulting energy savings under hot and humid tropical conditions was examined. In addition to enhancing thermal comfort and IAQ acceptability, the findings indicate that combining a small PV system with a large air conditioning system may cut energy usage by 15 to 30 percent [16]. In an office mockup, two kinds of pneumatic terminals for a personal ventilation system were fitted beside a complete volume mixing or offset ventilation system. The performance of the systems was assessed based on the concentration and temperature of pollutants in the inhaled air, as well as the temperature, velocity, and distribution of pollutants in the inhabited space. Personal ventilation will always improve the quality of the air breathed in rooms with mixed ventilation, according to the findings [17]. Various kinds of ATD devices Designed, evaluated, and compared. A typical office environment was replicated by simulating an office with ATD devices put in a climate chamber. ATD devices have been evaluated differently with regard to the temperature of the breathed air, which serves as an additional indication of air quality, as well as the corresponding temperature. The findings suggest that PV might dramatically lower the number of unsatisfied passengers with air quality. However, an ATD must be created to provide more successful classification and less mixing of assigned air with contaminated room air [18]. Multiple ATD devices were designed, compared, and evaluated. In a climate chamber, a typical office environment consisting of an office with ATD devices placed was recreated. ATD devices have been evaluated differently with regard to the temperature of the breathed air, which serves as an additional indication of air quality, as well as the corresponding temperature. The findings indicate that PV has the potential to dramatically decrease the number of travelers dealing with air quality. However, an ATD must be created to provide more efficient distribution and minimal mixing of the assigned air with the contaminated room air [19]. The development of a multi-layer model to simulate heat transport in rooms with mixed displacement ventilation and specialized ventilation systems. Solving heat and mass balance equations yields the temperatures and flow rates of the columns and ambient air in each stratum. The ambient air temperature and midline temperature of the heat source column were measured and compared to the predicted model findings. The simplified model properly predicted the ambient air temperature at higher altitudes, while underestimating it by 6% at lower altitudes [20]. Minimizing the SARS-CoV-2 virus transmission is essential to face the COVID-19 pandemic. This is even more important for highly crowded indoor environments, e.g. schools, where the mitigation solutions based on social distancing and hand washing seem to be not effective to reduce the virus airborne transmission mode, which is the main route of transmission. To minimize the airborne virus transmission a proper ventilation is necessary [21].

## 2. EXPERIMENTALLY WORK

### 2.1 Test office room

All tests for our project were accepted isolated attempted office room (sandwich panel) in a lab of air conditioning and refrigeration in Al-Mustaqbal university college as shown in Figure 1.

The office room was designed in an isolated form as sandwich panel, where the focus was on changes in temperature, speed and flow rate, as well as the places of people and the required respiratory and thermal comfort

through the use of impact ventilation first and personal ventilation in conjunction with IJV ventilation second within the climate of Iraq.

The room, designed with dimensions (3 m x 2 m x 3 m), contains two people in the form of a mannequin, two personal computers and a light source. Thermal loader inside the room as shown in Figure 2 and its location as in Table 1.

**Figure 1.** Front view of an isolated room

Many items are located in an isolated room and took on the thorough test were three sorts of thermal sources supplied in the test room, shown as two manikins (Human body) with 80-watts estates [18] addressed by a utilized human warm puppet set, two PC with heat flux 45 Watt and one lamb is set as a heat source and introduced in the suspended roof as depicted in subtleties in Figure 3. Additionally, an air conditioning system is utilized to transfer the cooled air to the inner region of the tested room.

The best position for people to sit was chosen in the office room, where the distribution of convection and air spread is homogeneous where the distribution of people sitting opposite in the office room [15].

For the second case (IJV) and (PV) combined, a two-person office, one grill positioned on the north side of the room, and a door in the west as shown in Figure 4. The basic requirements for this model have also been specified also they are summarized in Table 2.

The various items situated in proven space also took on during tests were 3 sorts of heat sources utilized in the test then depicted by: two person properties addressed by utilized person warm puppet, two computers with a heat source of 45 Watt for everyone also colorific light were put as heat-source and attached in the roof as portrayed in subtleties in Figure 4. Likewise, PV framework comprises of fan at various stream rates constrained by an electric controller where the air is pulled from base at (0.4 m) Through air terminal duct (ATD) to the top at the level of person seat of (1.1 m).

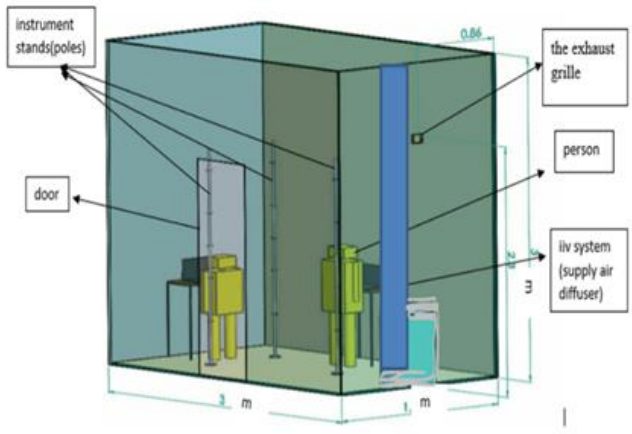


**Figure 2.** Schematic diagram model of ventilation (IJV)

**Table 1.** Isolated room configurations for ventilation (IJV) case-I

| Item | Location (m) | | | Size (m) | | | Heat. {18} w |
|---|---|---|---|---|---|---|---|
| | *X* | *Y* | *Z* | *XΔ* | *yΔ* | *zΔ* | |
| Room | 0 | 0 | 0 | 3 | 2 | 3 | - |
| Square air duct | 2.85 | 0.7 | 0.5 | 0.15 | 0.5 | 2.80 | - |
| Exhaust grille | 0 | 0.5 | 2.7 | 0.12 | 0.1 | 0 | - |
| Person no.1 | 0. 6 | 0.25 | 0 | 0.35 | 0.35 | 1.1 | 80 |
| Person no .2 | 1.5 | 0.25 | 0 | 0.35 | 0.35 | 1.1 | 80 |
| PC-simulator no.1 | 0.28 | 0.175 | 0 | 0.3 | 0.25 | 1 | 45 |
| PC-simulator no. 2 | 1.72 | 0.175 | 0 | 0.3 | 0.25 | 1 | 45 |
| Lamp | 3 | 1.49 | 0 | 0.1 | 0.1 | 0 | 100 |
| Table 1 | 0.1 | 0.1 | 0 | 1 | 0.4 | 0.7 | - |
| Table 2 | 1.9 | 0.1 | 0 | 1 | 0.4 | 0.7 | - |

**Table 2.** Isolated room configurations for ventilation (PV+IJV) case-II

| Item | Location (m) | | | Size (m) | | | Heat.{18} w |
|---|---|---|---|---|---|---|---|
| | *X* | *Y* | *Z* | *XΔ* | *yΔ* | *zΔ* | |
| Room | 0 | 0 | 0 | 3 | 2 | 3 | - |
| Square air duct | 2.85 | 0.7 | 0.5 | 0.15 | 0.5 | 2.80 | - |
| Exhaust grille | 0 | 0.5 | 2.7 | 0.12 | 0.1 | 0 | - |
| Person no.1 | 0. 6 | 0.25 | 0 | 0.35 | 0.35 | 1.1 | 80 |
| Person no .2 | 1.5 | 0.25 | 0 | 0.35 | 0.35 | 1.1 | 80 |
| PC-simulator no.1 | 0.28 | 0.175 | 0 | 0.3 | 0.25 | 1 | 45 |
| PC-simulator no. 2 | 1.72 | 0.175 | 0 | 0.3 | 0.25 | 1 | 45 |
| Lamp | 3 | 1.49 | 0 | 0.1 | 0.1 | 0 | 100 |
| Table 1 | 0.1 | 0.1 | 0 | 1 | 0.4 | 0.7 | - |
| Table 2 | 1.9 | 0.1 | 0 | 1 | 0.4 | 0.7 | - |
| Personal (pv) 1 | 0. 6 | 0.25 | 0 | | | | |
| Personal (pv) 2 | 1.5 | 0.25 | 0 | | | | |

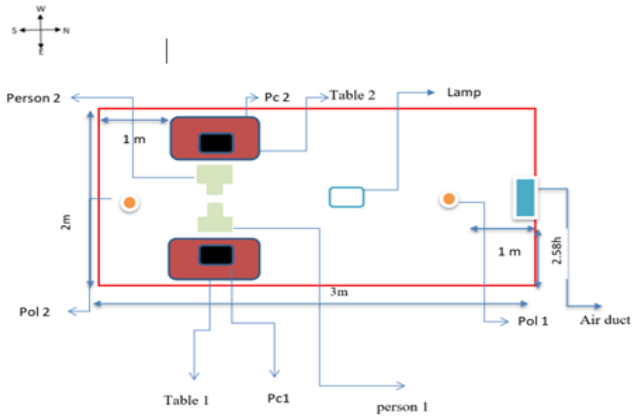


**Figure 3.** Configuration of impinging (IJV) ventilation only from the top view

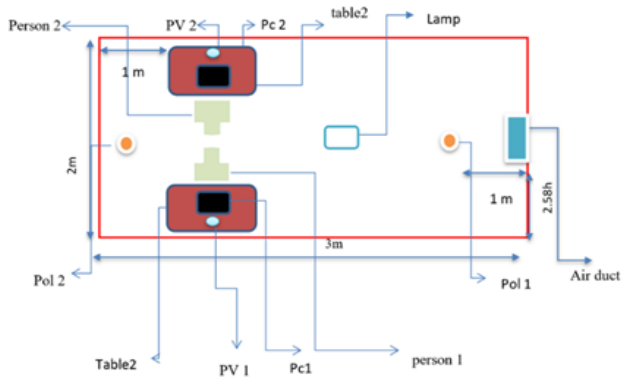


**Figure 4.** Configuration for impinging (IGV) ventilation and personal ventilation (PV) system from the top view

Human Thermal radiation It is the energy that an object transmits thanks to its temperature and through the infrared wavelengths of the electromagnetic spectrum. All objects without exception emit some infrared radiation, no matter how low their temperature. It happens that when they are in accelerated motion, electrically charged particles oscillate and, thanks to their kinetic energy, they constantly emit electromagnetic waves.

## 2.2 Air supply system

There is a means to observe the temperature of the air supply and ventilation rate for impinging ventilation applications. The methodology depends on the Iraqi cooling [22].

2.2.1 Air stream space of ventilation

The expected air stream rate as cooling load, is:

$$Q = \frac{0.295q_{oe} + 0.132q_l + 0.185q_{ex}}{\rho cp\Delta T_{hf}} \quad (1)$$

$$Q = (U \times A \times \Delta T) \quad (2)$$

$$U = \frac{1}{R}, R = \frac{1}{hi} + \frac{\Delta x}{k} + \frac{1}{ho} \quad (3)$$

2.2.2 Air supply temperature

To predict temperature of supplied air ($T_s$) used Eq. (4) was used [13].

$$T_s = t_{sp} - \frac{A_f * q_t}{0.584 * Q^2 + 1.208 * A * Q} \quad (4)$$

The Eq. (5) was find the value of the air change per hour (ACH) by and its determined as 8.32 [14],

$$A.C.H = (Q/V_{Room}) * 3600 \quad (5)$$

For air supplying diffuser gives one direction (IJV) as shown in Figure 4. While the diffuser of PV shown in Figure 5.

**Figure 5.** The supply air diffuser (IJV) Manufacturing

## 2.3 Procedures of measurement

1-Test units at every one of the tests there are three example units ,for each example unit has six level being set at different stature levels of (0 m,0.4 m, 0.8 m, 1.1 m, 1.4 m, 1.8m) and used to record the boundaries that are situated at 1st ($x=2^1$ m, $y=0^1$ m, $z=0.87^1$ m), 2nd pole($x=0.7^1$ m, $y=0^1$ m, $z=0.5^1$ m) and 3rd pole(x=0.7 m, y=0 m, z=1.25 m) for all cases as displayed in Figure 6.

2-Air speed: The hot wire thermo-anemometer sensors model YK.2005AH.

3-Tempe estimation devices: An enormous number of thermocouples type K were utilized to record air temperature. The thermocouples measure the temperature with time normal 600s.

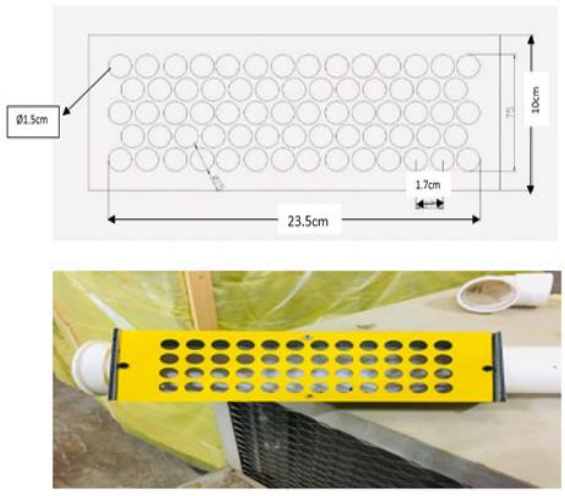


**Figure 6.** Air outlet supplying for ventilation (PV) diffuser

## 2.4 Procedures

All tests have done in two phases IJV with and without PV. Investigations were tested in April and march 2021.

2.4.1 Case-I (using first type of ventilation IJV only) (Table 3)

**Table 3.** Temperature degree in (℃) obtained by using IJV system

| Type of supply air duct | Pole no. | Thermocouple height from the foot level(m) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0 | 0.4 | 0.8 | 1.1 | 1.4 | 1.8 |
| | | Air temperature (℃) | | | | | |
| Impinging ventilation | Pole1 | 21 | 21.2 | 22.4 | 23 | 23.8 | 24.3 |
| | Pole2 | 22 | 22.2 | 23 | 24 | 24.5 | 25 |
| | Pole3 | 22 | 23.2 | 24 | 25.1 | 25.8 | 26.3 |

**Table 4.** Tempe degree in (℃) obtained by using IJV and PV ventilation system

| Type of supply air duct | Pole no. | Thermocouple height from the foot level(m) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0 | 0.4 | 0.8 | 1.1 | 1.4 | 1.8 |
| | | Air temperature (℃) | | | | | |
| Impinging and personal ventilation | Pole1 | 21 | 21 | 22 | 22.1 | 23 | 23.6 |
| | Pole2 | 22 | 22.1 | 22.5 | 22.3 | 23.3 | 23.8 |
| | Pole3 | 22.2 | 22.4 | 22.6 | 22.5 | 23.4 | 23.9 |

2.4.2 Case-II (combined IJV and PV system)

Air enters the room through a suppling device IJV and personal ventilation. Personal ventilation draws the air from inside the room at a height of 0.4 meters from the ground level. PV system consists of fans at different flow rates 5l/s and 10l/s where the air is flowing from the bottom to the top and through (ATD) to the seating human level (1.1m), as shown in Table 4.

A fan has best flow rate about (10 liter/sec) was used in this case to drag air at 0.4m high then blow air to breathing zone with 1.1m high [15].

## 3. RESULTS AND DISCUSSION

### 3.1 Test results

Results within the arranged space for case-I also case-II were analyzed. Preliminary outcomes got at different diffusers and regions for different inhabitant apportionments. Other than assessed air temperature scattering, speed apportionment from the poles for the cases learned at regions 1st pole (x=2 [1], y=0 [1], z=0.875 [1]) m, 2nd pole (x=0.7 [1], y=0 [1], z=0.5 [1]) m and 3rd pole (x=0.7 [1], y=0 [1], z=1.25 [1]) m. shows the relation between air temperature and level with the three poles. it was shown that the temperature changed with the height of the room. The clarification of this temperature values augmentation is a direct result of the addition of distance from the air supply level.

The air temperature is greatly affected by the heat sources in the space and the air temperature below 1 m height from the top readings at the pole is about 90% of the heat source (thermogenic and computer). The most extreme concentration in pole 1 (at a distance of 1 m from the north side) was lower than the different air temperatures in prisms (2 and 3) (located at a distance of 2.3 m from the channel source) for the first case since column 1 was closest to the tube Cold air station stock as shown in the Figure 6 for case-II of inhabitant dispersion in Figure 7, the three posts (1,2 and 3) give comparative variety values for smooth air temperature appropriation. In this way, the second instance of the tenant gives more ok ventilation due to the great circulation of air temperature inside the tried room.

PC and light effect on the environment of all room air temperature that reduces ventilation capability, for case-II suitable spread region and air course gained near the three warmth source result from the improvement of cold air from personal ventilation decrease heat transmitted by the thermal manikin, light and PC. In like manner, case-I and case-II in Figures 8 and 9 showed best air dissemination over condition while case-II at mass stream 10 l/s High estimations of velocity were gotten at the lower territory where the region of air effortlessly diffuser IJV exists during this zone. The air move process at this zone is progressively capable of diminishing the temperature of the hot space of warmth sources during this zone.

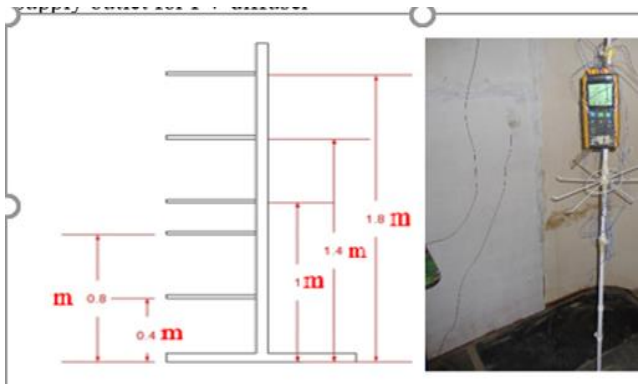


**Figure 7.** Image for poles and nodes level position with device of thermocouple

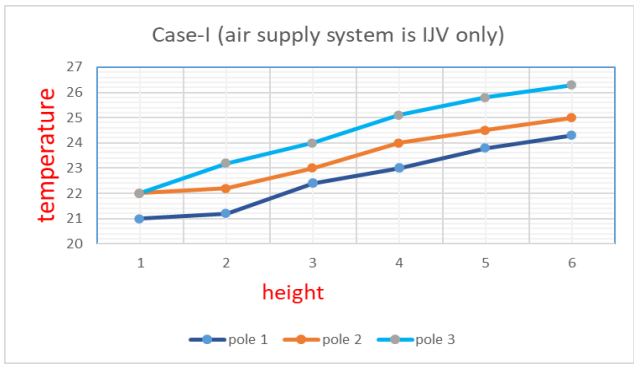


**Figure 8.** The relation of air temperature through pole (1, 2, 3) at case-II

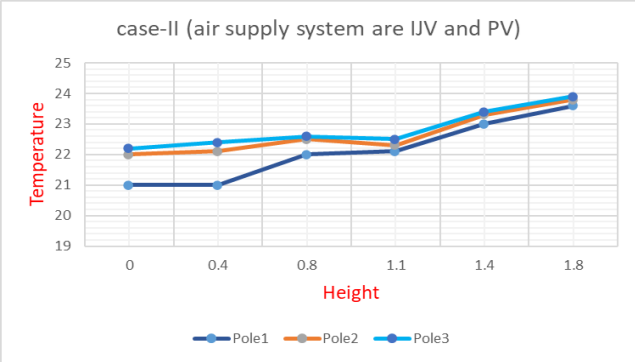


**Figure 9.** The relation of air temperature through pole (1, 2, 3) at case-II

### 3.2 Comparison results

Through the mentioned results, it was found that the use of ventilation in general led to an increase in thermal comfort for people, especially in office rooms, and thus we obtained energy at low prices compared to traditional air conditioning.

As the use of collisional ventilation reduced the heat generated by the thermal sources during the air-conditioned space, and where it was found that the temperature decreases the closer to the source of ventilation, as shown in the thermocouple holder close to the IJV ventilation where the temperatures are lower than if we move away. Also, the achieved speed was proportional to the work of diffusion of air to all corners of the room, as is evident when reading the temperatures of the carriers 2, 3.

Results of practical were studied and a comparison was made between the first and second cases. It was studied practically based on the different positions and way of the occupants and based on the presence of ventilation devices where the distribution of heat and speed of air was studied on three columns divided within the area designated for human comfort for all spaces. Figure 9 shows the association of air temperature at the space height through pols (1,2,3). Where the change in temperature is evident during the occupied space. This temperature thinking strategy is the addition of a good way to brilliantly air level.

As for the second case, when using PV and IJV ventilation, we see a clear improvement in temperatures close to the seat of the thermal mannequin at 1.1 m, as shown in Figure 10 which is t the height for people to sit according to Ashare Standard, and thus it has achieved thermal and respiratory comfort for the occupants.

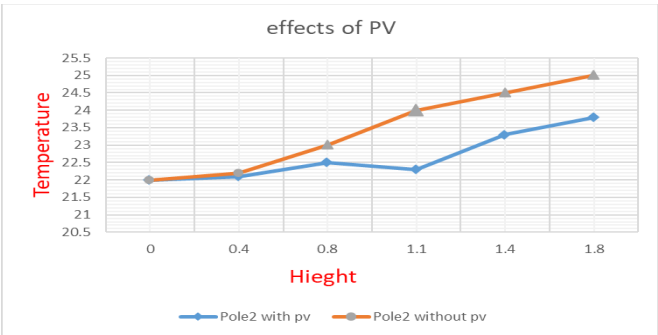


**Figure 10.** The relation of air temperature through pole (2) at case-1 and case-II

### 3.3 Concluding remarks

From the outcomes of the current audit, the going with closures can be summarized as follow:

1- The use of ventilation in general led to good thermal and respiratory comfort and less energy compared to traditional air conditioning.

2- It is found that impinging jet ventilation has tremendous application potential in both winter and summer office environments. This device dramatically enhances thermal comfort and air quality inside. Applying impinging jet ventilation (IJV) requires a thorough evaluation of the system's constraints and characteristics, such as supply air velocity, temperature, and air duct form.

3- The use of personal ventilation with impact ventilation has clearly improved the diffusion of air inside the air-conditioned space, especially where it is located.

4- Increasing the cooling efficiency inside the air-conditioned space in order for personal and collision ventilation to reduce the heat loads resulting from the available heat sources.

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## NOMENCLATURE

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|---|---|
| A | Surfaces Area for Wall.$m^2$ |
| Cp | Specific heats of the air at constant pressure |
| H | Convection heats transfer coefficient $W/m^2.K$ |
| p | pressure ($n/m^2$) |
| Q | Heats transfer through the wall. W |
| T | Temperature (°C) |
| U | Total heats transfer coefficient. $W/m^2.K$ |