# ASSESSMENT OF INDOOR AIR QUALITY IN CROWDED EDUCATIONAL SPACES

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# ABSTRACT

## ASSESSMENT OF INDOOR AIR QUALITY IN CROWDED EDUCATIONAL SPACES

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Indoor air quality has become a challenge together with the global aim ‘decreasing energy consumption’. Increasing insulation levels of building envelopes but implementing inaccurate building system details has caused excessive heat, accumulation of pollutants, *etc*. in spaces. In terms of educational spaces, the increase in complaints and illnesses due to unfavorable indoor air conditions leads to a decrease in concentration and so academic performance of students and staff. In the context, the aim of the study was indicating the poor indoor air quality conditions caused by inadequate fresh air supply in crowded educational spaces and making recommendations for the improvement.

In the study, a classroom and a design studio in the METU Faculty of Architecture building were investigated. In order to examine the existing situation, at two locations of each room the temperature, relative humidity and $CO_2$ were continuously recorded between 13 September 2011 and 24 February 2012 and air speed for ten-day periods between 26 November 2011 and 5 January 2012.

The evaluation of the collected data indicated that both of the rooms had temperature, so relative humidity and $CO_2$ accumulation problems mainly due to insufficient fresh air supply in the winter period. In order to eliminate the poor conditions in the rooms, the needed outdoor air can be provided through the inlet openings coupled with fan coils, which are in existence but not in use.

Keywords: Indoor Air Quality, Temperature, Relative Humidity, Air Speed, Carbon Dioxide, Human Comfort, Natural Ventilation, Educational Spaces, METU Faculty of Architecture.

# ÖZ

## KALABALIK EĞİTİM MEKANLARINDA İÇ HAVA KALİTESİNİN DEĞERLENDİRİLMESİ

Betuz, Naima Ebru
Yüksek Lisans, Yapı Bilimleri, Mimarlık Bölümü
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İç hava kalitesi, enerji tüketiminin azaltılması yönündeki küresel yaklaşımla birlikte sorun halini almıştır. Binaların yalıtım düzeylerinin artırılması fakat bina sistem detaylarının hatalı uygulanması; mekanlarda aşırı ısıya, kapalı ortam hava kirleticilerinin birikmesine, vb. sebep olmuştur. Eğitim mekanları açısından bakıldığında; bu elverişsiz iç hava koşullarından dolayı şikayet ve hastalıkların artması konsantrasyonun azalmasına ve böylece akademik performansın düşmesine yol açmaktadır. Bu bağlamda; çalışmanın amacı, kalabalık eğitim mekanlarında yeterli temiz hava sağlanamamasından kaynaklanan olumsuz iç hava kalitesi koşullarını göz önüne sermek ve iyileştirme için öneriler sunmaktır.

Çalışmada, ODTÜ Mimarlık Fakültesi binasında bulunan bir sınıf ve bir tasarım stüdyosu incelenmiştir. Bu mekanlardaki mevcut iç hava koşullarını değerlendirebilmek için, her bir mekanın iki noktasında, 13 Eylül 2011 – 24 Şubat 2012 tarihleri arasında sürekli olarak sıcaklık, bağıl nem ve karbondioksit ölçümleri ve 26 Kasım 2011 – 5 Ocak 2012 tarihleri arasında on günlük periyotlarla hava hızı ölçümleri yapılmıştır.

Kaydedilen verilerin değerlendirmesi sonucunda, incelenen mekanlarda kış döneminde yeterli temiz hava sağlanamamasına bağlı olarak sıcaklık, dolayısıyla bağıl nem problemleri ve $CO_2$ birikimi olduğu görülmüştür. Mekanlardaki bu olumsuz koşulları ortadan kaldırmak için gereken temiz hava ihtiyacı mevcutta var olan fakat kullanılmayan üflemeli konvektörler ile birleştirilmiş açıklıkların tekrar kullanılabilir hale getirilmesi ile karşılanabilir.

Anahtar Kelimeler: İç Hava Kalitesi, Sıcaklık, Bağıl Nem, Hava Hızı, Karbondioksit, İnsan Konforu, Doğal Havalandırma, Eğitim Mekanları, ODTÜ Mimarlık Fakültesi.

To my beloved family

for their endless support, trust and love…

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## ABBREVIATIONS

| | |
|---|---|
| ANSI | American National Standards Institute |
| ASHRAE | American Society of Heating Refrigerating and Air Conditioning Engineers |
| BRI | Building Related Illnesses |
| CO | Carbon Monoxide |
| $CO_2$ | Carbon Dioxide |
| EPA | United States Environmental Protection Agency |
| HVAC | Heating, Ventilation and Air-Conditioning |
| IAQ | Indoor Air Quality |
| METU | Middle East Technical University |
| $NO_x$ | Nitrogen Oxides |
| SBS | Sick Building Syndrome |
| VOCs | Volatile Organic Compounds |

## LIST OF UNITS

| | |
|---|---|
| cfm | Cubic feet per minute |
| CLO | Clothing insulation unit |
| cm | Centimeter |
| °C | Degrees Celsius |
| °F | Degrees Fahrenheit |
| Feet/minute | Feet per minute |
| Fpm | Feet per minute |
| kcal/h | Kilocalorie per hour |
| kph | Kilometers per hour |
| L/s | Liter per second |
| L/s $m^2$ | Liter per second per meter squared |
| L/s per | Liter per second per person |
| m | Meter |
| m/s | Meter per second |
| $m^2$ | Meter squared |
| $m^3$ | Meter cubed |
| $m^3/s$ | Meter cubed per second |
| $m^3/h$ | Meter cubed per hour |
| MET | Metabolic rate |
| mm | Millimeter |
| mph | Miles per hour |
| ppm | Parts per million |

## COPYRIGHT NOTICES

| | |
|---|---|
| Onset HOBO U12 data loggers | provided by the METU Building Simulation Lab. |
| SenseAir Esense(-D) $CO_2$ sensors | provided by the METU Building Simulation Lab. |
| Deltaohm HD403TS2 air speed sensor | provided by the METU Building Simulation Lab. |
| HOBOware Pro | licensed to the METU Building Simulation Lab. |
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| AutoCAD | licensed to METU |

# CHAPTER 1

# INTRODUCTION

In this chapter, firstly, the argument of the study is defined. It is followed by the description of the primary objectives. In the third section, the procedure in conducting the study is explained. Finally, the disposition of the following chapters is presented.

## 1.1. Argument

In general, buildings are outcomes of the desire to resist the natural forces such as weather and seismic loads. They have enabled people to control the environment around. On the other hand, they have also required the control of internal environment for the physical and physiological satisfaction of occupants.

In order to meet the occupant needs, each building type requires different conditions related with its function, which directly determine the level of satisfaction. Among building types, educational buildings have specific significance. Owing to their being the spaces of teaching and learning, academic performance and success are the main concerns in their existence and should be supported by the built environments. In addition to the teaching and learning materials, similar to every building, educational buildings should also include some basic necessities of physical environment such as cooling, heating, ventilation and daylighting. However, both technological and environmental changes in time lead to some problems related with physical comfort conditions, two of which are the concern of this study: human comfort and indoor air quality.

The indoor air problems firstly started with the difficulties in extracting fumes generated by dwellers of primitive shelters for meeting the need for heating, cooking, *etc*. In the medieval era, the unfavorable conditions in spaces due to living in overcrowded cities, such as London, caused deaths. The problems continued with the Industrial Revolution owing to mechanical and chemical emissions to spaces. However, depending on the technological changes resulting from industrialization, buildings started to be constructed with proper service systems to provide comfortable spaces to live and work. In 1970s, energy concerns have gained importance due to the energy crisis, which also affected the construction sector. In order to reduce the energy consumption, the air exchange between indoor and outdoor has been reduced and the need for heating and cooling has been minimized. As a result, buildings have become closed boxes full of contaminants which have triggered the health problems in relation to the increase in the amount of time spent in.

Throughout history, people have been aware of the negative effects of indoor air pollutants on health. The studies on human metabolism around 1800 have helped people to understand the physical conditions in spaces and to establish a relationship between indoor air quality, pollutants and environmental parameters. Indoor air quality is still a current subject for researchers in order to make buildings healthier. In the present day, people are trying to overcome the unfavorable physical conditions in buildings and implementing some standards and regulations considering health of occupants.

In the context, the problem addressed by the study is the poor comfort and indoor air quality conditions in educational buildings, which have a potential of resulting in academic performance loss, absenteeism and unfavorable health impacts. Owing to the fact that the most common cause of the poor conditions in buildings is inadequate ventilation, it is also significant to emphasize the effect of sufficient air flow on the comfort and indoor air quality. In addition, considering the possible causes related with the space or building features that lowering the air movement is essential for the improvement of conditions.

## 1.2. Objectives

The fundamental aim of the study is to improve the poor indoor air conditions in the two selected teaching spaces in the case study building in order to decrease or eliminate the possible adverse effects on both students and staff. In this respect, the objectives of the study are presented through two items:

- investigating the indoor air conditions of a classroom and a design studio in the METU Faculty of Architecture building on the basis of temperature, relative humidity, $CO_2$ and air speed, and
- making recommendations for the provision of sufficient air flow in the spaces investigated.

## 1.3. Procedure

The study focused on indoor air conditions in terms of temperature, relative humidity, $CO_2$ and air speed. It was carried out on the METU Faculty of Architecture building. A classroom and a design studio with a mezzanine floor were selected for the investigation.

In the first stage, the temperature, relative humidity and $CO_2$ were continuously recorded in the selected rooms by using data loggers. They were collected at two different locations of each room between the dates of 13 September 2011 and 24 February 2012. Moreover, air speed was recorded at each record location for ten days between 26 November 2011 and 5 January 2012.

In the second stage, the colleted raw data were downloaded from the data loggers to a computer and organized in graphical forms. Firstly, the represented overall data were analyzed. Secondly, the data of the time periods that the air speeds were recorded at each location were examined. The data were compared with relevant standards and possible causes of the problems were tried to be identified. At the end, the recommendations were given which would improve the indoor air conditions in the rooms investigated.

## 1.4. Disposition

The study is presented in five chapters:

In the first chapter; the argument and objectives of the study are explained, the general procedure of the study is summarized and the disposition of the subject matter is presented.

The second chapter is a summary of literature on the subject domain. General aspects of human comfort, indoor air quality and natural ventilation are explained in this chapter and educational buildings are examined in terms of these issues.

In the third chapter; firstly, the materials used in the study are described; *i.e.* the case study building and data loggers used for the data collection are introduced and the weather data of Ankara for the period of the study are presented. Secondly, the methodology of the study is explained in detail.

The fourth chapter displays the collected data through graphs and tables, and gives the results. It also includes the discussion on the outcomes of the study.

The fifth chapter presents the conclusion and recommendations.

# CHAPTER 2

# LITERATURE REVIEW

The chapter includes the concepts of human comfort, indoor air quality, natural ventilation and educational buildings, and the analysis of the literature. At first, the environmental conditions affecting human comfort are discussed and thermal sensation devices are introduced. Secondly, indoor air quality is explained through indoor air pollutants, carbon dioxide, and Sick Building Syndrome and Building Related Illnesses. Thirdly, natural ventilation is expressed together with the subtitles of 'Basic Principles of Air Flow' and 'Design for Ventilation'. Then, educational buildings are considered in terms of education space development, academic performance, indoor air pollutants and ventilation. Finally, the critical analysis of the literature is presented.

## 2.1. Human Comfort

Comfort is defined by Heerwagen (2004, p.3) as "the state of pursuing an activity without experiencing environmental stress." The author also refers to some other definitions one of which is Yaglou's: "comfortable air conditions are those under which a person can maintain a normal balance between production and loss of heat, at normal body temperature and without sweating." (Heerwagen, 2004, p.42) Accordingly, a space can be qualified as comfortable when a person does not need any thermoregulatory devices, such as sweating and shivering, to establish a thermal balance between his/her body and environment.

Human comfort in a space depends on some parameters. Fanger (1970) lists six parameters for comfort: activity level, thermal resistance of the clothing, air temperature, mean radiant temperature, relative air velocity and water vapor pressure in ambient air. The various combinations of these parameters can constitute comfort conditions. Fanger (1970) indicates the heat balance as the first requirement for comfort, which is affected by skin temperature and sweat secretion under a given activity level. “Air temperature affects the amount of heat lost or gained due to convection and affects evaporation of sweat.” (Nelson, 2011, p.63) In relation, Givoni (1976) notes that an increase in air temperature leads to increases in skin temperature and sweat rate in the case of constant vapor pressure and air velocity. Relative humidity also has an effect on the evaporation from the body – so on the cooling efficiency – in relation with its value, since high relative humidity values limit evaporation due to the saturated air around the body while low values of it increase irritations due to dryness. (Nelson, 2011) The effects of high humidity levels on occupants can be reduced through a rise in air velocity. In the case that air temperature is lower than skin temperature the cooling effect of air velocity increases while air temperature decreases, since air movement eases the evaporation and provides heat loss from the body. (Harvey, 2006)

A rise in air temperature increases its ability of holding moisture on account of a rise in the saturation level with the temperature increase. Owing to the fact that relative humidity is “the ratio of the partial pressure (or density) of the water vapor in the air to the saturation pressure (or density) of water vapor at the same temperature and the same total pressure”, relative humidity decreases along with the rise in saturation level which is the result of temperature increase. (ANSI/ASHRAE Standard 55-2004, p.2) Furthermore, variations in air temperature cause air pressure differences which lead to air flow and determine air speed and direction. (Valsson & Bharat, 2011)

The comfort conditions in a space were determined after thermal sensation studies. Some equations were developed to consider changing values of the parameters. However, the complexity of them resulted in the development of some thermal sensation devices. Graphs are the mostly used ones that show the relations between

the comfort parameters. In a detailed representation, Fanger (1970) presents twelve diagrams to show the relations between relative velocity, humidity and ambient temperature under the combinations of three activity levels and four clothing insulation levels. On the other hand, the Bioclimatic Chart and the Psychrometric Chart were presented as single graphs showing winter and summer comfort zones.

Olgyay's 'Bioclimatic Chart' was "built up with dry-bulb temperature as ordinate and relative humidity as abscissa." (Olgyay, 1969, p.22) (Figure 2.01) The comfort zone is in the center of the chart and defined between the air temperatures of 20 to 26.7 °C and the relative humidity values of 20 to 80 percent. As Olgyay (1969) explains, the winter comfort zone is a little lower than the summer comfort zone which is already plotted on the chart. One of the significant characteristics of the Bioclimatic Chart is its representation of the corrective measures plotted through the lines around the comfort zone. These corrective measures are helpful for restoring the feeling of comfort when the conditions fall outside the comfort zone. In the case of a value above the higher boundary, winds can be used to shift the value into the zone. On the other hand, when the value is below the lower boundary, solar radiation is needed for comfort.

Similarly, the 'Psychrometric Chart' represents the comfort conditions through air temperature, humidity ratio and relative humidity. As shown in Figure 2.02, the one by the ASHRAE Standard 55-2004 defines two comfort zones for two clothing insulation levels (0.5 clo and 1.0 clo) in the case of the air speed lower than 0.20 m/s and activity levels between 1.0 and 1.3 met. It indicates no lower limit for humidity ratio. On the chart, if either the air temperature or humidity ratio value is changed, then the relative humidity also changes. Moving on the chart vertically describes whether the air becomes wetter or dryer and moving horizontally describes whether it becomes colder or hotter. Lechner (2009) presents the comfort zone and various discomfort areas on the Psychrometric Chart, as shown in Figure 2.03.

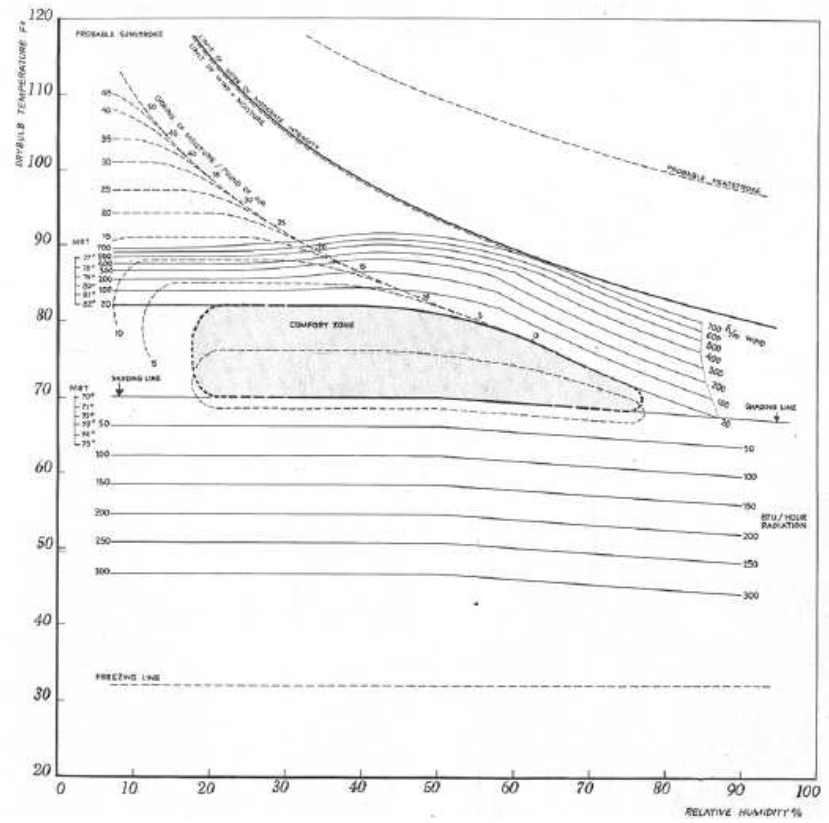


**Figure 2.01.** The Bioclimatic Chart
Source: Olgyay (1969, p.22)

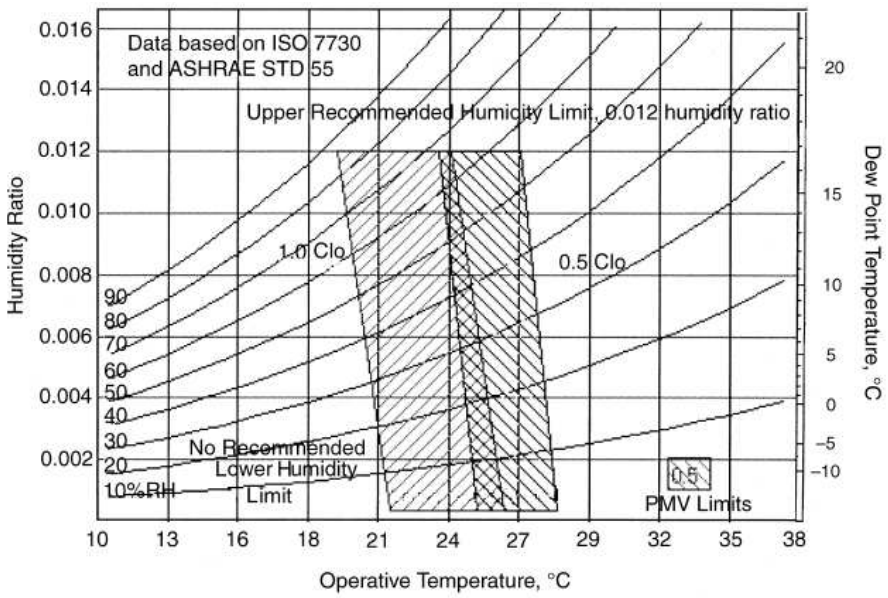


**Figure 2.02.** Acceptable range of operative temperature and humidity for spaces
Source: ASHRAE Standard 55-2004 (p.5)

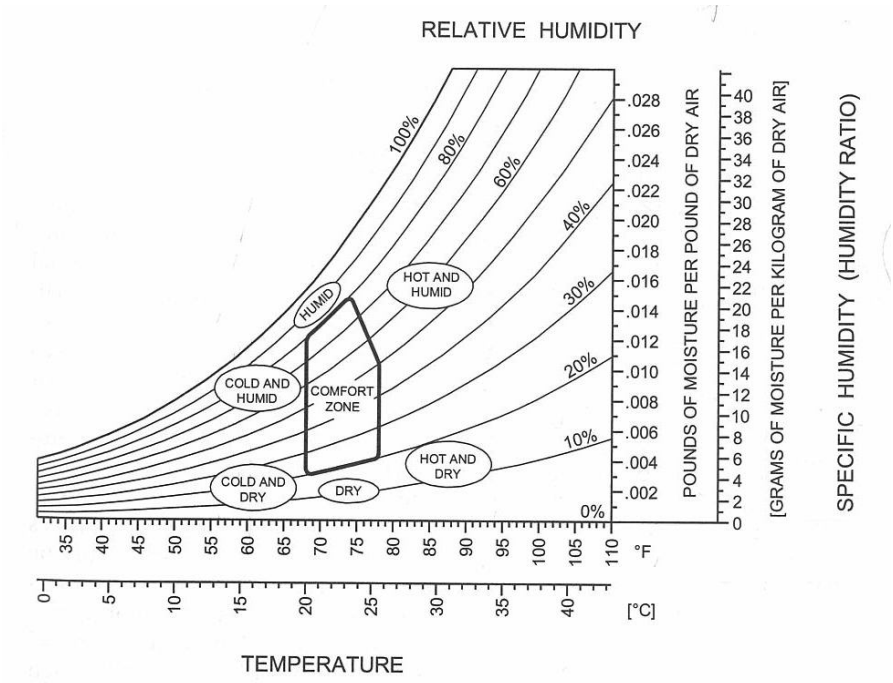


**Figure 2.03.** The comfort zone and discomfort areas on the Psychrometric Chart
Source: Lechner (2009, p.65)

In relation to the graphs, Lechner (2009, p.60) notes the range of air temperature as 20 °C (68 °F) in winter to 25 °C (78 °F) in summer and the value of relative humidity as "above 20 percent all year, below 60 percent in the summer, and below 80 percent in the winter." Additionally, the author specifies the range of air movement for comfort as 0.1 m/s to 0.3 m/s (20 to 60 feet/minute) and states that 0.3 to 1 m/s (60 to 200 feet/minute) can be acceptable in relation to the activity while more than 1 m/s (200 feet/minute) can be disturbing. As slightly different, Heerwagen (2004) indicates the comfort values by noting:

> …an air temperature of between 20 to 27 °C (68 to 80 °F); the mean radiant temperature at the occupant's location equal to the air temperature; a relative humidity somewhere between 25 and 55 percent; the relative air velocity less than or equal to 0.36 m/s (70 feet per minute); an activity rate of I.O MET (i.e. that of a sedentary person); and clothing insulation of about 0.6 CLO. (Heerwagen, 2004, p.51)

The values different than the ones cited above can still provide thermal comfort in the case of establishing thermal balance. However, as Heerwagen (2004) emphasizes, it is difficult to establish a thermal balance for a person in the case of the

air temperature's being higher than the skin and respired gases temperatures. In addition, it should also be noted that there is an effect of culture, health, weight, gender, *etc.* on the sensation, which also differentiates the ranges.

## 2.2. Indoor Air Quality

Indoor air quality is determined by sources, such as building materials, office equipments and consumer products, sinks depositing contaminants and air movement among rooms and between the building and outside. Therefore, the indoor air quality system consists of the occupants, their activities, the air pathway and the HVAC, the building envelope and its environmental setting. (Burroughs & Hansen, 2008) It is characterized by the amounts of air contaminants, air temperature and humidity in a building. In connection, ANSI/ASHRAE Standard 62.1-2007 defines the acceptable indoor air quality as "air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction."

According to the ASHRAE Standard 62-1989, there are two ways of achieving acceptable indoor air quality. The first is the Ventilation Rate Procedure which specifies the ventilation rates for various spaces and the outside air quality for ventilation. The second is the Indoor Air Quality Procedure which emphasizes the control of contaminants to keep them in acceptable levels. Among two procedures, as Shaw (1997) notes, the Ventilation Rate Procedure is the mostly used one which is effective for re-establishing the indoor air quality and for speeding up the removal of contaminants. One of the equations of this procedure presented in the ASHRAE Standard 62.1-2007 (p.11) is the breathing zone outdoor air flow which is "the design outdoor airflow required in the breathing zone of the occupiable space" and defines the breathing zone as the region between 7.5 and 180 cm above floor and more than 60 cm from walls. The equation is;

$$V_{bz} = R_p \,.\, P_z + R_a \,.\, A_z$$

where $A_z$ is the floor area, $P_z$ is the maximum expected population, $R_p$ is the outdoor air flow rate per person and $R_a$ is the outdoor air flow rate per unit area.

Indoor air quality's becoming a problem in buildings has some reasons behind. The energy crisis in 1970s has mainly constituted the basis of current situation, since it has led to an increase in the concentration of the pollutants in buildings through tighter building envelopes which reduces the air infiltration. The conditions get worse with technological changes adding new materials and furnishings to construction industry all of which give off chemicals into the air. HVAC systems also become a source of biological contaminants distributed through ventilation systems, which can be a result of poor maintenance. In addition, the changes in building use and so interior layouts, and the preference of the 'least cost' design technique based on saving on first cost cause poor indoor quality conditions in buildings.

In the present day, indoor air quality is a significant issue due to occupants' becoming more conscious of it in their spaces. Increasing concerns for health, productivity, absenteeism, vacant facilities and the treat of lawsuits call attention to poor indoor air quality conditions in buildings and make it a key element of improvement, renovation and new construction activities. In the context, it is also one of the criteria considered in the design of green buildings which are the results of integrated design approach considering land, landscape, climate, orientation, form, materials, energy, indoor air quality, thermal comfort, lighting, *etc.* Green building assessment systems such as BREEAM, LEED, Green Globes and CASBEE – developed to evaluate and validate green buildings in terms of environmental impacts, resource consumption and occupant health – also include indoor air quality as a factor of rating buildings. (Kibert, 2005) As an illustration, the mostly used one, LEED includes six evaluation categories which are sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, innovation in design and regional priority, each of which has subcategories with prerequisites. The indoor environmental quality category involving minimum indoor air quality performance as a prerequisite gives 15 possible points to the building on the basis of 100 points.

### 2.2.1. Indoor Air Pollutants

Indoor air quality affects human comfort in various ways depending on the pollutant. There are thousands of indoor air pollutants affecting human body in the case of being in high concentrations. Burroughs and Hansen (2008) categorize the pollutants in two groups: particles including both solid and liquid pollutants and gases or vapors. According to this classification, particles include groups of respirable particulates, tobacco smoke, asbestos fibers, allergens and pathogens. On the other hand, vapors and gases include carbon monoxide (CO), radon, formaldehyde, other volatile organic compounds (VOCs), nitrogen oxides ($NO_x$) and odors.

Indoor air pollutants can be taken into a space from outside the building or can be created in the building by construction materials, furnishings, operation and cleaning of equipments (especially in offices), HVAC systems, consumer products, occupants and purposeful activities. In the building, as Burroughs and Hansen (2008) indicates, they can react, interact, decay and attach to surfaces or remain unchanged, then they can be inhaled or exhaled by occupants or leave the building with exhaust air.

The control of indoor air pollutants in a building is important for reducing or eliminating their negative effects on occupants. The most significant strategy is being aware of the potential sources of indoor air pollutants and taking precautions to reduce or eliminate their emissions. The second effective one is the ventilation of spaces. Although the pollutants exist in almost every building, they mainly create indoor air quality problems in the case of inadequate ventilation of spaces. Accordingly, the concentrations of pollutants in spaces can be reduced through ventilation of the indoor air which is named as dilution. On the other hand, the pollutants can also be controlled by extraction which is the filtration of the pollutants; however it is not a healthy way of control due to its depending on recirculation of the air in air conditioning systems.

### 2.2.2. Carbon Dioxide

Carbon dioxide ($CO_2$) concentration in spaces is used as a reliable indicator of the space acceptability in terms of body odor and a limited indicator of indoor air quality. (Persily, 1997) It also displays insufficient ventilation in spaces and buildings. $CO_2$ is useful for "…estimating expected levels of occupant comfort in terms of human body odor, studying occupancy patterns, investigating the levels of contaminants that are related to occupant activity, and screening for the sufficiency of ventilation rates relative to occupancy." (ASTM, 2012, p.2) $CO_2$ may indicate the indoor level of other contaminants which also depend on the occupancy level, such as odor-causing bioeffluents; however there are many pollutant sources in a space such as building materials and furnishings, and it is not useful for informing researchers about their concentrations. (Persily, 1997)

According to MDH (2010), the level of $CO_2$ in a space is determined by the occupancy level, the length of space occupation, the fresh air amount supplied to the space, the space dimensions, the existence of combustion by-products around and the outdoor $CO_2$ level. It can be in high concentrations particularly under heavy occupancy conditions due to its main source's being metabolic activities, which also makes the occupant activity levels significant since $CO_2$ generation – and also oxygen consumption – increases with the increase in the activity rate. (Figure 2.04) Combustion activities, motor vehicles, *etc.* also increase the $CO_2$ level in both outdoor and indoor environments.

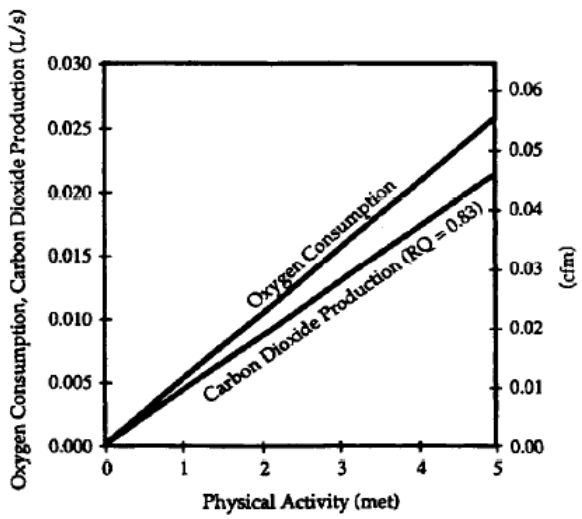


**Figure 2.04.** $CO_2$ generation and oxygen consumption as a function of physical activity
Source: Persily (1997, p.2)

The outdoor $CO_2$ level ranges between 350 and 400 ppm, and may be more in environments with traffic, industrial activity, *etc*. (MDH, 2010) On the other hand, in spaces it varies in accordance with the determining factors. The highest acceptable level of $CO_2$ by ASHRAE Standard 62-1989 is 1000 ppm. However, as Bayer, Crow and Fischer (2000) indicate, there are some studies presenting the threshold $CO_2$ value as 600 ppm or 800 ppm. In terms of higher concentrations, there are various standards recommending different $CO_2$ levels. ACGIH (American Conference of Governmental Industrial Hygienists) states the time weighted average value of 5000 ppm as the threshold limit value for 8-hour work. (ACGIH, 1991) In addition, NIOSH (The National Institute for Occupational Safety and Health) indicates 10000 ppm as the time weighted average concentration for a 10-hour work shift and a 40-hour workweek and 30000 ppm as the short-term exposure limit for up to 10 minutes. (NIOSH, 1976) Moreover, OSHA (Occupational Safety and Health Administration) notes the time weighted average value of 5000 ppm as the transitional limit, and the time weighted average value of 10000 ppm and the short-term exposure limit of 30000 ppm as the final rule limits. (OSHA, n.d.)

The opinions on the impacts of $CO_2$ on health are changing. Persily (1997) refers some studies showing no relationship between the $CO_2$ levels and the prevalence of symptoms while noting some other investigations showing a relationship between a

$CO_2$ level from 600 to 1000 ppm or higher and stuffiness, irritation, *etc*. In relation MDH (2010, p.2) states that "occupants may experience health effects in buildings where $CO_2$ is elevated, but the symptoms are usually due to the other contaminants in the air that also build up as a result of insufficient ventilation."

Monitoring $CO_2$ concentration in spaces continuously can be helpful for improving ventilation and indoor air quality; however places selected for records are significant due to the fact that $CO_2$ concentration in a space is not homogenous in general. (ASTM, 2012) The level widely varies in a space particularly in the case of open windows and $CO_2$ generation. Steiger, Hellwig and Junker (2008) refer to the study by Max von Pettenkofer which reports higher $CO_2$ concentrations below the ceiling in contrast to the ones above the floor despite the fact that $CO_2$ is heavier than ambient air, and explains the result through the rise of warm air containing $CO_2$ mixed in it after exhaling. In addition, the authors note that due to the levels are more stable near the walls in contrast to middle of the space, it is appropriate to monitor $CO_2$ in classrooms at a wall, at a distance from openings and at breathing height or higher to prevent data logger damages.

### 2.2.3. Sick Building Syndrome and Building Related Illnesses

Sick Building Syndrome (SBS) is "a building where a set of varied symptoms were experienced predominantly by people working in an air conditioned environment." (Burroughs & Hansen, 2008, p.28) Its prevalence depends on building characteristics, ventilation systems and HVAC systems. (Seppanen & Fisk, 2002) The risk in air conditioned buildings is higher than in mechanically ventilated buildings which also have a higher risk than naturally ventilated ones. (Seppanen & Fisk, 2002) As for symptoms, SBS does not have specific signs in general. According to the World Health Organization, the most common symptoms are eye, nose and throat irritation, skin problems, headaches, mental fatigue, *etc*. These signs generally appear through a day, become worse through a week, but disappear in the case of being away from the building for a time.

On the other hand, Building Related Illness (BRI) is “a building associated, clinically verifiable and diagnosable disease.” (Burroughs & Hansen, 2008, p.3) In contrast to SBS, the BRI allows the identification of the pollutant and so the source. In addition, it does not disappear in the case of being away from the building. Some of the BRI are allergies such as asthma and rhinitis, humidifier fever and infections such as bacterial, fungal and viral infections.

In essence, SBS and BRI are caused by poor indoor air conditions in spaces and result in economic losses through lost workdays. The estimation of the committee of the World Health Organization represents the 30 percent of new or remodeled buildings as causes of sick building complaints in high rates. (EPA, 1990) Furthermore, as Fisk (2000, p.543) indicates, “In the United States, 4 common respiratory illnesses (common cold, influenza, pneumonia, and bronchitis) cause about 176 million days lost from work and an additional 121 million work days of substantially restricted activity.” However, in addition to creating healthier spaces, the improvements in indoor air conditions provide economic gains through reducing lost workdays and medical cost which are the results of both SBS and BRI. In relation, according to the study noted by Levin (1999), improvements in SBS provide $ 10-20 billion annual savings or productivity gain to the U.S. Similarly, the other study cited by Kosonen and Tan (2004) indicates that reductions in SBS can result in $ 15-38 billion through productivity gain.

### 2.3. Natural Ventilation

Ventilation is an essential necessity for health, comfort and well-being, which affects the human body directly through air motion and indirectly through the temperature and humidity in a space. (Givoni, 1976) It is a fundamental need caused by occupancy. As both Baker and Steemers (2000) and Givoni (1976) state, there are three main purposes of ventilation. The first purpose is fresh air supply for better indoor air quality, the second is the provision of thermal comfort by air movement around and the third includes cooling the building structure and heat avoidance.

Natural ventilation is a passive ventilation method which provides thermal comfort through evaporation from the skin during the day and night. (Lechner, 2009) It is driven by two forces which are wind and buoyancy. Natural ventilation is mainly based on the temperature and vapor pressure in a space. (Givoni, 1976) In the case of ventilation, temperature and humidity exchange occurs in relation to the difference between the outdoor and indoor air mixed in a space. Therefore, the most effective condition for natural ventilation is the indoor temperature and humidity's being higher than the outdoor ones. In connection, the change in the heat in a space (Q) is related with the ventilation rate (V), the heat capacity of air (c, 0.28 kcal/°C for air) and the temperature difference between the outdoor and indoor ($\Delta t$), which is described through the specific heat equation (Givoni, 1976);

$$Q = V \cdot c \cdot \Delta t$$

Natural ventilation has some advantages in contrast to other ventilation strategies. As Hays (2008) states, these advantages are occupants' being able to control the environment, fresh air's being healthier in contrast to re-circulated air and its use of less energy in contrast to mechanical one – according to Loftness (2008), 40 to 70 percent of cooling load can be reduced through natural ventilation and productivity can be increased about 0.4 to 18 percent. In terms of indoor air quality, the most important advantage of natural ventilation is that it helps to keep indoor air pollutants at acceptable levels through dilution, since an increase in the air flow in a space leads to a decrease in the pollutant levels as shown in Figure 2.05.

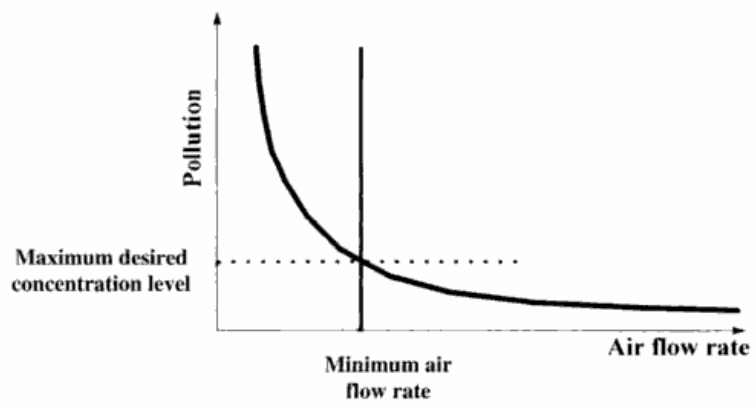


**Figure 2.05.** Natural ventilation for indoor air quality
Source: Allard (1998, p.3)

There are various categorizations of natural ventilation types. Emmerich, Dols and Axley (2001) classify it in relation with the driving forces and divide into three categories which are wind-driven cross ventilation, buoyancy-driven stack ventilation and single sided ventilation. On the other hand, Allocca, Chen and Glicksman (2003) categorize natural ventilation under two main types which are cross ventilation and single-sided ventilation, and divide single-sided ventilation into three groups which are buoyancy-driven flow, wind-driven flow and combined buoyancy and wind-driven flow. By taking these categorizations into account, as the first, cross ventilation is the result of pressure differences created by wind, and provided by the air flow through openings on opposite walls. The second, stack ventilation occurs as a result of buoyancy based on air density differences – cold air is denser than warm air – which permits to enter the outdoor air from lower opening and to exhaust the indoor air from higher one. The third, single-sided ventilation results from the air exchange "…through the same openings on one side of a space at the same height or with the flow of air into a space through one or more inlet openings and flow out from different exit openings when the inlet and exit openings are at different levels." (Gan, 2000, p.66) As subcategories, buoyancy-driven single-sided ventilation is provided through a large opening or different openings on a wall at different levels while wind-driven one is the result of small wind pressure differences on a facade. (Allocca, Chen & Glicksman, 2003, p.786) Single-sided ventilation can also be obtained with both temperature and wind effect, which named by Allocca, Chen and Glicksman (2003) as combined buoyancy and wind-driven flow. Among main types, single-sided ventilation is the least effective ventilation strategy and mostly used one particularly in the case of offices, classrooms, *etc.* In addition, background ventilation is also a way of fresh air supply to spaces through small controllable ventilation openings when windows, doors, *etc.* are closed.

As criticism, regarding natural ventilation, Lechner (2009) states that providing comfort ventilation as completely passive is rarely possible, since in most climates needed air velocities cannot be provided by the winds. Additionally, the author notes that it is a method that the warm air still continues to heat the building although thermal comfort is achieved through evaporative cooling on the skin. In relation,

Givoni (1994) describes comfort ventilation as just a part of building climatology and climate appropriate design. Allard (1998) also indicates that natural ventilation potential considerably decreases in dense urban areas and in rural and low-dense urban areas with high obstructions such as trees. Furthermore, Allocca, Chen and Glicksman (2003) note local noise and pollution levels as factors affecting and limiting the use of natural ventilation.

### 2.3.1. Basic Principles of Air Flow

Air flow is a continuous motion which changes direction through curves. It is a result of temperature and pressure differences. It flows from positive pressure areas to negative ones. Therefore, air creates positive or negative pressure areas around objects or buildings. It constitutes positive pressure at the windward side and negative pressure at the leeward and remaining sides. According to Lechner (2009), there are four different kinds of airflow which are laminar, separated, turbulent and eddy (Figure 2.06).

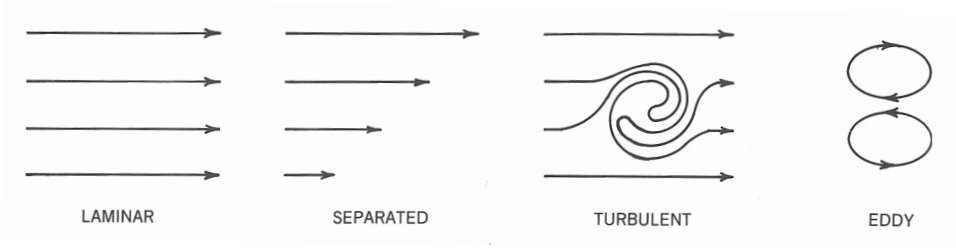


**Figure 2.06.** The kinds of air flow
Source: Lechner (2009, p.268)

In order to maintain sufficient air flow in buildings for effective ventilation, it is significant to have information on the three principles, which are stack effect, the Bernoulli effect and the Venturi effect. Both stack effect and the Bernoulli effect are based on air pressure differences. Stack effect uses air temperature differences to provide ventilation through the rise of warm air due to the fact that warm air has low density and low pressure. On the other hand, the Bernoulli effect is the result of the differences in wind speed and based on the principle “an increase in the velocity of a fluid decreases its static pressure.” (Lechner, 2009, p.269) As air speed increases

with height owing to less obstruction, it has lower pressure at upper levels and provides air flow from high pressure to low pressure. (Figure 2.07) The third, the Venturi effect results from the increase in air speed in the case of flowing through small openings. It can be used for exhausting the inside air through roof openings and can be disturbing in the case of urban planning including narrow passageways, corners of buildings too close together, *etc*. (Figure 2.07 and 2.08) (Lechner, 2009 and Allard, 1998)

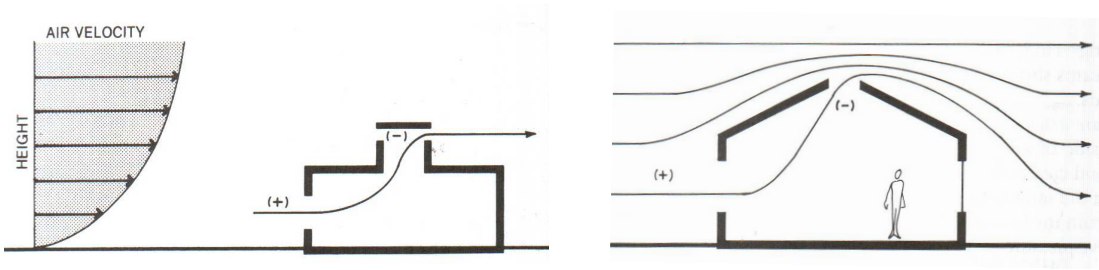


**Figure 2.07.** The Bernoulli effect (left) and the Venturi effect (right)
Source: Lechner (2009, p.270)

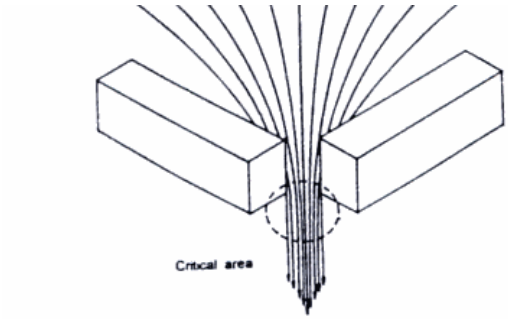


**Figure 2.08.** Critical positions for pedestrian discomfort due to wind on an urban site
Source: Allard (1998, p.198)

### 2.3.2. Design for Ventilation

The details of design are significant in order to achieve the convenient conditions for effective ventilation. There are some parameters needed to evaluate the indoor ventilation conditions which can be exemplified as air speed at the inlet opening, maximum speed at any point in the space, average air speed in the space and average speed at occupancy level which is about 1 m above the floor. (Givoni, 1994) These

parameters are influenced by designs. Wind conditions around a building and design details of it determine the rate of air flow and the distribution of air velocities, and if not considered carefully they can reduce air movement in spaces and buildings. (Allard, 1998 and Givoni, 1994)

Pressure distribution and so air flow pattern around a building is affected by site conditions. Topography, the height of buildings around, the spacing between buildings, the orientation of streets and the distribution of open areas such as gardens are some environmental issues that determine the access of sun and wind to a building. (Givoni, 1976) Therefore, in terms of natural ventilation, buildings should be located in a way that getting benefit from the summer winds while avoiding from the cold winter winds and excessive solar gains. (Figure 2.09)

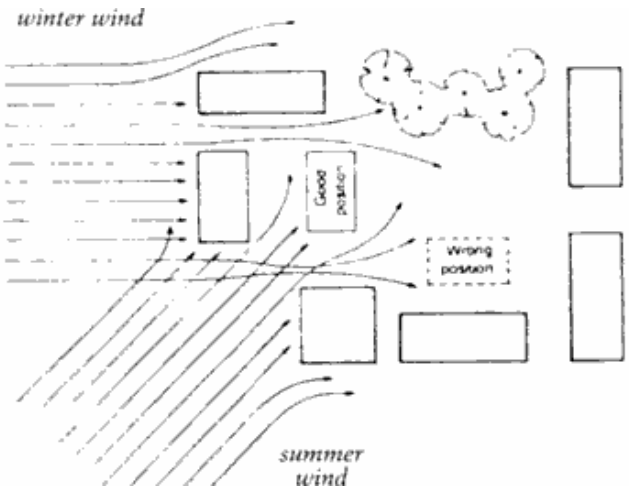


**Figure 2.09.** Examples of good and bad locations of a building on an urban site with respect to wind
Source: Allard (1998, p.197)

Air can be directed as desired with the help of landscaping, windbreakers, building form, wing walls, overhangs, *etc*. (Lechner, 2009) The position of the element designed or placed to direct air, its distance from the building and its size require supplemental attention for effective air flow. (Figure 2.10) In relation, Allard (1998) emphasizes the advantage of landscaping as an element of directing air by indicating its positive effect on air quality through decreasing the heat content of the air

crossing a plant, increasing the humidity content, removing the dust particles, absorbing the carbon dioxide and introducing the oxygen.

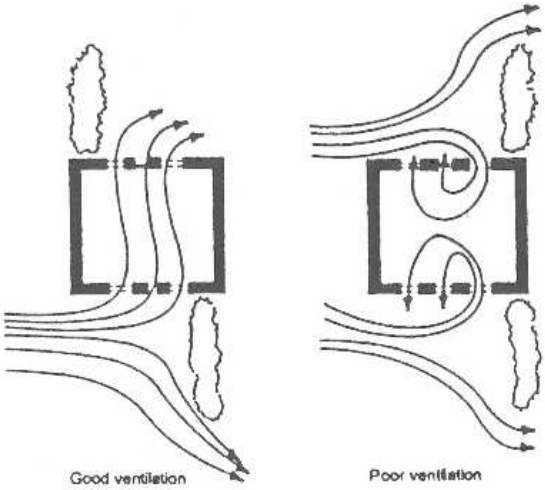


**Figure 2.10.** The effect of hedge positioning on the airflow pattern through a building
Source: Allard (1998, p.200)

The design of building itself is the other factor which requires particular attention for air flow. It includes the designs of building form, space distribution, interior partitioning and opening position, size and type. The form of a building is defined by the ratio of a building's length to its width which is named as an *aspect ratio*. It should not be too high to prevent pressure decrease on the middle of the windward facade and "…the dimension of the cross section along the prevalent summer wind direction should be kept to a functional minimum in order to enhance the use of cross ventilation." (Allard, 1998, p.205) In relation, Givoni (1994) notes: "the more spread out the building and the more irregular its shape, the better the potential for cross ventilation." due to the opportunity of having more opening on the greater number of external walls. On the other hand, the height of building affects the stack effect and increasing it enhances the airflow in vertical zones such as stairwells. In addition, the roof shape determines the positive and negative pressure areas through its type (flat, single-slope or double-slope) and angle and defines the air flow path.

In buildings, generally, the ventilation of a space is interrelated with other spaces. Thus, horizontal distribution of spaces is significant particularly for cross ventilation.

In the context, single-loaded corridor plans are better than the double-loaded ones, however transoms or clerestory windows can improve indoor ventilation in double-loaded corridor arrangements. (Figure 2.11) (Lechner, 2009) In relation, Allard (1998) indicates that spaces such as offices and classrooms should be located on the windward side for effective ventilation and the corridor spaces with large operable windows should be placed on the leeward side. On the other hand, vertical distribution of spaces affects stack ventilation and allows to design atriums, stairwells and shafts as ventilation elements.

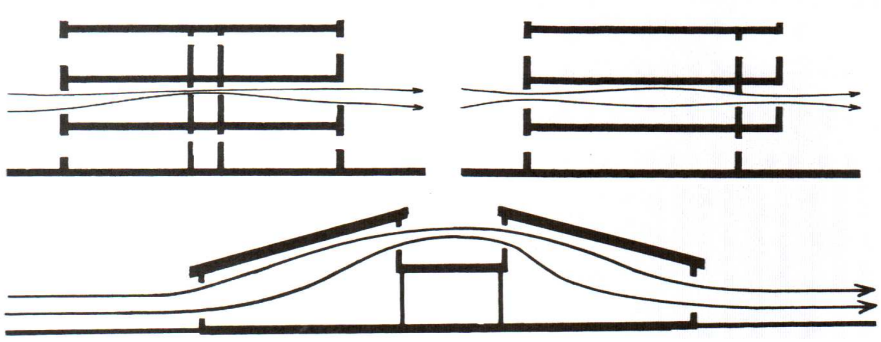

**Figure 2.11.** Single-loaded and double-loaded corridor plans (up) and the use of transoms or clerestory windows for double-loaded plans (bottom)
Source: Lechner (2009, p.278)

Interior partitions have a blocking effect on air flow and decrease the ventilation potential. Therefore, open plan layouts are more suitable for effective ventilation in buildings. (Lechner, 2009) However, in the case of subdividing spaces internal partitions should be parallel to the air flow as much as possible in order to not block the air movement. (Allard, 1998) In addition, the studies – investigating the effect of a partition, which is perpendicular to the air flow path, in the case of subdividing a space into unequal parts – stated by Givoni (1976) show that better ventilation conditions were obtained when the partition was near the outlet window in contrast to its being near the inlet which leads to direction change of air in a short time after entering the room.

Openings affect ventilation efficiency through their position, size and type. Flourentzou, Maas and Roulet (1998) note the position and size of the openings as a dominant parameter of determining the sufficiency of ventilation rate to extract pollutants or heat from the space. The primary principle under positioning is that "windows should be located in opposing pressure zones." (ANSI/ASHRAE Standard 62.1-2007) They can be on one wall, on adjacent walls or on opposite walls of a space. In the case of being on opposite walls, the efficiency depends on the inlet and outlet sizes, the axis between inlet and outlet, and the wind direction. (Givoni, 1976) The direction of wind is important for covering more area of a space. The parallel placement of the axis to the wind direction leads to limited ventilation of the space due to the straight airflow. Therefore, in this opening arrangement oblique winds are better to ventilate more area through creating more turbulent winds (Figure 2.12). (Lechner, 2009) In contrast, openings on adjacent walls require perpendicular winds rather than oblique ones for effective ventilation and allow ventilation of more area through forcing the air to change direction. (ANSI/ASHRAE Standard 62.1-2007 and Givoni, 1976)

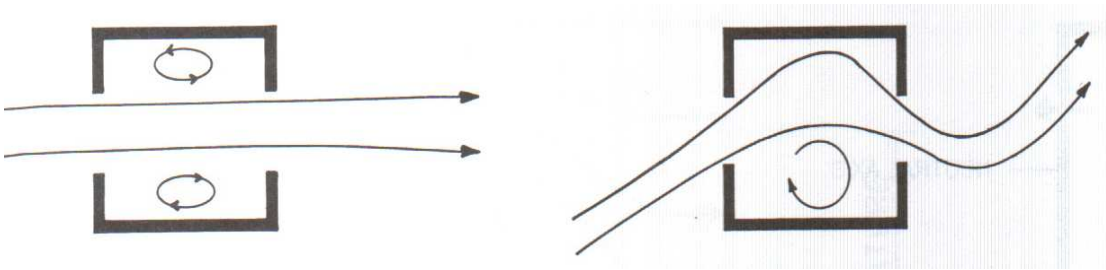

**Figure 2.12.** Head-on winds (left) and oblique winds (right)
Source: Lechner (2009, p.272)

In the case of designing single-sided ventilation, similar to the arrangement of openings on opposite walls, oblique winds are the key factor due to creating pressure differences in its path. (Givoni, 1976) In addition, asymmetric placement of windows is better than symmetric one due to the same reason (Figure 2.13). (Lechner, 2009) Placing fin walls to the windows or designing balconies with side walls, which is less effective that fin walls, is also useful for creating different pressure areas (Figure 2.14).

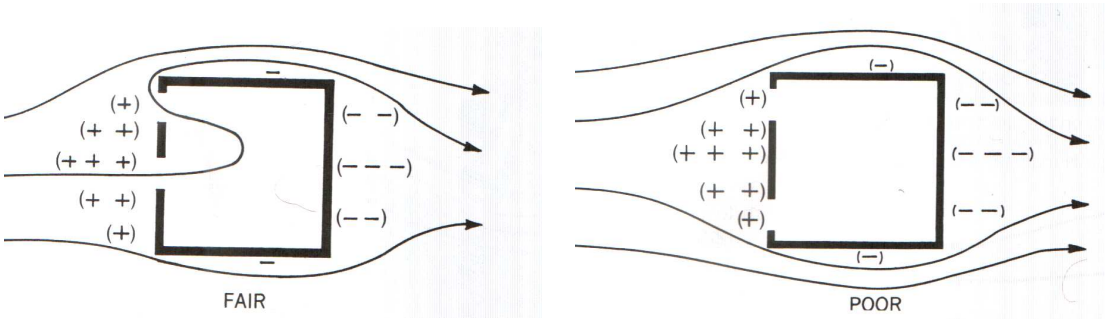


**Figure 2.13.** Asymmetrical (left) and symmetrical (right) placement of windows
Source: Lechner (2009, p.273)

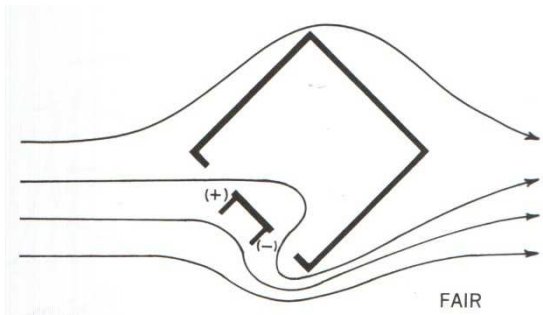


**Figure 2.14.** Placing fin walls for the windows on the same wall
Source: Lechner (2009, p.273)

Room depth has particular significance in the case of single-sided ventilation. “The effective depth for single-sided natural ventilation, analogous to the throw of a forced air jet, is the longitudinal distance that fresh air travels from the inlet opening to the position where room air prevails.” and affected by opening sizes and heat gains. (Gan, 2000, p.65) In designs, room depth should not be more than the effective depth in order to achieve comfort and indoor air quality conditions. The useful depths for three opening configurations are represented in Figure 2.15.

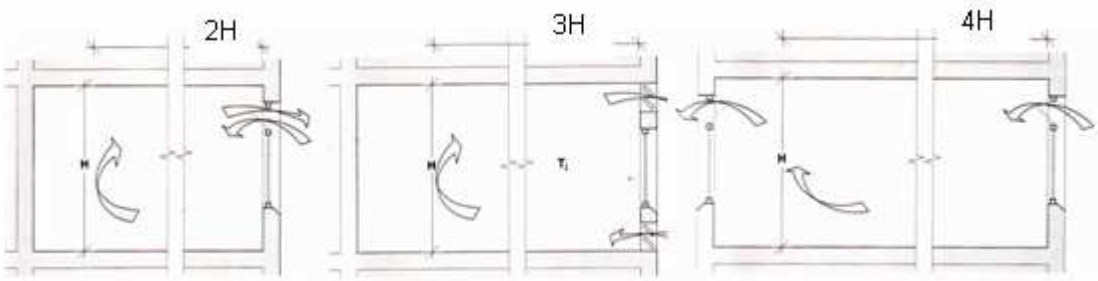


**Figure 2.15.** Useful depths for three opening configurations
Source: Baker and Steemers (2000, p.58)

The desired air flow pattern determines the vertical placement of windows. In the case of comfort ventilation, the windows should be at the level of occupants (Figure 2.15). In relation, Givoni (1976) states that windows of offices, classes, *etc*. should be placed to direct the air to the head level (120-150 cm above the floor) for comfort, however a decrease in air velocity should be provided at the desk level (about 70 cm) in order to not cause disturbance. The author also emphasizes the significance of the sill height of inlet window, since a sudden decrease in air speed exists below the sill level. On the other hand, "if openings are at the same level and near the ceiling, much of the flow may bypass the occupied level and be ineffective in diluting contaminants there." (ANSI/ASHRAE Standard 62.1-2007) However; high windows can be preferable in order to exhaust the hot air (Figure 2.16).

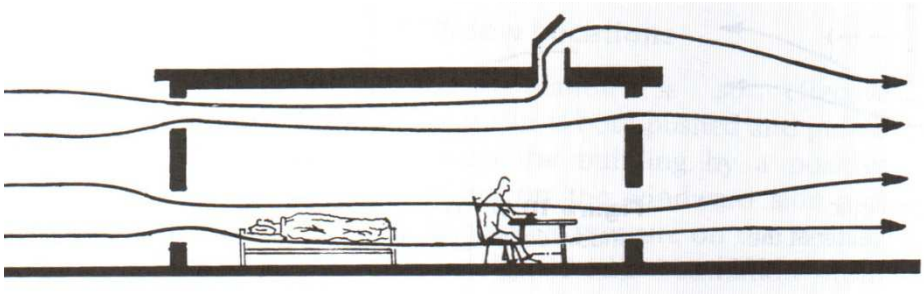

**Figure 2.16.** Placing windows at the occupant level for comfort ventilation and at higher level for exhausting the hot air
Source: Lechner (2009, p.274)

The size of openings is the second dominant parameter of determining the sufficiency of ventilation rate. In terms of the relation between the space dimensions and the percentage of the openable area, ANSI/ASHRAE Standard 62.1-2007 recommends "... the openable area of which is a minimum of 4% of the net occupiable floor area." In connection with the needed air flow rate, as Turnbull (n..d.) notes, the openable inlet area can be simply calculated through the flow rate equation which is;

$$Q = A \cdot V$$

where Q is the flow rate, A is the cross sectional area and V is the average velocity.

In cross ventilated spaces, increasing both inlet and outlet openings at the same time affects the internal air flow greatly. In a more detailed manner; Givoni (1976) notes that in the case of designing windows in different sizes, the average indoor air velocity depends on the smaller opening. The author also indicates that designing a larger outlet opening in contrast to an inlet one creates higher maximum air velocities, especially near the inlet opening; however results in lower air flow in other parts of the space. On the other hand, in the case of single-sided ventilated spaces opening size has a low effect on air flow except for the one provided by oblique winds.

In addition to positioning and sizing openings, choosing the appropriate type is also a fundamental factor in ventilation design. Allard (1998) groups windows under three categories: simple openings that operate by sliding, vertical-vane openings that operate by pivoting on a vertical axis and horizontal-vane openings that operate by pivoting on a horizontal axis. In general, single hung windows, double-hung windows and horizontal sliding windows – simple openings – have not a direction changing effect on air. Side-hinged windows, folding windows and vertical pivoted windows – vertical-vane openings – enable the control of both the air amount and direction. Projected sash windows, awning windows, hopper windows, horizontal pivoted windows and jalousies –horizontal-vane openings – allow directing the air upwards, downwards or any level. In addition to window selection, inclusion of fly-screen is also a design decision which has a reducing effect on air flow, particularly in the case of oblique winds. Moreover, there is a choice of trickle vents for silent background ventilation, which provides draught avoidance, rain protection and security. In general, they are placed in a window frame, in a window glazing or independently. According to the Building Regulations 2000, they are located at 1.7 m above the room floor or higher in order to not cause disturbance. They are properly sized with equivalent area, which is the area air passing through, to help the prediction of the air flow rate.

## 2.4. Educational Buildings

Educational buildings are large scale structures consisting of various teaching spaces which serve students, educators, parents, *etc*. The main objective of educational institutions is facilitating and supporting the learning process. In this context, environmental conditions in classrooms should be one of the main concerns in design for physically comfortable teaching areas due to the relation between the conditions and concentration, and so learning. In the present day, owing to becoming more conscious of health and performance, the ones who take parts in design and construction process work on better-conditioned buildings.

### 2.4.1. Development of Educational Spaces

The design of an educational building is one of the challenges that designers have been facing for years. As Baker (2012) indicates, in the early American years, education was in a one-room schoolhouse. Subsequently, it required buildings along with the increase in city and town populations. These buildings did not have appropriate environmental conditions around and consisted of rectangular classes with desk rows, windows on both sides of the room and some other facilities. In time, the educational buildings began to be standardized as a result of the need for more student capacity. In spite of the standardized school buildings and classes with larger spaces, the classrooms were crowded and impersonal due to the increasing demand.

In 1930s and 1940s, new designs based on student-centered learning emerged. It is called as ‘open air school’ which emphasized fresh air, light, outdoor activity, easy circulation, *etc.* for active learning. (Baker, 2012) However, no significant changes were emerged in terms of indoor environmental quality due to economical problems.

In between 1945-1960, one-story flat-roofed educational buildings were constructed with glass and metal window wall systems or brick and concrete ones, and air conditioning was installed firstly. (Tanner & Lackney, 2005) The windows were

floor-to-ceiling to provide light and had a doorway access from each class to directly outside. (Hille, 2011) In addition, the finger-plan concept of design was emerged which is defined by Baker (2012, p.11) as "…corridors spread out across the plan, forming fingers off of which each classroom extends. This configuration allowed each classroom to have access to maximum amounts of fresh air and light…" In this period, thermal comfort became an important issue and more researches on heating and ventilation were done.

In the period of 1960-1980, the relation between school facilities and learning was started to be noticed. Subsequent to the energy crisis in 1973, reducing energy consumption through energy codes and regulations also affected educational buildings. The existing buildings were renovated for energy efficiency. Particularly, large windows were closed off for saving energy and so natural ventilation and natural light were blocked. (Baker, 2012) However, in spite of the energy conservation the use of mechanical systems was continued.

In 1990s and 2000s, indoor air quality problems due to indoor air pollutants and high $CO_2$ levels were realized in educational buildings. The basic needs of heating, ventilation and indoor air quality were taken into consideration more seriously and the comfort limits of physical parameters were used. Natural ventilation and mixed-mode systems became an interest for comfort. Additionally, 'green building' movement was emerged in this period, and the use of renewable energy and healthier indoor environment were encouraged in school designs.

In the future, teaching spaces will continue to change due to the technological developments, the demand for healthier environments, *etc.* They will become more flexible and adaptable spaces for different teaching and learning activities. However, more research is needed on these spaces in terms of the effect of physical environment on comfort, satisfaction, creativity, attention, *etc.* to build better conditioned buildings.

### 2.4.2. Academic Performance in Educational Buildings

Classrooms are the spaces that students and educators should spend their school days productively. Owing to the educational concerns, it is significant to consider teaching spaces as human-responsive environments. Since the unfavorable indoor conditions in educational buildings, in general, lead to rise in illnesses and absenteeism, and fall in academic performance.

According to EPA (2003a); pollution source control, adequate ventilation, proper temperature and humidity conditions and responsibility to students and educators should be the concerns in design, construction and maintenance of educational buildings, and a problem in one of them leads to negative effects on health, comfort and performance of students and staff. In the same source, as an illustration, the study of 800 students from 8 schools is indicated with the result of concentration loss and health problems due to reduced ventilation rates. In addition, Bayer, Crow and Fischer (2000, p.43) state that "Reports of impaired performance were more common in schools with lower air exchange rates, higher relative humidities, and higher concentrations of respirable dust, formaldehyde, VOCs, and total bacteria or molds." In terms of the effects of indoor $CO_2$ concentrations on students, Shendell, *et al*. (2004) state that high $CO_2$ levels indicating low ventilation rates lead to communicable respiratory illnesses, and add that 1000 ppm difference between $CO_2$ levels of outdoor and indoor causes a relative 10-20 percent increase in student absenteeism. Moreover; Myhrvold, Olsen and Lauridsen (1996) report that the $CO_2$ concentration above 1500 ppm leads to headache, dizziness, concentration difficulties, *etc*. on pupils, and note that symptoms such as throat irritation, nose irritation, *etc*. are also observed along with the increasing levels. In relation, the authors find out a poor academic performance in teaching spaces with high $CO_2$ levels in accordance with the performance index in regard to $CO_2$ concentrations.

On the other hand, it is obvious by researches that there is a positive effect of healthy environment on student success, since physical comfort directly affects concentration and comprehension which are related to learning. To clarify, the research reports of

the U.S. Department of Education show that "…students attending schools in poor condition score 11 percent lower on standardized tests than students who attend schools in good condition." (EPA, 2003b)

### 2.4.3. Indoor Air Pollution in Educational Buildings

According to EPA's Science Advisory Board, indoor air pollution is in the top five environmental risks affecting public health. (EPA, 2003b) In relation, in terms of educational buildings, the U.S. government's General Accounting Office indicates that among five U.S. public schools, one has poor indoor air quality conditions. (Bayer, Crow & Fischer, 2000) Additionally, Buchanan (2007) states – by referring the U.S. Government Accountability Office – that "…more than half of U.S. schools have indoor air quality problems in at least some part of their campuses." Old schools particularly have high potential of creating problems due to lack of maintenance. As Air Quality Sciences (2006) presents, all these situations risk the health of 10 percent of the U.S. population.

The most common indoor air pollutants identified in school buildings are formaldehyde, total VOCs, $CO_2$ and bioaerosols. (Bayer, Crow & Fischer, 2000) In general, the indoor sources causing air problems in educational buildings are "…mold, mildew, paint fumes, cleaning chemicals, and even pet dander from classroom pets." which lead to "…sneezing and coughing; eye, nose, and throat irritation; congestion; fatigue; shortness of breath; and headaches." (Buchanan, 2007) Other than these, air pollutants can also be the causes of more serious diseases on students and educators, and lead to absenteeism. To illustrate, asthma is the most common chronic disease resulting from poor indoor air quality. As Buchanan (2007) states, it affects student academic performance negatively through causing more than 14 million lost school days. Furthermore, according to the National Heart, Lung, and Blood Institute, in terms of health care and productivity loss asthma cost 14 billion dollars in 2002. (EPA, 2003b)

In the context, it is significant to take precautions against indoor air quality problems in educational buildings to eliminate and/or reduce health problems and so to raise academic performance and productivity of students and educators. EPA (2003b) states that controlling the indoor conditions can lessen diseases and related costs 10 to 30 percent. In a similar manner, by referring the estimation of Lanphear and colleagues, Cummins and Jackson (2001) indicate that removing the causes of indoor air pollution provides 39 percent reduction in asthma in the U.S. and 402 million dollar saving. Providing adequate outdoor air ventilation, controlling the space relative humidity and providing effective particulate filtration are the some key points to avoid from indoor air quality problems. (Bayer, Crow & Fischer, 2000) Therefore, observing for an early repair and maintenance, implementing an indoor air quality program and informing students, educators and parents about laws and regulations for healthy indoor environment can be some simple precautions against indoor air quality problems in educational buildings. (Buchanan, 2007)

### 2.4.4. Ventilation in Educational Buildings

Bayer, Crow and Fischer (2000) indicate two studies to mention the situation in educational buildings in terms of ventilation. The one by National Institute for Occupational Safety and Health expresses that in workspaces the most common cause of indoor air problems is insufficient ventilation. In a similar manner, the second study reported by Henckel and Angell, which was conducted on Minnesota schools, also represents inadequate fresh air supply as a most common factor affecting indoor air quality, and poor air distribution in a space as the third. In addition to these two studies, according to the report of the National Center for Education Statistics of the Department of Education, approximately one in four public schools in the U.S. has unsatisfactory ventilation which results in indoor air quality problems. (EPA, 2003b)

Physical comfort problems in non-domestic buildings have some reasons that increase the need for ventilation in spaces. At first, the accumulation of air pollutants in increasing numbers in such buildings worsens the indoor air quality more and

requires fresh air supply to reduce their concentrations for health. Secondly, the unfavorable temperature and humidity conditions due to the internal heat sources in addition to external gains affect the thermal comfort in these buildings. In general, the main gains that lead to overheating and so increase in the need for ventilation are represented in Figure 2.17.

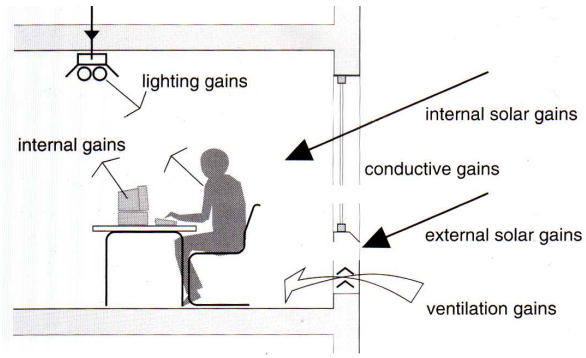


**Figure 2.17.** The sources of heat gains likely to cause overheating
Source: Baker and Steemers (2000, p.30)

The energy generated in the body, which changes in accordance with the activity, also increases the occupant ventilation need. It affects the sensation of environmental conditions and increases the $CO_2$ generation. Thus, in terms of ventilation it is significant to consider heat production values of the possible activities determined by the function of spaces. Typical heat generation values for possible classroom activities are presented in Table 2.01.

**Table 2.01.** Typical metabolic heat generation for various activities
Source: ASHRAE (2009)

| | Btu/h·ft$^2$ | met* |
|---|---|---|
| Resting | | |
| Seated, quiet | 18 | 1.0 |
| Standing, relaxed | 22 | 1.2 |
| Walking (on level surface) | | |
| 2.9 fps (2 mph) | 37 | 2.0 |
| 4.4 fps (3 mph) | 48 | 2.6 |
| 5.9 fps (4 mph) | 70 | 3.8 |
| Office Activities | | |
| Reading, seated | 18 | 1.0 |
| Writing | 18 | 1.0 |

On the other hand, in addition to the reasons increasing the need for ventilation in spaces, there are some design-based causes preventing and/or reducing ventilation. One of them can be incorrect construction of building details, which obstruct air infiltration. Additionally, the missing considerations in design processes lead to poor environmental conditions in spaces. To illustrate, as Baker and Steemers (2000) indicate, non-domestic buildings are generally designed to have lower surface area to volume ratios in contrast to domestic ones, which reduces the possibility of ventilating spaces effectively. Furthermore, in terms of layout designs Yeang (1996, p.76) states that "Internal layouts should give maximum opportunity for openable windows to be accessible to all." Separately, there may be causes due to building occupants *i.e.* densely occupation of teaching spaces makes ventilation difficult and results in the spread of illnesses easily. ASHRAE Standard 62.1-2007 recommends maximum 65 occupants for every 100 m² in lecture classrooms and maximum 20 occupants for every 100 m² in art classrooms. Accordingly, the occupancy level above the capacity of class floor area worsens the physical conditions; particularly winters can be more problematic due to heat accumulation which also affects concentration and learning. Moreover, the situation can also cause mold problems due to the high levels of moisture released by occupants.

Ventilation of spaces is considered through "the amount of outdoor air required to control moisture, carbon dioxide ($CO_2$), odors, and tobacco smoke generated by occupants." (ANSI/ASHRAE Standard 62.1-2007) It is defined by a minimum rate of outdoor air supply per occupant. The regulations for the issue point out that classrooms, lecture rooms, *etc.* should be ventilated constantly through fresh air supply. As a design criterion for classrooms, the International Standard EN ISO 7730:2005 specifies a maximum mean air velocity of 0.24 m/s for summers and 0.21 m/s for winters. In addition, Ertürk (2007) notes an air exchange coefficient of 3 to 7 in an hour in educational buildings while calculating the needed amount of fresh air in accordance with the space volume; *i.e.* the amount of needed fresh air can be calculated through multiplying the space volume by the air exchange coefficient. Furthermore, ASHRAE Standard 62.1-2007 requires a minimum ventilation rate of 7.5 cfm/person (3.8 L/s person) or 0.06 cfm/ft² (0.3 L/s m²) for lecture classrooms

and 10 cfm/person (5 L/s person) or 0.18 cfm/ft² (0.9 L/s m²) for art classrooms. According to the National Research Council's report, "...there is good evidence that increasing the ventilation rate beyond the ASHRAE standard will further improve comfort and productivity." (Air Quality Sciences, 2006) To illustrate, a study cited in EPA (2010) shows that improving ventilation conditions in classes results in 14-15 percent higher test scores by students. In short, ventilating teaching spaces sufficiently is a key factor for improving indoor air quality, and eventually for reducing illnesses and increasing student performance and test scores.

# CHAPTER 3

# MATERIAL AND METHOD

This chapter presents the details of the research study in two subsections: the material and the method. In the 'Material' section, the case study building, the data loggers used for data collection and the weather data for Ankara are introduced. Then, as the 'Method' section, the collection and evaluation of the data are described.

## 3.1. Material

The study was conducted in the Faculty of Architecture building on the METU campus in Ankara. In measurements, five data loggers were used along with four $CO_2$ and one air speed sensors to record the temperature, relative humidity, air speed and $CO_2$ concentration in two rooms of the building. In this section, the case study building and the data loggers used for data collection are defined in detail, and Ankara weather data for the period of data collection is presented.

### 3.1.1. Case Study Building

In the study, indoor air quality was examined on the METU Faculty of Architecture building. The building is located in the METU campus in Ankara. The building was designed by Behruz Çinici and Altuğ Çinici at the campus. The construction was started in 1962 and was completed in 1963.

The METU Faculty of Architecture building is a low-rise structure made of exposed concrete. It is elongated on the north-south axis in the campus. The building program mainly includes design studios, classrooms and offices of academic and administrative staff. Figure 3.01 presents the ground floor plan of the building with the indication of rooms investigated in the study.

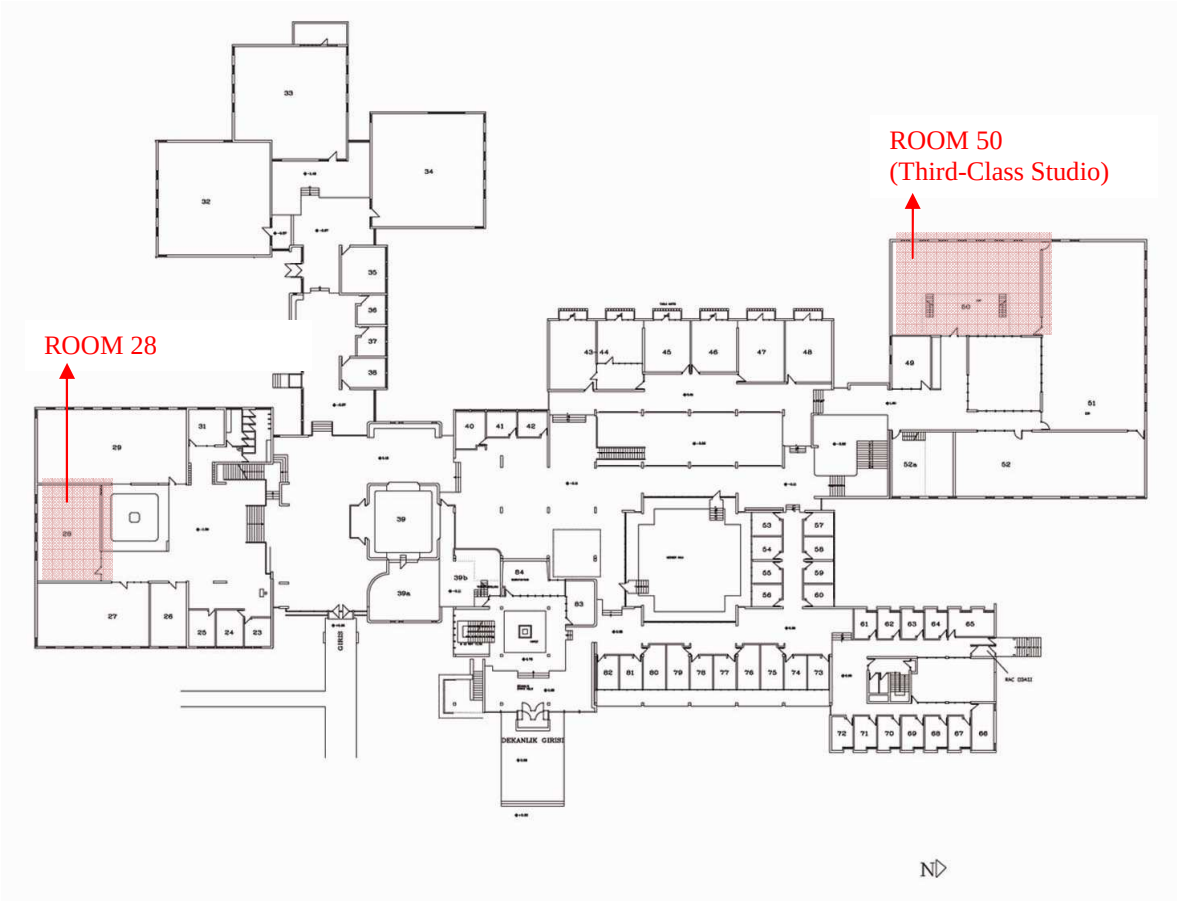


**Figure 3.01.** Ground floor plan of the METU Faculty of Architecture building (provided by the METU Building Simulation Lab.)

In the study, due to having limited numbers of $CO_2$ and air speed sensors, two rooms were examined; *i.e.* Room 28 and Room 50 were selected for data collection. Room 28 was chosen since it is the largest classroom in the faculty and Room 50 was preferred owing to its being a design studio that faces south. Both rooms face the same direction and are on the ground floor of the building. The constructional features of the rooms are presented in Table 3.01.

**Table 3.01.** The constructional features of Room 28 and Room 50

| | **Room 28** | **Room 50** |
|---|---|---|
| **Location** | Ground floor | Ground floor |
| **Facing facade** | South | West and south |
| **Purpose of use** | Classroom | Design studio |
| **Floor area** | 98.5 $m^2$ | 225 $m^2$ (ground floor)<br>+<br>113.4 $m^2$ (mezzanine floor) |
| **Height / Volume** | 4.6 m / 453.1 $m^3$ | 4.9 m / 1102.5 $m^3$ |
| **Walls** | Exposed concrete | Exposed concrete |
| **Windows** | Double-glazed,<br>from floor to ceiling | Double-glazed,<br>from floor to ceiling |
| **Number and direction of windows** | 4 south-facing | 7 west-facing,<br>1with six vertical panes facing atrium on the east |
| **Floors** | Laminate parquet | Ground floor: Ceramic tiles<br>Mezzanine floor: Linoleum flooring |
| **Roof / Ceiling** | Concrete ceiling | Concrete roof with water and thermal insulation |
| **Ventilation system** | Natural ventilation<br>(the closed off system of inlet openings coupled with fan coils) | Natural ventilation<br>(the closed off system of inlet openings coupled with fan coils) |
| **Heating system** | Central heating | Central heating |

In order to identify the time period when the rooms were occupied, the weekly course schedules of each room are given in Table 3.02 and 3.03. The schedules were obtained from the departmental secretaries and the data were evaluated accordingly. The number of students registered to the courses is also indicated in these tables below the each course name to clarify the occupancy levels. The absenteeism is neglected throughout the evaluation. In addition, in Table 3.04 the final examination dates and times of Room 28 are given along with the course names and registered student numbers, which were used throughout the evaluation of the data belonging to the final examination period. Some of the exams for larger classes were conducted in two rooms hence the occupancy level was lower.

**Table 3.02.** The weekly course schedule of Room 28 – 2011-2012 fall semester

| HOUR | MON. | TUE. | WED. | THU. | FRI. |
|---|---|---|---|---|---|
| 8:40-9:30 | ARCH 221<br>*99 students* | ARCH 221<br>*99 students* | | ENG 211 (CRP)(16)<br>*20 students* | |
| 9:40-10:30 | ARCH 221<br>*99 students* | ARCH 221<br>*99 students* | ARCH 381<br>*83 students* | CRP 211<br>*85 students* | |
| 10:40-11:30 | ARCH 351<br>*84 students* | ARCH 321<br>*90 students* | ARCH 381<br>*83 students* | CRP 211<br>*85 students* | ARCH 321<br>*90 students* |
| 11:40-12:30 | ARCH 351<br>*84 students* | ARCH 321<br>*90 students* | ARCH 381<br>*83 students* | CRP 211<br>*85 students* | ARCH 321<br>*90 students* |
| 13:40-14:30 | | IS 100<br>*100 students* | CRP 231<br>*59 students* | | |
| 14:40-15:30 | | IS 100<br>*100 students* | CRP 231<br>*59 students* | ID 121<br>*61 students* | |
| 15:40-16:30 | | IS 100<br>*100 students* | CRP 231<br>*59 students* | ID 121<br>*61 students* | |
| 16:40-17:30 | | | | ID 121<br>*61 students* | |

**Table 3.03.** The weekly course schedule of Room 50 – 2011-2012 fall semester

| HOUR | MON. | TUE. | WED. | THU. | FRI. |
|---|---|---|---|---|---|
| 8:40-9:30 | | | | | |
| 9:40-10:30 | | | | | |
| 10:40-11:30 | | | | | |
| 11:40-12:30 | | | | | |
| 13:40-14:30 | ARCH 301<br>*70 students* | ARCH 351<br>*84 students* | ARCH 301<br>*70 students* | | ARCH 301<br>*70 students* |
| 14:40-15:30 | ARCH 301<br>*70 students* | ARCH 351<br>*84 students* | ARCH 301<br>*70 students* | | ARCH 301<br>*70 students* |
| 15:40-16:30 | ARCH 301<br>*70 students* | ARCH 351<br>*84 students* | ARCH 301<br>*70 students* | | ARCH 301<br>*70 students* |
| 16:40-17:30 | ARCH 301<br>*70 students* | ARCH 351<br>*84 students* | ARCH 301<br>*70 students* | | ARCH 301<br>*70 students* |

**Table 3.04.** The Final examination schedule of Room 28 – 2011-2012 fall semester

| COURSE | REGISTERED STUDENT | EXAMINATION DATE | TIME |
|---|---|---|---|
| ARCH 221 | 99 | 09.01.2012 | 01:30 PM |
| ARCH 708 | 30 | 10.01.2012 | 04:30 PM |
| ARCH 121 | 110 | 11.01.2012 | 09:30 AM |
| ARCH 351 | 84 | 11.01.2012 | 01:30 PM |
| ARCH 441 | 40 | 16.01.2012 | 09:30 AM |
| ARCH 419 | 30 | 19.01.2012 | 01:30 PM |
| ARCH 491 | 43 | 20.01.2012 | 09:30 AM |

The information on the cleaning of the rooms was obtained from the faculty cleaning staff. According to the cleaning staff, the rooms were cleaned before classes. It took approximately 10-15 minutes in each room. The room floors were cleaned with a surface cleaner detergent by using a mop. The teacher's desk and blackboard were wiped with a wet cloth and the students' desks were wiped with a cream surface cleaner detergent. In addition, owing to the security issues, at the end of the school day the windows were closed and the doors were locked. Both windows and doors were opened at around 07:00 AM in the morning of next school day.

### 3.1.2. Data Loggers

In the study, three kinds of instruments were placed in the rooms to record the temperature, relative humidity, air speed and $CO_2$. (Figure 3.02) Onset HOBO U12 data loggers are the main instruments used in records. They measure and record the temperature and relative humidity themselves. For $CO_2$ concentration records, SenseAir eSENSE (-D) $CO_2$ sensors were plugged in to these data loggers. In addition, for air speed records a Deltaohm HD403TS2 air speed sensor was plugged in to each Onset HOBO U12 data logger for a 10-day period. In order to readout and launch the data loggers, HOBOware Pro software was used. The recorded data were downloaded to the computer with this software in both tabular and graphical forms.


**Figure 3.02.** The data loggers: Onset HOBO U12 data logger (left), SenseAir eSENSE (-D) $CO_2$ (middle) and Deltaohm HD403TS2 air speed (right) sensors (Source: http://www.onsetcomp.com/products/data-loggers/u12-013 http://www.senseair.se/products/wall-mount/esense/ http://degre5.com/ )

### 3.1.3. Weather Data for Ankara

Ankara weather data were obtained from the Turkish State Meteorological Service. Hourly records of temperature, relative humidity and wind speed at 10 m were taken in tabular form and reorganized as graphics. The temperature, relative humidity and wind speed data for Ankara for the period of data collection are presented in Figure 3.03, 3.04 and 3.05.

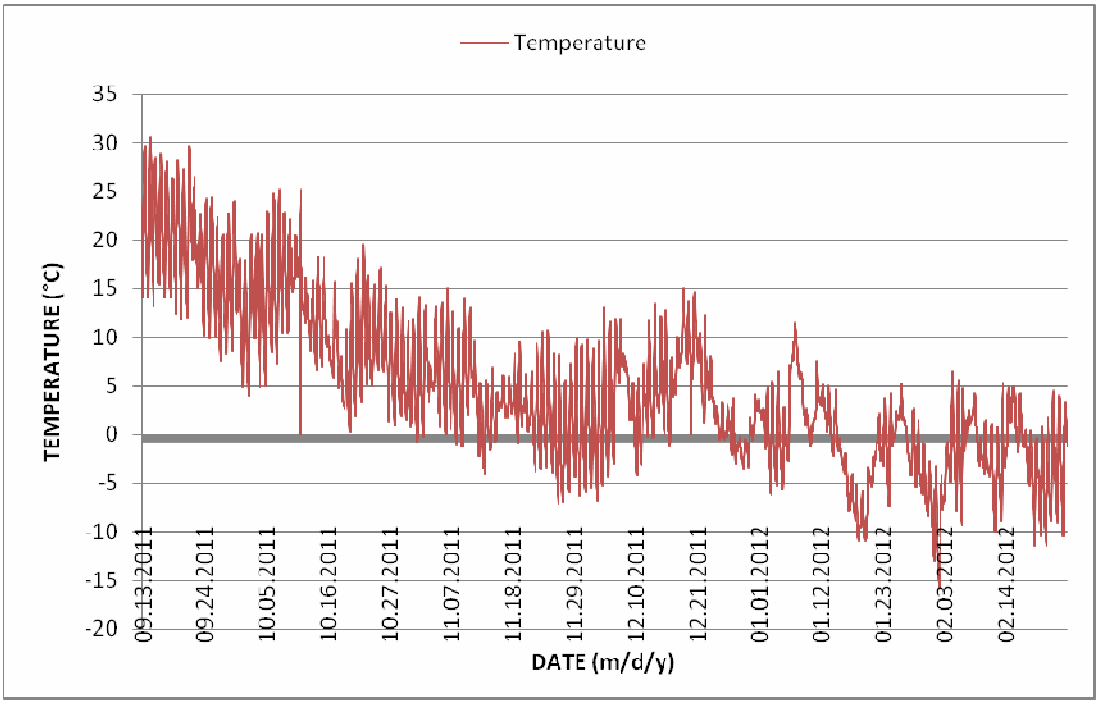


**Figure 3.03.** Temperature chart for Ankara (13 September 2011 to 24 February 2012)
(Source: Data obtained from the Turkish State Meteorological Service)

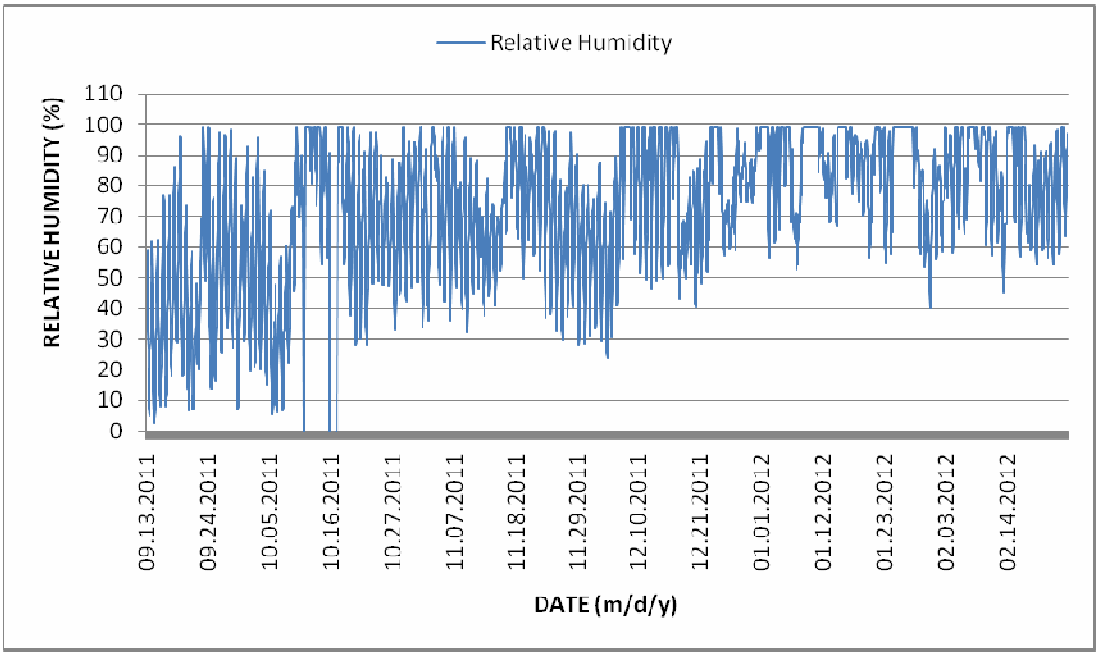


**Figure 3.04.** Relative humidity chart for Ankara (13 September 2011 to 24 February 2012) (Source: Data obtained from the Turkish State Meteorological Service)

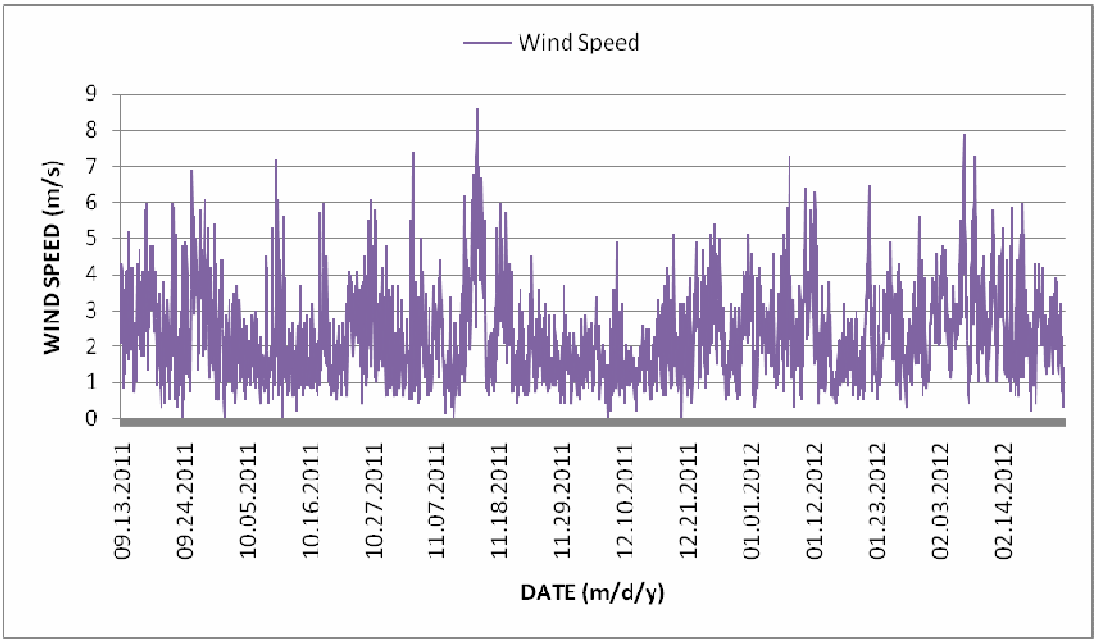


**Figure 3.05.** Wind speed chart for Ankara (13 September 2011 to 24 February 2012) (Source: Data obtained from the Turkish State Meteorological Service)

## 3.2. Method

The study was performed in two stages. At first, as a field study, the temperature, relative humidity, air speed and $CO_2$ were recorded in the selected rooms of the case study building by using the data loggers. Then, the collected data were evaluated and interpreted to understand the existing situation and its potential causes. In the following sections, the stages of the study are explained in detail.

### 3.2.1. Data Collection

Temperature, relative humidity, air speed and $CO_2$ data were collected from the two rooms of the METU Faculty of Architecture building. The data were continuously recorded at the two locations of each room with 15 minutes intervals at 2 m height from the floors. (Figure 3.06, 3.07, 3.08 and 3.09) In relation, the placement of the data loggers in spaces requires attention to obtain accurate records. Locating them in such places exposed directly to the sun and/or air movements and places close to heat, moisture or pollutant sources negatively affect the values recorded. In addition to these general considerations, the electricity need to run the $CO_2$ sensors and the air speed sensor was a limitation on the placement of the data loggers.

The temperature, relative humidity and $CO_2$ records were taken between 13 September 2011 and 24 February 2012. This period includes the fall semester of the 2011-2012 academic year (26 September 2011 to 21 January 2012) to evaluate the conditions during the classes. The rooms were empty between the dates 13-25 September 2011 (before the fall semester), 6-9 November 2011 (the Religious holiday) and 21 January-15 February 2012 (the semester break). The air speed was recorded at each of four locations for 10 days between 26 November 2011 and 5 January 2012. For some unknown reason data were not recorded by the data loggers for short periods in the rooms. This could have happened due to electricity outages. In addition, minus $CO_2$ concentrations were recorded occasionally, which could also be the result of electricity problems. Table 3.05 and 3.06 show the data logger locations, the data logger codes and the time periods that the data recorded.

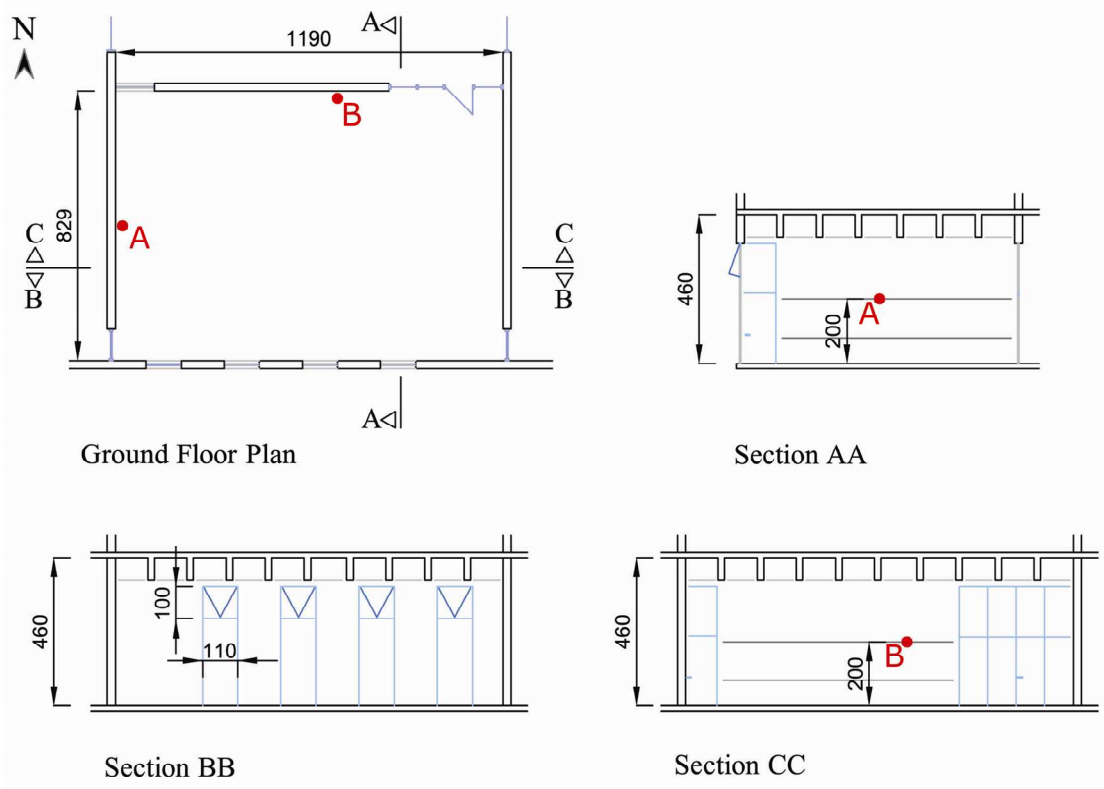


**Figure 3.06.** Determination of the locations for recording in Room 28


**Figure 3.07.** The locations for recording in Room 28 (left) and the data loggers at the location 'A' at the back of the room (right)

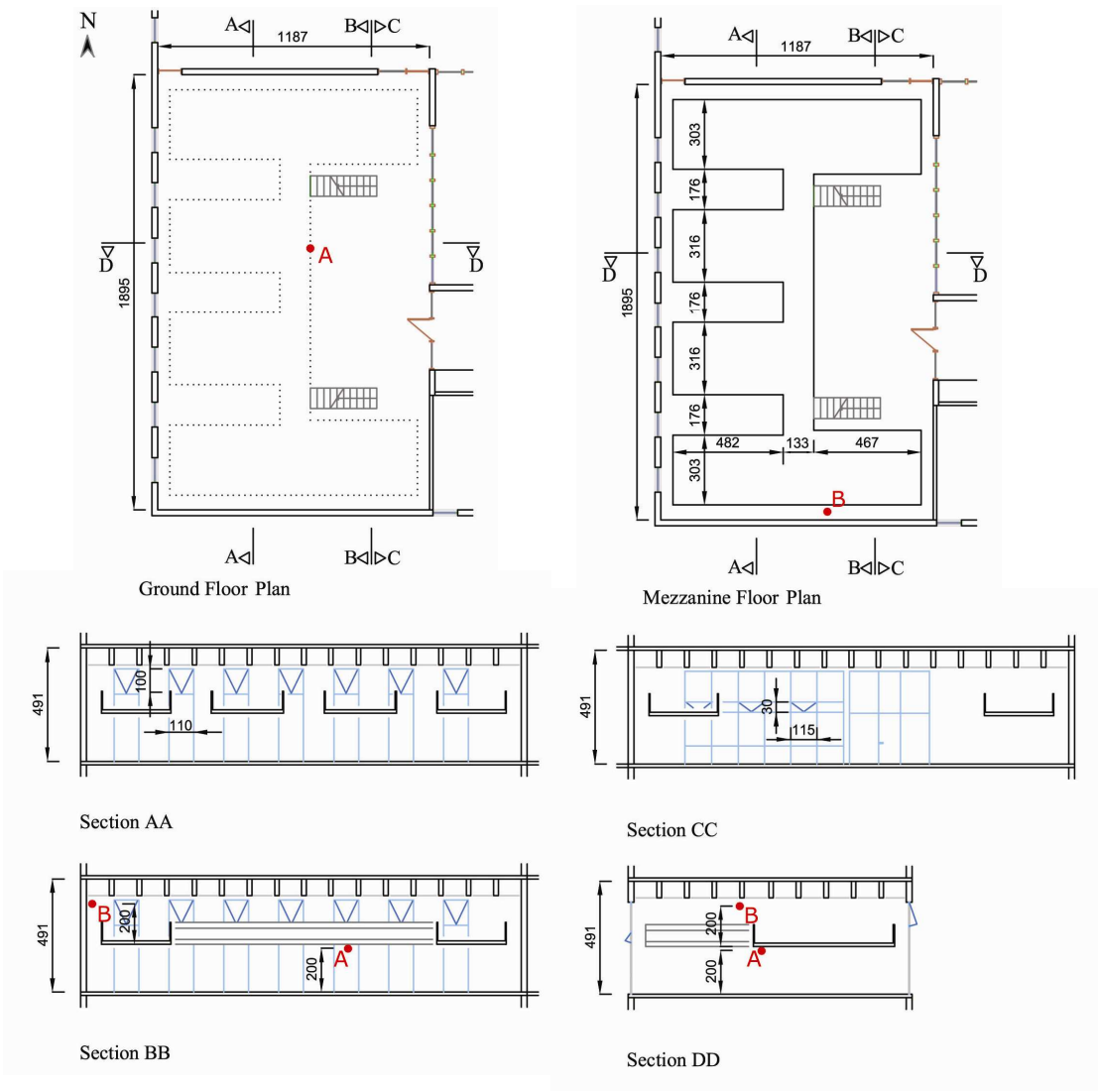


**Figure 3.08.** Determination of the locations for recording in Room 50


**Figure 3.09.** The locations for recording in Room 50

**Table 3.05.** Temperature, relative humidity and $CO_2$ data record periods

| LOCATION | DATA LOGGER | DATA RECORD PERIOD |
|---|---|---|
| Room 28 Location 'A' | DL10 - EQ3 | 13.09.2011 09:00 AM to 19.02.2012 05:00 AM |
| Room 28 Location 'B' | DL12 - EQ1 | 13.09.2011 09:00 AM to 24.02.2012 01:00 PM |
| Room 50 Location 'A' | DL17 - EQ2 | 13.09.2011 09:00 AM to 04.01.2012 06:45 AM |
| Room 50 Location 'B' | DL07 - EQ4 | 13.09.2011 09:00 AM to 09.11.2011 06:15 AM |
| | DL11 - EQ4 | 25.11.2011 02:30 PM to 24.02.2012 01:00 PM |

**Table 3.06.** Air speed data record periods

| LOCATION | DATA LOGGER | DATA RECORD PERIOD |
|---|---|---|
| Room 28 Location 'A' | DL09 - A.S.S. | 26.11.2011 02:30 PM to 06.12.2011 12:30 PM |
| Room 28 Location 'B' | DL09 - A.S.S. | 06.12.2011 02:30 PM to 16.12.2011 12:30 PM |
| Room 50 Location 'A' | DL09 - A.S.S. | 16.12.2011 02:30 PM to 26.12.2011 12:30 PM |
| Room 50 Location 'B' | DL09 - A.S.S. | 26.12.2011 02:30 PM to 05.01.2012 12:30 PM |

### 3.2.2. Data Evaluation

The data collected from Room 28 and Room 50 were downloaded from the data loggers to a computer with the HOBOware Pro software. The downloaded data were reorganized in tabular and graphical forms for clear representation.

The data were evaluated in two stages for each of the two rooms. Firstly, the overall data recorded at each location were examined. Then, the data of the time period that the air speed was recorded at each location were analyzed.

# CHAPTER 4

# RESULTS AND DISCUSSION

In this chapter, the results, analyses and discussions on the outcomes of the data collection are presented. The following sections include the graphical and tabular representation and evaluation of the temperature, relative humidity, $CO_2$ and air speed data collected from the two rooms of the METU Faculty of Architecture building. The raw data of five days are presented in Appendix A.

## 4.1. Room 28

As explained in the Section 3.1.1., Room 28 is a south-facing classroom on the ground floor of the METU Faculty of Architecture building. Its dimensions are 8.29 m by 11.90 m with a height of 4.60 m. It has four south-facing floor-to-ceiling windows. The openable sections (1.1m x 1m) of these windows are on the top. They are top-hinged and open outwards. The room does not have any special ventilation system other than the natural ventilation opportunity. It is heated by central heating system. The temperature, relative humidity, $CO_2$ and air speed data recorded at the two locations of the room are presented in the following subsections.

### 4.1.1. Temperature Data

The temperature data recorded at the location ‘A’ at the back of the room from 13 September 2011 to 19 February 2012 are shown in Figure 4.01 and the ones at the location ‘B’ near the door from 13 September 2011 to 24 February 2012 are in Figure 4.02. The minimum and maximum values are given along with the outdoor ones obtained from the Turkish State Meteorological Service in Table 4.01.

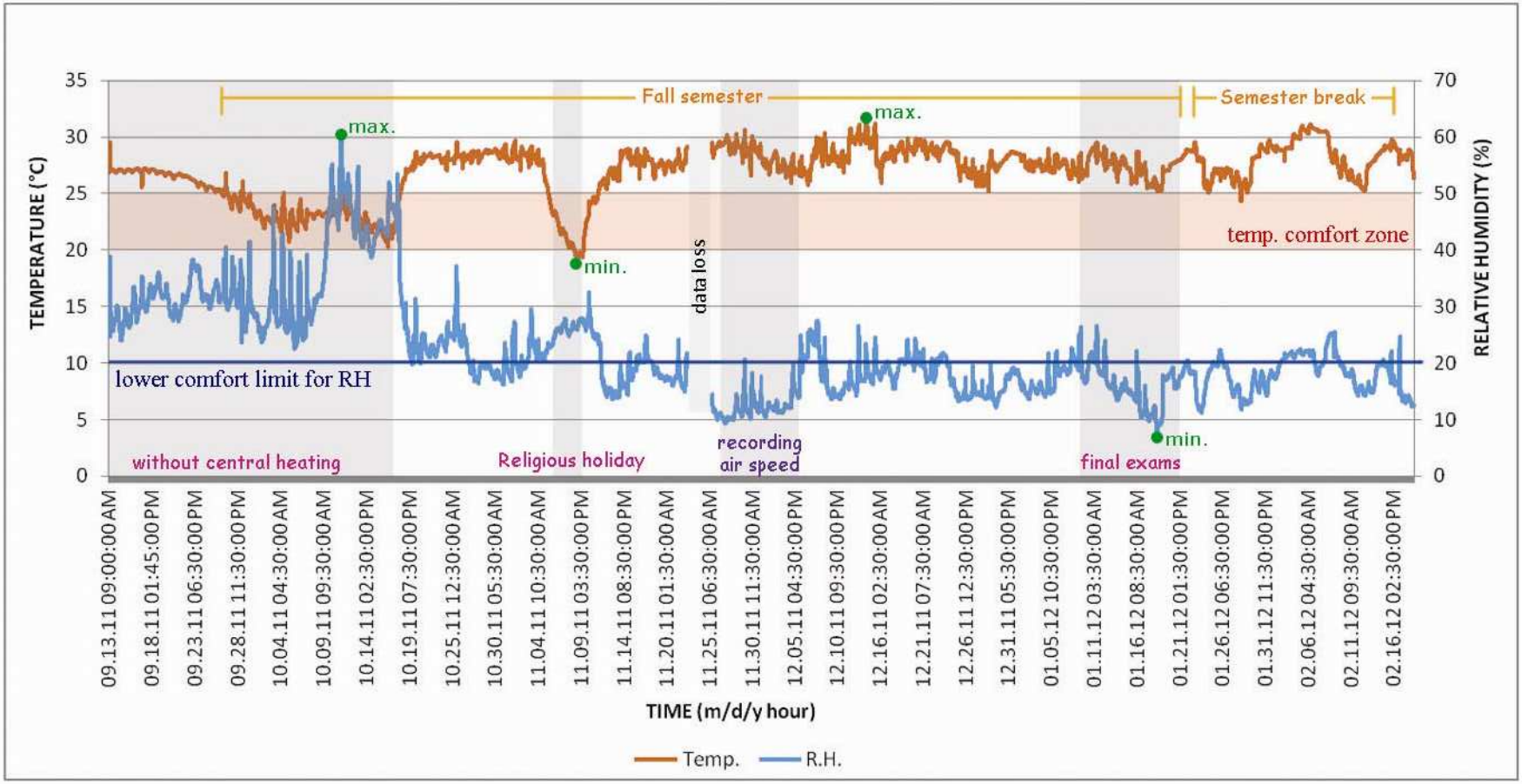


**Figure 4.01.** Room 28 - location 'A' at the back of the room: Temperature and relative humidity chart (13 September 2011 to 19 February 2012)

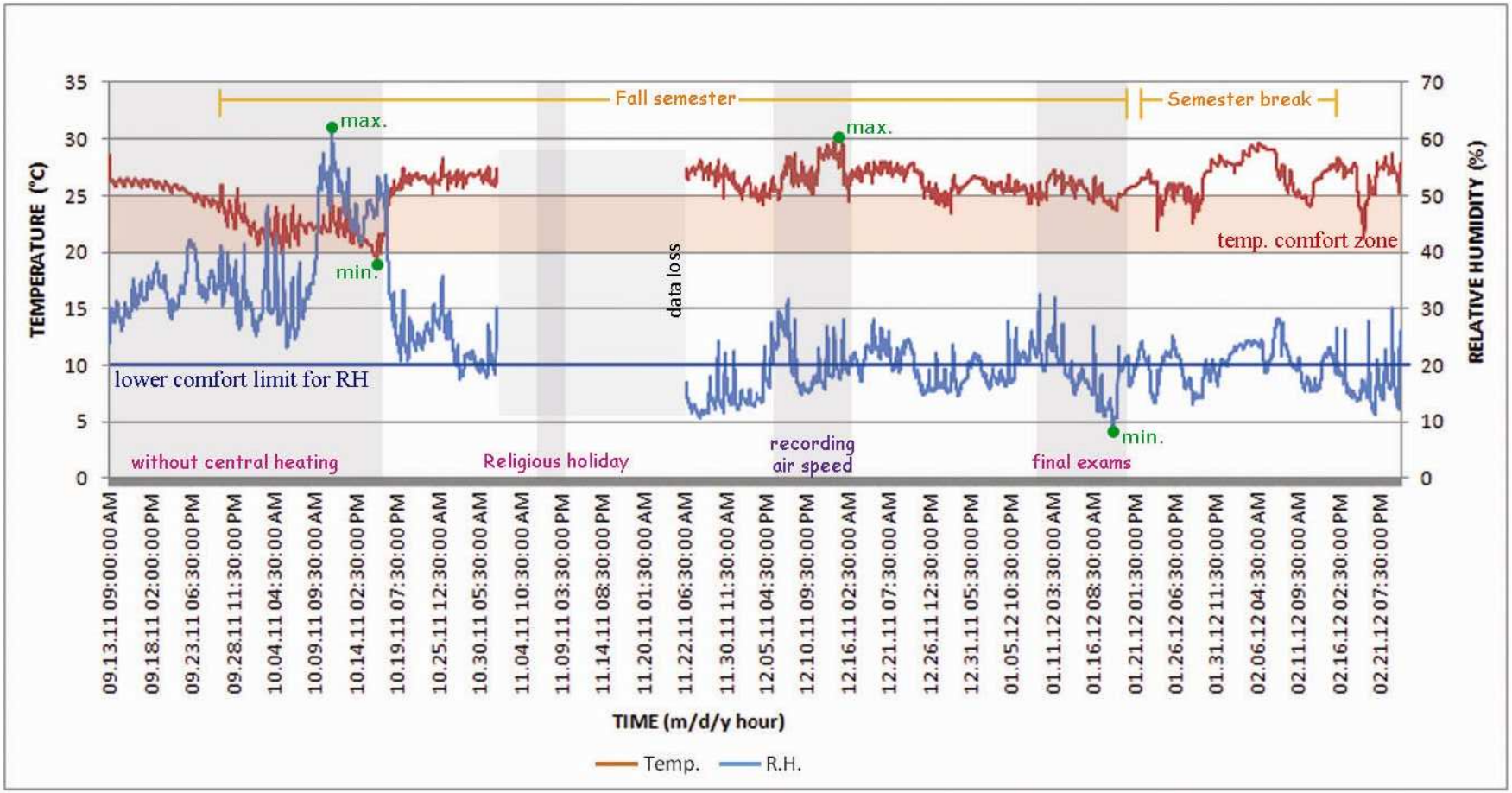


**Figure 4.02.** Room 28 - location 'B' near the door: Temperature and relative humidity chart (13 September 2011 to 24 February 2012)

**Table 4.01.** The minimum and maximum temperature values recorded in Room 28 and outdoor ones

| ROOM 28 | TEMPERATURE (°C) | | | |
|---|---|---|---|---|
| | MIN. | DATE and HOUR of MIN. | MAX. | DATE and HOUR of MAX. |
| Location 'A' | 19.08 | 09 November 2011<br>08:15 AM | 31.40 | 14 December 2011<br>12:30 PM |
| Location 'B' | 18.98 | 17 October 2011<br>08:00 AM | 29.79 | 14 December 2011<br>12:30 PM |
| OUTDOOR | -15.80 | 02 February 2012<br>03:00 AM and 05:00 AM | 30.60 | 14 September 2011<br>12:00 PM |

As indicated in the graphs, the data present the indoor conditions in different contexts. From 13 September 2011 to 26 September 2011, there was no occupancy and no central heating in the room. On 26 September 2011 the fall semester began; however the central heating system was not worked until 17 October 2011. In relation with the seasonal weather conditions, generally in both periods, the room temperature fell gradually. As distinct from the period until 26 September 2011, along with the beginning of the semester the room temperature was affected by occupancy levels, occupant activities and additional internal gains such as lighting. Occupants slightly increased the room temperature through the energy emitted by their bodies. In terms of comfort conditions, in this part of the semester the temperature varied in the comfort range of 20-25 °C defined on Psychrometric Chart.

On 17 October 2011, the central heating system started to work and affect the environmental conditions in the room as well. It affected the room temperature by increasing and, in general, relocated the room air in the 'hot' discomfort zone of the Psychrometric chart. From the start of the central heating till the end of the classes (06 January 2012), apart from the Religious holiday (6-9 November 2011), the temperature in the room ranged between 18.98 and 31.40 °C and mostly changed between 25 and 30 °C. The maximum temperature values of the data collection period were recorded on 14 December 2011 at 12:30 PM at both record locations and the minimum value of the location 'B' near the door were recorded on 17 October 2011 at 08:00 AM. The exceptional data of the Religious holiday (6-9 November 2011) presented a great decrease in the room temperature due to the seasonal weather conditions and the lack of occupancy. The minimum temperature value of the

location ‘A’ at the back of the room was recorded in this period as 19.08 °C on 09 November 2011 at 08:15 AM. Throughout the semester break (21 January 2012 to 16 February 2012) the temperature varied similar to the way in the period of the fall semester with the central heating; however there were a difference in terms of the occupancy effect due to having no classes. It changed between 21.89 and 31.12 °C in this period.

The data recorded throughout the fall semester at both record locations indicate that on weekdays the temperature started to increase after 08:40 AM – the starting time of the classes – with the effects of central heating system and other internal gains such as occupancy, lighting, *etc.* It became high particularly around 11:00 AM. It is observed that a small decrease existed during the lunch breaks; however it was not enough to constitute comfort conditions in the room. The temperature continued to increase during the afternoon classes, particularly became high between 03:00 and 04:00 PM. Afterwards, it began to fall due to shutting down the heating system and end of classes. Throughout the final exam weeks (9-20 January 2012), between the values at the beginning of the exams and the ones during them, temperature increases up to 2.5 °C are observed. The maximum temperature values of the final exam weeks were recorded on 11 January 2012 at 02:45 PM at both record locations; 29.59 °C at the location ‘A’ at the back of the room and 27.28 °C at the location ‘B’ near the door. The reason behind the high values on 11 January 2012 could be to have two examinations of two courses with high numbers of registered students (Arch 121 with 110 students and Arch 351 with 84 students) in the room in that day.

In addition, Figure 4.03 and 4.04 show the temperature data between 26 November 2011 and 6 December 2011 at the location ‘A’ at the back of the room and between 6 December 2011 and 16 December 2011 at the location ‘B’ near the door, when the air speeds were recorded at both locations. These charts clearly present that there was a sharp decrease in the room temperature on weekdays approximately between 07:00 and 08:30 AM. This could be caused by the air exchange through the door which was locked after the end of courses and opened before the beginning of the classes by the cleaning staff.

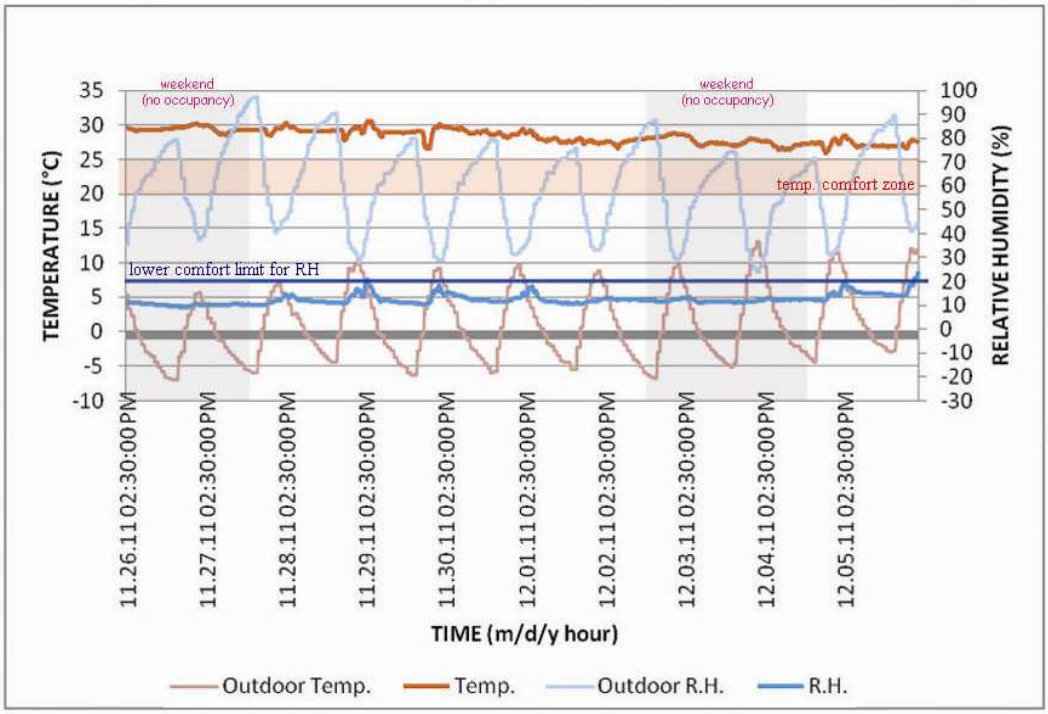


**Figure 4.03.** Room 28 - location 'A' at the back of the room: Temperature and relative humidity chart (26 November 2011 to 06 December 2011)

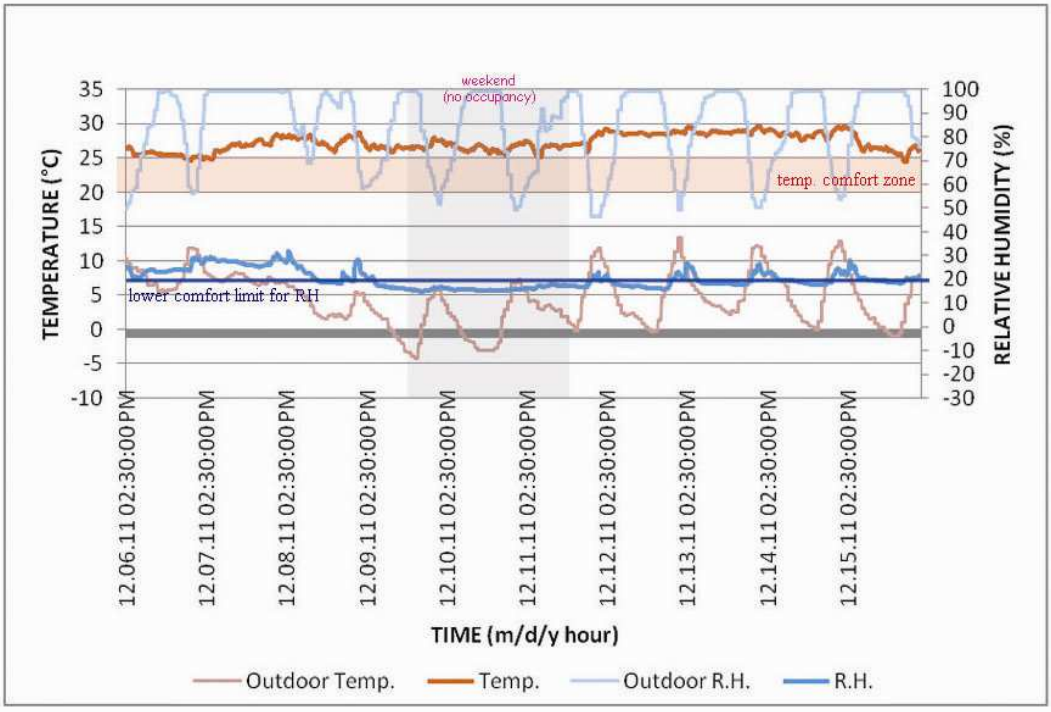


**Figure 4.04.** Room 28 - location 'B' near the door: Temperature and relative humidity chart (06 December 2011 to 16 December 2011)

The comparison of the overall data recorded at the two locations of the room indicates that the temperature at the location 'A' at the back of the room was higher than the one at the location 'B' near the door with a difference of 1.61 °C between the maximum values which were recorded at the same date and time. Higher temperature at the location 'A' at the back of the room could be the indicators of lower air flow rates around the record location.

### 4.1.2. Relative Humidity Data

Figure 4.01 and 4.02 indicate the relative humidity data simultaneously recorded along with the temperature data. The minimum and maximum relative humidity values are presented along with the outdoor ones obtained from the Turkish State Meteorological Service in Table 4.02.

**Table 4.02.** The minimum and maximum relative humidity values recorded in Room 28 and outdoor ones

| ROOM 28 | RELATIVE HUMIDITY (%) | | | |
|---|---|---|---|---|
| | MIN. | DATE and HOUR of MIN. | MAX. | DATE and HOUR of MAX. |
| Location 'A' | 7.75 | 18 January 2012<br>10:00 PM | 60.43 | 11 October 2011<br>04:00 PM |
| Location 'B' | 9.02 | 18 January 2012<br>10:00 PM | 61.30 | 11 October 2011<br>04:00 PM |
| OUTDOOR | 2.60 | 14 September 2011<br>01:00 PM | 99.00 | recorded many times |

As seen in the graphs, in the period without the central heating system between 13 September 2011 and 17 October 2011, the relative humidity in the room varied in accordance with the changes in the temperature and generally rose as a result of the temperature decrease. However, the beginning of the fall semester on 26 September 2011 created a difference on the data in contrast to the period between 13 September 2011 and 26 September 2011 due to the effect of occupancy; *i.e.* occupants increased the relative humidity in the room through exhalation which results in the addition of water vapor to the room air. In this period of the semester, the relative humidity changed above the Bioclimatic Chart's lower comfort limit of 20 %. The highest values of the data collection period were recorded in the third week of the semester

(10-14 October 2011). The maximum recorded relative humidity was in this week, on 11 October 2011 at 04:00 PM at both locations when the outdoor one was 99 %.

The start of central heating system on 17 October 2011 had a decreasing effect on the relative humidity due to the increase in the room temperature. Therefore, the room air was mostly in the 'dry' discomfort zone of the Bioclimatic chart. From the start of the central heating till the end of the classes (06 January 2012), the relative humidity varied from 9.30 to 53.79 % and it mostly changed in between 10-30 %. Throughout the Religious holiday (6-9 November 2011) it was affected by the decrease in the temperature and so generally showed an increase. In the period of the semester break (21 January 2012 to 16 February 2012), the relative humidity values was similar to the semester period with the central heating; however there was not an effect of occupants due to having no classes. In this interval, the relative humidity ranged between 11.25 and 28.20 % in the room.

In a school day, the relative humidity data also showed variations in time at which the temperature presented changes. On weekdays the relative humidity started to show an increase after 08:40 AM, when the classes start, due to the occupancy effect. It became high around 11:00 AM and showed a small decrease during the lunch breaks. It continued to increase during the afternoon classes, particularly became high between 03:00 and 04:00 PM and began to fall due to the end of classes. In addition, as seen in Figure 4.03 and 4.04 showing the data of the period that the air speeds were recorded, the relative humidity presented an increase on weekdays approximately between 07:00 and 08:30 AM, which could be due to the temperature decrease resulting from the air exchange through the door which was locked after the end of courses and opened before the beginning of the classes by the cleaning staff.

In the period of the final exam weeks (9-20 January 2012), relative humidity changes between 3 and 11 % are observed between the values at the beginning of the exams and the ones during them. The maximum relative humidity value of the final exam weeks at the location 'A' at the back of the room was recorded as 26.64 % on 11 January 2012 at 02:30 PM while the one at the location 'B' near the door was

32.53 % on 09 January 2012 at 02:15 PM. As in the temperature, the high relative humidity values on 11 January 2012 could be due to the two examinations of two courses with high numbers of registered students (Arch 121 with 110 students and Arch 351 with 84 students) in that day. Similarly, the high relative humidity value on 09 January 2012 could also be a result of an examination with high student attendance (Arch 221 with 99 students). It should also be noted that there could be an additional effect of high outdoor humidity (99 % on 09 January 2012 and 94 % on 11 January 2012) on the room relative humidity if there were any open windows for fresh air supply. In addition to all, the minimum relative humidity values of the data collection period at both locations were also recorded in this period on 18 January 2012 at 10:00 PM.

The comparison of the overall data recorded at the two locations presents that the relative humidity at the location 'A' at the back of the room was lower than the one at the location 'B' near the door with a difference of 0.87 % between the maximum values which were also recorded at the same date and time. Lower relative humidity values as a result of higher temperature at the location 'A' at the back of the room could be caused by lower air flow rates around the record location.

### 4.1.3. $CO_2$ Data

The $CO_2$ data collected in Room 28 in the same periods of time at the two record locations are presented in Figure 4.05 and 4.06. The minimum and maximum $CO_2$ values recorded at the locations are given in Table 4.03.

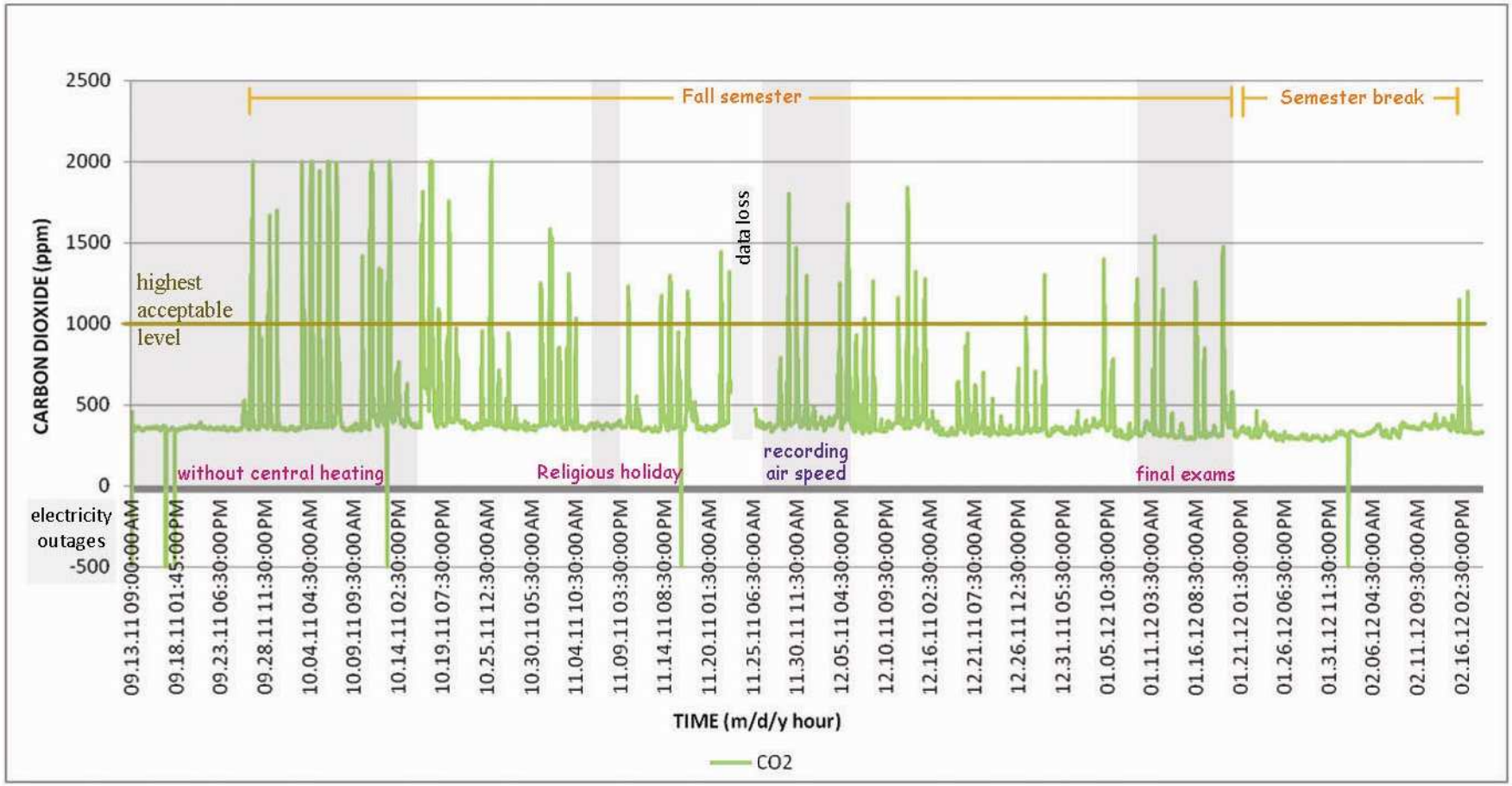


**Figure 4.05.** Room 28 - location 'A' at the back of the room: $CO_2$ chart (13 September 2011 to 19 February 2012)

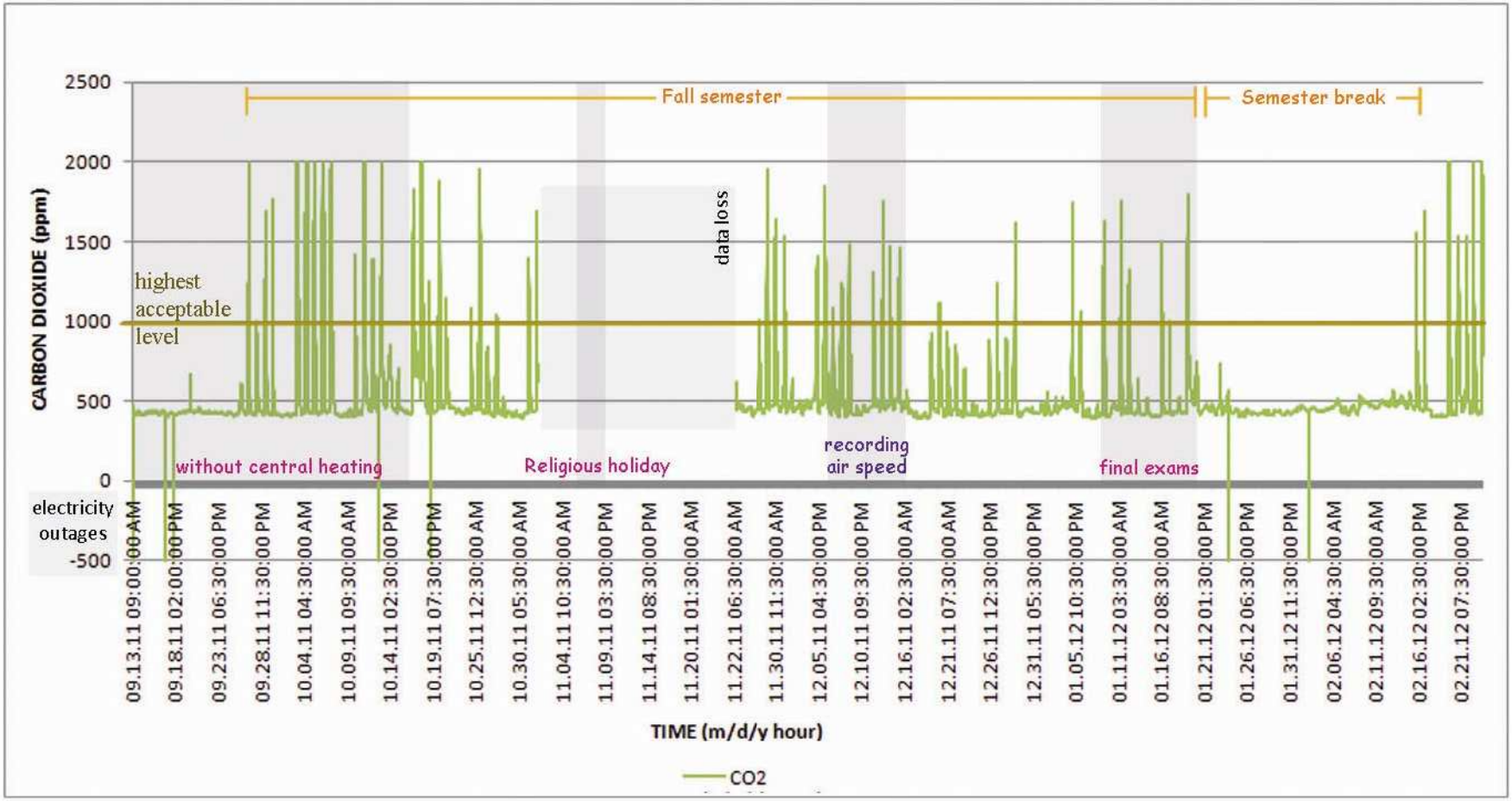


**Figure 4.06.** Room 28 - location 'B' near the door: $CO_2$ chart (13 September 2011 to 24 February 2012)

**Table 4.03.** The minimum and maximum $CO_2$ values recorded in Room 28

| ROOM 28 | $CO_2$ (ppm) | | | |
|---|---|---|---|---|
| | MIN. | DATE and HOUR of MIN. | MAX. | DATE and HOUR of MAX. |
| Location 'A' | 277.89 | 26 January 2012<br>03:00 PM<br>and<br>31 January 2012<br>09:30 AM to 11:15 AM | 1999.08 | recorded many times |
| Location 'B' | 385.93 | 8 January 2012<br>05:00 AM and 05:30 AM | 1997.86 | recorded many times |

The recorded $CO_2$ data clearly present the occupancy pattern in the room during the data collection period due to having no other $CO_2$ sources (combustion by-products, heavy traffic, industrial area, *etc.*) in and around the room. As seen in the charts, apart from the exceptional minus values caused by electricity outages, the $CO_2$ level never fell to 0 ppm; *i.e.* there was always a relatively small amount of $CO_2$ in the space. From 13 September 2011 to 26 September 2011, owing to no occupancy in the room, the $CO_2$ concentration changed between 338.32 and 476.26 ppm. This interval indicates the range of outdoor level. There is an exception of 669.74 ppm recorded at the location 'B' near the door on 20 September 2011 at 01:00 PM, which is the result of the author's getting close to the data loggers for check.

After 26 September 2011, along with the beginning of the room use, the $CO_2$ concentration in the room started to rise; *i.e.* occupants increased the concentration through exhaling it as a result of respiration. On weekdays, the $CO_2$ build-up began when students started to occupy the room. In relation to the course lengths, the number of the students attending the courses, the activities of the students and the provision of fresh air through opening windows and/or a door, the $CO_2$ in the room reached high levels. It mostly exceeded the highest acceptable level of 1000 ppm by ASHRAE 62-1989 and on many days rose up to the maximum of 1999.08 ppm at the location 'A' at the back of the room and 1997.86 ppm at the location 'B' near the door. The level remained high until the end of the classes. Particularly on Tuesdays, the $CO_2$ concentration reached the maximum value of the weeks. This could be the result of the daily course schedule which required all day long occupation of the room by the courses having high numbers of student capacities (Arch 221 with 99

students, Arch 321 with 90 students and Is 100 with 100 students). It should also be noted that between 2 and 4 January 2012 the concentrations were also at lower levels which could be due to having no courses since the next week was final exam week. On weekends and during the Religious holiday (6-9 November 2011), due to the lack of occupancy the $CO_2$ concentrations in the room were at lower levels representing the outdoor concentration.

In final exam weeks, the $CO_2$ level in the room reached the maximum value generally in the second hour. The concentrate exceeded the highest acceptable level of 1000 ppm in all exams. The maximum value measured at the location 'A' at the back of the room is 1537.05 ppm on 11 January 2012 at 02:30 PM and the one at the location 'B' near the door is 1796.45 ppm on 19 January 2012 at 03:30 PM. However, the overall $CO_2$ variations in the room show that the levels of the final exam week were lower than the ones throughout the first weeks of the fall semester. This could be due to having courses one after the other during the semester, which caused all day long occupation of the room and so more $CO_2$ accumulation while it was occupied only for the duration of an exam on each day in the final exam weeks resulting in lower accumulation in comparison. In addition, the higher relative humidity values in the room in the first weeks of the semester could also have an increasing effect on the respiration rate through limiting evaporation, which also increased the $CO_2$ generation and so the concentration. Moreover, the fact that some of the ventilation windows were opened during the examinations might also have had a decreasing effect on the room $CO_2$ level. Figure 4.07 shows that during an examination in Room 28 the top vents of the windows were opened despite it being winter. During the semester break (21 January 2012 to 16 February 2012) the $CO_2$ concentrations in the room were also at lower levels and varied from 277.89 to 737.49 ppm.

**Figure 4.07.** A moment of an examination in Room 28 (photo by S. T. Elias Ozkan)

The comparison of the $CO_2$ data recorded at the two record locations indicates that, in general, the $CO_2$ concentration at the location 'A' at the back of the room was lower than the one at the location 'B' near the door; however, the maximum recorded value at the location 'A' was higher than the one at the location 'B' with a difference of 1.22 ppm. The possible cause of higher concentrations at the location 'B' could be the movement of air including $CO_2$ towards the open door, since the air speed recorded at the location was higher and more variable (Figure 4.08 and 4.09).

### 4.1.4. Air Speed Data along with the $CO_2$ Data in the Period

The air speed data are presented along with the $CO_2$ data of the time periods that the air speeds were recorded at each location. Figure 4.08 show the air speed and $CO_2$ data of the location 'A' at the back of the room from 26 November 2011 to 6 December 2011, and Figure 4.09 present the ones recorded at the location 'B' near the door from 6 December 2011 to 16 December 2011. The data for outdoor air speed has been superimposed on the charts with its own scale ranging from 0.00 to 6.00 m/s whereas the indoor air speed scale range from -0.02 to 0.20 m/s. The minimum and maximum air speed values recorded at the two record locations are given along with the outdoor ones obtained from the Turkish State Meteorological Service in Table 4.04 and the minimum and maximum $CO_2$ concentrations recorded are given in Table 4.05.

**Table 4.04.** The minimum and maximum air speed values recorded in Room 28 and outdoor ones

| ROOM 28 | AIR SPEED (m/s) | | | |
|---|---|---|---|---|
| | MIN. | DATE and HOUR of MIN. | MAX. | DATE and HOUR of MAX. |
| Location 'A' | 0.00 | recorded many times | 0.06 | 28 November 2011<br>01:00 PM |
| Outdoor | 0.40 | recorded many times | 3.70 | 29 November 2011<br>09:00 AM and 10:00 AM |
| Location 'B' | 0.00 | recorded many times | 0.13 | 7 December 2011<br>10:30 AM |
| Outdoor | 0.20 | 7 December 2011<br>02:00 PM<br>and<br>12 December 2011<br>03:00 AM | 4.90 | 8 December 2011<br>04:00 PM |

**Table 4.05.** The minimum and maximum $CO_2$ values recorded in Room 28 in the time periods that the air speeds were measured

| ROOM 28 | $CO_2$ (ppm) | | | |
|---|---|---|---|---|
| | MIN. | DATE and HOUR of MIN. | MAX. | DATE and HOUR of MAX. |
| Location 'A' | 334.05 | 27 November 2011<br>02:45 PM and 03:30 PM | 1799.50 | 29 November 2011<br>02:30 PM |
| Location 'B' | 398.13 | 8 December 2011<br>04:45 AM | 1758.61 | 13 December 2011<br>02:30 PM |

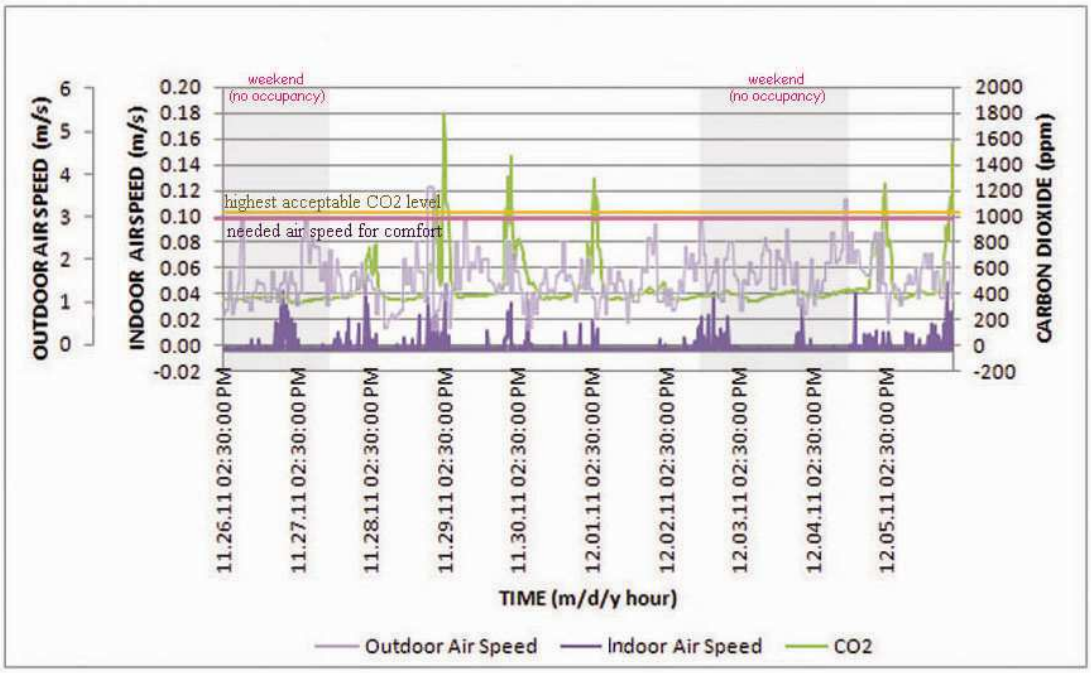


**Figure 4.08.** Room 28 - location 'A' at the back of the room: Air speed and $CO_2$ chart with two superimposed scales for air speeds (26 November 2011 to 6 December 2011)

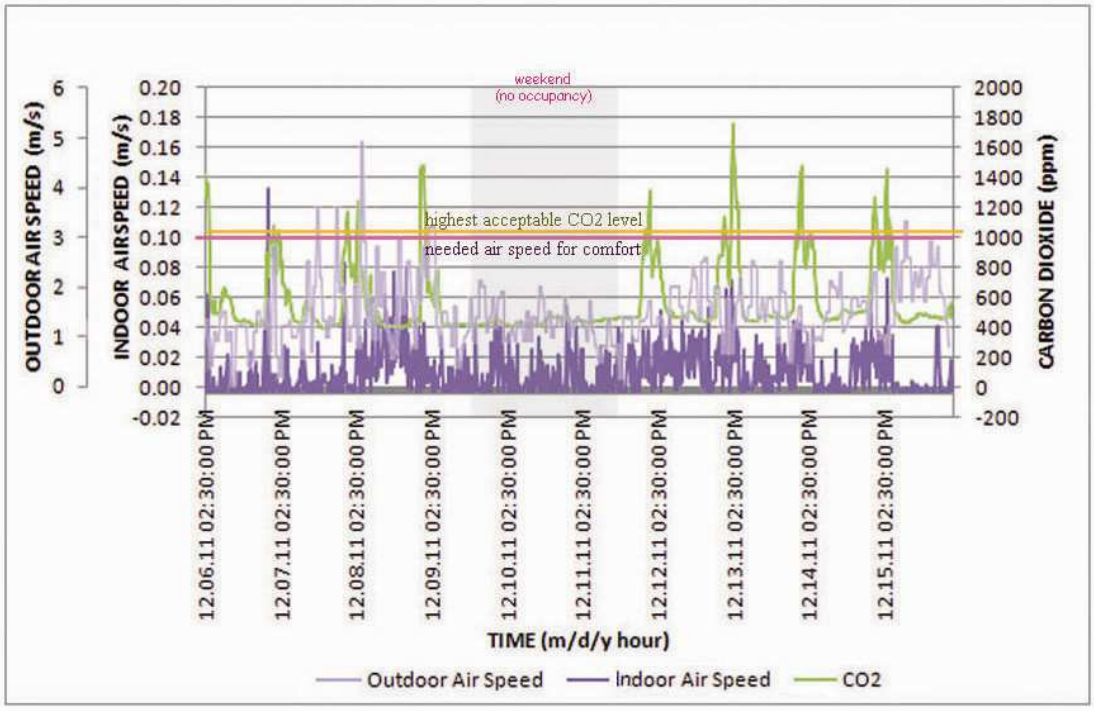


**Figure 4.09.** Room 28 - location 'B' near the door: Air speed and $CO_2$ chart with two superimposed scales for air speeds (6 December 2011 to 16 December 2011)

It can be seen from the Figure 4.08 and 4.09 that, apart from the air speed of 0.13 m/s recorded at the location 'B' near the door on 7 December 2011 at 10:30 AM, the air speed in Room 28 never reached 0.1 m/s which is the needed value presented for comfort on the Bioclimatic chart when the temperature was relatively above the comfort range. The exception is an extraordinary record that could be caused by the human intervention to the data logger through blowing. The maximum value of 0.06 m/s at the location 'A' at the back of the room and the second maximum value – the first is an exception – of the 0.08 m/s at the location 'B' near the door indicate that in the record periods the room air was mostly stagnant due to insufficient air flow through the room. The comparison of the air speed data of the two record locations in terms of variation indicates that the air speed fluctuated more at the location 'B' near the door. The possible cause of the result could be the effect of the air flow towards the open door, and the existence of more human movement around the record location.

In order to investigate the relationship between the air speed and $CO_2$ data of Room 28, the scatter diagrams of the daytime of weekdays – between 08:30 AM and 06:00 PM – are given for the two record locations in Figure 4.10 and 4.11. It is expected that, under constant circumstances, there should be a negative association between these two variables since an increase in air speed causes a decrease in $CO_2$ level in a space due to the dilution effect of air movement on the $CO_2$ concentration. However, as seen in the diagrams, no relationships were observed between these two variables at each record location. This indicates that there was an effect of third variable on the data collected. The $CO_2$ generation of the occupants in the room increased the level while there was no considerable change in the air speed conditions. On account of this situation, the diagrams represent various $CO_2$ concentrations at the same air speed value owing to the accumulation resulted from occupancy.

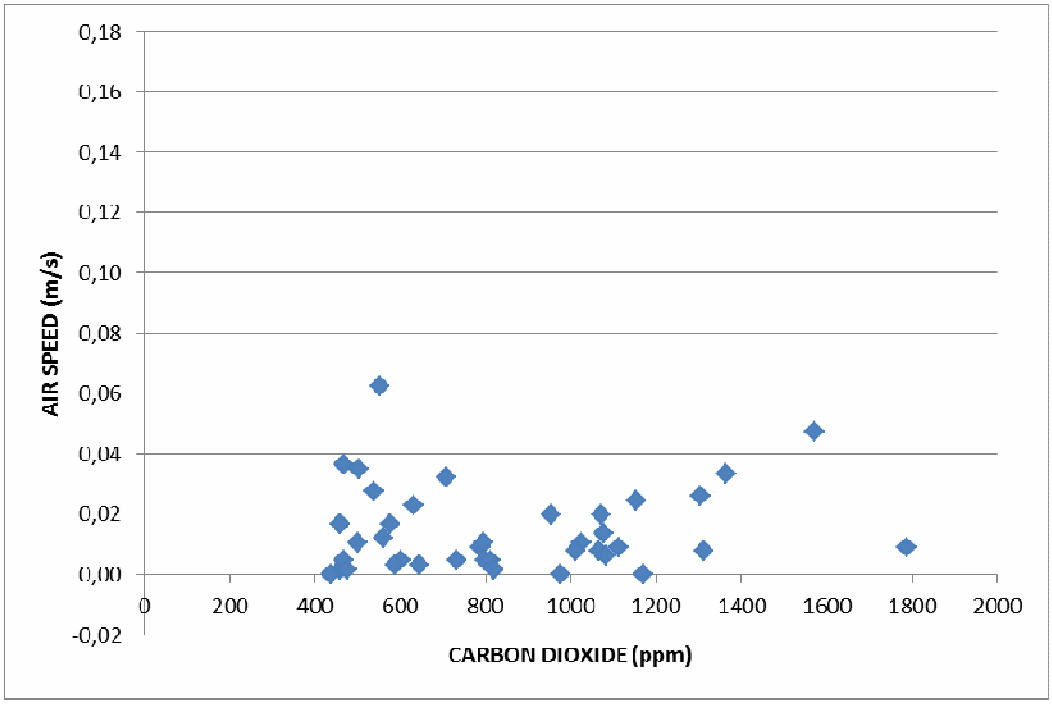


**Figure 4.10.** Room 28 – location 'A' at the back of the room: Air speed-$CO_2$ scatter diagram (28 November 2011 to 02 December 2011, between 08:30 AM and 06:00 PM of each day)

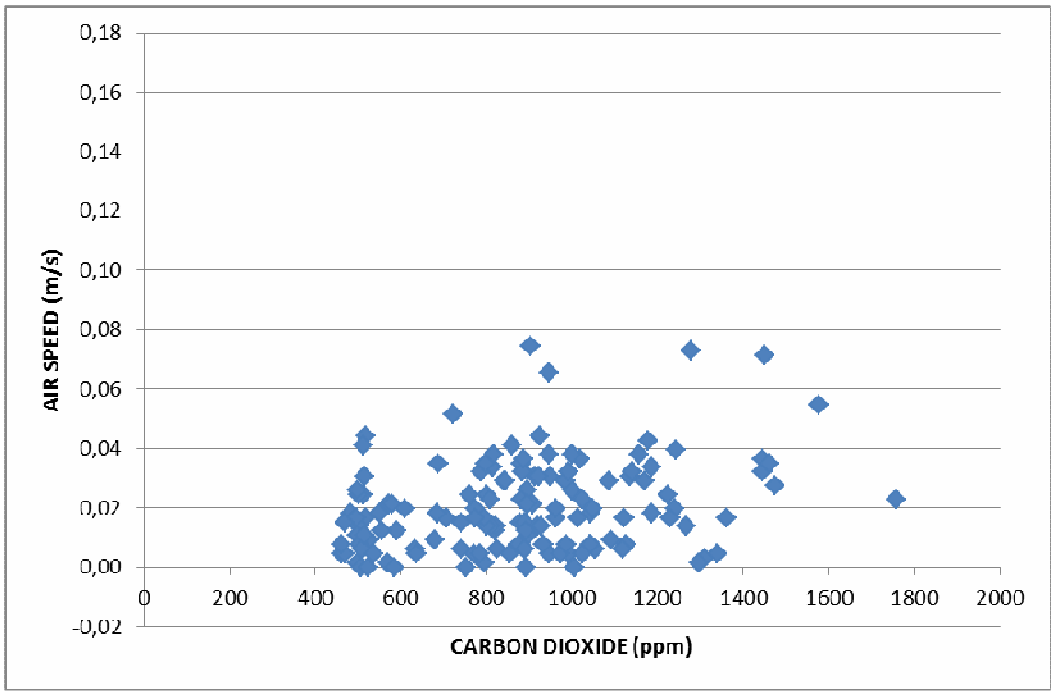


**Figure 4.11.** Room 28 – location 'B' near the door: Air speed-$CO_2$ scatter diagram (12 December 2011 to 16 December 2011, between 08:30 AM and 06:00 PM of each day)

### 4.1.5. The Features of Room 28 in Relation to The Results

As presented through the section of Room 28 in Figure 4.12, the recorded data show that the air speeds at both locations were insufficient for human comfort in the winter; however the location 'B' near the door had higher values than the location 'A' at the back of the room. In connection, due to the inefficiency of low air movements in removing the heat the location 'A' at the back of the room had higher temperature and so lower relative humidity values. Moreover, in spite of the fact that lower air speed values cause more accumulation of $CO_2$, lower $CO_2$ levels were recorded at the location 'A'. This could be explained through the movement of air with $CO_2$ towards the open door.

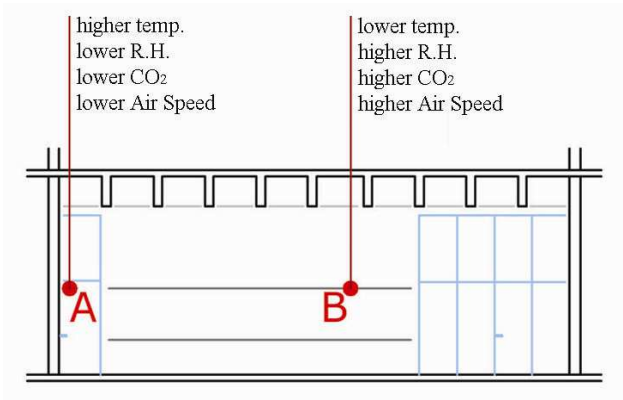


**Figure 4.12.** The longitudinal section of Room 28 showing the comparison of the data recorded at the two locations

In connection with the features of Room 28, in general, the percentage of the window openable sections are in accordance with the ASHRAE Standard 62.1.2007 suggesting a minimum of 4 % openable area of the net floor area – the openable sections of the room windows is 4.40 m² (1.1m x 1m x 4) while 4 % of the room floor area (98.5 m²) is 3.94 m².

In addition, the room floor area also has significance in terms of occupant capacity; *i.e.* excessive occupancy in a space has adverse effects on the indoor comfort and air quality conditions. In the case of Room 28, the room floor area (98.5 m²) allows the maximum of 64 occupants according to the ASHRAE Standard 62.1-2007 recommending 65 occupants for 100 m² area in lecture classrooms. However, apart from three courses (CRP 231 with 59 students, ENG 211 with 20 students and ID 121 with 61 students), the room was used for six courses with higher numbers of students – up to 100 students.

### 4.1.6. Calculations for Fresh Air Supply

The fundamental aim in reconsidering the air supply to a space should be providing the needed fresh air continuously in a controlled way. Thus, the starting point should be the determination of the required air. According to the breathing zone outdoor air flow equation of the Ventilation Rate Procedure of the ASHRAE Standard 62.1-2007 explained in the Section 2.2, the needed air in Room 28 is:

$V_{bz} = R_p . P_z + R_a . A_z$

$V_{bz}$ = 3.8 L/s per 100 person + 0.3 L/s m² 98.5 m²

$V_{bz}$ = 409.55 L/s = 0.41 m³/s = 1476 m³/h

In relation, to have an idea, the inlet opening area needed for this amount of air can be calculated through the flow rate equation described in the Section 2.3.2. The average outdoor air speed value (2.1 m/s) taken is the value of the fall semester period – from 26 September 2011 to 21 January 2012. It should be noted that the calculated areas are likely to be larger when the average outdoor air speed value of years for Ankara is used and the changing air speed conditions are considered.

Q = A . V

0.41 m³/s = A 2.1 m/s  A = 0.20 m²

The calculated area means that there should be four inlet openings on the four existing windows with net dimensions of 0.90 m and 0.055 m. It is unfeasible to have such openings in winter due to possible strong draughts. Therefore, reconsidering the existing inlet openings behind the fan coils – designed for fresh air intake in winter and closed off in present situation due to draught complaints – would be useful for controlled air intake. In relation to the original mechanical drawings (Appendix B), Room 28 has three fan coils having inlet openings behind, with the heat capacities of 10,000, 10,000 and 7,500 kcal/h. If the inlets would be reconnected to these fan coils, the amount of fresh air that would be supplied to the room can be calculated in relation to their heat capacities. According to the specific heat equation given in the Section 2.3.2., the amounts of air that would be supplied by each fan coil are:

Q = V . c . Δt

10,000 kcal/h = m . 0.28 kcal/°C . [20-(-12)]  m = 1116.07 m³/h

7,500 kcal/h = m . 0.28 kcal/°C . [20-(-12)]  m = 837.05 m³/h

In total, the fan coils in Room 28 would provide 3069.19 m³/h (2 x 1116.07 m³/h + 837.05 m³/h) fresh air to the room. This amount is more than two times of the

calculated breathing zone outdoor air flow amount of 1476 m³/h. Additionally, it is also more than the fresh air need that can be determined through multiplying the room volume by air exchange coefficient, which is 2265.5 m³/h (453.1 m³ x 5 $h^{-1}$) for Room 28.

## 4.2. Room 50

As explained in the Section 3.1.1., Room 50 is a west and south facing design studio with a mezzanine floor on the ground floor of the METU Faculty of Architecture building. Its dimensions are 11.87 m by 18.95 m with a height of 4.91 m. It has seven west-facing floor-to-ceiling windows having openable sections (1.1m x 1m) on the top and one east-facing window with six vertical panes having three openable sections (1.15m x 0.3m) at a height of 2.20 m. All openable sections are top-hinged and open outwards. The room is ventilated by natural ventilation and heated by central heating system. The temperature, relative humidity, $CO_2$ and air speed data recorded at the two locations of the room are presented in the following subsections.

### 4.2.1. Temperature Data

The temperature data recorded at the location 'A' at the middle of the room from 13 September 2011 to 4 January 2012 are shown in Figure 4.13 and the ones at the location 'B' at the side of the room from 13 September 2011 to 24 February 2012 are in Figure 4.14. The minimum and maximum values are given along with the outdoor ones obtained from the Turkish State Meteorological Service in Table 4.06.

**Table 4.06.** The minimum and maximum temperature values recorded in Room 50 and outdoor ones

| ROOM 50 | TEMPERATURE (°C) | | | |
|---|---|---|---|---|
| | MIN. | DATE and HOUR of MIN. | MAX. | DATE and HOUR of MAX. |
| Location 'A' | 16.01 | 18 October 2011<br>10:00 AM | 29.59 | 13 September 2011<br>02:15 PM |
| Location 'B' | 18.08 | 18 October 2011<br>10:00 AM | 33.57 | 16 September 2011<br>06:00 PM |
| OUTDOOR | -15.80 | 02 February 2012<br>03:00 AM and 05:00 AM | 30.60 | 14 September 2011<br>12:00 PM |

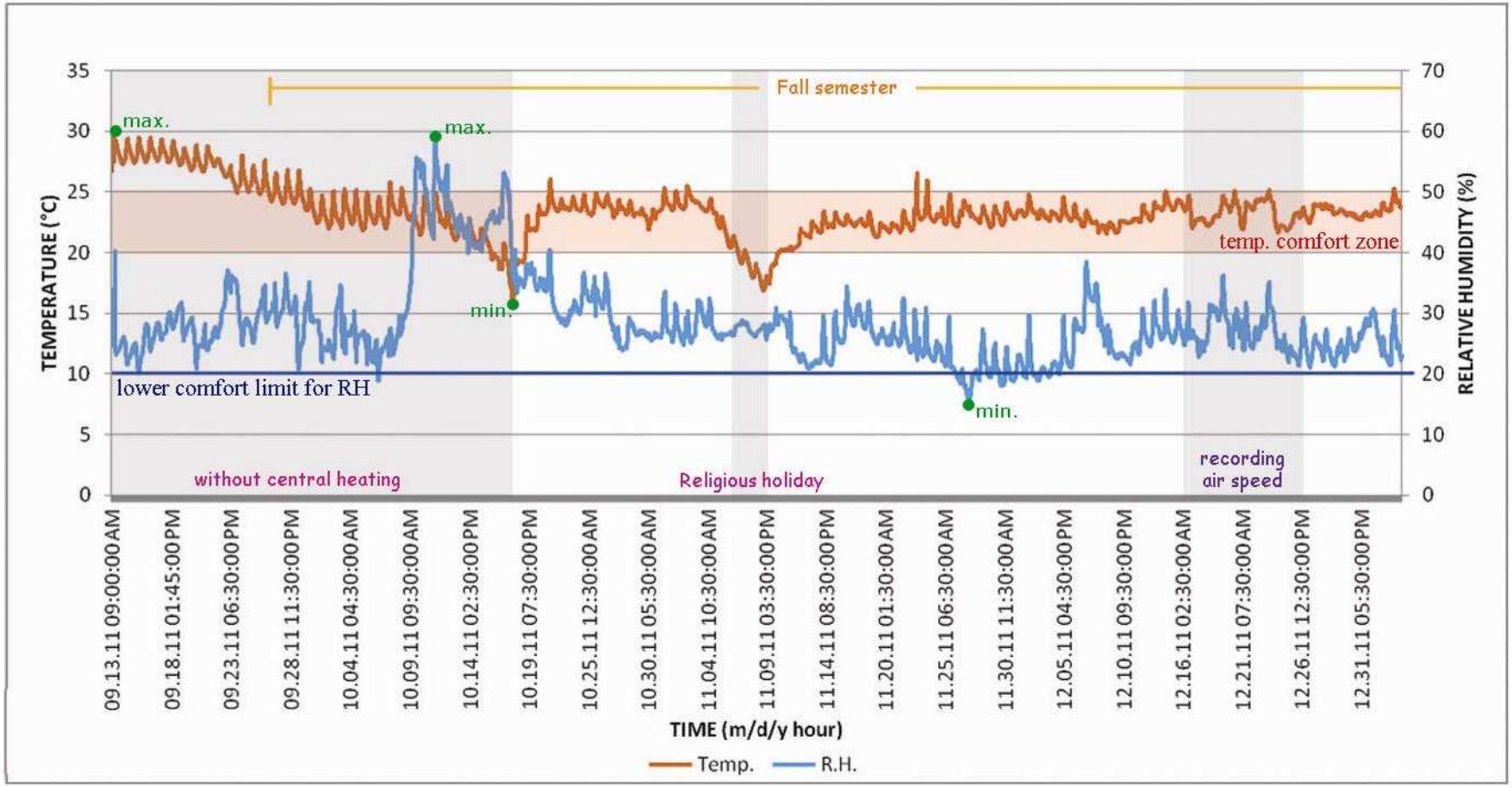


**Figure 4.13.** Room 50 - location 'A' at the middle of the room: Temperature and relative humidity chart (13 September 2011 to 4 January 2012)

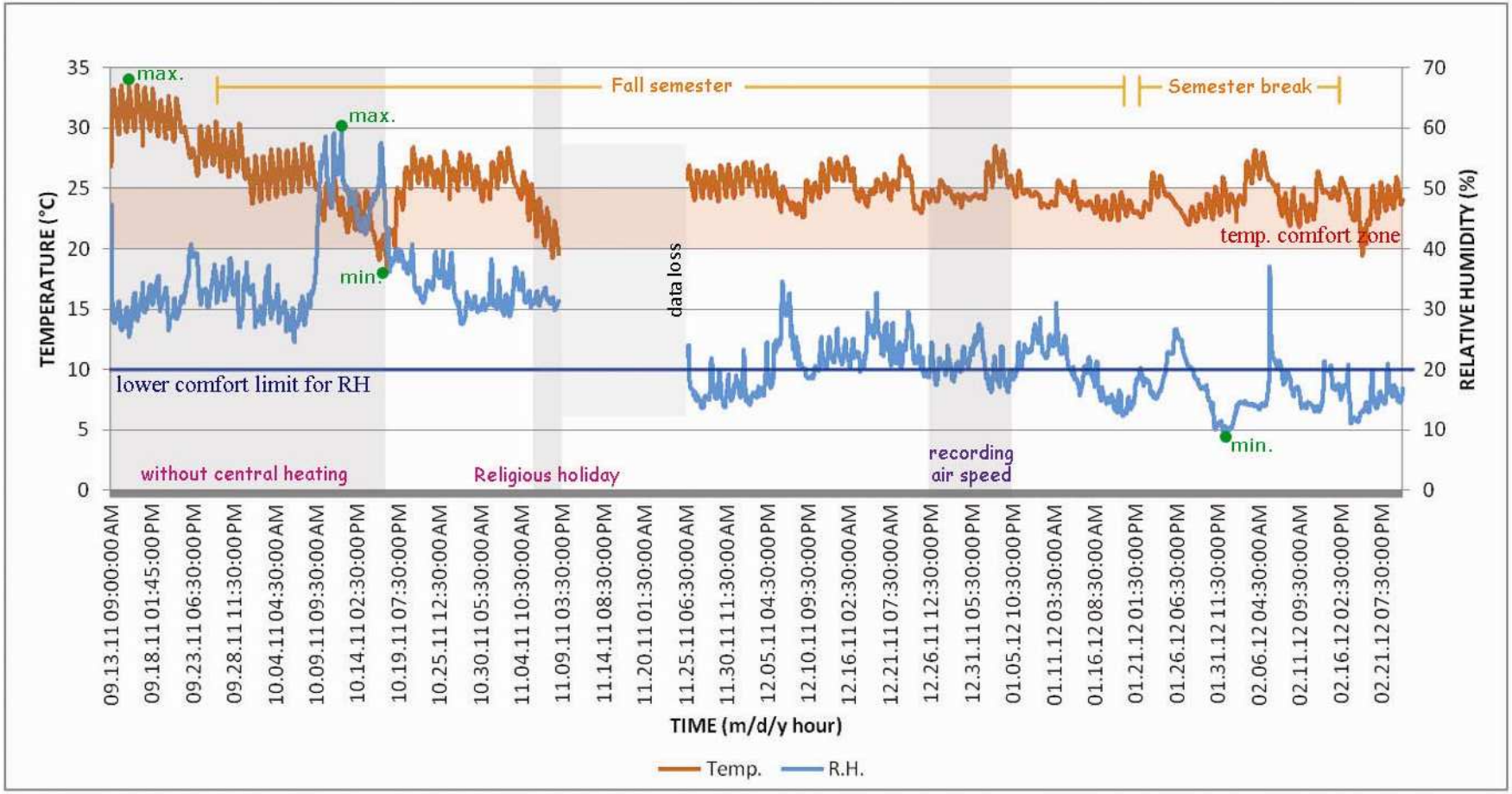


**Figure 4.14.** Room 50 - location 'B' at the side of the room: Temperature and relative humidity chart (13 September 2011 to 24 February 2012)

As seen in the graphs, the data show the environmental conditions in the room in different contexts. From 13 September 2011 to 26 September 2011, the room was not occupied and not heated. The maximum temperature values of the data collection period were recorded in this period on 13 September 2011 at 02:15 PM at the location 'A' at the middle of the room and on 16 September 2011 at 06:00 PM at the location 'B' at the side of the room. This was due to the highest outdoor temperatures of the data collection period in the week which increased the indoor temperature through solar heat gains. Along with the beginning of the fall semester on 26 September 2011, the room started to be used for studio courses; however it was not heated until 17 October 2011. In both periods, the temperature in the room fell gradually with the effect of seasonal air temperatures. As distinct from the interval until 26 September 2011, in the period after the beginning of the semester, the temperature was affected by the number of occupants, their activities and other internal heat sources such as lighting, laptops, *etc.* The existence of occupants and their being more active (not sedentary) in a design studio in contrast to a standard classroom environment had an increasing effect on the room temperature as a result of energy emitted by their bodies. In terms of comfort conditions, in this part of the semester the temperature changed between 19.43 and 30.54 °C in the room and it was generally in the Psychrometric Chart's comfort range of 20-25 °C at the location 'A' at the middle of the room while it was mostly above the range at the location 'B' at the side of the room.

On 17 October 2011, the central heating system started to work and affected the room conditions as well. It increased the temperature in the room. From the start of the central heating till the end of the semester (20 January 2012), apart from the Religious holiday (6-9 November 2011), the temperature in the room ranged between 16.01 and 28.49 °C and it was mostly in the comfort range of 20-25 °C at the location 'A' at the middle of the room while it was generally around the higher limit of the comfort range at the location 'B' at the side of the room. The minimum temperature values of the data collection period at both locations were recorded on 18 October 2011 at 10:00 AM. Throughout the exception of the Religious holiday (6-9 November 2011) the temperature in the room decreased as a result of the seasonal

weather conditions and the lack of occupancy. The data of the semester break (21 January 2012 to 16 February 2012) recorded at the location 'B' at the side of the room (the one at the location 'A' at the middle of the room were lost) show that the temperature changed similar to the one during the semester with central heating; however there was no occupancy effect on the data owing to having no classes. It changed between 21.77 and 28.19 °C in this period.

Room 50 has a flexible use of occupants due to being a design studio; *i.e.* it is impossible to define a pattern of occupation although there are certain course hours, since students have a chance to work in the room all day and night – particularly in the periods of project submissions and juries. In connection, the data of the fall semester recorded at the two locations of the room indicate that the room temperature increased throughout the daytime of weekdays due to the central heating; however it increased more in a short time when the room was occupied. Towards the evenings, the temperature in the room fell along with shutting down the heating system and with the end of classes or the reduced number of occupants.

In addition, Figure 4.15 and 4.16 show the temperature data between 16 December 2011 and 26 December 2011 at the location 'A' at the middle of the room and between 26 December 2011 and 5 January 2012 at the location 'B' at the side of the room, when the air speeds were recorded at both locations. In these periods, as presented by the changes in the $CO_2$ concentrations in Figure 4.19 and 4.20, there were occupants affecting the temperature in the room both on weekdays and weekends. However, on weekends the temperature was more stable than the one on weekdays which could be due to the occupancy level difference.

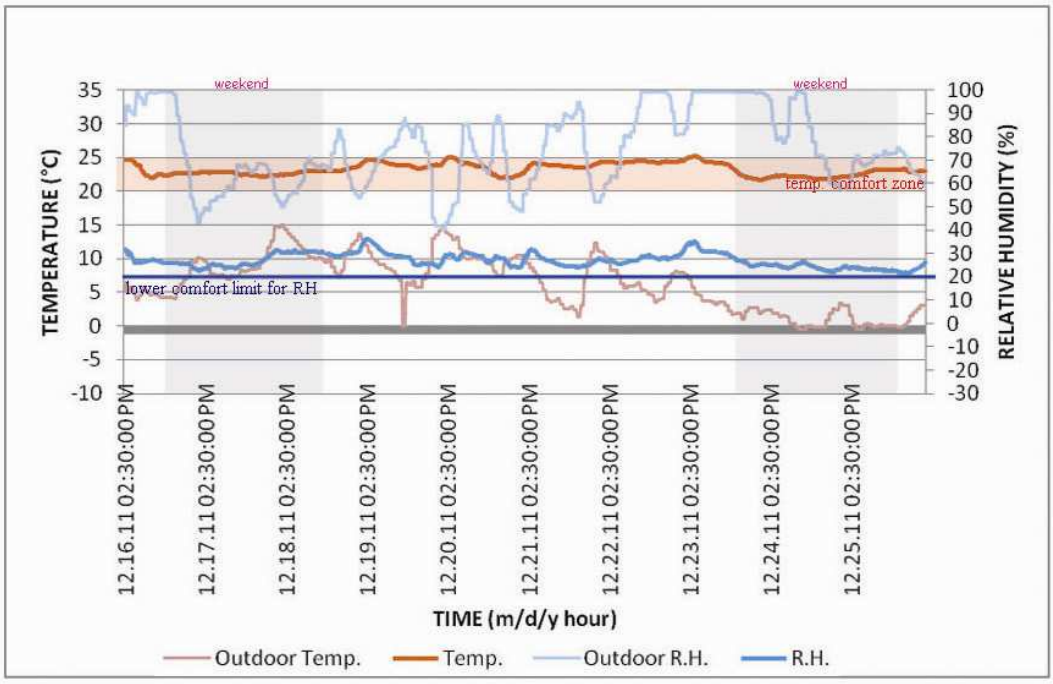


**Figure 4.15.** Room 50 - location 'A' at the middle of the room: Temperature and relative humidity chart (16 December 2011 to 26 December 2011)

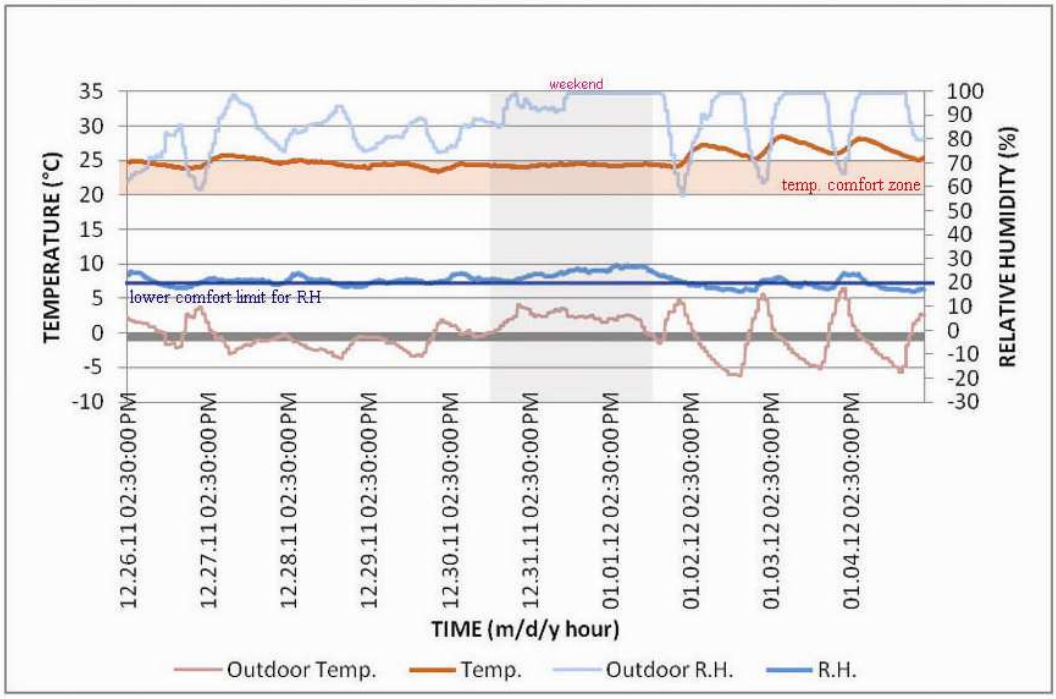


**Figure 4.16.** Room 50 - location 'B' at the side of the room: Temperature and relative humidity chart (26 December 2011 to 5 January 2012)

The comparison of the overall data recorded at the two locations of the room indicates that, as recognized from the charts, the temperature at the location 'A' at the middle of the room was generally lower than the one at the location 'B' at the side of the room. Lower values at the location 'A' could be due to the air flow caused by the door across. Moreover, there could be an additional effect of the height difference between the two locations resulting in higher values at the higher location which is the location 'B', due to the principle that warm air rises.

### 4.2.2. Relative Humidity Data

Figure 4.13 and 4.14 indicate the relative humidity data simultaneously recorded along with the temperature data. The minimum and maximum relative humidity values are presented along with the outdoor ones obtained from the Turkish State Meteorological Service in Table 4.07.

**Table 4.07.** The minimum and maximum relative humidity values recorded in Room 50 and outdoor ones

| ROOM 50 | RELATIVE HUMIDITY (%) | | | |
|---|---|---|---|---|
| | MIN. | DATE and HOUR of MIN. | MAX. | DATE and HOUR of MAX. |
| Location 'A' | 15.84 | 27 November 2011<br>11:00 AM | 58.53 | 11 October 2011<br>03:45 PM |
| Location 'B' | 9.91 | 2 February 2012<br>08:30 AM | 59.34 | 12 October 2011<br>03:45 PM |
| OUTDOOR | 2.60 | 14 September 2011<br>01:00 PM | 99.00 | recorded many times |

As seen in the graphs, in the period without the central heating system between 13 September 2011 and 17 October 2011, the relative humidity in the room changed in accordance with the temperature fluctuations and generally showed an increase due to the decrease in the temperature. However, after the beginning of the fall semester on 26 September 2011, the existence of occupants and their higher metabolic activity rate (not sedentary) in a design studio led to a difference on the data through increasing the relative humidity in the room; *i.e.* the water vapor in the exhaled air had an increasing effect on the room relative humidity. In addition, the use of kettles for making tea and coffee by students also increased the level in the room. In this

period of the semester, apart from the values recorded on 6 October 2011 at between 02:45 PM and 05:30 PM at the location ‘A’ at the middle of the room, at both record locations the relative humidity varied above the lower comfort limit of 20 % defined on the Bioclimatic Chart. The highest values of the data collection period were recorded in the third semester week (10-14 October 2011) and changed between 39.93 and 59.34 %. In relation, the maximum values were in this week, on 11 October 2011 at 03:45 PM at the location ‘A’ at the middle of the room and on 12 October 2011 at 03:45 PM at the location ‘B’ at the side of the room when the outdoor ones were 99 % and 80.7 % respectively.

The start of central heating system on 17 October 2011 caused a decrease in the relative humidity as a result of its increasing effect on the room temperature. From the start of the central heating till the end of the classes (06 January 2012), the relative humidity varied from 13.63 to 57.53 % and it was mostly above the lower comfort limit of 20 % at the location ‘A’ at the middle of the room while it was fluctuated above and below the limit at the location ‘B’ at the side of the room. The minimum relative humidity value at the location ‘A’ at the middle of the room was recorded on 27 November 2011 at 11:00 AM. Throughout the Religious holiday (6-9 November 2011) the relative humidity varied in accordance with the decrease in the temperature. In the period of the semester break (21 January 2012 to 16 February 2012), according to the data recorded at the location ‘B’ at the side of the room, the relative humidity changed similar to the semester period with the central heating with a difference of the lack of occupancy effect due to having no classes. It decreased or increased generally in relation to the changes in the temperature in this period and ranged between 9.91 and 37.02 %. In addition, the minimum relative humidity value of the data collection period at the location ‘B’ at the side of the room was recorded in this period, on 2 February 2012 at 08:30 AM.

As explained previously, the flexible use of the room prevented defining an occupancy pattern in the room. Therefore, it can only be said that the decreased relative humidity due to the increase in temperature as a result of the central heating also showed a rise with occupancy. Towards the evenings, the relative humidity in

the room fell along with the reduced number of occupants or with the end of classes. In addition, as seen in Figure 4.15 and 4.16 showing the data of the period that the air speeds were recorded, on weekends there were obvious changes in the relative humidity which were due to the increasing effect of occupants who were studying in the room as presented by the $CO_2$ data (Figure 4.19 and 4.20).

The comparison of the overall data recorded at the two locations presents that the relative humidity at the location 'A' at the middle of the room was higher than the one at the location 'B' at the side of the room. Lower relative humidity values at the location 'B' were caused by the higher temperature values at the location.

### 4.2.3. $CO_2$ Data

The $CO_2$ data collected in Room 50 in the same periods of time at the two record locations are presented in Figure 4.17 and 4.18. The minimum and maximum $CO_2$ values recorded at the locations are given in Table 4.08.

**Table 4.08.** The minimum and maximum $CO_2$ values recorded in Room 50

| ROOM 50 | $CO_2$ (ppm) | | | |
|---|---|---|---|---|
| | MIN. | DATE and HOUR of MIN. | MAX. | DATE and HOUR of MAX. |
| Location 'A' | 320.01 | 9 October 2011<br>10:30 AM and 11:00 AM | 1999.08 | 17 October 2011<br>02:15 PM,<br>19 October 2011<br>05:00 PM,<br>21 October 2011<br>01:30 PM to 05:00 PM<br>and<br>2 December 2011<br>03:00 PM to 03:30 PM |
| Location 'B' | 321.23 | 9 October 2011<br>11:30 AM | 1977.72 | 12 October 2011<br>04:30 PM<br>and<br>17 October 2011<br>03:00 PM and 03:15 PM |

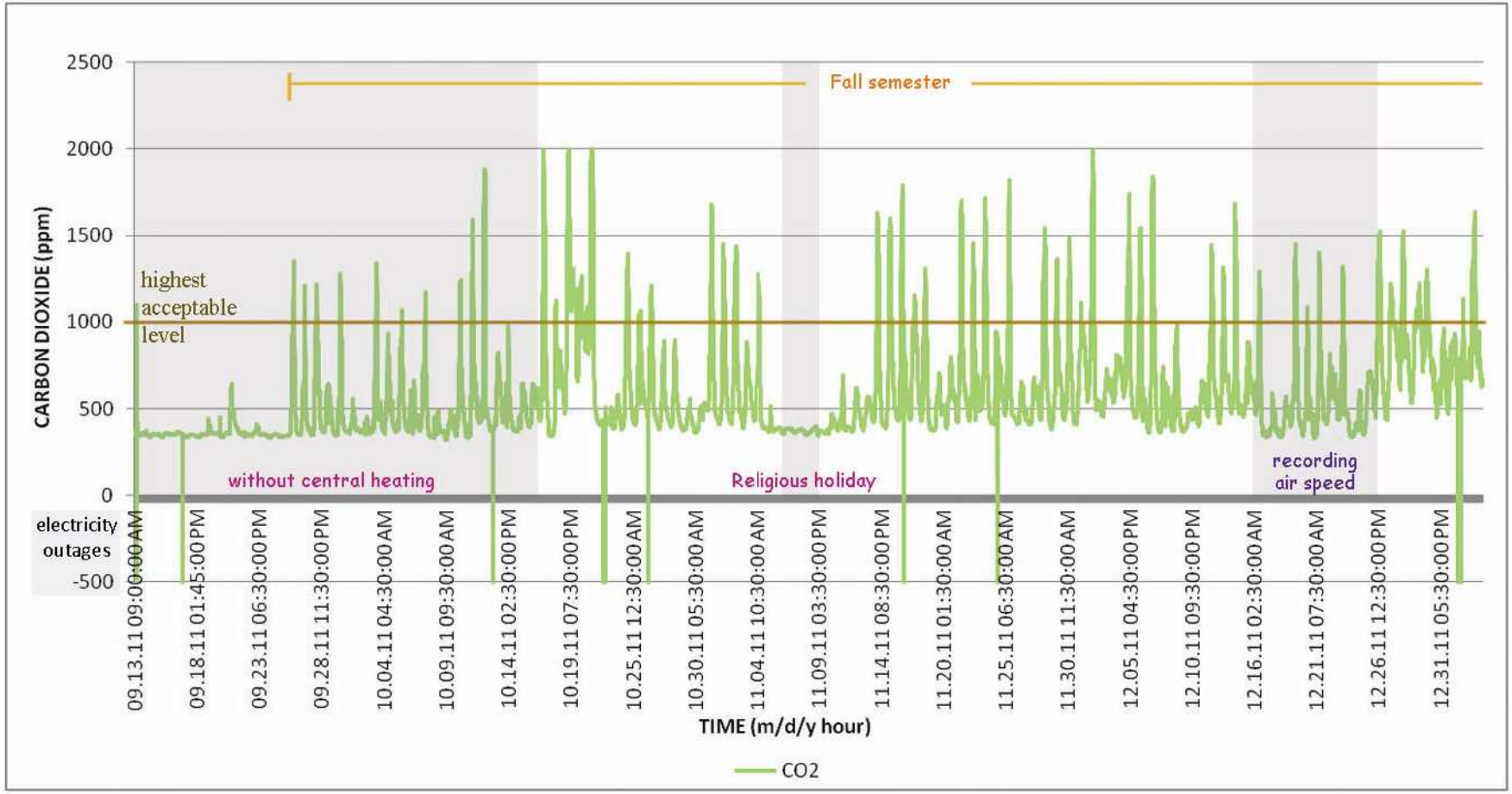


**Figure 4.17.** Room 50 - location 'A' at the middle of the room: $CO_2$ chart (13 September 2011 to 4 January 2012)

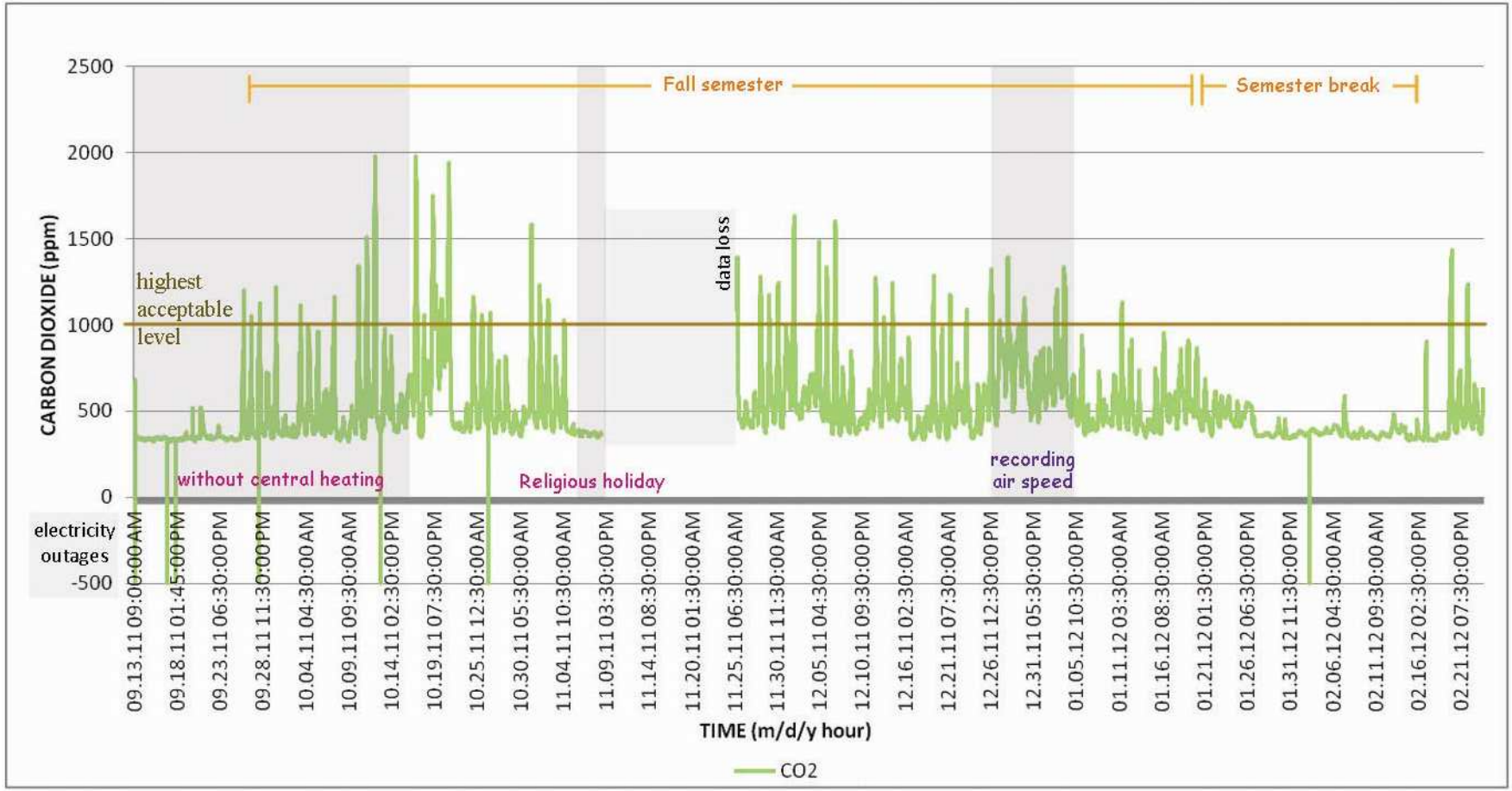


**Figure 4.18.** Room 50 - location 'B' at the side of the room: $CO_2$ chart (13 September 2011 to 24 February 2012)

The recorded $CO_2$ data in Room 50 clearly show the occupancy pattern throughout the data collection period, since there were no $CO_2$ sources (combustion by-products, heavy traffic, industrial area, *etc.*) other than the occupants in and around the room. As the charts present, except for the minus values recorded due to electricity outages, the $CO_2$ concentration in the room never fell to 0 ppm, which indicates the existence of a relatively small amount of $CO_2$ in the room all the time. From 13 September 2011 to 26 September 2011, the level in the room changed between 323.06 and 587.95 ppm and it was mostly under 450 ppm indicating the outdoor $CO_2$ level owing to no occupancy in the room in this period. There are exceptional high values of 1101.26 ppm on 13 September 2011 at 02:15 PM and 647.77 ppm on 21 September 2011 at 12:15 PM at the location 'A' at the middle of the room, and 681.95 ppm on 13 September 2011 at 02:00 PM at the location 'B' at the side of the room. These values are recorded as a result of the author's getting close to the data loggers for check.

The beginning of the fall semester on 26 September 2011 caused increases in the $CO_2$ concentration in the room. The level began to rise after students started to occupy the room as a result of the $CO_2$ generation; however there is no relation between the course schedule and the variations in the $CO_2$ concentration due to the flexible use of the room explained previously. In spite of the fact that the scheduled courses began at 01:40 PM, the data indicate various times of each day when the occupation of the room began. In fact, the data present the use of the room on Thursdays when there were no classes officially. The $CO_2$ level in the room changed in relation to the duration that the room was occupied, the number of the students occupying the room, the activities of the students and whether air flow was provided through opening windows and/or a door. It mostly exceeded the highest acceptable level of 1000 ppm by ASHRAE 62-1989 and rose up to the maximum of 1999.08 ppm at the location 'A' at the middle of the room in the afternoons on 17, 19 and 21 October 2011 and 2 December 2011, and 1977.72 ppm at the location 'B' at the side of the room in the afternoons on 12 and 17 October 2011, all of which were during the design studio course ARCH 301. In relation, as seen in the charts, throughout the semester generally the concentration increased more on Mondays, Wednesdays and

Fridays when the design studio courses took place. The data also present considerable changes in the $CO_2$ level in the room at nights and on weekends, which could be due to the existence of students studying in the room. As distinct from the school period, throughout the Religious holiday (6-9 November 2011), owing to no occupancy in the room the $CO_2$ concentrations were at lower levels representing the outdoor concentration. Similarly, during the semester break (21 January 2012 to 16 February 2012), the concentrations were also at lower levels and changed between 341.37 and 689.88 ppm according to the data recorded at the location 'B' at the side of the room.

The comparison of the $CO_2$ data recorded at the two locations indicates that, in spite of the fact that the $CO_2$ level increases with height in a space due to its rise with warm air, the $CO_2$ concentration at the location 'A' at the middle of the room was mostly higher than the one at the location 'B' at the side of the room on the mezzanine floor. The possible cause of higher levels at the location 'A' could be gathering of students around the location for lectures and the existence of mezzanine floor causing the accumulation of $CO_2$ under it.

### 4.2.4. Air Speed Data along with the $CO_2$ Data in the Period

The air speed data are presented along with the $CO_2$ data of the time periods that the air speeds were recorded at each location. Figure 4.19 show the air speed and $CO_2$ data of the location 'A' at the middle of the room from 16 December 2011 to 26 December 2011 and Figure 4.20 present the ones recorded at the location 'B' at the side of the room from 26 December 2011 to 5 January 2012. The data for outdoor air speed has been superimposed on the charts with its own scale ranging from 0.00 to 6.00 m/s whereas the indoor air speed scale range from -0.02 to 0.20 m/s. The minimum and maximum air speed values recorded at the two record locations are given along with the outdoor ones obtained from the Turkish State Meteorological Service in Table 4.09 and the minimum and maximum $CO_2$ concentrations recorded are given in Table 4.10.

**Table 4.09.** The minimum and maximum air speed values recorded in Room 50 and outdoor ones

| ROOM 50 | AIR SPEED (m/s) | | | |
|---|---|---|---|---|
| | MIN. | DATE and HOUR of MIN. | MAX. | DATE and HOUR of MAX. |
| Location 'A' | 0.00 | recorded many times | 0.19 | 16 December 2011 09:00 PM |
| Outdoor | 0.40 | 21 December 2011 05:00 PM | 5.40 | 25 December 2011 05:00 PM |
| Location 'B' | 0.00 | recorded many times | 0.16 | 27 December 2011 02:45 PM |
| Outdoor | 0.30 | 1 January 2012 04:00 PM | 5.10 | 31 December 2011 05:00 PM |

**Table 4.10.** The minimum and maximum $CO_2$ values recorded in Room 50 in the time periods that the air speeds were measured

| ROOM 50 | $CO_2$ (ppm) | | | |
|---|---|---|---|---|
| | MIN. | DATE and HOUR of MIN. | MAX. | DATE and HOUR of MAX. |
| Location 'A' | 332.21 | 21 December 2011 04:15 AM | 1454.04 | 19 December 2011 03:00 PM |
| Location 'B' | 414.61 | 27 December 2011 07:15 AM to 08:00 AM | 1394.23 | 28 December 2011 04:00 PM |

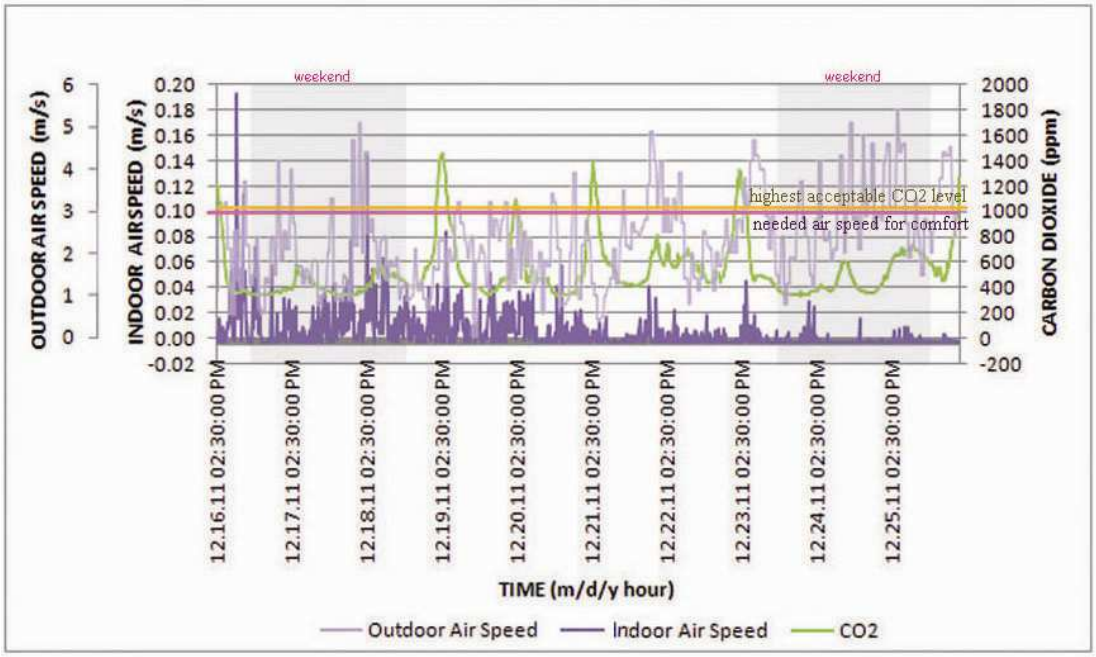


**Figure 4.19.** Room 50 - location 'A' at the middle of the room: Air speed and $CO_2$ chart with two superimposed scales for air speeds (16 December 2011 to 26 December 2011)

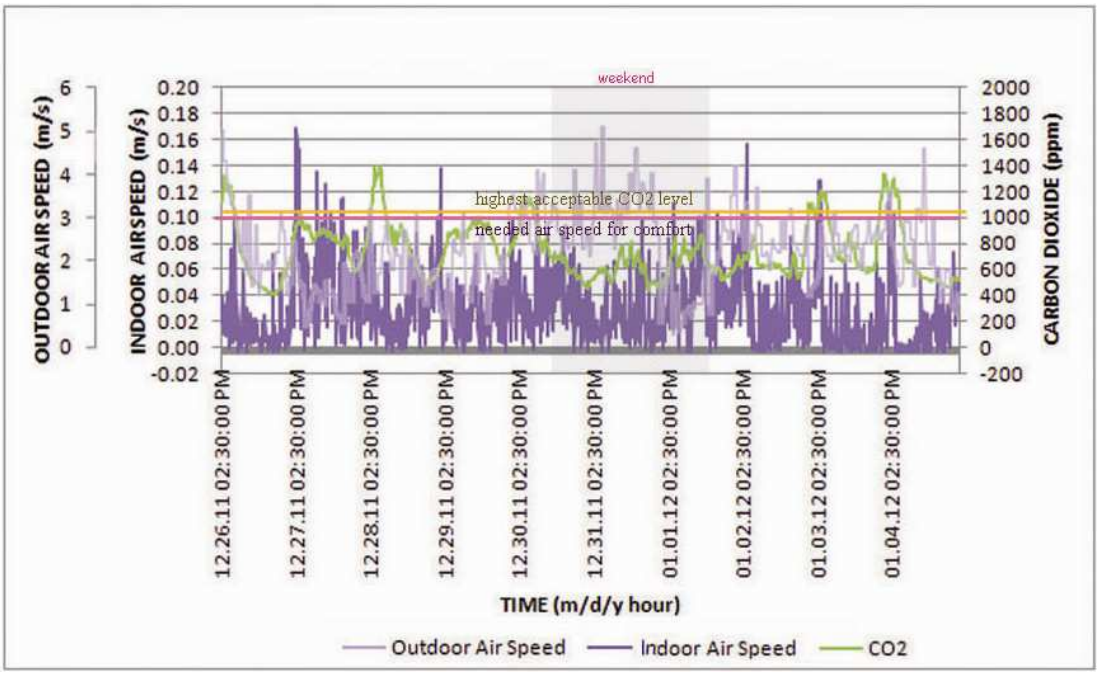


**Figure 4.20.** Room 50 - location 'B' at the side of the room: Air speed and $CO_2$ chart with two superimposed scales for air speeds (26 December 2011 to 5 January 2012)

The air speed data recorded at both locations in the two periods indicate that the room air was mostly stagnant due to insufficient air flow through the room. Despite the fact that the location 'A' at the middle of the room mostly had comfort conditions in terms of temperature and relative humidity, it needed higher air flow around due to the high $CO_2$ levels. As seen in Figure 4.19, at the location 'A' the air movement was mostly stagnant apart from three high values, which are 0.19 m/s on 16 December 2011 at 09:00 PM, 0.11 m/s on 16 December 2011 at 11:00 PM and 0.14 m/s on 18 December 2011 at 02:45 PM. According to the fluctuations at relatively high values on the dates and three exceptions above the lower limit, there could be open window(s) forgotten on the last school day of the week (16 September 2011), which slightly increased the air flow in the room. In relation, the decrease in the air speed gradually throughout the record period could be owing to closing the room off. On the other hand, at the location 'B' at the side of the room the air speed was mostly under the needed value of 0.1 m/s presented for comfort on the Bioclimatic chart when the temperature was relatively above the comfort range. The comparison of the air speed data of the two record locations in terms of variation indicates that the air speed at the location 'B' at the side of the room was more fluctuating. The possible

reasons could be the air movement along the side wall due to the window which close to the room corner, the increasing effect of the existence of more human movement and so more air flow around the location 'B' and the blocking effect of the mezzanine floor on the air flow at the location 'A'.

In order to investigate the relationship between the air speed and $CO_2$ data of Room 50, the scatter diagrams of the daytime of weekdays – between 08:30 AM and 08:00 PM – are given for the two record locations in Figure 4.21 and 4.22. Owing to the fact that, under constant circumstances, an increase in air speed decreases the $CO_2$ level in a space through dilution, there should be a negative association between these two variables. However, the diagrams present no relationships between the variables of each record location. This indicates the effect of third variable on the data; *i.e.* occupants increased the $CO_2$ concentration in the room through respiration while the air speed conditions were not changed considerably. Therefore, various $CO_2$ levels were recorded at the same air speed value due to the accumulation.

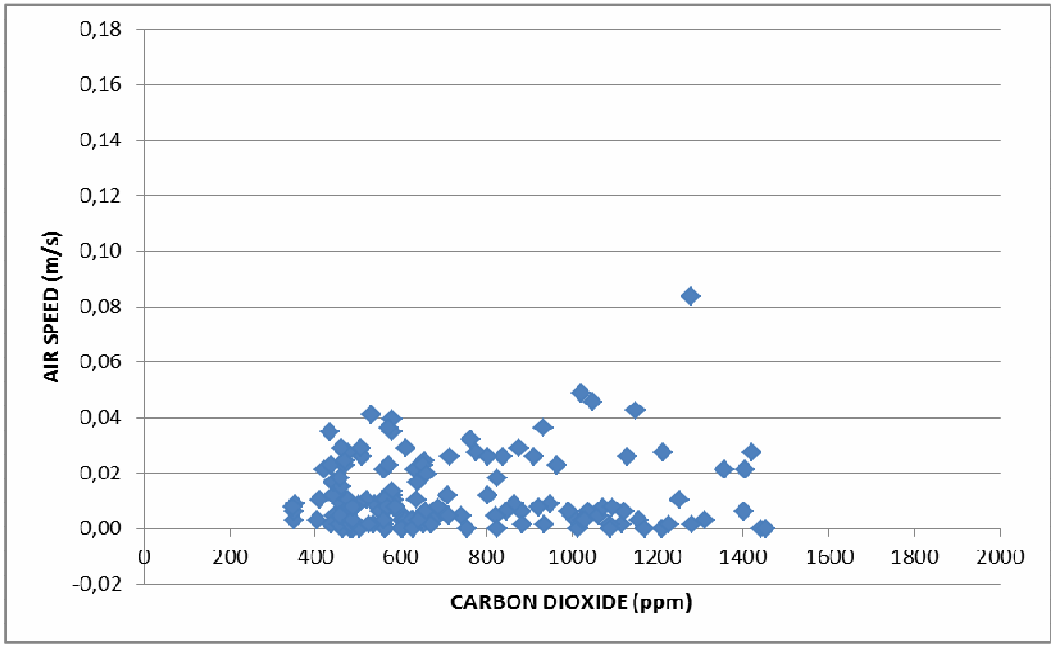


**Figure 4.21.** Room 50 – location 'A' at the middle of the room: Air speed-$CO_2$ scatter diagram (19 December 2011 to 23 December 2011, between 08:30 AM and 08:00 PM of each day)

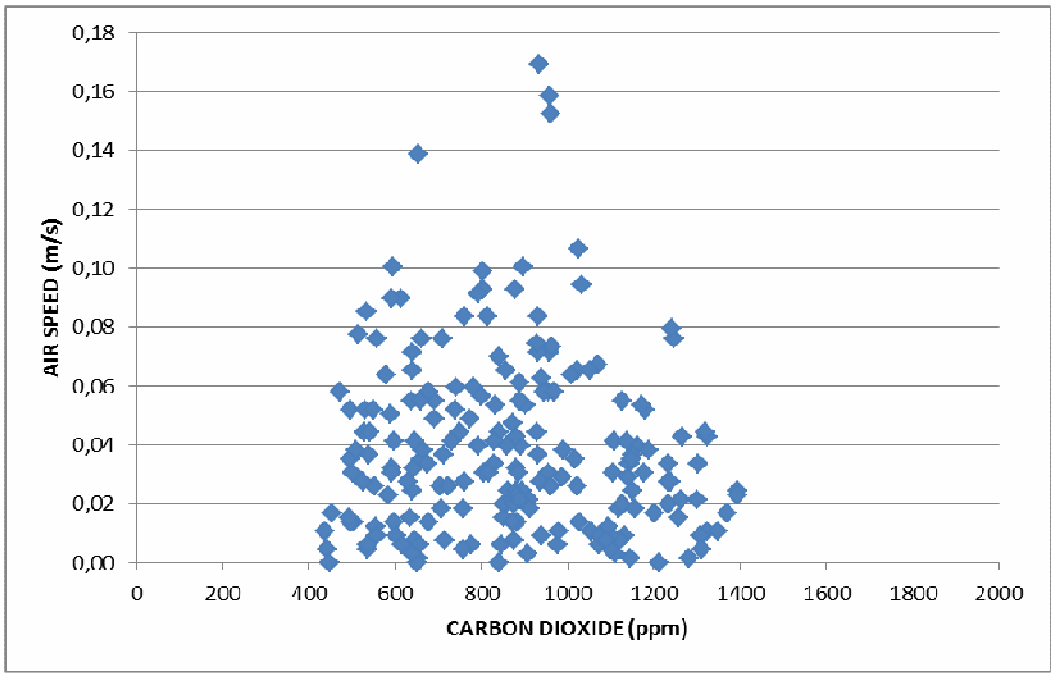


**Figure 4.22.** Room 50 – location 'B' at the side of the room: Air speed-$CO_2$ scatter diagram (26 December 2011 to 30 December 2011, between 08:30 AM and 08:00 PM of each day)

### 4.2.5. The Features of Room 50 in Relation to The Results

As presented through the section in Figure 4.23, the recorded data show that the air speeds at both locations were insufficient for comfort in the winter; however the location 'B' at the side of the room had higher values than the location 'A' at the middle of the room. In connection, due to the fact that less air movement causes the accumulation of more $CO_2$, the location 'A' at the middle of the room had higher $CO_2$ values. Furthermore, in spite of the fact that the location 'A' at the middle of the room mostly had comfort conditions in terms of temperature and relative humidity, the location 'B' at the side of the room was warmer and so drier as a result of the low air flow which was insufficient to reduce the effects of internal heat sources.

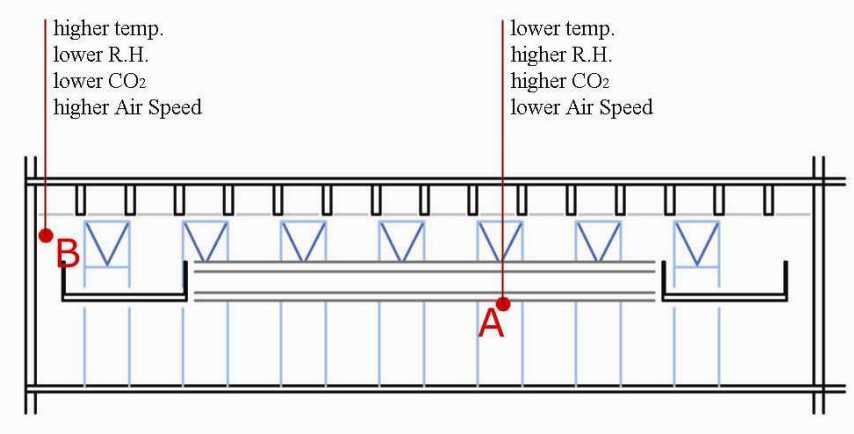


**Figure 4.23.** The longitudinal section of Room 50 showing the comparison of the data recorded at the two locations

In connection with the features of Room 50, in general, the mezzanine floor built later could be a factor creating difficulties for air flow and resulting in lower air speed values under it in relation with the window configuration. The ventilation windows on the top are suitable to provide air movement for the comfort of occupants using the desks on the mezzanine floor while they can be disadvantageous for the ones on the room ground floor due to the possible limitation effect of the mezzanine floor on the air movement under it. The combined adverse effect of the mezzanine floor and window configuration on the air speed at the location 'A' at the middle of the room also led to accumulation of $CO_2$ under the mezzanine floor more due to decreasing the possibility of dilution. On the contrary, the higher temperature and lower relative humidity values at the location 'B' can be explained through the height difference between the locations and through the ventilation effect of the door on the location 'A' at the middle of the room.

On the other hand, as an advantage for an effective air flow, the room allows cross ventilation through the windows on the two opposing walls, on the west and east. In relation with the room dimensions, the room meets the recommended effective depth criterion for this ventilation strategy; *i.e.* the room height is 4.9 m and its depth (the dimension between the two walls having windows) is 11.87 m while the effective depth for the case is four times the room height, which is 19.60 m and larger than the room depth as recommended. However, the percentage of the window openable

sections is not in accordance with the ASHRAE Standard 62.1.2007 suggesting a minimum of 4 % openable area of the net floor area – the openable sections of the room windows is 8.73 m² (1.1m x 1m x 7 + 1.15m x 0.3m x 3) while 4 % of the room floor area (225m² + 113.4m²) is 13.54 m² which is larger than 8.73 m².

In addition to all, for favorable indoor environmental conditions the room floor area also has significance in terms of occupant capacity, since excessive occupant levels also have adverse effects on the indoor comfort and air quality conditions. The ground floor area of Room 50 (225m² + 113.4m²) allows the maximum of 68 occupants according to the ASHRAE Standard 62.1-2007 recommending 20 occupants for 100 m² for art classrooms. In connection with the course student capacities, there was excessive occupancy in the room in the data collection period due to the use of the room for two courses with higher numbers of students (ARCH 301 with 70 students and ARCH 351 with 84 students).

### 4.2.6. Calculations for Fresh Air Supply

The determination of the needed air should be the starting point in reconsidering the fresh air supply to a space continuously in a controlled way. The needed air in Room 50 can be calculated according to the breathing zone outdoor air flow equation of the Ventilation Rate Procedure of the ASHRAE Standard 62.1-2007 explained in the Section 2.2.:

$V_{bz} = R_p \cdot P_z + R_a \cdot A_z$

$V_{bz}$ = 5 L/s per 84 person + 0.9 L/s m² (225 m² + 113.4 m²)

$V_{bz}$ = 724.56 L/s = 0.72 m³/s = 2592 m³/h

In order to have an idea, the flow rate equation described in the Section 2.3.2. can be used to determine the inlet opening area needed for this amount of air. The average outdoor air speed value (2.1 m/s) of the fall semester period – from 26 September 2011 to 21 January 2012 – is taken as the reference. The calculated areas are likely to

be larger when the average outdoor air speed value of years for Ankara is used and the changing air speed conditions are considered.

$Q = A . V$

$0.72\ m^3/s = A\ 2.1\ m/s \qquad A = 0.34\ m^2$

The calculated area can be achieved through seven inlet openings on the existing west windows with net dimensions of 0.90 m and 0.054 m. Owing to the unfeasibility of having such openings in the winter due to possible strong draughts causing discomfort, reconsidering the existing inlet openings behind the fan coils – designed for fresh air intake in winter and closed off in present situation due to draught complaints – would be useful for controlled air intake in to the room. In relation to the original mechanical drawings (Appendix B), Room 50 has five fan coils with currently available inlet openings (the others are cement-filled) and each has the heat capacity of 10,000 kcal/h. The amount of fresh air that would be supplied to the room in the case of reconnecting the inlet openings to these fan coils can be calculated in relation to their heat capacities. According to the specific heat equation given in the Section 2.3.2., the amount of air that would be supplied by each fan coil is:

$Q = V . c . \Delta t$

$10{,}000\ kcal/h = m . 0.28\ kcal/°C . [20-(-12)] \qquad m = 1116.07\ m^3/h$

In total, the fan coils in Room 50 would provide 5580.35 $m^3/h$ (5 x 1116.07 $m^3/h$) fresh air to the room. This amount is more than two times of the calculated breathing zone outdoor air flow amount of 2592 $m^3/h$. Moreover, it is also more than the fresh air need that can be determined through multiplying the room volume by air exchange coefficient, which is 5512.5 $m^3/h$ (1102.5 $m^3$ x 5 $h^{-1}$) for Room 50.

# CHAPTER 5

# CONCLUSION AND RECOMMENDATIONS

Human comfort and indoor air quality are two issues which are essential for accommodating occupants without environmental stress. On the other hand, ventilation is a vital necessity for health and comfort and a basic need in an occupied space. Thus, these three issues are interrelated; *i.e.* ventilation is the key factor for achieving comfort through air movement and heat avoidance and for better indoor air quality through keeping the pollutants at acceptable levels.

Indoor air quality and ventilation are significant for human beings with regard to their health, performance and productivity, which are negatively affected by inadequate physical conditions of spaces while an improved environment decreases complaints. In this context, educational buildings should also be investigated in terms of these issues due to their impact on student performance.

In educational buildings, in Turkey, classrooms are generally ventilated by natural ventilation and the indoor air quality and comfort problems are mostly the result of its insufficiency. The inadequacy of fresh air intake into these spaces leads to accumulation of pollutants, excessive heat and air dryness or dampness due to various sources. The use of classrooms almost continuously throughout a school day and the over use of their capacity increase these problems.

In this study, it was also clearly observed through the collected temperature, relative humidity, $CO_2$ and air speed data that the main problems in the investigated rooms in the winter were $CO_2$ and heat accumulation, air dryness and air movement lower than

the needed to provide heat removal and $CO_2$ dilution. The use of the rooms by too many occupants and not meeting the amounts of fresh air required for the occupancy levels and for the room volumes caused such unfavorable conditions in the rooms. In addition, the problems were also resulted from closing off the air inlet openings that were coupled with fan coils.

According to the calculations given in the Section 4.1.6. and 4.2.6., the closed off inlets are sufficient to the needed amount of fresh air for the rooms. Therefore, for the improvement of indoor environmental conditions in the rooms, restoring the system is the most feasible solution; *i.e.* the three fan coils having inlet openings behind in Room 28 and five fan coils with currently available inlet openings (the others are cement-filled) in Room 50 can be reopened to meet the needed fresh air. (Figure 5.01 and 5.02) However, the openings should be properly connected to the fan coils by using insulated air ducts to prevent the draughts caused by leakages.

In consequence, being aware of the comfort and indoor air quality conditions and of the need for fresh air in spaces are essential for accommodating people in the favorable ambient environments, particularly in the spaces with functions requiring concentration and performance as in educational buildings. Ideally, the consideration of the issues should be at the design stage as done and applied in the case study building. However, ignoring the benefits of the systems designed for human comfort and preventing their operation in the case of a problem instead of producing a solution lead to unpleasant spaces as observed in the rooms investigated.

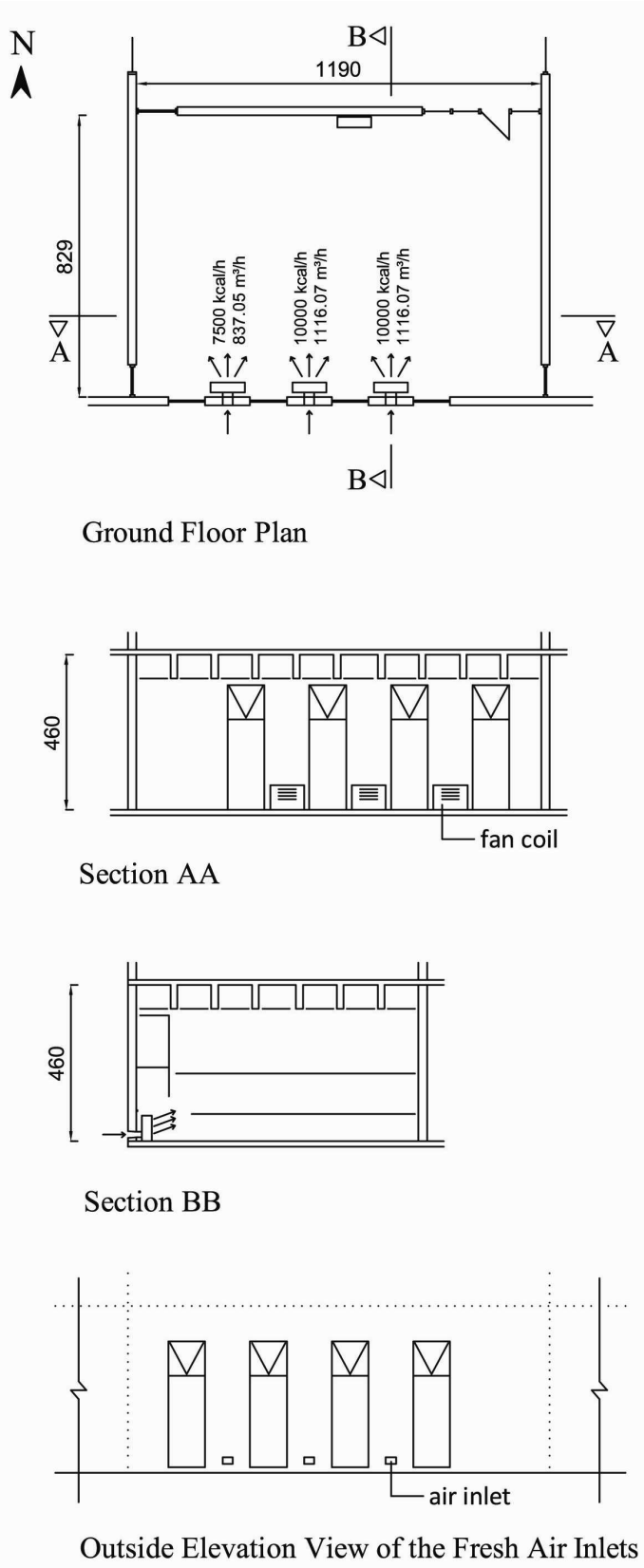


**Figure 5.01.** The fresh air supply through restoring the opening-fan coil strategy in existence in Room 28

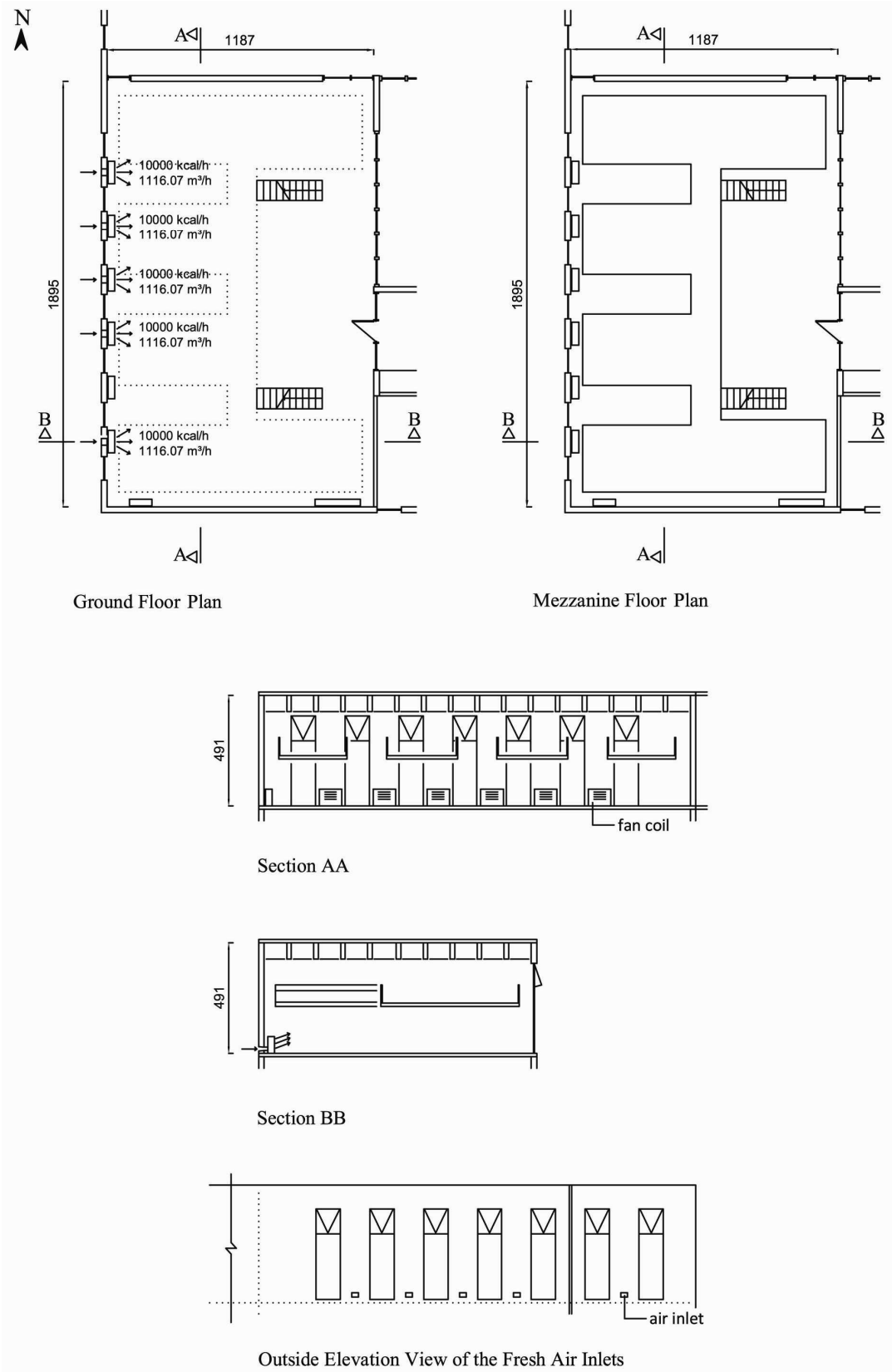


**Figure 5.02.** The fresh air supply through restoring the opening-fan coil strategy in existence in Room 50

## BIBLIOGRAPHY


ACGIH (1991). *Documentation of the Threshold Limit Values and Biological Exposure Indices* (6th ed.). Cincinnati: American Conference of Governmental Industrial Hygienists Inc.

Air Quality Sciences (2006). *Reviewing and Refocusing on IAQ in Schools*, Retrieved June 3, 2012 from the World Wide Web: http://www.greenguard.org/Libraries/GG_Documents/Reformat_Reviewing_Refocusing_on_IAQ_in_Schools_Final_with_revisions.sflb.ashx

Allard, F. (Ed.) (1998). *Natural Ventilation in Buildings: a Design Handbook*. London: James & James Ltd.

Allocca, C., Chen, Q., & Glicksman, L. R. (2003). Design Analysis of Single-Sided Natural Ventilation. *Energy and Buildings*, 35, 785-795.

ANSI/ASHRAE Standard 55-2004. *Thermal Environmental Conditions for Human Occupancy*. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers.

ASHRAE Standard 62-1989. *Ventilation for Acceptable Indoor Air Quality*. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers.

ANSI/ASHRAE Standard 62.1-2007. *Ventilation for Acceptable Indoor Air Quality*. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers.

ASHRAE (2009). *2009 Ashrae Handbook: Fundamentals* (Inch-Pound ed.). Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers.

ASTM (2012). Standard Guide for Using Indoor Carbon Dioxide Concentrations to Evaluate Indoor Air Quality and Ventilation, Retrieved September 20, 2012 from the World Wide Web: http://209.195.157.104/DOWNLOAD/D6245.1113544-1.pdf

Baker, L. (2012). *A History of School Design and Its Indoor Environmental Standards, 1900 to Today.* Washington: National Clearinghouse for Educational Facilities.

Baker, N., & Steemers, K. (2000). *Energy and Environment in Architecture: a Technical Design Guide*. London: E & FN Spon.

Bayer, C. W., Crow, S. A., & Fischer, J. (2000). *Causes of Indoor Air Quality Problems in Schools: Summary of Scientific Research* (Revised ed.). Columbia: Semco Inc.

Buchanan, B. (June 2007). Sick Buildings, Sick Students. *American School Board Journal*, 48-50.

Burroughs, H. E., & Hansen, S. J. (2008). *Managing Indoor Air Quality* (4th ed.). The United States of America: The Fairmont Press.

Cummins, S. K., & Jackson, R. J. (2001). The Built Environment and Children's Health. *Pediatric Clinics of North America*, V48(5), 1241-1252.

Emmerich, S. J., Dols, W. S., & Axley, J. W. (2001). *Natural Ventilation Review and Plan for Design and Analysis Tools*, Retrieved September 25, 2012 from the World Wide Web: http://www.bfrl.nist.gov/IAQanalysis/docs/NISTIR_6781_NatVentTool.pdf

EPA. (1990). Ventilation and Air Quality in Offices: Fact Sheet. *Air and Radiation*.

EPA (2003a). *Indoor Air Quality & Student Performance,* Retrieved June 3, 2012 from the World Wide Web: http://www.cisforegon.org/resources/documents/Indoor%20Air%20Quality%20&%20Student%20Performance.pdf

EPA (2003b). *Indoor Air Quality Tools for Schools: Communications Guide,* Retrieved June 3, 2012 from the World Wide Web: http://www.epa.gov/iaq/schools/pdfs/publications/communicationsguide.pdf

EPA (2010). *How Does Indoor Air Quality Impact Student Health and Academic Performance?: The case for Comprehensive IAQ Management in Schools,* Retrieved June 3, 2012 from the World Wide Web: http://www.epa.gov/iaq/schools/pdfs/student_performance_findings.pdf

Ertürk, M. (2007). Farklı Amaçlar için Kullanılan İç İçe Geçmiş Kapalı Hacimlerde Negatif Basınç Yöntemiyle Havalandırma Sistemi Uygulaması. *Tesisat Mühendisliği Dergisi,* 99, 82-94.

Fanger, P. O. (1970). *Thermal Comfort: Analysis and Applications in Environmental Engineering.* Copenhagen: Danish Technical Press.

Flourentzou, F., Maas, J. V. D., & Roulet, C. A. (1998). Natural Ventilation for Passive Cooling: Measurement of Discharge Coefficients. *Energy and Buildings*, 27, 283-292.

Fisk, W. J. (2000). Health and Productivity Gains from Better Indoor Environments and their Relationship with Building Energy Efficiency. *Annual Review Energy Environment*, 25, 537-566.

Gan, G. (2000). Effective Depth of Fresh Air Distribution in Rooms with Single-Sided Natural Ventilation. *Energy and Buildings*, 31, 65-73.

Givoni, B. (1976). *Man, Climate and Architecture* (2nd ed.). London: Applied Science Publishers.

Givoni, B. (1994). *Passive and Low Energy Cooling of Buildings*. New York: Van Nostrand Reinhold.

Harvey, L. D. D. (2006). *A Handbook on Low-Energy Buildings and District-Energy Systems: Fundamentals, Techniques and Examples*. London: Earthscan.

Hays, C. (2008). The Designer's Perspective. In C. Grech & D. Walters (Eds.), *Future Office: Design, Practice and Applied Research* (p.119-124). London: Taylor & Francis.

Heerwagen, D. (2004). *Passive and Active Environmental Controls: Informing the Schematic Designing of Buildings*. New York: McGraw-Hill.

Hille, T. (2011). *Modern Schools: A Century of Design for Education*. The United States of America: John Wiley & Sons.

International Standard ISO 7730:2005. *Ergonomics of the Thermal Environment – Analytical determination and Interpretation of Thermal Comfort Using Calculation of the PMV and PPD Indices and Local Thermal Comfort Criteria*.

Kibert, C. J. (2005). *Sustainable Construction: Green Building Design and Delivery*. New Jersey: John Wiley and Sons.

Kosonen, R., & Tan, F. (2004). Assessment of Productivity Loss in Air-conditioned Buildings Using PMV Index. *Energy and Buildings*, 36, 987-993.

Lechner, N. (2009). *Heating, Cooling, Lighting: Sustainable Design Methods for Architects* (3rd ed.). The United States of America: John Wiley and Sons.

Levin, H. (1999). Commercial Building Indoor Air Quality: an Introduction to the Problem. Northeast Energy Efficiency Partnerships Inc.

Loftness, V. (2008). Future Office Environments. In C. Grech & D. Walters (Eds.), *Future Office: Design, Practice and Applied Research* (p.19-21). London: Taylor & Francis.

MDH (2010). Carbon Dioxide ($CO_2$) in the Indoor Environment. *Minnesota Department of Health Fact Sheet*. Retrieved September 20, 2012 from the World Wide Web: http://www.health.state.mn.us/divs/eh/indoorair/co2/carbondioxide.pdf

Myhrvold, A. N., Olsen, E., & Lauridsen, O. (1996.). Indoor Environment in Schools – Pupils Health and Performance in Regard to $CO_2$ Concentrations. *Indoor Air*.

Nelson, V. (2011). *Introduction to Renewable Energy.* London: Taylor & Francis.

NIOSH (1976). Criteria for a Recommended Standard: Occupational Exposure to Carbon Dioxide. U.S. Department of Health, Education, and Welfare, Retrieved September 20, 2012 from the World Wide Web: http://www.cdc.gov/niosh/pdfs/76-194c.pdf

Olgyay, V. (1969). *Design with Climate: Bioclimatic Approach to Architectural Regionalism*. Princeton: Princeton University Press.

OSHA (n.d.). Carbon Dioxide in Workplace Atmospheres. Retrieved September 20, 2012 from the World Wide Web: http://www.osha.gov/dts/sltc/methods/inorganic/id172/id172.html

Persily, A. K. (1997). Evaluating Building IAQ and Ventilation with Indoor Carbon Dioxide. *ASHRAE Transactions*, 103. Retrieved September 20, 2012 from the World Wide Web: http://fire.nist.gov/bfrlpubs/build97/PDF/b97044.pdf

Seppanen, O., & Fisk, W. J. (2002). Relationship of SBS-Symptoms and Ventilation System Type in Office Buildings. Lawrence Berkeley National Laboratory.

Shaw, C. Y. (1997). Maintaining Acceptable Air Quality in Office Buildings through Ventilation. *Construction Technology Update No.3*. Institute for Research in Construction.

Shendell, D. G., Prill, R., Fisk, W. J., Apte, M. G., Blak, D., & Faulkner, D. (2004). Associations between Classroom $CO_2$ Concentrations and Student Attendance in Washington and Idaho. *Indoor Air*, 14, 333-341.

Steiger, S., Hellwig, R. T., & Junker, E. (2008). Distribution of Carbon Dioxide in a Naturally Ventilated Room with High Internal Heat Load. *Nordic Symposium on Building Physics.*

Tanner, C. K., & Lackney, J. A. (2005). *Educational Facilities Planning*. Boston: Pearson Allyn and Bacon.

The Building Regulations 2000 (2010). *Approved Document F1: Ventilation.* London: NBS.

Turnbull, J. E. (n.d.) Fresh Air Inlets. Retrieved September 20, 2012 from the World Wide Web: http://www.cps.gov.on.ca/english/plans/E9000/9710/M-9710L.pdf

Valsson, S., & Bharat, A. (2011). Impact of Air Temperature on Relative Humidity – a Study. *Architecture - Time Space & People*, 38-41.

Yeang, K. (1996). *The Skyscraper Bioclimatically Considered: a Design Premier*. Great Britain: Wiley-Academy.

# APPENDIX A

## AIR SPEED, TEMPERATURE, RELATIVE HUMIDITY AND $CO_2$ DATA OF FIVE DAYS FOR ROOM 28 AND ROOM 50

**Table A.01.** The air speed, temperature, relative humidity and $CO_2$ data of five days for the record locations 'A' and 'B' in Room 28

| Room 28 - location 'A' | | | | | Room 28 - location 'B' | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Date** | **m/s** | **°C** | **%** | **ppm** | **Date** | **m/s** | **°C** | **%** | **ppm** |
| 11.28.11 12:00 AM | -0,0030 | 29,24 | 10,38 | 371,28 | 12.12.11 12:00 AM | -0,0020 | 26,43 | 17,39 | 457,34 |
| 11.28.11 12:15 AM | -0,0020 | 29,29 | 10,35 | 366,39 | 12.12.11 12:15 AM | 0,0061 | 26,35 | 17,43 | 454,28 |
| 11.28.11 12:30 AM | -0,0030 | 29,27 | 10,38 | 366,39 | 12.12.11 12:30 AM | -0,0030 | 26,55 | 17,4 | 456,12 |
| 11.28.11 12:45 AM | -0,0030 | 29,29 | 10,27 | 367 | 12.12.11 12:45 AM | 0,0030 | 26,57 | 17,44 | 459,17 |
| 11.28.11 01:00 AM | -0,0020 | 29,27 | 10,31 | 361,51 | 12.12.11 01:00 AM | 0,0152 | 26,72 | 17,45 | 457,34 |
| 11.28.11 01:15 AM | -0,0030 | 29,27 | 10,27 | 360,9 | 12.12.11 01:15 AM | 0,0030 | 26,74 | 17,45 | 461,61 |
| 11.28.11 01:30 AM | -0,0030 | 29,29 | 10,31 | 360,9 | 12.12.11 01:30 AM | 0,0122 | 26,84 | 17,53 | 459,78 |
| 11.28.11 01:45 AM | -0,0030 | 29,27 | 10,23 | 358,46 | 12.12.11 01:45 AM | 0,0396 | 26,87 | 17,53 | 466,49 |
| 11.28.11 02:00 AM | -0,0030 | 29,32 | 10,23 | 361,51 | 12.12.11 02:00 AM | 0,0046 | 26,77 | 17,37 | 464,05 |
| 11.28.11 02:15 AM | -0,0030 | 29,24 | 10,23 | 363,95 | 12.12.11 02:15 AM | -0,0030 | 26,84 | 17,38 | 464,66 |
| 11.28.11 02:30 AM | 0,0000 | 29,29 | 10,23 | 366,39 | 12.12.11 02:30 AM | 0,0106 | 26,84 | 17,34 | 461,61 |
| 11.28.11 02:45 AM | 0,0046 | 29,29 | 10,35 | 366,39 | 12.12.11 02:45 AM | -0,0030 | 26,89 | 17,31 | 461,61 |
| 11.28.11 03:00 AM | -0,0030 | 29,29 | 10,31 | 366,39 | 12.12.11 03:00 AM | 0,0365 | 26,84 | 17,38 | 461,61 |
| 11.28.11 03:15 AM | -0,0030 | 29,29 | 10,31 | 365,78 | 12.12.11 03:15 AM | -0,0030 | 26,92 | 17,31 | 466,49 |
| 11.28.11 03:30 AM | -0,0030 | 29,24 | 10,23 | 368,84 | 12.12.11 03:30 AM | -0,0030 | 26,82 | 17,38 | 466,49 |
| 11.28.11 03:45 AM | -0,0030 | 29,29 | 10,11 | 365,78 | 12.12.11 03:45 AM | -0,0020 | 26,89 | 17,38 | 461 |
| 11.28.11 04:00 AM | 0,0106 | 29,27 | 10,07 | 371,28 | 12.12.11 04:00 AM | -0,0030 | 26,94 | 17,31 | 466,49 |
| 11.28.11 04:15 AM | -0,0020 | 29,27 | 10,07 | 373,11 | 12.12.11 04:15 AM | -0,0030 | 27,01 | 17,31 | 463,44 |
| 11.28.11 04:30 AM | -0,0030 | 29,32 | 10,15 | 370,67 | 12.12.11 04:30 AM | -0,0030 | 26,99 | 17,16 | 464,66 |
| 11.28.11 04:45 AM | 0,0046 | 29,29 | 10,15 | 371,28 | 12.12.11 04:45 AM | 0,0167 | 26,94 | 17,23 | 461,61 |
| 11.28.11 05:00 AM | -0,0030 | 29,32 | 10,15 | 375,55 | 12.12.11 05:00 AM | 0,0183 | 27,01 | 17,09 | 459,17 |
| 11.28.11 05:15 AM | -0,0030 | 29,27 | 10,07 | 375,55 | 12.12.11 05:15 AM | 0,0137 | 27,01 | 17,01 | 459,17 |
| 11.28.11 05:30 AM | -0,0030 | 29,27 | 9,994 | 374,94 | 12.12.11 05:30 AM | 0,0289 | 27,09 | 17,01 | 461,61 |
| 11.28.11 05:45 AM | -0,0030 | 29,32 | 10,07 | 377,99 | 12.12.11 05:45 AM | 0,0061 | 27,06 | 16,94 | 465,88 |

**Table A.01.** (Continued)

| Room 28 - location 'A' | | | | | Room 28 - location 'B' | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Date** | **m/s** | **°C** | **%** | **ppm** | **Date** | **m/s** | **°C** | **%** | **ppm** |
| 11.28.11 06:00 AM | -0,0030 | 29,27 | 9,994 | 378,6 | 12.12.11 06:00 AM | 0,0030 | 26,94 | 16,93 | 466,49 |
| 11.28.11 06:15 AM | -0,0030 | 29,29 | 9,839 | 381,04 | 12.12.11 06:15 AM | -0,0030 | 26,94 | 16,97 | 465,88 |
| 11.28.11 06:30 AM | -0,0030 | 29,29 | 9,917 | 375,55 | 12.12.11 06:30 AM | 0,0061 | 27,01 | 16,94 | 465,88 |
| 11.28.11 06:45 AM | 0,0106 | 29,29 | 9,839 | 378,6 | 12.12.11 06:45 AM | 0,0335 | 27,11 | 16,87 | 461,61 |
| 11.28.11 07:00 AM | -0,0030 | 29,41 | 9,922 | 375,55 | 12.12.11 07:00 AM | -0,0030 | 27,14 | 16,79 | 461,61 |
| 11.28.11 07:15 AM | -0,0030 | 29,44 | 10,16 | 375,55 | 12.12.11 07:15 AM | 0,0244 | 27,16 | 16,83 | 461,61 |
| 11.28.11 07:30 AM | 0,0213 | 29,41 | 10 | 383,48 | 12.12.11 07:30 AM | 0,0106 | 27,16 | 16,72 | 467,1 |
| 11.28.11 07:45 AM | -0,0030 | 29,46 | 10,16 | 383,48 | 12.12.11 07:45 AM | -0,0020 | 27,21 | 16,79 | 466,49 |
| 11.28.11 08:00 AM | 0,0030 | 29,41 | 10,16 | 388,37 | 12.12.11 08:00 AM | 0,0106 | 27,14 | 16,79 | 466,49 |
| 11.28.11 08:15 AM | -0,0030 | 29,22 | 10,07 | 390,2 | 12.12.11 08:15 AM | -0,0030 | 27,06 | 16,79 | 468,32 |
| 11.28.11 08:30 AM | -0,0030 | 28,92 | 10,29 | 387,76 | 12.12.11 08:30 AM | -0,0030 | 26,74 | 16,85 | 471,37 |
| 11.28.11 08:45 AM | -0,0030 | 28,59 | 10,43 | 397,52 | 12.12.11 08:45 AM | 0,0183 | 25,89 | 17,03 | 483,58 |
| 11.28.11 09:00 AM | -0,0030 | 28,57 | 10,67 | 403,02 | 12.12.11 09:00 AM | 0,0167 | 25,96 | 17,48 | 517,76 |
| 11.28.11 09:15 AM | -0,0030 | 28,57 | 10,82 | 409,73 | 12.12.11 09:15 AM | 0,0061 | 26,55 | 18,34 | 634,34 |
| 11.28.11 09:30 AM | -0,0030 | 28,57 | 10,98 | 412,17 | 12.12.11 09:30 AM | 0,0198 | 27,21 | 18,82 | 774,72 |
| 11.28.11 09:45 AM | -0,0030 | 28,49 | 11,17 | 417,05 | 12.12.11 09:45 AM | 0,0228 | 27,6 | 19,74 | 884,58 |
| 11.28.11 10:00 AM | -0,0030 | 28,57 | 11,21 | 419,49 | 12.12.11 10:00 AM | 0,0381 | 27,78 | 20,35 | 946,84 |
| 11.28.11 10:15 AM | -0,0030 | 28,74 | 11,37 | 451,84 | 12.12.11 10:15 AM | 0,0259 | 27,97 | 21,07 | 999,33 |
| 11.28.11 10:30 AM | -0,0030 | 28,94 | 11,61 | 456,73 | 12.12.11 10:30 AM | 0,0061 | 28,1 | 21,41 | 1.054,87 |
| 11.28.11 10:45 AM | 0,0167 | 29,09 | 11,73 | 459,78 | 12.12.11 10:45 AM | 0,0076 | 28,22 | 21,49 | 1.045,10 |
| 11.28.11 11:00 AM | -0,0030 | 29,44 | 11,98 | 524,48 | 12.12.11 11:00 AM | 0,0259 | 28,17 | 20,82 | 894,96 |
| 11.28.11 11:15 AM | -0,0030 | 29,52 | 11,94 | 481,14 | 12.12.11 11:15 AM | 0,0167 | 28,44 | 21,13 | 962,1 |
| 11.28.11 11:30 AM | -0,0030 | 29,57 | 11,79 | 468,93 | 12.12.11 11:30 AM | 0,0046 | 28,54 | 21,21 | 991,39 |
| 11.28.11 11:45 AM | -0,0030 | 29,44 | 11,78 | 453,67 | 12.12.11 11:45 AM | 0,0381 | 28,59 | 22,29 | 1.157,41 |
| 11.28.11 12:00 PM | -0,0030 | 29,41 | 11,82 | 484,19 | 12.12.11 12:00 PM | 0,0030 | 28,82 | 23,23 | 1.311,83 |
| 11.28.11 12:15 PM | -0,0030 | 29,41 | 12,02 | 483,58 | 12.12.11 12:15 PM | 0,0046 | 28,59 | 21,07 | 948,06 |
| 11.28.11 12:30 PM | -0,0030 | 29,57 | 12,18 | 503,11 | 12.12.11 12:30 PM | 0,0122 | 28,49 | 20,17 | 820,5 |
| 11.28.11 12:45 PM | -0,0020 | 29,62 | 12,1 | 473,82 | 12.12.11 12:45 PM | -0,0030 | 28,42 | 19,38 | 735,05 |
| 11.28.11 01:00 PM | 0,0624 | 29,41 | 12,29 | 551,94 | 12.12.11 01:00 PM | 0,0137 | 28,44 | 19,87 | 823,55 |
| 11.28.11 01:15 PM | -0,0030 | 29,59 | 13,18 | 664,86 | 12.12.11 01:15 PM | 0,0137 | 28,59 | 20,02 | 811,34 |
| 11.28.11 01:30 PM | -0,0030 | 29,84 | 13,57 | 679,5 | 12.12.11 01:30 PM | 0,0289 | 28,87 | 20,34 | 840,64 |
| 11.28.11 01:45 PM | 0,0320 | 29,99 | 13,73 | 709,41 | 12.12.11 01:45 PM | 0,0000 | 29,07 | 20,87 | 893,74 |
| 11.28.11 02:00 PM | 0,0046 | 30,09 | 14,28 | 733,22 | 12.12.11 02:00 PM | 0,0304 | 29,14 | 21,1 | 913,88 |
| 11.28.11 02:15 PM | -0,0030 | 30,24 | 13,98 | 721,62 | 12.12.11 02:15 PM | 0,0304 | 29,22 | 21,33 | 950,5 |
| 11.28.11 02:30 PM | -0,0030 | 30,29 | 14,48 | 756,41 | 12.12.11 02:30 PM | 0,0289 | 29,24 | 21,93 | 984,07 |
| 11.28.11 02:45 PM | -0,0030 | 30,07 | 13,74 | 579,41 | 12.12.11 02:45 PM | 0,0106 | 29,14 | 20,69 | 899,23 |
| 11.28.11 03:00 PM | -0,0030 | 29,89 | 13,42 | 555,6 | 12.12.11 03:00 PM | 0,0335 | 28,97 | 19,97 | 814,39 |
| 11.28.11 03:15 PM | -0,0030 | 29,77 | 13,15 | 548,89 | 12.12.11 03:15 PM | -0,0030 | 28,89 | 19,82 | 782,04 |
| 11.28.11 03:30 PM | 0,0046 | 29,59 | 13,49 | 600,16 | 12.12.11 03:30 PM | 0,0244 | 28,87 | 19,52 | 760,68 |

**Table A.01.** (Continued)

| Room 28 - location 'A' | | | | | Room 28 - location 'B' | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Date** | **m/s** | **°C** | **%** | **ppm** | **Date** | **m/s** | **°C** | **%** | **ppm** |
| 11.28.11 03:45 PM | -0,0030 | 29,69 | 14,03 | 696,59 | 12.12.11 03:45 PM | 0,0517 | 28,82 | 19,29 | 722,84 |
| 11.28.11 04:00 PM | -0,0020 | 29,79 | 14,34 | 766,17 | 12.12.11 04:00 PM | 0,0167 | 28,82 | 19,29 | 707,58 |
| 11.28.11 04:15 PM | 0,0091 | 29,77 | 14,41 | 788,15 | 12.12.11 04:15 PM | 0,0046 | 28,84 | 18,95 | 638 |
| 11.28.11 04:30 PM | -0,0030 | 29,69 | 14,03 | 638,61 | 12.12.11 04:30 PM | 0,0122 | 28,84 | 18,61 | 591,61 |
| 11.28.11 04:45 PM | -0,0030 | 29,64 | 13,8 | 574,52 | 12.12.11 04:45 PM | 0,0122 | 28,79 | 18,39 | 554,99 |
| 11.28.11 05:00 PM | -0,0030 | 29,64 | 13,64 | 559,88 | 12.12.11 05:00 PM | 0,0091 | 28,74 | 18,23 | 527,53 |
| 11.28.11 05:15 PM | -0,0030 | 29,52 | 13,18 | 454,28 | 12.12.11 05:15 PM | 0,0244 | 28,69 | 18,08 | 512,88 |
| 11.28.11 05:30 PM | -0,0030 | 29,39 | 12,78 | 423,16 | 12.12.11 05:30 PM | 0,0137 | 28,67 | 17,93 | 500,67 |
| 11.28.11 05:45 PM | -0,0030 | 29,29 | 12,4 | 408,51 | 12.12.11 05:45 PM | 0,0106 | 28,64 | 17,78 | 498,23 |
| 11.28.11 06:00 PM | -0,0030 | 29,22 | 12,24 | 392,64 | 12.12.11 06:00 PM | 0,0167 | 28,69 | 17,7 | 495,18 |
| 11.28.11 06:15 PM | -0,0030 | 29,19 | 12,08 | 387,76 | 12.12.11 06:15 PM | 0,0228 | 28,69 | 17,55 | 498,23 |
| 11.28.11 06:30 PM | -0,0030 | 29,14 | 11,93 | 381,04 | 12.12.11 06:30 PM | 0,0487 | 28,72 | 17,48 | 511,05 |
| 11.28.11 06:45 PM | -0,0030 | 29,17 | 11,93 | 377,99 | 12.12.11 06:45 PM | 0,0076 | 28,72 | 17,48 | 515,32 |
| 11.28.11 07:00 PM | -0,0030 | 29,19 | 11,97 | 381,04 | 12.12.11 07:00 PM | 0,0304 | 28,74 | 17,4 | 509,83 |
| 11.28.11 07:15 PM | -0,0030 | 29,17 | 11,93 | 376,77 | 12.12.11 07:15 PM | 0,0198 | 28,59 | 17,25 | 488,46 |
| 11.28.11 07:30 PM | -0,0030 | 29,14 | 11,93 | 373,11 | 12.12.11 07:30 PM | 0,0198 | 28,44 | 17,09 | 471,37 |
| 11.28.11 07:45 PM | -0,0030 | 29,14 | 11,85 | 373,72 | 12.12.11 07:45 PM | 0,0076 | 28,37 | 17,01 | 466,49 |
| 11.28.11 08:00 PM | -0,0030 | 29,17 | 11,93 | 371,28 | 12.12.11 08:00 PM | -0,0020 | 28,37 | 17,04 | 464,05 |
| 11.28.11 08:15 PM | -0,0030 | 29,09 | 11,77 | 368,23 | 12.12.11 08:15 PM | 0,0244 | 28,39 | 17,08 | 466,49 |
| 11.28.11 08:30 PM | -0,0030 | 29,12 | 11,77 | 365,78 | 12.12.11 08:30 PM | 0,0122 | 28,47 | 17,09 | 464,05 |
| 11.28.11 08:45 PM | -0,0030 | 29,09 | 11,77 | 363,95 | 12.12.11 08:45 PM | -0,0020 | 28,47 | 17,01 | 462,22 |
| 11.28.11 09:00 PM | -0,0030 | 29,09 | 11,77 | 361,51 | 12.12.11 09:00 PM | 0,0061 | 28,49 | 17,05 | 462,22 |
| 11.28.11 09:15 PM | -0,0030 | 29,09 | 11,77 | 360,9 | 12.12.11 09:15 PM | 0,0228 | 28,49 | 17,05 | 471,98 |
| 11.28.11 09:30 PM | -0,0030 | 29,09 | 11,77 | 359,68 | 12.12.11 09:30 PM | 0,0183 | 28,57 | 17,02 | 470,15 |
| 11.28.11 09:45 PM | -0,0030 | 29,07 | 11,77 | 361,51 | 12.12.11 09:45 PM | 0,0015 | 28,52 | 16,94 | 468,93 |
| 11.28.11 10:00 PM | -0,0030 | 29,07 | 11,73 | 358,46 | 12.12.11 10:00 PM | 0,0046 | 28,59 | 16,94 | 471,98 |
| 11.28.11 10:15 PM | -0,0030 | 29,09 | 11,69 | 359,07 | 12.12.11 10:15 PM | 0,0472 | 28,59 | 16,98 | 466,49 |
| 11.28.11 10:30 PM | -0,0030 | 29,12 | 11,69 | 359,68 | 12.12.11 10:30 PM | 0,0183 | 28,52 | 16,94 | 466,49 |
| 11.28.11 10:45 PM | -0,0030 | 29,14 | 11,69 | 358,46 | 12.12.11 10:45 PM | 0,0365 | 28,54 | 17,02 | 471,37 |
| 11.28.11 11:00 PM | -0,0030 | 29,14 | 11,69 | 355,41 | 12.12.11 11:00 PM | 0,0304 | 28,54 | 17,02 | 478,7 |
| 11.28.11 11:15 PM | 0,0015 | 29,14 | 11,69 | 357,85 | 12.12.11 11:15 PM | 0,0213 | 28,52 | 17,01 | 478,7 |
| 11.28.11 11:30 PM | -0,0030 | 29,14 | 11,54 | 354,19 | 12.12.11 11:30 PM | 0,0198 | 28,57 | 17,02 | 488,46 |
| 11.28.11 11:45 PM | -0,0030 | 29,12 | 11,54 | 353,58 | 12.12.11 11:45 PM | 0,0076 | 28,59 | 17,09 | 492,74 |
| 11.29.11 12:00 AM | -0,0030 | 29,12 | 11,54 | 354,19 | 12.13.11 12:00 AM | 0,0076 | 28,62 | 17,1 | 492,74 |
| 11.29.11 12:15 AM | -0,0020 | 29,12 | 11,46 | 353,58 | 12.13.11 12:15 AM | 0,0244 | 28,64 | 17,1 | 500,06 |
| 11.29.11 12:30 AM | -0,0030 | 29,12 | 11,46 | 353,58 | 12.13.11 12:30 AM | 0,0350 | 28,64 | 17,13 | 503,11 |
| 11.29.11 12:45 AM | -0,0030 | 29,12 | 11,46 | 351,14 | 12.13.11 12:45 AM | 0,0061 | 28,64 | 17,02 | 503,11 |
| 11.29.11 01:00 AM | -0,0030 | 29,14 | 11,46 | 353,58 | 12.13.11 01:00 AM | 0,0198 | 28,67 | 16,95 | 503,11 |
| 11.29.11 01:15 AM | -0,0030 | 29,14 | 11,46 | 354,19 | 12.13.11 01:15 AM | 0,0259 | 28,64 | 16,79 | 505,55 |

**Table A.01.** (Continued)

| Room 28 - location 'A' | | | | | Room 28 - location 'B' | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Date** | **m/s** | **°C** | **%** | **ppm** | **Date** | **m/s** | **°C** | **%** | **ppm** |
| 11.29.11 01:30 AM | -0,0030 | 29,14 | 11,39 | 348,69 | 12.13.11 01:30 AM | 0,0122 | 28,57 | 16,71 | 505,55 |
| 11.29.11 01:45 AM | 0,0061 | 29,14 | 11,31 | 348,69 | 12.13.11 01:45 AM | 0,0381 | 28,59 | 16,56 | 500,67 |
| 11.29.11 02:00 AM | -0,0030 | 29,17 | 11,31 | 351,14 | 12.13.11 02:00 AM | 0,0061 | 28,54 | 16,49 | 495,18 |
| 11.29.11 02:15 AM | -0,0030 | 29,19 | 11,31 | 354,19 | 12.13.11 02:15 AM | 0,0244 | 28,57 | 16,49 | 486,02 |
| 11.29.11 02:30 AM | -0,0020 | 29,19 | 11,31 | 353,58 | 12.13.11 02:30 AM | 0,0106 | 28,42 | 16,4 | 473,82 |
| 11.29.11 02:45 AM | -0,0030 | 29,19 | 11,23 | 353,58 | 12.13.11 02:45 AM | 0,0228 | 28,37 | 16,25 | 471,37 |
| 11.29.11 03:00 AM | -0,0030 | 29,19 | 11,23 | 353,58 | 12.13.11 03:00 AM | 0,0320 | 28,22 | 16,17 | 459,17 |
| 11.29.11 03:15 AM | -0,0030 | 29,19 | 11,16 | 353,58 | 12.13.11 03:15 AM | 0,0259 | 28,2 | 16,17 | 448,79 |
| 11.29.11 03:30 AM | -0,0030 | 29,19 | 11,16 | 351,75 | 12.13.11 03:30 AM | 0,0213 | 28,35 | 16,17 | 446,96 |
| 11.29.11 03:45 AM | -0,0030 | 29,19 | 11,16 | 353,58 | 12.13.11 03:45 AM | 0,0365 | 28,39 | 16,18 | 450,62 |
| 11.29.11 04:00 AM | -0,0030 | 29,22 | 11,16 | 356,02 | 12.13.11 04:00 AM | 0,0183 | 28,49 | 16,18 | 451,23 |
| 11.29.11 04:15 AM | 0,0046 | 29,22 | 11,16 | 359,07 | 12.13.11 04:15 AM | 0,0015 | 28,49 | 16,14 | 447,57 |
| 11.29.11 04:30 AM | -0,0030 | 29,22 | 11,08 | 356,63 | 12.13.11 04:30 AM | 0,0381 | 28,49 | 16,07 | 443,91 |
| 11.29.11 04:45 AM | -0,0030 | 29,22 | 11,08 | 360,9 | 12.13.11 04:45 AM | 0,0137 | 28,49 | 16,18 | 445,13 |
| 11.29.11 05:00 AM | -0,0030 | 29,22 | 11 | 363,34 | 12.13.11 05:00 AM | 0,0167 | 28,57 | 16,34 | 440,25 |
| 11.29.11 05:15 AM | -0,0030 | 29,19 | 10,92 | 366,39 | 12.13.11 05:15 AM | 0,0000 | 28,57 | 16,34 | 437,81 |
| 11.29.11 05:30 AM | -0,0030 | 29,22 | 11 | 371,28 | 12.13.11 05:30 AM | 0,0167 | 28,52 | 16,26 | 432,92 |
| 11.29.11 05:45 AM | -0,0020 | 29,24 | 10,93 | 375,55 | 12.13.11 05:45 AM | 0,0320 | 28,49 | 16,18 | 438,42 |
| 11.29.11 06:00 AM | -0,0030 | 29,24 | 10,85 | 378,6 | 12.13.11 06:00 AM | -0,0030 | 28,54 | 16,18 | 434,75 |
| 11.29.11 06:15 AM | -0,0030 | 29,24 | 10,85 | 387,76 | 12.13.11 06:15 AM | 0,0030 | 28,54 | 16,26 | 437,81 |
| 11.29.11 06:30 AM | 0,0244 | 29,24 | 10,93 | 390,81 | 12.13.11 06:30 AM | 0,0533 | 28,52 | 16,18 | 444,52 |
| 11.29.11 06:45 AM | -0,0030 | 29,24 | 10,93 | 383,48 | 12.13.11 06:45 AM | 0,0244 | 28,49 | 16,18 | 446,96 |
| 11.29.11 07:00 AM | -0,0030 | 29,24 | 10,85 | 375,55 | 12.13.11 07:00 AM | 0,0046 | 28,47 | 16,1 | 449,4 |
| 11.29.11 07:15 AM | -0,0030 | 29,27 | 10,85 | 383,48 | 12.13.11 07:15 AM | 0,0167 | 28,49 | 15,88 | 447,57 |
| 11.29.11 07:30 AM | -0,0030 | 28,72 | 10,44 | 390,2 | 12.13.11 07:30 AM | -0,0030 | 28,49 | 15,73 | 454,28 |
| 11.29.11 07:45 AM | -0,0030 | 27,9 | 10,79 | 392,64 | 12.13.11 07:45 AM | -0,0030 | 28,49 | 15,88 | 461 |
| 11.29.11 08:00 AM | -0,0030 | 27,7 | 10,94 | 392,64 | 12.13.11 08:00 AM | -0,0030 | 28,49 | 15,88 | 468,32 |
| 11.29.11 08:15 AM | -0,0030 | 27,92 | 11,18 | 400,57 | 12.13.11 08:15 AM | 0,0015 | 28,39 | 15,87 | 456,73 |
| 11.29.11 08:30 AM | -0,0030 | 28,02 | 11,26 | 398,13 | 12.13.11 08:30 AM | 0,0046 | 28,42 | 16,03 | 461,61 |
| 11.29.11 08:45 AM | -0,0030 | 28,39 | 11,43 | 410,34 | 12.13.11 08:45 AM | 0,0046 | 28,49 | 16,18 | 470,76 |
| 11.29.11 09:00 AM | -0,0030 | 28,62 | 11,75 | 424,99 | 12.13.11 09:00 AM | 0,0244 | 28,59 | 16,6 | 503,11 |
| 11.29.11 09:15 AM | 0,0365 | 28,82 | 12,26 | 468,32 | 12.13.11 09:15 AM | 0,0213 | 28,54 | 17,28 | 573,3 |
| 11.29.11 09:30 AM | 0,0274 | 28,99 | 13 | 537,9 | 12.13.11 09:30 AM | 0,0183 | 28,47 | 18,44 | 686,22 |
| 11.29.11 09:45 AM | -0,0030 | 29,19 | 13,47 | 588,56 | 12.13.11 09:45 AM | 0,0244 | 28,57 | 19,35 | 800,96 |
| 11.29.11 10:00 AM | -0,0030 | 29,29 | 13,93 | 620,91 | 12.13.11 10:00 AM | 0,0350 | 28,79 | 20,19 | 881,53 |
| 11.29.11 10:15 AM | 0,0030 | 29,44 | 14,09 | 645,32 | 12.13.11 10:15 AM | 0,0152 | 28,92 | 20,19 | 879,09 |
| 11.29.11 10:30 AM | -0,0030 | 29,49 | 14,4 | 620,3 | 12.13.11 10:30 AM | 0,0320 | 28,99 | 20,35 | 884,58 |
| 11.29.11 10:45 AM | 0,0167 | 29,54 | 14,17 | 577,58 | 12.13.11 10:45 AM | 0,0228 | 28,87 | 20,41 | 881,53 |
| 11.29.11 11:00 AM | 0,0228 | 29,39 | 14,32 | 630,68 | 12.13.11 11:00 AM | 0,0076 | 28,77 | 20,86 | 876,65 |

**Table A.01.** (Continued)

| Room 28 - location 'A' | | | | | Room 28 - location 'B' | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Date** | **m/s** | **°C** | **%** | **ppm** | **Date** | **m/s** | **°C** | **%** | **ppm** |
| 11.29.11 11:15 AM | -0,0020 | 29,59 | 15,7 | 932,8 | 12.13.11 11:15 AM | 0,0365 | 28,79 | 21,75 | 1.018,25 |
| 11.29.11 11:30 AM | 0,0000 | 29,82 | 16,55 | 1.168,40 | 12.13.11 11:30 AM | -0,0030 | 28,79 | 22,42 | 1.043,27 |
| 11.29.11 11:45 AM | -0,0030 | 29,84 | 17,08 | 1.040,83 | 12.13.11 11:45 AM | 0,0304 | 28,89 | 23,16 | 1.135,44 |
| 11.29.11 12:00 PM | 0,0106 | 29,39 | 15,81 | 794,86 | 12.13.11 12:00 PM | 0,0076 | 28,89 | 23,01 | 1.128,11 |
| 11.29.11 12:15 PM | 0,0106 | 29,57 | 15,93 | 1.026,18 | 12.13.11 12:15 PM | 0,0320 | 28,72 | 22,26 | 992 |
| 11.29.11 12:30 PM | 0,0244 | 29,74 | 16,36 | 1.153,14 | 12.13.11 12:30 PM | 0,0654 | 28,72 | 22,04 | 947,45 |
| 11.29.11 12:45 PM | -0,0030 | 29,46 | 14,74 | 758,85 | 12.13.11 12:45 PM | 0,0061 | 28,67 | 21,63 | 889,47 |
| 11.29.11 01:00 PM | -0,0020 | 28,87 | 13,49 | 537,9 | 12.13.11 01:00 PM | 0,0152 | 28,82 | 20,86 | 741,76 |
| 11.29.11 01:15 PM | -0,0030 | 28,79 | 13,41 | 459,17 | 12.13.11 01:15 PM | 0,0091 | 28,89 | 20,34 | 679,5 |
| 11.29.11 01:30 PM | 0,0015 | 28,89 | 13,26 | 459,78 | 12.13.11 01:30 PM | -0,0030 | 28,72 | 20,18 | 681,34 |
| 11.29.11 01:45 PM | 0,0106 | 28,97 | 13,38 | 501,28 | 12.13.11 01:45 PM | -0,0020 | 28,59 | 20,7 | 798,52 |
| 11.29.11 02:00 PM | -0,0030 | 29,19 | 14,92 | 900,45 | 12.13.11 02:00 PM | 0,0183 | 28,64 | 23,22 | 1.186,71 |
| 11.29.11 02:15 PM | -0,0020 | 29,87 | 18,41 | 1.468,08 | 12.13.11 02:15 PM | 0,0715 | 29,07 | 25,27 | 1.450,99 |
| 11.29.11 02:30 PM | -0,0030 | 30,34 | 19,45 | 1.799,50 | 12.13.11 02:30 PM | 0,0228 | 29,41 | 26,94 | 1.758,61 |
| 11.29.11 02:45 PM | 0,0091 | 30,44 | 20,73 | 1.787,90 | 12.13.11 02:45 PM | 0,0548 | 29,49 | 26,47 | 1.578,55 |
| 11.29.11 03:00 PM | 0,0472 | 30,57 | 19,5 | 1.571,23 | 12.13.11 03:00 PM | 0,0365 | 29,49 | 26,07 | 1.446,11 |
| 11.29.11 03:15 PM | 0,0091 | 30,37 | 18,25 | 1.113,46 | 12.13.11 03:15 PM | 0,0167 | 29,44 | 25,99 | 1.362,49 |
| 11.29.11 03:30 PM | -0,0020 | 30,39 | 18,25 | 1.099,43 | 12.13.11 03:30 PM | 0,0335 | 29,39 | 24,89 | 1.187,32 |
| 11.29.11 03:45 PM | -0,0030 | 30,52 | 18,03 | 1.082,34 | 12.13.11 03:45 PM | 0,0198 | 29,34 | 24,59 | 1.241,03 |
| 11.29.11 04:00 PM | 0,0076 | 30,62 | 17,81 | 1.010,93 | 12.13.11 04:00 PM | 0,0396 | 29,57 | 24,75 | 1.243,47 |
| 11.29.11 04:15 PM | -0,0030 | 30,5 | 16,97 | 906,56 | 12.13.11 04:15 PM | 0,0289 | 29,41 | 24,82 | 1.169,62 |
| 11.29.11 04:30 PM | -0,0030 | 30,02 | 15,27 | 642,88 | 12.13.11 04:30 PM | 0,0015 | 28,69 | 22,78 | 796,69 |
| 11.29.11 04:45 PM | -0,0030 | 29,59 | 14,71 | 549,5 | 12.13.11 04:45 PM | 0,0046 | 28,72 | 22,56 | 772,28 |
| 11.29.11 05:00 PM | -0,0030 | 29,49 | 14,4 | 501,28 | 12.13.11 05:00 PM | -0,0020 | 28,74 | 21,45 | 642,27 |
| 11.29.11 05:15 PM | -0,0030 | 29,39 | 14,17 | 473,21 | 12.13.11 05:15 PM | -0,0020 | 28,74 | 20,7 | 586,73 |
| 11.29.11 05:30 PM | -0,0030 | 29,34 | 13,93 | 450,01 | 12.13.11 05:30 PM | -0,0030 | 28,72 | 20,14 | 539,73 |
| 11.29.11 05:45 PM | -0,0030 | 29,29 | 13,55 | 434,14 | 12.13.11 05:45 PM | 0,0259 | 28,69 | 19,58 | 498,23 |
| 11.29.11 06:00 PM | -0,0030 | 29,27 | 13,32 | 429,26 | 12.13.11 06:00 PM | -0,0030 | 28,59 | 19,35 | 477,48 |
| 11.29.11 06:15 PM | -0,0030 | 29,19 | 12,78 | 415,22 | 12.13.11 06:15 PM | -0,0020 | 28,69 | 19,13 | 470,76 |
| 11.29.11 06:30 PM | -0,0030 | 28,77 | 11,99 | 392,64 | 12.13.11 06:30 PM | -0,0020 | 28,64 | 18,9 | 468,93 |
| 11.29.11 06:45 PM | -0,0030 | 28,44 | 11,67 | 380,43 | 12.13.11 06:45 PM | 0,0030 | 28,49 | 18,6 | 451,23 |
| 11.29.11 07:00 PM | -0,0030 | 28,25 | 11,58 | 375,55 | 12.13.11 07:00 PM | 0,0046 | 28,57 | 18,45 | 446,96 |
| 11.29.11 07:15 PM | -0,0030 | 28,35 | 11,89 | 370,67 | 12.13.11 07:15 PM | 0,0106 | 28,67 | 18,38 | 444,52 |
| 11.29.11 07:30 PM | -0,0030 | 28,69 | 12,06 | 373,11 | 12.13.11 07:30 PM | -0,0020 | 28,62 | 18,34 | 446,96 |
| 11.29.11 07:45 PM | -0,0030 | 28,87 | 11,99 | 373,11 | 12.13.11 07:45 PM | -0,0020 | 28,57 | 18,22 | 445,74 |
| 11.29.11 08:00 PM | -0,0030 | 28,89 | 11,99 | 373,72 | 12.13.11 08:00 PM | -0,0020 | 28,39 | 18,06 | 445,74 |
| 11.29.11 08:15 PM | -0,0030 | 28,94 | 11,96 | 376,16 | 12.13.11 08:15 PM | -0,0020 | 28,27 | 18,06 | 437,81 |
| 11.29.11 08:30 PM | -0,0030 | 28,97 | 11,92 | 375,55 | 12.13.11 08:30 PM | -0,0020 | 28,35 | 18,14 | 438,42 |
| 11.29.11 08:45 PM | -0,0030 | 28,94 | 11,84 | 378,6 | 12.13.11 08:45 PM | -0,0020 | 28,32 | 18,13 | 438,42 |

**Table A.01.** (Continued)

| Room 28 - location 'A' | | | | | Room 28 - location 'B' | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Date** | **m/s** | **°C** | **%** | **ppm** | **Date** | **m/s** | **°C** | **%** | **ppm** |
| 11.29.11 09:00 PM | -0,0030 | 28,97 | 11,84 | 383,48 | 12.13.11 09:00 PM | 0,0000 | 28,49 | 17,99 | 440,25 |
| 11.29.11 09:15 PM | -0,0030 | 28,97 | 11,84 | 381,04 | 12.13.11 09:15 PM | 0,0167 | 28,59 | 18 | 440,25 |
| 11.29.11 09:30 PM | -0,0030 | 28,97 | 11,76 | 383,48 | 12.13.11 09:30 PM | 0,0046 | 28,72 | 18,08 | 445,13 |
| 11.29.11 09:45 PM | -0,0030 | 29,02 | 11,84 | 385,93 | 12.13.11 09:45 PM | 0,0350 | 28,89 | 18,17 | 445,13 |
| 11.29.11 10:00 PM | -0,0030 | 28,97 | 11,69 | 382,87 | 12.13.11 10:00 PM | 0,0015 | 28,99 | 18,25 | 448,18 |
| 11.29.11 10:15 PM | -0,0030 | 28,94 | 11,61 | 385,93 | 12.13.11 10:15 PM | 0,0091 | 28,84 | 18,24 | 443,3 |
| 11.29.11 10:30 PM | -0,0030 | 28,94 | 11,53 | 385,93 | 12.13.11 10:30 PM | 0,0274 | 28,89 | 18,24 | 446,96 |
| 11.29.11 10:45 PM | -0,0030 | 28,92 | 11,45 | 385,93 | 12.13.11 10:45 PM | 0,0167 | 28,84 | 18,24 | 454,9 |
| 11.29.11 11:00 PM | -0,0030 | 28,92 | 11,45 | 385,31 | 12.13.11 11:00 PM | 0,0106 | 28,97 | 18,28 | 454,9 |
| 11.29.11 11:15 PM | -0,0030 | 28,94 | 11,45 | 385,93 | 12.13.11 11:15 PM | 0,0046 | 29,02 | 18,32 | 460,39 |
| 11.29.11 11:30 PM | -0,0030 | 28,94 | 11,38 | 388,37 | 12.13.11 11:30 PM | 0,0289 | 28,94 | 18,39 | 468,93 |
| 11.29.11 11:45 PM | -0,0030 | 28,94 | 11,38 | 388,37 | 12.13.11 11:45 PM | 0,0030 | 28,92 | 18,32 | 471,37 |
| 11.30.11 12:00 AM | -0,0030 | 28,94 | 11,3 | 387,76 | 12.14.11 12:00 AM | 0,0061 | 28,77 | 18,31 | 475,65 |
| 11.30.11 12:15 AM | -0,0030 | 28,94 | 11,22 | 388,37 | 12.14.11 12:15 AM | -0,0030 | 28,79 | 18,24 | 476,26 |
| 11.30.11 12:30 AM | -0,0030 | 28,87 | 11,22 | 388,37 | 12.14.11 12:30 AM | 0,0015 | 28,77 | 18,23 | 476,26 |
| 11.30.11 12:45 AM | -0,0030 | 28,87 | 11,14 | 390,2 | 12.14.11 12:45 AM | 0,0152 | 28,69 | 18,19 | 473,21 |
| 11.30.11 01:00 AM | -0,0030 | 28,89 | 11,14 | 388,37 | 12.14.11 01:00 AM | 0,0183 | 28,79 | 18,2 | 478,7 |
| 11.30.11 01:15 AM | -0,0030 | 28,87 | 11,14 | 387,76 | 12.14.11 01:15 AM | -0,0030 | 28,77 | 18,23 | 481,14 |
| 11.30.11 01:30 AM | -0,0030 | 28,82 | 11,06 | 383,48 | 12.14.11 01:30 AM | 0,0000 | 28,74 | 18,16 | 481,14 |
| 11.30.11 01:45 AM | -0,0030 | 28,82 | 11,06 | 387,76 | 12.14.11 01:45 AM | 0,0152 | 28,77 | 18,16 | 481,14 |
| 11.30.11 02:00 AM | -0,0030 | 28,87 | 11,06 | 390,81 | 12.14.11 02:00 AM | -0,0030 | 28,64 | 18,15 | 480,53 |
| 11.30.11 02:15 AM | -0,0030 | 28,97 | 11,19 | 393,86 | 12.14.11 02:15 AM | 0,0000 | 28,67 | 18,15 | 479,31 |
| 11.30.11 02:30 AM | -0,0030 | 28,94 | 11,15 | 393,25 | 12.14.11 02:30 AM | 0,0046 | 28,72 | 18,19 | 470,76 |
| 11.30.11 02:45 AM | -0,0030 | 28,89 | 11,07 | 390,2 | 12.14.11 02:45 AM | -0,0030 | 28,77 | 18,23 | 476,26 |
| 11.30.11 03:00 AM | -0,0030 | 28,94 | 11,07 | 392,64 | 12.14.11 03:00 AM | 0,0076 | 28,72 | 18,19 | 476,26 |
| 11.30.11 03:15 AM | -0,0030 | 28,94 | 11,03 | 390,81 | 12.14.11 03:15 AM | 0,0030 | 28,64 | 18,15 | 476,87 |
| 11.30.11 03:30 AM | -0,0030 | 28,92 | 10,91 | 390,81 | 12.14.11 03:30 AM | 0,0046 | 28,69 | 18,08 | 471,37 |
| 11.30.11 03:45 AM | -0,0030 | 28,92 | 10,83 | 388,37 | 12.14.11 03:45 AM | 0,0061 | 28,59 | 18,07 | 474,43 |
| 11.30.11 04:00 AM | -0,0030 | 28,97 | 10,84 | 390,2 | 12.14.11 04:00 AM | 0,0076 | 28,69 | 18 | 471,37 |
| 11.30.11 04:15 AM | -0,0030 | 29,04 | 10,92 | 390,81 | 12.14.11 04:15 AM | 0,0061 | 28,79 | 18,01 | 466,49 |
| 11.30.11 04:30 AM | -0,0030 | 29,09 | 10,92 | 390,81 | 12.14.11 04:30 AM | 0,0030 | 28,89 | 17,94 | 464,05 |
| 11.30.11 04:45 AM | 0,0122 | 29,02 | 10,84 | 392,64 | 12.14.11 04:45 AM | 0,0320 | 28,94 | 18,02 | 465,88 |
| 11.30.11 05:00 AM | -0,0030 | 29,02 | 10,84 | 393,86 | 12.14.11 05:00 AM | 0,0046 | 28,89 | 17,94 | 464,05 |
| 11.30.11 05:15 AM | -0,0030 | 29,02 | 10,84 | 393,25 | 12.14.11 05:15 AM | -0,0020 | 28,89 | 17,98 | 473,21 |
| 11.30.11 05:30 AM | -0,0030 | 29,04 | 10,76 | 393,25 | 12.14.11 05:30 AM | 0,0320 | 28,92 | 17,94 | 469,54 |
| 11.30.11 05:45 AM | -0,0030 | 29,07 | 10,76 | 395,08 | 12.14.11 05:45 AM | 0,0137 | 28,99 | 17,95 | 471,37 |
| 11.30.11 06:00 AM | -0,0030 | 29,09 | 10,8 | 393,25 | 12.14.11 06:00 AM | 0,0106 | 29,02 | 18,02 | 471,37 |
| 11.30.11 06:15 AM | -0,0030 | 29,09 | 10,69 | 393,25 | 12.14.11 06:15 AM | 0,0167 | 28,97 | 17,87 | 466,49 |
| 11.30.11 06:30 AM | -0,0030 | 29,07 | 10,61 | 397,52 | 12.14.11 06:30 AM | 0,0046 | 28,94 | 17,83 | 468,93 |

**Table A.01.** (Continued)

| Room 28 - location 'A' | | | | | Room 28 - location 'B' | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Date** | **m/s** | **°C** | **%** | **ppm** | **Date** | **m/s** | **°C** | **%** | **ppm** |
| 11.30.11 06:45 AM | -0,0030 | 29,09 | 10,69 | 397,52 | 12.14.11 06:45 AM | 0,0289 | 28,89 | 17,79 | 459,17 |
| 11.30.11 07:00 AM | -0,0030 | 29,09 | 10,69 | 398,13 | 12.14.11 07:00 AM | 0,0152 | 28,97 | 17,79 | 459,17 |
| 11.30.11 07:15 AM | -0,0030 | 29,09 | 10,61 | 397,52 | 12.14.11 07:15 AM | 0,0183 | 28,94 | 17,87 | 464,05 |
| 11.30.11 07:30 AM | -0,0030 | 28,92 | 10,21 | 401,18 | 12.14.11 07:30 AM | 0,0183 | 28,92 | 17,87 | 461,61 |
| 11.30.11 07:45 AM | -0,0030 | 28 | 10,02 | 412,17 | 12.14.11 07:45 AM | 0,0106 | 28,99 | 17,95 | 462,22 |
| 11.30.11 08:00 AM | -0,0030 | 27,28 | 10,07 | 407,29 | 12.14.11 08:00 AM | 0,0152 | 28,99 | 17,98 | 464,66 |
| 11.30.11 08:15 AM | -0,0030 | 26,7 | 10,36 | 412,78 | 12.14.11 08:15 AM | 0,0046 | 28,94 | 18,02 | 466,49 |
| 11.30.11 08:30 AM | -0,0030 | 26,62 | 10,67 | 415,22 | 12.14.11 08:30 AM | -0,0020 | 28,97 | 18,1 | 475,65 |
| 11.30.11 08:45 AM | -0,0020 | 27,06 | 10,61 | 420,1 | 12.14.11 08:45 AM | 0,0167 | 28,77 | 18,39 | 495,79 |
| 11.30.11 09:00 AM | -0,0030 | 26,82 | 10,67 | 420,1 | 12.14.11 09:00 AM | -0,0020 | 28,67 | 18,61 | 504,33 |
| 11.30.11 09:15 AM | -0,0030 | 26,6 | 10,9 | 428,04 | 12.14.11 09:15 AM | 0,0076 | 28,57 | 18,67 | 504,94 |
| 11.30.11 09:30 AM | -0,0030 | 26,72 | 10,9 | 437,19 | 12.14.11 09:30 AM | 0,0441 | 28,35 | 18,89 | 517,76 |
| 11.30.11 09:45 AM | 0,0000 | 26,55 | 11,05 | 437,19 | 12.14.11 09:45 AM | 0,0213 | 28,32 | 19,34 | 578,8 |
| 11.30.11 10:00 AM | -0,0030 | 27,6 | 12,25 | 553,16 | 12.14.11 10:00 AM | 0,0061 | 28,67 | 20,81 | 741,76 |
| 11.30.11 10:15 AM | 0,0046 | 28,69 | 13,9 | 797,91 | 12.14.11 10:15 AM | 0,0152 | 28,99 | 21,95 | 889,47 |
| 11.30.11 10:30 AM | 0,0000 | 29,24 | 14,73 | 976,75 | 12.14.11 10:30 AM | 0,0000 | 29,09 | 23,1 | 1.006,04 |
| 11.30.11 10:45 AM | 0,0076 | 29,52 | 16 | 1.066,47 | 12.14.11 10:45 AM | 0,0183 | 29,19 | 23,7 | 1.045,10 |
| 11.30.11 11:00 AM | 0,0046 | 29,57 | 15,09 | 813,17 | 12.14.11 11:00 AM | 0,0441 | 29,19 | 22,77 | 925,48 |
| 11.30.11 11:15 AM | 0,0061 | 29,57 | 16,01 | 1.082,34 | 12.14.11 11:15 AM | 0,0167 | 29,32 | 23,12 | 1.013,98 |
| 11.30.11 11:30 AM | 0,0259 | 29,64 | 16,54 | 1.302,67 | 12.14.11 11:30 AM | 0,0244 | 29,49 | 24,53 | 1.224,55 |
| 11.30.11 11:45 AM | 0,0076 | 29,64 | 16,85 | 1.310,61 | 12.14.11 11:45 AM | 0,0320 | 29,72 | 25,86 | 1.444,27 |
| 11.30.11 12:00 PM | 0,0198 | 29,62 | 16,01 | 952,94 | 12.14.11 12:00 PM | 0,0426 | 29,62 | 24,32 | 1.178,77 |
| 11.30.11 12:15 PM | 0,0335 | 29,92 | 17,39 | 1.363,71 | 12.14.11 12:15 PM | 0,0046 | 29,72 | 24,98 | 1.341,13 |
| 11.30.11 12:30 PM | -0,0020 | 30,09 | 18,23 | 1.468,08 | 12.14.11 12:30 PM | 0,0274 | 29,79 | 26,53 | 1.475,40 |
| 11.30.11 12:45 PM | -0,0030 | 30,14 | 17,29 | 1.167,79 | 12.14.11 12:45 PM | 0,0091 | 29,44 | 23,94 | 1.092,10 |
| 11.30.11 01:00 PM | 0,0015 | 29,99 | 16,18 | 819,89 | 12.14.11 01:00 PM | 0,0213 | 29,09 | 22,84 | 909 |
| 11.30.11 01:15 PM | -0,0030 | 29,87 | 15,22 | 674,62 | 12.14.11 01:15 PM | 0,0289 | 28,97 | 22,43 | 845,52 |
| 11.30.11 01:30 PM | -0,0030 | 29,77 | 14,8 | 667,3 | 12.14.11 01:30 PM | 0,0228 | 28,84 | 22,05 | 808,9 |
| 11.30.11 01:45 PM | -0,0030 | 29,74 | 14,57 | 701,48 | 12.14.11 01:45 PM | 0,0137 | 28,74 | 21,82 | 800,96 |
| 11.30.11 02:00 PM | -0,0030 | 29,69 | 14,49 | 697,2 | 12.14.11 02:00 PM | 0,0365 | 28,97 | 22,35 | 887,02 |
| 11.30.11 02:15 PM | -0,0030 | 29,69 | 14,79 | 790,59 | 12.14.11 02:15 PM | 0,0137 | 29,09 | 22,44 | 918,76 |
| 11.30.11 02:30 PM | -0,0030 | 29,74 | 15,02 | 814,39 | 12.14.11 02:30 PM | 0,0046 | 29,02 | 22,65 | 974,3 |
| 11.30.11 02:45 PM | -0,0030 | 29,74 | 15,1 | 821,72 | 12.14.11 02:45 PM | 0,0228 | 29,09 | 22,95 | 1.023,74 |
| 11.30.11 03:00 PM | -0,0030 | 29,72 | 15,18 | 815 | 12.14.11 03:00 PM | 0,0076 | 29,17 | 22,48 | 932,8 |
| 11.30.11 03:15 PM | -0,0030 | 29,69 | 15,18 | 807,07 | 12.14.11 03:15 PM | 0,0076 | 29,12 | 22,81 | 987,12 |
| 11.30.11 03:30 PM | -0,0020 | 29,69 | 15,18 | 788,76 | 12.14.11 03:30 PM | 0,0046 | 29,17 | 23,11 | 1.023,74 |
| 11.30.11 03:45 PM | -0,0030 | 29,69 | 15,1 | 775,94 | 12.14.11 03:45 PM | 0,0381 | 29,19 | 22,96 | 1.001,16 |
| 11.30.11 04:00 PM | -0,0030 | 29,69 | 15,02 | 753,97 | 12.14.11 04:00 PM | 0,0137 | 29,07 | 22,51 | 928,53 |

**Table A.01.** (Continued)

| Room 28 - location 'A' | | | | | Room 28 - location 'B' | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Date** | **m/s** | **°C** | **%** | **ppm** | **Date** | **m/s** | **°C** | **%** | **ppm** |
| 11.30.11 04:15 PM | -0,0020 | 29,67 | 14,87 | 723,45 | 12.14.11 04:15 PM | -0,0030 | 29,02 | 22,28 | 901,06 |
| 11.30.11 04:30 PM | -0,0030 | 29,44 | 14,74 | 664,86 | 12.14.11 04:30 PM | -0,0020 | 29,02 | 21,91 | 845,52 |
| 11.30.11 04:45 PM | -0,0030 | 29,39 | 14,63 | 645,32 | 12.14.11 04:45 PM | 0,0000 | 28,89 | 21,9 | 752,75 |
| 11.30.11 05:00 PM | -0,0030 | 29,41 | 14,7 | 616,64 | 12.14.11 05:00 PM | -0,0030 | 28,82 | 21,19 | 647,77 |
| 11.30.11 05:15 PM | 0,0030 | 29,44 | 14,51 | 586,73 | 12.14.11 05:15 PM | 0,0015 | 28,62 | 20,62 | 569,64 |
| 11.30.11 05:30 PM | -0,0030 | 29,52 | 14,4 | 575,13 | 12.14.11 05:30 PM | -0,0030 | 28,54 | 20,32 | 534,85 |
| 11.30.11 05:45 PM | 0,0122 | 29,62 | 14,33 | 559,27 | 12.14.11 05:45 PM | -0,0020 | 28,47 | 19,94 | 509,83 |
| 11.30.11 06:00 PM | 0,0350 | 29,44 | 13,9 | 503,72 | 12.14.11 06:00 PM | 0,0015 | 28,39 | 19,71 | 499,45 |
| 11.30.11 06:15 PM | 0,0000 | 29,34 | 13,78 | 481,75 | 12.14.11 06:15 PM | 0,0030 | 28,25 | 19,63 | 486,02 |
| 11.30.11 06:30 PM | -0,0020 | 29,46 | 13,86 | 473,82 | 12.14.11 06:30 PM | -0,0030 | 28,25 | 19,63 | 475,65 |
| 11.30.11 06:45 PM | 0,0015 | 29,54 | 13,71 | 473,21 | 12.14.11 06:45 PM | 0,0122 | 28,47 | 19,57 | 471,98 |
| 11.30.11 07:00 PM | 0,0015 | 29,59 | 13,72 | 481,14 | 12.14.11 07:00 PM | 0,0183 | 28,57 | 19,57 | 467,1 |
| 11.30.11 07:15 PM | -0,0030 | 29,57 | 13,72 | 488,46 | 12.14.11 07:15 PM | -0,0030 | 28,62 | 19,58 | 461,61 |
| 11.30.11 07:30 PM | -0,0030 | 29,49 | 13,63 | 490,91 | 12.14.11 07:30 PM | 0,0000 | 28,69 | 19,58 | 459,78 |
| 11.30.11 07:45 PM | -0,0030 | 29,37 | 13,48 | 478,09 | 12.14.11 07:45 PM | 0,0000 | 28,74 | 19,51 | 455,51 |
| 11.30.11 08:00 PM | -0,0030 | 29,29 | 13,32 | 463,44 | 12.14.11 08:00 PM | -0,0020 | 28,69 | 19,58 | 456,73 |
| 11.30.11 08:15 PM | -0,0030 | 29,22 | 13,24 | 453,67 | 12.14.11 08:15 PM | -0,0020 | 28,67 | 19,58 | 454,28 |
| 11.30.11 08:30 PM | -0,0030 | 29,12 | 13,16 | 450,01 | 12.14.11 08:30 PM | -0,0020 | 28,69 | 19,66 | 454,9 |
| 11.30.11 08:45 PM | -0,0030 | 29,07 | 13 | 431,09 | 12.14.11 08:45 PM | -0,0020 | 28,52 | 19,72 | 452,45 |
| 11.30.11 09:00 PM | -0,0030 | 29,02 | 12,85 | 417,66 | 12.14.11 09:00 PM | -0,0030 | 28,54 | 19,5 | 450,01 |
| 11.30.11 09:15 PM | -0,0030 | 28,89 | 12,69 | 398,13 | 12.14.11 09:15 PM | 0,0015 | 28,49 | 19,72 | 447,57 |
| 11.30.11 09:30 PM | -0,0030 | 28,84 | 12,53 | 388,98 | 12.14.11 09:30 PM | -0,0030 | 28,52 | 19,42 | 452,45 |
| 11.30.11 09:45 PM | -0,0030 | 28,77 | 12,37 | 378,6 | 12.14.11 09:45 PM | -0,0030 | 28,27 | 19,56 | 454,9 |
| 11.30.11 10:00 PM | -0,0030 | 28,74 | 12,29 | 368,84 | 12.14.11 10:00 PM | 0,0091 | 28,39 | 19,49 | 451,84 |
| 11.30.11 10:15 PM | -0,0030 | 28,72 | 12,22 | 363,34 | 12.14.11 10:15 PM | 0,0030 | 28,22 | 19,63 | 451,84 |
| 11.30.11 10:30 PM | -0,0030 | 28,77 | 12,22 | 358,46 | 12.14.11 10:30 PM | -0,0020 | 28,44 | 19,53 | 454,9 |
| 11.30.11 10:45 PM | -0,0030 | 28,79 | 12,14 | 359,07 | 12.14.11 10:45 PM | -0,0030 | 28,42 | 19,34 | 460,39 |
| 11.30.11 11:00 PM | -0,0030 | 28,77 | 12,14 | 358,46 | 12.14.11 11:00 PM | 0,0076 | 28,52 | 19,27 | 456,73 |
| 11.30.11 11:15 PM | -0,0030 | 28,89 | 12,3 | 358,46 | 12.14.11 11:15 PM | 0,0259 | 28,67 | 19,13 | 459,78 |
| 11.30.11 11:30 PM | -0,0030 | 29,02 | 12,31 | 368,84 | 12.14.11 11:30 PM | -0,0030 | 28,62 | 19,13 | 454,9 |
| 11.30.11 11:45 PM | -0,0030 | 29,09 | 12,46 | 375,55 | 12.14.11 11:45 PM | -0,0020 | 28,59 | 18,98 | 461,61 |
| 12.01.11 12:00 AM | -0,0030 | 29,12 | 12,39 | 383,48 | 12.15.11 12:00 AM | -0,0020 | 28,42 | 18,67 | 459,17 |
| 12.01.11 12:15 AM | -0,0030 | 28,97 | 12,15 | 377,99 | 12.15.11 12:15 AM | -0,0030 | 28,05 | 18,65 | 464,05 |
| 12.01.11 12:30 AM | -0,0030 | 28,87 | 12,07 | 373,11 | 12.15.11 12:30 AM | 0,0061 | 27,6 | 18,7 | 473,82 |
| 12.01.11 12:45 AM | -0,0030 | 28,79 | 11,99 | 368,84 | 12.15.11 12:45 AM | -0,0030 | 27,43 | 19,06 | 494,57 |
| 12.01.11 01:00 AM | -0,0030 | 28,84 | 12,15 | 363,95 | 12.15.11 01:00 AM | -0,0020 | 27,65 | 18,85 | 507,39 |
| 12.01.11 01:15 AM | -0,0030 | 29,04 | 12,31 | 365,78 | 12.15.11 01:15 AM | -0,0020 | 27,75 | 18,78 | 512,27 |
| 12.01.11 01:30 AM | -0,0020 | 29,14 | 12,23 | 370,67 | 12.15.11 01:30 AM | -0,0020 | 27,8 | 18,63 | 520,81 |
| 12.01.11 01:45 AM | -0,0020 | 29,09 | 12,27 | 373,11 | 12.15.11 01:45 AM | -0,0030 | 27,73 | 18,51 | 520,81 |

**Table A.01.** (Continued)

| Room 28 - location 'A' | | | | | Room 28 - location 'B' | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Date** | **m/s** | **°C** | **%** | **ppm** | **Date** | **m/s** | **°C** | **%** | **ppm** |
| 12.01.11 02:00 AM | -0,0030 | 29,17 | 12,31 | 375,55 | 12.15.11 02:00 AM | 0,0015 | 27,97 | 18,3 | 515,32 |
| 12.01.11 02:15 AM | -0,0030 | 29,17 | 12,39 | 376,77 | 12.15.11 02:15 AM | -0,0030 | 28,15 | 18,2 | 515,32 |
| 12.01.11 02:30 AM | -0,0030 | 29,22 | 12,32 | 381,04 | 12.15.11 02:30 AM | -0,0030 | 28,22 | 18,28 | 517,76 |
| 12.01.11 02:45 AM | -0,0030 | 29,02 | 12,15 | 381,04 | 12.15.11 02:45 AM | -0,0030 | 28,2 | 18,2 | 514,71 |
| 12.01.11 03:00 AM | -0,0030 | 28,89 | 12,07 | 376,16 | 12.15.11 03:00 AM | -0,0020 | 28,12 | 18,12 | 507,39 |
| 12.01.11 03:15 AM | -0,0030 | 28,79 | 11,91 | 376,16 | 12.15.11 03:15 AM | -0,0020 | 28,25 | 17,98 | 503,72 |
| 12.01.11 03:30 AM | -0,0030 | 28,74 | 11,91 | 376,16 | 12.15.11 03:30 AM | -0,0030 | 28,25 | 17,83 | 503,11 |
| 12.01.11 03:45 AM | -0,0030 | 28,69 | 11,75 | 371,28 | 12.15.11 03:45 AM | -0,0030 | 28,22 | 17,83 | 498,23 |
| 12.01.11 04:00 AM | -0,0030 | 28,64 | 11,6 | 366,39 | 12.15.11 04:00 AM | 0,0046 | 27,95 | 17,89 | 493,96 |
| 12.01.11 04:15 AM | -0,0030 | 28,62 | 11,44 | 365,78 | 12.15.11 04:15 AM | 0,0289 | 27,97 | 17,89 | 492,74 |
| 12.01.11 04:30 AM | -0,0030 | 28,59 | 11,44 | 363,95 | 12.15.11 04:30 AM | 0,0183 | 28,35 | 17,76 | 492,74 |
| 12.01.11 04:45 AM | -0,0030 | 28,57 | 11,32 | 363,95 | 12.15.11 04:45 AM | 0,0289 | 28,54 | 17,7 | 495,79 |
| 12.01.11 05:00 AM | -0,0030 | 28,59 | 11,32 | 370,67 | 12.15.11 05:00 AM | 0,0320 | 28,64 | 17,63 | 492,74 |
| 12.01.11 05:15 AM | -0,0030 | 28,59 | 11,52 | 373,72 | 12.15.11 05:15 AM | -0,0020 | 28,69 | 17,67 | 493,35 |
| 12.01.11 05:30 AM | -0,0030 | 28,69 | 11,52 | 371,28 | 12.15.11 05:30 AM | 0,0091 | 28,72 | 17,78 | 493,96 |
| 12.01.11 05:45 AM | -0,0030 | 28,79 | 11,6 | 371,28 | 12.15.11 05:45 AM | 0,0167 | 28,79 | 17,78 | 498,23 |
| 12.01.11 06:00 AM | -0,0030 | 28,84 | 11,68 | 371,28 | 12.15.11 06:00 AM | 0,0046 | 28,82 | 17,79 | 498,23 |
| 12.01.11 06:15 AM | 0,0106 | 28,89 | 11,68 | 374,33 | 12.15.11 06:15 AM | 0,0274 | 28,82 | 17,79 | 498,23 |
| 12.01.11 06:30 AM | -0,0030 | 28,92 | 11,84 | 375,55 | 12.15.11 06:30 AM | 0,0198 | 28,87 | 17,71 | 503,11 |
| 12.01.11 06:45 AM | -0,0030 | 28,87 | 11,53 | 380,43 | 12.15.11 06:45 AM | 0,0228 | 28,87 | 17,71 | 505,55 |
| 12.01.11 07:00 AM | -0,0030 | 28,67 | 11,44 | 381,04 | 12.15.11 07:00 AM | 0,0137 | 28,84 | 17,79 | 503,11 |
| 12.01.11 07:15 AM | -0,0030 | 28,59 | 11,36 | 378,6 | 12.15.11 07:15 AM | 0,0198 | 28,82 | 17,79 | 505,55 |
| 12.01.11 07:30 AM | -0,0030 | 28,57 | 11,28 | 382,87 | 12.15.11 07:30 AM | 0,0015 | 28,74 | 17,93 | 515,32 |
| 12.01.11 07:45 AM | -0,0030 | 28,35 | 11,28 | 381,04 | 12.15.11 07:45 AM | 0,0304 | 28,22 | 17,53 | 505,55 |
| 12.01.11 08:00 AM | -0,0030 | 28,37 | 11,43 | 380,43 | 12.15.11 08:00 AM | 0,0122 | 28,07 | 17,67 | 508 |
| 12.01.11 08:15 AM | -0,0030 | 28,44 | 11,51 | 390,81 | 12.15.11 08:15 AM | -0,0020 | 27,97 | 17,59 | 505,55 |
| 12.01.11 08:30 AM | -0,0030 | 28,47 | 11,51 | 400,57 | 12.15.11 08:30 AM | 0,0000 | 27,58 | 18,06 | 508 |
| 12.01.11 08:45 AM | -0,0030 | 28,35 | 11,43 | 404,85 | 12.15.11 08:45 AM | 0,0411 | 27,65 | 18,47 | 513,49 |
| 12.01.11 09:00 AM | -0,0030 | 28,12 | 11,5 | 409,73 | 12.15.11 09:00 AM | 0,0061 | 27,88 | 18,49 | 510,44 |
| 12.01.11 09:15 AM | -0,0030 | 28,22 | 11,89 | 415,22 | 12.15.11 09:15 AM | 0,0304 | 28,07 | 18,61 | 515,32 |
| 12.01.11 09:30 AM | -0,0030 | 28,3 | 12,04 | 422,55 | 12.15.11 09:30 AM | 0,0106 | 28,27 | 18,7 | 516,54 |
| 12.01.11 09:45 AM | -0,0030 | 28,37 | 12,13 | 434,75 | 12.15.11 09:45 AM | -0,0020 | 28,39 | 18,63 | 512,88 |
| 12.01.11 10:00 AM | -0,0030 | 28,54 | 12,25 | 450,01 | 12.15.11 10:00 AM | 0,0198 | 28,49 | 19,72 | 610,53 |
| 12.01.11 10:15 AM | -0,0030 | 28,62 | 12,21 | 453,67 | 12.15.11 10:15 AM | 0,0167 | 28,84 | 21,19 | 795,47 |
| 12.01.11 10:30 AM | -0,0030 | 28,69 | 12,68 | 468,32 | 12.15.11 10:30 AM | 0,0746 | 28,99 | 21,98 | 904,11 |
| 12.01.11 10:45 AM | -0,0030 | 28,67 | 12,68 | 464,05 | 12.15.11 10:45 AM | 0,0304 | 29,12 | 22,21 | 921,2 |
| 12.01.11 11:00 AM | 0,0167 | 28,59 | 12,83 | 459,17 | 12.15.11 11:00 AM | 0,0198 | 29,19 | 22,74 | 962,1 |
| 12.01.11 11:15 AM | -0,0030 | 28,64 | 13,02 | 468,32 | 12.15.11 11:15 AM | 0,0320 | 29,41 | 24,23 | 1.140,32 |
| 12.01.11 11:30 AM | -0,0030 | 28,62 | 13,14 | 464,66 | 12.15.11 11:30 AM | 0,0167 | 29,59 | 24,53 | 1.228,82 |

**Table A.01.** (Continued)

| Room 28 - location 'A' | | | | | Room 28 - location 'B' | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Date** | **m/s** | **°C** | **%** | **ppm** | **Date** | **m/s** | **°C** | **%** | **ppm** |
| 12.01.11 11:45 AM | -0,0030 | 28,54 | 13,06 | 449,4 | 12.15.11 11:45AM | 0,0137 | 29,62 | 24,54 | 1.268,49 |
| 12.01.11 12:00 PM | -0,0030 | 28,57 | 13,06 | 473,82 | 12.15.11 12:00 PM | 0,0289 | 29,44 | 23,49 | 1.086,61 |
| 12.01.11 12:15 PM | -0,0030 | 28,74 | 13,06 | 481,14 | 12.15.11 12:15 PM | 0,0061 | 29,57 | 24,02 | 1.118,35 |
| 12.01.11 12:30 PM | -0,0030 | 28,89 | 13,07 | 483,58 | 12.15.11 12:30 PM | 0,0122 | 29,37 | 22,45 | 893,74 |
| 12.01.11 12:45 PM | -0,0020 | 28,99 | 13,15 | 529,97 | 12.15.11 12:45 PM | 0,0320 | 29,19 | 21,92 | 788,76 |
| 12.01.11 01:00 PM | -0,0030 | 29,07 | 13,46 | 569,03 | 12.15.11 01:00 PM | 0,0381 | 29,24 | 22,19 | 818,66 |
| 12.01.11 01:15 PM | -0,0020 | 29,32 | 14,16 | 708,8 | 12.15.11 01:15 PM | 0,0213 | 29,57 | 22,91 | 896,79 |
| 12.01.11 01:30 PM | -0,0020 | 29,49 | 14,71 | 805,85 | 12.15.11 01:30 PM | -0,0020 | 29,79 | 23,81 | 1.013,37 |
| 12.01.11 01:45 PM | -0,0030 | 29,49 | 15,17 | 743,59 | 12.15.11 01:45 PM | 0,0061 | 29,54 | 22,24 | 825,99 |
| 12.01.11 02:00 PM | -0,0030 | 29,12 | 14,69 | 630,68 | 12.15.11 02:00 PM | 0,0350 | 29,39 | 21,94 | 798,52 |
| 12.01.11 02:15 PM | -0,0030 | 28,89 | 14,3 | 592,22 | 12.15.11 02:15 PM | 0,0046 | 29,46 | 21,79 | 784,48 |
| 12.01.11 02:30 PM | -0,0030 | 28,74 | 14,14 | 563,54 | 12.15.11 02:30 PM | 0,0167 | 29,52 | 21,76 | 774,72 |
| 12.01.11 02:45 PM | -0,0030 | 28,79 | 13,91 | 574,52 | 12.15.11 02:45 PM | 0,0411 | 29,44 | 22,16 | 859,56 |
| 12.01.11 03:00 PM | -0,0030 | 28,69 | 15,43 | 836,98 | 12.15.11 03:00 PM | -0,0020 | 29,27 | 24 | 1.076,84 |
| 12.01.11 03:15 PM | 0,0198 | 28,94 | 16,81 | 1.070,74 | 12.15.11 03:15 PM | 0,0015 | 29,22 | 26,41 | 1.296,57 |
| 12.01.11 03:30 PM | -0,0020 | 29,19 | 17,24 | 1.295,96 | 12.15.11 03:30 PM | 0,0350 | 29,27 | 28,08 | 1.461,98 |
| 12.01.11 03:45 PM | -0,0020 | 29,22 | 16,9 | 1.109,19 | 12.15.11 03:45 PM | 0,0731 | 29,27 | 26,74 | 1.277,65 |
| 12.01.11 04:00 PM | -0,0030 | 28,89 | 17,19 | 953,55 | 12.15.11 04:00 PM | 0,0046 | 28,94 | 24,75 | 855,29 |
| 12.01.11 04:15 PM | -0,0030 | 29,07 | 17,72 | 1.162,90 | 12.15.11 04:15 PM | 0,0167 | 28,84 | 25,87 | 1.120,79 |
| 12.01.11 04:30 PM | 0,0137 | 29,14 | 17,73 | 1.075,62 | 12.15.11 04:30 PM | 0,0198 | 28,74 | 25,43 | 1.049,38 |
| 12.01.11 04:45 PM | -0,0030 | 28,49 | 15,38 | 758,85 | 12.15.11 04:45 PM | 0,0076 | 28,64 | 25,38 | 1.045,10 |
| 12.01.11 05:00 PM | -0,0030 | 28,39 | 15,72 | 748,47 | 12.15.11 05:00 PM | -0,0020 | 28,47 | 24,75 | 964,54 |
| 12.01.11 05:15 PM | -0,0030 | 28,47 | 15,65 | 748,47 | 12.15.11 05:15 PM | 0,0350 | 28,22 | 22,75 | 689,27 |
| 12.01.11 05:30 PM | -0,0030 | 28,57 | 15,65 | 745,42 | 12.15.11 05:30 PM | 0,0000 | 27,6 | 22,12 | 586,12 |
| 12.01.11 05:45 PM | -0,0030 | 28,44 | 14,58 | 657,53 | 12.15.11 05:45 PM | -0,0030 | 27,43 | 21,29 | 527,53 |
| 12.01.11 06:00 PM | -0,0030 | 28,05 | 13,88 | 537,29 | 12.15.11 06:00 PM | -0,0020 | 27,21 | 20,87 | 515,32 |
| 12.01.11 06:15 PM | -0,0030 | 27,95 | 13,53 | 465,27 | 12.15.11 06:15 PM | 0,0030 | 26,97 | 20,71 | 498,23 |
| 12.01.11 06:30 PM | -0,0030 | 27,95 | 13,11 | 426,82 | 12.15.11 06:30 PM | 0,0015 | 26,72 | 20,66 | 488,46 |
| 12.01.11 06:45 PM | -0,0030 | 27,97 | 12,88 | 407,9 | 12.15.11 06:45 PM | 0,0030 | 26,43 | 20,42 | 490,3 |
| 12.01.11 07:00 PM | -0,0030 | 27,9 | 12,41 | 392,64 | 12.15.11 07:00 PM | 0,0000 | 26,13 | 20,4 | 483,58 |
| 12.01.11 07:15 PM | -0,0030 | 27,9 | 12,34 | 377,99 | 12.15.11 07:15 PM | -0,0030 | 25,99 | 20,61 | 483,58 |
| 12.01.11 07:30 PM | -0,0030 | 27,97 | 12,22 | 370,67 | 12.15.11 07:30 PM | -0,0020 | 26,04 | 20,84 | 481,14 |
| 12.01.11 07:45 PM | -0,0030 | 27,9 | 11,87 | 366,39 | 12.15.11 07:45 PM | -0,0030 | 26,26 | 20,41 | 456,73 |
| 12.01.11 08:00 PM | -0,0030 | 27,8 | 11,79 | 363,95 | 12.15.11 08:00 PM | -0,0020 | 26,43 | 20,42 | 444,52 |
| 12.01.11 08:15 PM | -0,0030 | 27,7 | 11,6 | 359,07 | 12.15.11 08:15 PM | -0,0030 | 26,62 | 20,24 | 437,81 |
| 12.01.11 08:30 PM | -0,0030 | 27,6 | 11,55 | 353,58 | 12.15.11 08:30 PM | -0,0030 | 26,72 | 19,99 | 437,19 |
| 12.01.11 08:45 PM | -0,0030 | 27,7 | 11,71 | 353,58 | 12.15.11 08:45 PM | -0,0030 | 26,84 | 19,92 | 436,58 |
| 12.01.11 09:00 PM | -0,0030 | 27,88 | 11,72 | 353,58 | 12.15.11 09:00 PM | -0,0020 | 26,97 | 19,7 | 437,81 |
| 12.01.11 09:15 PM | -0,0030 | 27,9 | 11,6 | 353,58 | 12.15.11 09:15 PM | -0,0020 | 26,65 | 19,54 | 431,7 |

**Table A.01.** (Continued)

| Room 28 - location 'A' | | | | | Room 28 - location 'B' | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Date** | **m/s** | **°C** | **%** | **ppm** | **Date** | **m/s** | **°C** | **%** | **ppm** |
| 12.01.11 09:30 PM | -0,0030 | 27,83 | 11,33 | 356,63 | 12.15.11 09:30 PM | 0,0000 | 26,52 | 19,53 | 434,75 |
| 12.01.11 09:45 PM | -0,0030 | 27,85 | 11,49 | 359,07 | 12.15.11 09:45 PM | -0,0030 | 26,23 | 19,74 | 432,92 |
| 12.01.11 10:00 PM | -0,0030 | 27,88 | 11,49 | 361,51 | 12.15.11 10:00 PM | -0,0030 | 26,43 | 19,82 | 435,36 |
| 12.01.11 10:15 PM | -0,0030 | 27,92 | 11,41 | 363,34 | 12.15.11 10:15 PM | -0,0020 | 26,52 | 19,68 | 442,69 |
| 12.01.11 10:30 PM | -0,0030 | 27,9 | 11,49 | 365,78 | 12.15.11 10:30 PM | -0,0020 | 26,5 | 19,68 | 440,25 |
| 12.01.11 10:45 PM | -0,0030 | 28,02 | 11,49 | 370,67 | 12.15.11 10:45 PM | -0,0020 | 26,52 | 19,46 | 432,31 |
| 12.01.11 11:00 PM | -0,0030 | 28,12 | 11,5 | 373,11 | 12.15.11 11:00 PM | -0,0030 | 26,48 | 19,82 | 444,52 |
| 12.01.11 11:15 PM | -0,0030 | 28,17 | 11,5 | 371,28 | 12.15.11 11:15 PM | -0,0030 | 26,57 | 19,9 | 459,17 |
| 12.01.11 11:30 PM | -0,0030 | 28,05 | 11,5 | 373,72 | 12.15.11 11:30 PM | 0,0046 | 26,55 | 19,38 | 459,17 |
| 12.01.11 11:45 PM | -0,0030 | 28,05 | 11,42 | 370,67 | 12.15.11 11:45 PM | 0,0015 | 26,43 | 19,52 | 456,73 |
| 12.02.11 12:00 AM | -0,0030 | 27,88 | 11,18 | 368,23 | 12.16.11 12:00 AM | -0,0020 | 26,28 | 19,59 | 453,67 |
| 12.02.11 12:15 AM | -0,0030 | 27,78 | 11,25 | 363,95 | 12.16.11 12:15 AM | -0,0030 | 26,3 | 19,67 | 451,84 |
| 12.02.11 12:30 AM | -0,0030 | 27,68 | 11,02 | 359,07 | 12.16.11 12:30 AM | -0,0020 | 26,5 | 19,64 | 464,05 |
| 12.02.11 12:45 AM | -0,0030 | 27,48 | 10,97 | 356,63 | 12.16.11 12:45 AM | -0,0020 | 26,52 | 19,31 | 465,88 |
| 12.02.11 01:00 AM | -0,0030 | 27,43 | 10,93 | 353,58 | 12.16.11 01:00 AM | -0,0020 | 26,33 | 19,44 | 461,61 |
| 12.02.11 01:15 AM | -0,0030 | 27,63 | 10,94 | 356,63 | 12.16.11 01:15 AM | 0,0015 | 26,33 | 19,37 | 486,63 |
| 12.02.11 01:30 AM | -0,0030 | 27,43 | 10,78 | 358,46 | 12.16.11 01:30 AM | -0,0030 | 26,18 | 19,66 | 492,74 |
| 12.02.11 01:45 AM | -0,0030 | 27,53 | 10,86 | 363,95 | 12.16.11 01:45 AM | -0,0020 | 26,38 | 19,67 | 487,85 |
| 12.02.11 02:00 AM | -0,0030 | 27,55 | 10,86 | 371,28 | 12.16.11 02:00 AM | -0,0030 | 26,52 | 19,46 | 493,96 |
| 12.02.11 02:15 AM | -0,0030 | 27,51 | 10,86 | 375,55 | 12.16.11 02:15 AM | 0,0000 | 26,6 | 19,31 | 493,35 |
| 12.02.11 02:30 AM | -0,0030 | 27,53 | 10,82 | 373,11 | 12.16.11 02:30 AM | 0,0000 | 26,52 | 18,78 | 490,3 |
| 12.02.11 02:45 AM | -0,0030 | 27,41 | 10,77 | 373,11 | 12.16.11 02:45 AM | -0,0030 | 26,13 | 18,61 | 473,21 |
| 12.02.11 03:00 AM | -0,0030 | 27,55 | 10,94 | 378,6 | 12.16.11 03:00 AM | -0,0030 | 26,06 | 18,72 | 483,58 |
| 12.02.11 03:15 AM | -0,0030 | 27,7 | 10,86 | 387,76 | 12.16.11 03:15 AM | -0,0030 | 26,11 | 18,76 | 481,14 |
| 12.02.11 03:30 AM | -0,0030 | 27,7 | 10,94 | 382,87 | 12.16.11 03:30 AM | -0,0030 | 26,16 | 18,69 | 486,02 |
| 12.02.11 03:45 AM | -0,0030 | 27,7 | 10,63 | 381,04 | 12.16.11 03:45 AM | -0,0030 | 26,06 | 18,76 | 485,41 |
| 12.02.11 04:00 AM | -0,0030 | 27,6 | 10,71 | 382,87 | 12.16.11 04:00 AM | 0,0015 | 26,11 | 18,65 | 487,85 |
| 12.02.11 04:15 AM | -0,0030 | 27,51 | 10,47 | 385,31 | 12.16.11 04:15 AM | -0,0020 | 25,99 | 18,79 | 481,75 |
| 12.02.11 04:30 AM | -0,0030 | 27,55 | 10,66 | 383,48 | 12.16.11 04:30 AM | -0,0020 | 25,82 | 18,67 | 478,7 |
| 12.02.11 04:45 AM | -0,0030 | 27,53 | 10,63 | 387,76 | 12.16.11 04:45 AM | -0,0030 | 25,67 | 18,88 | 475,65 |
| 12.02.11 05:00 AM | -0,0030 | 27,55 | 10,7 | 393,25 | 12.16.11 05:00 AM | -0,0030 | 25,74 | 18,74 | 476,26 |
| 12.02.11 05:15 AM | -0,0030 | 27,68 | 10,71 | 398,74 | 12.16.11 05:15 AM | -0,0020 | 25,72 | 18,66 | 471,37 |
| 12.02.11 05:30 AM | -0,0030 | 27,85 | 10,83 | 398,13 | 12.16.11 05:30 AM | -0,0030 | 25,6 | 18,58 | 466,49 |
| 12.02.11 05:45 AM | -0,0030 | 27,95 | 10,87 | 397,52 | 12.16.11 05:45 AM | -0,0030 | 25,53 | 18,58 | 471,37 |
| 12.02.11 06:00 AM | -0,0030 | 28 | 10,88 | 402,4 | 12.16.11 06:00 AM | -0,0020 | 25,55 | 18,5 | 470,76 |
| 12.02.11 06:15 AM | -0,0030 | 28 | 10,8 | 403,02 | 12.16.11 06:15 AM | -0,0020 | 25,57 | 18,36 | 470,76 |
| 12.02.11 06:30 AM | -0,0030 | 28,05 | 10,72 | 401,18 | 12.16.11 06:30 AM | -0,0030 | 25,62 | 18,36 | 473,82 |
| 12.02.11 06:45 AM | -0,0030 | 28,1 | 10,72 | 395,08 | 12.16.11 06:45 AM | 0,0015 | 25,48 | 18,35 | 471,37 |
| 12.02.11 07:00 AM | -0,0030 | 28,07 | 10,72 | 397,52 | 12.16.11 07:00 AM | -0,0030 | 25,11 | 18,48 | 464,05 |

**Table A.01.** (Continued)

| Room 28 - location 'A' | | | | | Room 28 - location 'B' | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Date** | **m/s** | **°C** | **%** | **ppm** | **Date** | **m/s** | **°C** | **%** | **ppm** |
| 12.02.11 07:15 AM | -0,0030 | 27,88 | 10,48 | 407,9 | 12.16.11 07:15 AM | 0,0411 | 24,97 | 18,7 | 464,05 |
| 12.02.11 07:30 AM | -0,0030 | 27,55 | 10,63 | 410,34 | 12.16.11 07:30 AM | 0,0198 | 24,65 | 19,05 | 466,49 |
| 12.02.11 07:45 AM | -0,0030 | 27,31 | 10,69 | 407,29 | 12.16.11 07:45 AM | 0,0137 | 24,41 | 19,55 | 466,49 |
| 12.02.11 08:00 AM | -0,0030 | 27,21 | 10,88 | 410,95 | 12.16.11 08:00 AM | 0,0411 | 24,48 | 19,89 | 464,05 |
| 12.02.11 08:15 AM | -0,0030 | 27,33 | 11 | 407,29 | 12.16.11 08:15 AM | -0,0030 | 24,53 | 20,23 | 449,4 |
| 12.02.11 08:30 AM | -0,0030 | 27,53 | 11,09 | 407,29 | 12.16.11 08:30 AM | 0,0076 | 24,94 | 20,4 | 462,83 |
| 12.02.11 08:45 AM | -0,0030 | 27,68 | 11,29 | 422,55 | 12.16.11 08:45 AM | -0,0030 | 25,43 | 20,28 | 468,32 |
| 12.02.11 09:00 AM | -0,0030 | 27,68 | 11,48 | 429,87 | 12.16.11 09:00 AM | -0,0030 | 25,67 | 20,07 | 464,66 |
| 12.02.11 09:15 AM | -0,0030 | 27,73 | 11,56 | 434,75 | 12.16.11 09:15 AM | -0,0030 | 25,99 | 20,24 | 456,73 |
| 12.02.11 09:30 AM | -0,0030 | 27,83 | 11,56 | 446,96 | 12.16.11 09:30 AM | -0,0030 | 26,28 | 20,04 | 464,05 |
| 12.02.11 09:45 AM | -0,0030 | 27,7 | 11,56 | 437,81 | 12.16.11 09:45 AM | -0,0030 | 26,4 | 20,08 | 468,32 |
| 12.02.11 10:00 AM | -0,0030 | 27,63 | 11,55 | 434,75 | 12.16.11 10:00 AM | -0,0020 | 26,52 | 20,01 | 468,93 |
| 12.02.11 10:15 AM | -0,0030 | 27,7 | 11,79 | 431,7 | 12.16.11 10:15 AM | -0,0030 | 26,62 | 19,91 | 464,05 |
| 12.02.11 10:30 AM | -0,0030 | 27,78 | 11,79 | 424,38 | 12.16.11 10:30 AM | -0,0030 | 26,67 | 20,02 | 465,88 |
| 12.02.11 10:45 AM | -0,0030 | 27,51 | 11,43 | 417,66 | 12.16.11 10:45 AM | -0,0020 | 26,79 | 20,14 | 478,7 |
| 12.02.11 11:00 AM | -0,0030 | 27,41 | 11,62 | 409,73 | 12.16.11 11:00 AM | -0,0030 | 26,77 | 20,47 | 537,9 |
| 12.02.11 11:15 AM | -0,0030 | 27,38 | 11,78 | 403,02 | 12.16.11 11:15 AM | 0,0046 | 26,67 | 20,51 | 537,29 |
| 12.02.11 11:30 AM | -0,0030 | 27,46 | 11,78 | 404,24 | 12.16.11 11:30 AM | 0,0000 | 26,3 | 20,71 | 524,48 |
| 12.02.11 11:45 AM | -0,0030 | 27,36 | 11,77 | 403,02 | 12.16.11 11:45 AM | 0,0152 | 25,96 | 21,02 | 470,15 |
| 12.02.11 12:00 PM | -0,0020 | 27,41 | 11,7 | 407,9 | 12.16.11 12:00 PM | 0,0183 | 26,18 | 21,36 | 549,5 |
| 12.02.11 12:15 PM | -0,0030 | 27,21 | 11,85 | 410,34 | 12.16.11 12:15 PM | -0,0030 | 26,23 | 21,29 | 568,42 |
| 12.02.11 12:30 PM | -0,0030 | 27,31 | 12 | 417,66 | 12.16.11 12:30 PM | -0,0030 | 26,38 | 21,49 | 559,88 |

**Table A.02.** The air speed, temperature, relative humidity and $CO_2$ data of five days for the record locations 'A' and 'B' in Room 50

| Room 50 - location 'A' | | | | | Room 50 - location 'B' | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Date** | **m/s** | **°C** | **%** | **ppm** | **Date** | **m/s** | **°C** | **%** | **ppm** |
| 12.19.11 02:30 PM | 0,0000 | 24,61 | 36,02 | 1.443,66 | 12.26.11 02:30 PM | 0,0183 | 24,56 | 23,24 | 1.117,74 |
| 12.19.11 02:45 PM | 0,0274 | 24,65 | 35,96 | 1.419,86 | 12.26.11 02:45 PM | 0,0198 | 24,61 | 23,03 | 1.125,67 |
| 12.19.11 03:00 PM | 0,0000 | 24,68 | 36,16 | 1.454,04 | 12.26.11 03:00 PM | 0,0396 | 24,65 | 23,25 | 1.161,68 |
| 12.19.11 03:15 PM | -0,0030 | 24,7 | 35,9 | 1.336,24 | 12.26.11 03:15 PM | 0,0213 | 24,73 | 24,13 | 1.261,78 |
| 12.19.11 03:30 PM | 0,0213 | 24,75 | 35,64 | 1.355,77 | 12.26.11 03:30 PM | 0,0106 | 24,8 | 24,5 | 1.325,26 |
| 12.19.11 03:45 PM | 0,0837 | 24,73 | 35,4 | 1.277,65 | 12.26.11 03:45 PM | 0,0335 | 24,8 | 24,28 | 1.303,89 |
| 12.19.11 04:00 PM | 0,0274 | 24,7 | 34,97 | 1.213,56 | 12.26.11 04:00 PM | 0,0091 | 24,8 | 24,31 | 1.308,78 |
| 12.19.11 04:15 PM | 0,0030 | 24,68 | 34,7 | 1.157,41 | 12.26.11 04:15 PM | 0,0274 | 24,8 | 24,06 | 1.232,48 |
| 12.19.11 04:30 PM | 0,0015 | 24,61 | 34,36 | 1.115,30 | 12.26.11 04:30 PM | 0,0167 | 24,8 | 23,91 | 1.202,58 |
| 12.19.11 04:45 PM | 0,0487 | 24,53 | 33,89 | 1.023,13 | 12.26.11 04:45 PM | 0,0426 | 24,85 | 24,21 | 1.264,83 |
| 12.19.11 05:00 PM | -0,0030 | 24,48 | 33,61 | 959,05 | 12.26.11 05:00 PM | 0,0335 | 24,87 | 23,92 | 1.233,09 |
| 12.19.11 05:15 PM | 0,0015 | 24,46 | 33,51 | 935,24 | 12.26.11 05:15 PM | 0,0000 | 24,85 | 23,84 | 1.212,95 |
| 12.19.11 05:30 PM | 0,0061 | 24,44 | 33,07 | 880,92 | 12.26.11 05:30 PM | 0,0761 | 24,87 | 24,21 | 1.247,13 |
| 12.19.11 05:45PM | -0,0030 | 24,46 | 32,84 | 895,57 | 12.26.11 05:45 PM | 0,0517 | 24,87 | 23,77 | 1.181,21 |
| 12.19.11 06:00 PM | 0,0091 | 24,48 | 32,48 | 866,27 | 12.26.11 06:00 PM | 0,0381 | 24,85 | 23,92 | 1.187,93 |
| 12.19.11 06:15 PM | 0,0061 | 24,48 | 31,97 | 846,74 | 12.26.11 06:15 PM | 0,0533 | 24,87 | 24,21 | 1.172,06 |
| 12.19.11 06:30 PM | -0,0030 | 24,48 | 31,91 | 812,56 | 12.26.11 06:30 PM | 0,0030 | 24,85 | 23,99 | 1.111,02 |
| 12.19.11 06:45 PM | 0,0274 | 24,46 | 31,47 | 775,94 | 12.26.11 06:45 PM | 0,0106 | 24,82 | 23,73 | 1.054,87 |
| 12.19.11 07:00 PM | -0,0030 | 24,44 | 31,3 | 723,45 | 12.26.11 07:00 PM | 0,1065 | 24,8 | 23,4 | 1.026,18 |
| 12.19.11 07:15 PM | 0,0259 | 24,44 | 30,93 | 715,52 | 12.26.11 07:15 PM | 0,0061 | 24,77 | 23,26 | 976,75 |
| 12.19.11 07:30 PM | 0,0015 | 24,41 | 30,52 | 630,07 | 12.26.11 07:30 PM | 0,0365 | 24,75 | 22,89 | 931,58 |
| 12.19.11 07:45 PM | 0,0350 | 24,34 | 30,21 | 581,24 | 12.26.11 07:45 PM | 0,0198 | 24,7 | 22,37 | 855,9 |
| 12.19.11 08:00 PM | 0,0061 | 24,27 | 30 | 553,77 | 12.26.11 08:00 PM | -0,0020 | 24,63 | 22,08 | 816,22 |
| 12.19.11 08:15 PM | 0,0274 | 24,22 | 29,83 | 522,03 | 12.26.11 08:15 PM | -0,0030 | 24,61 | 21,89 | 781,43 |
| 12.19.11 08:30 PM | 0,0304 | 24,17 | 29,69 | 500,06 | 12.26.11 08:30 PM | 0,0091 | 24,61 | 21,85 | 777,77 |
| 12.19.11 08:45 PM | 0,0152 | 24,15 | 29,59 | 487,24 | 12.26.11 08:45 PM | 0,0106 | 24,61 | 21,56 | 751,53 |
| 12.19.11 09:00 PM | 0,0381 | 24,12 | 29,42 | 477,48 | 12.26.11 09:00 PM | 0,0000 | 24,58 | 21,41 | 721,62 |
| 12.19.11 09:15 PM | 0,0076 | 24,1 | 29,48 | 472,6 | 12.26.11 09:15 PM | 0,0167 | 24,56 | 21,34 | 725,89 |
| 12.19.11 09:30 PM | 0,0061 | 24,05 | 29,34 | 467,71 | 12.26.11 09:30 PM | 0,0487 | 24,53 | 21,19 | 686,83 |
| 12.19.11 09:45 PM | 0,0106 | 24,05 | 29,24 | 455,51 | 12.26.11 09:45 PM | 0,0594 | 24,53 | 20,97 | 677,06 |
| 12.19.11 10:00 PM | 0,0015 | 24,03 | 29,17 | 455,51 | 12.26.11 10:00 PM | 0,0046 | 24,51 | 20,78 | 657,53 |
| 12.19.11 10:15 PM | -0,0030 | 24 | 29,14 | 440,86 | 12.26.11 10:15 PM | 0,0030 | 24,51 | 20,74 | 672,18 |
| 12.19.11 10:30 PM | -0,0020 | 23,98 | 29,07 | 431,09 | 12.26.11 10:30 PM | 0,0213 | 24,51 | 20,67 | 667,3 |
| 12.19.11 10:45 PM | 0,0152 | 23,95 | 28,96 | 428,65 | 12.26.11 10:45 PM | -0,0030 | 24,51 | 20,45 | 647,16 |
| 12.19.11 11:00 PM | 0,0122 | 23,93 | 28,93 | 420,72 | 12.26.11 11:00 PM | 0,0304 | 24,46 | 20,08 | 605,04 |

**Table A.02.** (Continued)

| Room 50 - location 'A' | | | | | Room 50 - location 'B' | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Date** | **m/s** | **°C** | **%** | **ppm** | **Date** | **m/s** | **°C** | **%** | **ppm** |
| 12.19.11 11:15 PM | -0,0020 | 23,93 | 28,93 | 421,33 | 12.26.11 11:15 PM | 0,0030 | 24,41 | 19,93 | 585,51 |
| 12.19.11 11:30 PM | -0,0030 | 23,93 | 28,93 | 418,88 | 12.26.11 11:30 PM | 0,0091 | 24,41 | 19,63 | 555,6 |
| 12.19.11 11:45 PM | 0,0106 | 23,91 | 28,86 | 414 | 12.26.11 11:45 PM | 0,0259 | 24,39 | 19,55 | 546,45 |
| 12.20.11 12:00 AM | 0,0061 | 23,91 | 28,86 | 416,44 | 12.27.11 12:00 AM | 0,0015 | 24,39 | 19,41 | 531,8 |
| 12.20.11 12:15 AM | 0,0015 | 23,91 | 28,79 | 415,83 | 12.27.11 12:15 AM | 0,0198 | 24,39 | 19,33 | 534,24 |
| 12.20.11 12:30 AM | 0,0030 | 23,88 | 28,72 | 409,12 | 12.27.11 12:30 AM | 0,0046 | 24,39 | 19,37 | 545,84 |
| 12.20.11 12:45 AM | 0,0091 | 23,88 | 28,72 | 403,63 | 12.27.11 12:45 AM | 0,0228 | 24,36 | 19,33 | 541,56 |
| 12.20.11 01:00 AM | 0,0015 | 23,86 | 28,65 | 401,79 | 12.27.11 01:00 AM | 0,0183 | 24,32 | 19,14 | 521,42 |
| 12.20.11 01:15 AM | -0,0030 | 23,86 | 28,58 | 399,35 | 12.27.11 01:15 AM | 0,0030 | 24,32 | 19,03 | 517,15 |
| 12.20.11 01:30 AM | 0,0106 | 23,86 | 28,58 | 398,74 | 12.27.11 01:30 AM | 0,0198 | 24,29 | 18,92 | 502,5 |
| 12.20.11 01:45 AM | 0,0030 | 23,86 | 28,52 | 398,74 | 12.27.11 01:45 AM | 0,0228 | 24,29 | 18,88 | 511,66 |
| 12.20.11 02:00 AM | 0,0046 | 23,83 | 28,45 | 394,47 | 12.27.11 02:00 AM | 0,0167 | 24,29 | 18,73 | 500,06 |
| 12.20.11 02:15 AM | 0,0000 | 23,83 | 28,41 | 393,86 | 12.27.11 02:15 AM | 0,0046 | 24,27 | 18,66 | 487,85 |
| 12.20.11 02:30 AM | 0,0122 | 23,83 | 28,31 | 394,47 | 12.27.11 02:30 AM | 0,0046 | 24,24 | 18,51 | 480,53 |
| 12.20.11 02:45 AM | 0,0304 | 23,83 | 28,24 | 394,47 | 12.27.11 02:45 AM | 0,0076 | 24,22 | 18,43 | 479,31 |
| 12.20.11 03:00 AM | 0,0030 | 23,81 | 28,24 | 393,86 | 12.27.11 03:00 AM | 0,0030 | 24,2 | 18,28 | 468,32 |
| 12.20.11 03:15 AM | -0,0030 | 23,81 | 28,17 | 388,98 | 12.27.11 03:15 AM | -0,0030 | 24,17 | 18,35 | 473,82 |
| 12.20.11 03:30 AM | -0,0030 | 23,79 | 28 | 386,54 | 12.27.11 03:30 AM | -0,0030 | 24,15 | 18,24 | 463,44 |
| 12.20.11 03:45 AM | 0,0030 | 23,76 | 27,29 | 376,77 | 12.27.11 03:45 AM | 0,0000 | 24,15 | 18,2 | 465,88 |
| 12.20.11 04:00 AM | 0,0000 | 23,69 | 26,71 | 367 | 12.27.11 04:00 AM | 0,0198 | 24,12 | 18,13 | 456,73 |
| 12.20.11 04:15 AM | -0,0030 | 23,67 | 26,4 | 364,56 | 12.27.11 04:15 AM | 0,0046 | 24,1 | 18,05 | 449,4 |
| 12.20.11 04:30 AM | 0,0046 | 23,59 | 25,58 | 354,8 | 12.27.11 04:30 AM | 0,0244 | 24,1 | 17,98 | 449,4 |
| 12.20.11 04:45 AM | 0,0061 | 23,52 | 25,23 | 352,36 | 12.27.11 04:45 AM | 0,0091 | 24,07 | 17,9 | 449,4 |
| 12.20.11 05:00 AM | 0,0000 | 23,45 | 24,88 | 344,42 | 12.27.11 05:00 AM | 0,0061 | 24,05 | 17,82 | 444,52 |
| 12.20.11 05:15 AM | 0,0061 | 23,4 | 24,74 | 343,2 | 12.27.11 05:15 AM | 0,0091 | 24,03 | 17,79 | 436,58 |
| 12.20.11 05:30 AM | 0,0259 | 23,35 | 24,88 | 347,47 | 12.27.11 05:30 AM | -0,0020 | 24,03 | 17,75 | 431,09 |
| 12.20.11 05:45 AM | 0,0183 | 23,35 | 25,15 | 349,91 | 12.27.11 05:45 AM | -0,0020 | 24 | 17,64 | 421,33 |
| 12.20.11 06:00 AM | 0,0517 | 23,35 | 25,22 | 349,91 | 12.27.11 06:00 AM | 0,0091 | 23,98 | 17,6 | 421,94 |
| 12.20.11 06:15 AM | 0,0320 | 23,38 | 25,15 | 354,8 | 12.27.11 06:15 AM | 0,0000 | 23,95 | 17,52 | 424,38 |
| 12.20.11 06:30 AM | 0,0381 | 23,38 | 25,15 | 359,68 | 12.27.11 06:30 AM | 0,0061 | 23,93 | 17,52 | 421,33 |
| 12.20.11 06:45 AM | 0,0091 | 23,4 | 25,97 | 369,45 | 12.27.11 06:45 AM | 0,0091 | 23,91 | 17,52 | 419,49 |
| 12.20.11 07:00 AM | -0,0030 | 23,45 | 25,74 | 371,89 | 12.27.11 07:00 AM | -0,0030 | 23,91 | 17,52 | 416,44 |
| 12.20.11 07:15 AM | 0,0122 | 23,5 | 25,77 | 374,33 | 12.27.11 07:15 AM | 0,0715 | 23,91 | 17,44 | 414,61 |
| 12.20.11 07:30 AM | 0,0411 | 23,52 | 25,6 | 374,94 | 12.27.11 07:30 AM | 0,0000 | 23,93 | 17,45 | 414,61 |
| 12.20.11 07:45 AM | 0,0061 | 23,55 | 25,57 | 374,33 | 12.27.11 07:45 AM | 0,0167 | 23,93 | 17,45 | 414,61 |
| 12.20.11 08:00 AM | -0,0030 | 23,59 | 25,68 | 379,21 | 12.27.11 08:00 AM | -0,0020 | 23,93 | 17,52 | 414,61 |

**Table A.02.** (Continued)

| Room 50 - location 'A' | | | | | Room 50 - location 'B' | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Date** | **m/s** | **°C** | **%** | **ppm** | **Date** | **m/s** | **°C** | **%** | **ppm** |
| 12.20.11 08:15 AM | 0,0122 | 23,64 | 25,72 | 388,98 | 12.27.11 08:15 AM | 0,0061 | 23,95 | 17,75 | 427,43 |
| 12.20.11 08:30 AM | 0,0030 | 23,69 | 25,82 | 404,24 | 12.27.11 08:30 AM | 0,0106 | 23,95 | 18,04 | 437,19 |
| 12.20.11 08:45 AM | 0,0106 | 23,71 | 25,79 | 409,12 | 12.27.11 08:45 AM | -0,0030 | 23,95 | 18,12 | 433,53 |
| 12.20.11 09:00 AM | -0,0020 | 23,74 | 25,52 | 420,72 | 12.27.11 09:00 AM | 0,0046 | 23,93 | 18,19 | 442,69 |
| 12.20.11 09:15 AM | 0,0167 | 23,79 | 25,86 | 443,3 | 12.27.11 09:15 AM | 0,0000 | 23,93 | 18,27 | 446,96 |
| 12.20.11 09:30 AM | -0,0030 | 23,83 | 25,87 | 455,51 | 12.27.11 09:30 AM | 0,0167 | 23,93 | 18,34 | 453,06 |
| 12.20.11 09:45 AM | 0,0061 | 23,86 | 25,8 | 460,39 | 12.27.11 09:45 AM | 0,0578 | 23,93 | 18,41 | 471,98 |
| 12.20.11 10:00 AM | 0,0091 | 23,91 | 25,53 | 462,83 | 12.27.11 10:00 AM | 0,0365 | 23,93 | 19,08 | 538,51 |
| 12.20.11 10:15 AM | 0,0000 | 23,91 | 25,32 | 465,27 | 12.27.11 10:15 AM | 0,0046 | 23,95 | 19,08 | 536,68 |
| 12.20.11 10:30 AM | 0,0274 | 23,93 | 25,22 | 477,48 | 12.27.11 10:30 AM | 0,0061 | 23,98 | 19,08 | 534,85 |
| 12.20.11 10:45 AM | -0,0020 | 23,93 | 24,88 | 451,23 | 12.27.11 10:45 AM | 0,0137 | 24 | 19,6 | 597,11 |
| 12.20.11 11:00 AM | 0,0228 | 23,95 | 24,82 | 470,76 | 12.27.11 11:00 AM | 0,0122 | 24 | 19,38 | 553,77 |
| 12.20.11 11:15 AM | -0,0030 | 23,93 | 24,61 | 480,53 | 12.27.11 11:15 AM | -0,0020 | 24,03 | 19,38 | 548,89 |
| 12.20.11 11:30 AM | 0,0244 | 23,93 | 24,44 | 470,15 | 12.27.11 11:30 AM | 0,0091 | 24,03 | 19,38 | 556,21 |
| 12.20.11 11:45 AM | 0,0289 | 23,91 | 24,23 | 461 | 12.27.11 11:45 AM | 0,0259 | 24,07 | 19,42 | 551,33 |
| 12.20.11 12:00 PM | 0,0046 | 23,91 | 24,37 | 475,04 | 12.27.11 12:00 PM | 0,0320 | 24,07 | 19,61 | 592,22 |
| 12.20.11 12:15 PM | 0,0259 | 23,93 | 24,85 | 509,22 | 12.27.11 12:15 PM | 0,0244 | 24,07 | 19,98 | 641,66 |
| 12.20.11 12:30 PM | 0,0213 | 23,93 | 25,39 | 561,1 | 12.27.11 12:30 PM | 0,0015 | 24,1 | 20,05 | 653,26 |
| 12.20.11 12:45 PM | 0,0228 | 24,03 | 25,91 | 652,04 | 12.27.11 12:45 PM | 0,0137 | 24,12 | 20,28 | 676,45 |
| 12.20.11 01:00 PM | 0,0046 | 24,22 | 27,19 | 821,72 | 12.27.11 01:00 PM | 0,0548 | 24,22 | 20,28 | 691,71 |
| 12.20.11 01:15 PM | 0,0259 | 24,34 | 27,81 | 838,81 | 12.27.11 01:15 PM | 0,0411 | 24,27 | 20,51 | 731,38 |
| 12.20.11 01:30 PM | 0,0289 | 24,48 | 28,13 | 877,87 | 12.27.11 01:30 PM | 0,0837 | 24,32 | 20,55 | 761,9 |
| 12.20.11 01:45 PM | 0,0046 | 24,63 | 29,19 | 1.061,58 | 12.27.11 01:45 PM | 0,0837 | 24,36 | 20,85 | 813,78 |
| 12.20.11 02:00 PM | 0,0228 | 24,77 | 28,93 | 966,37 | 12.27.11 02:00 PM | 0,0152 | 24,41 | 21,03 | 850,4 |
| 12.20.11 02:15 PM | 0,0000 | 24,9 | 29,01 | 1.015,20 | 12.27.11 02:15 PM | 0,0928 | 24,48 | 21,15 | 877,26 |
| 12.20.11 02:30 PM | 0,0015 | 24,94 | 29,38 | 1.090,88 | 12.27.11 02:30 PM | 0,1004 | 24,58 | 21,19 | 897,4 |
| 12.20.11 02:45 PM | 0,0046 | 24,99 | 29,22 | 1.000,55 | 12.27.11 02:45 PM | 0,1690 | 24,7 | 21,42 | 934,02 |
| 12.20.11 03:00 PM | 0,0030 | 25,02 | 29,49 | 1.025,57 | 12.27.11 03:00 PM | 0,1583 | 24,8 | 21,57 | 958,44 |
| 12.20.11 03:15 PM | 0,0030 | 25,07 | 29,76 | 1.030,46 | 12.27.11 03:15 PM | 0,0715 | 24,92 | 21,47 | 957,21 |
| 12.20.11 03:30 PM | 0,0061 | 25,09 | 29,6 | 993,23 | 12.27.11 03:30 PM | 0,0578 | 25,02 | 21,44 | 955,38 |
| 12.20.11 03:45 PM | 0,0365 | 25,07 | 29,36 | 932,19 | 12.27.11 03:45 PM | 0,1522 | 25,11 | 21,52 | 962,1 |
| 12.20.11 04:00 PM | 0,0259 | 25,04 | 29,15 | 910,83 | 12.27.11 04:00 PM | 0,0654 | 25,19 | 21,82 | 1.021,30 |
| 12.20.11 04:15 PM | 0,0259 | 24,99 | 28,44 | 804,63 | 12.27.11 04:15 PM | 0,0137 | 25,23 | 21,89 | 1.028,63 |
| 12.20.11 04:30 PM | 0,0183 | 24,92 | 28,6 | 826,6 | 12.27.11 04:30 PM | 0,0381 | 25,28 | 21,68 | 990,17 |
| 12.20.11 04:45 PM | 0,0198 | 24,85 | 27,92 | 661,8 | 12.27.11 04:45 PM | 0,0304 | 25,31 | 21,53 | 955,99 |
| 12.20.11 05:00 PM | 0,0289 | 24,77 | 27,5 | 611,15 | 12.27.11 05:00 PM | 0,0837 | 25,38 | 21,39 | 932,8 |

**Table A.02.** (Continued)

| Room 50 - location 'A' | | | | | Room 50 - location 'B' | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Date** | **m/s** | **°C** | **%** | **ppm** | **Date** | **m/s** | **°C** | **%** | **ppm** |
| 12.20.11 05:15 PM | -0,0020 | 24,68 | 27,36 | 575,74 | 12.27.11 05:15 PM | -0,0020 | 25,38 | 21,24 | 913,88 |
| 12.20.11 05:30 PM | 0,0106 | 24,58 | 27,28 | 519,59 | 12.27.11 05:30 PM | 0,0213 | 25,43 | 21,1 | 909 |
| 12.20.11 05:45 PM | 0,0046 | 24,41 | 27,47 | 445,74 | 12.27.11 05:45 PM | 0,0183 | 25,48 | 21,17 | 913,88 |
| 12.20.11 06:00 PM | 0,0015 | 24,29 | 28,08 | 438,42 | 12.27.11 06:00 PM | 0,0578 | 25,53 | 21,29 | 945,62 |
| 12.20.11 06:15 PM | 0,0350 | 24,2 | 28,64 | 433,53 | 12.27.11 06:15 PM | 0,0715 | 25,57 | 21,25 | 932,8 |
| 12.20.11 06:30 PM | 0,0122 | 24,15 | 29,18 | 443,91 | 12.27.11 06:30 PM | 0,0624 | 25,65 | 21,18 | 940,12 |
| 12.20.11 06:45 PM | 0,0167 | 24,1 | 29,48 | 443,91 | 12.27.11 06:45 PM | 0,0091 | 25,67 | 21,26 | 938,9 |
| 12.20.11 07:00 PM | 0,0000 | 24,07 | 29,82 | 487,24 | 12.27.11 07:00 PM | 0,0441 | 25,67 | 21,11 | 929,14 |
| 12.20.11 07:15 PM | 0,0289 | 24,12 | 30,09 | 506,77 | 12.27.11 07:15 PM | 0,0396 | 25,67 | 20,89 | 891,91 |
| 12.20.11 07:30 PM | 0,0106 | 24,15 | 30,5 | 559,27 | 12.27.11 07:30 PM | 0,0244 | 25,7 | 20,74 | 863,22 |
| 12.20.11 07:45 PM | 0,0365 | 24,2 | 30,64 | 573,3 | 12.27.11 07:45 PM | 0,0198 | 25,72 | 20,52 | 851,01 |
| 12.20.11 08:00 PM | 0,0015 | 24,22 | 30,71 | 536,68 | 12.27.11 08:00 PM | 0,0335 | 25,72 | 20,37 | 829,65 |
| 12.20.11 08:15 PM | 0,0000 | 24,24 | 30,44 | 529,36 | 12.27.11 08:15 PM | 0,0548 | 25,67 | 20,37 | 838,2 |
| 12.20.11 08:30 PM | -0,0020 | 24,24 | 30,3 | 534,24 | 12.27.11 08:30 PM | 0,0396 | 25,65 | 20,37 | 821,11 |
| 12.20.11 08:45 PM | 0,0091 | 24,2 | 30,06 | 499,45 | 12.27.11 08:45 PM | 0,0000 | 25,65 | 20,44 | 833,92 |
| 12.20.11 09:00 PM | -0,0030 | 24,03 | 30,05 | 450,62 | 12.27.11 09:00 PM | 0,0700 | 25,62 | 20,52 | 847,96 |
| 12.20.11 09:15 PM | -0,0030 | 24,03 | 29,88 | 445,74 | 12.27.11 09:15 PM | 0,0213 | 25,62 | 20,66 | 867,49 |
| 12.20.11 09:30 PM | -0,0030 | 24 | 29,81 | 461 | 12.27.11 09:30 PM | 0,1355 | 25,62 | 20,74 | 884,58 |
| 12.20.11 09:45 PM | -0,0030 | 24 | 29,71 | 465,27 | 12.27.11 09:45 PM | 0,0381 | 25,62 | 20,74 | 882,14 |
| 12.20.11 10:00 PM | -0,0030 | 23,95 | 29,47 | 465,88 | 12.27.11 10:00 PM | 0,0076 | 25,62 | 20,66 | 865,05 |
| 12.20.11 10:15 PM | -0,0020 | 23,93 | 29,33 | 467,71 | 12.27.11 10:15 PM | 0,0441 | 25,62 | 20,66 | 867,49 |
| 12.20.11 10:30 PM | 0,0000 | 23,88 | 29,33 | 472,6 | 12.27.11 10:30 PM | 0,0837 | 25,62 | 20,74 | 873,6 |
| 12.20.11 10:45 PM | -0,0020 | 23,83 | 29,16 | 472,6 | 12.27.11 10:45 PM | 0,0624 | 25,57 | 20,73 | 867,49 |
| 12.20.11 11:00 PM | -0,0030 | 23,74 | 28,91 | 448,79 | 12.27.11 11:00 PM | 0,0365 | 25,57 | 21,03 | 901,67 |
| 12.20.11 11:15 PM | -0,0020 | 23,69 | 28,77 | 438,42 | 12.27.11 11:15 PM | 0,0959 | 25,57 | 21,03 | 914,49 |
| 12.20.11 11:30 PM | 0,0000 | 23,71 | 28,84 | 445,74 | 12.27.11 11:30 PM | 0,0639 | 25,57 | 21,03 | 906,56 |
| 12.20.11 11:45 PM | -0,0030 | 23,74 | 28,91 | 453,67 | 12.27.11 11:45 PM | 0,0928 | 25,55 | 20,88 | 887,02 |
| 12.21.11 12:00 AM | -0,0030 | 23,76 | 28,78 | 453,06 | 12.28.11 12:00 AM | 0,0213 | 25,55 | 20,96 | 894,96 |
| 12.21.11 12:15 AM | -0,0020 | 23,76 | 28,98 | 460,39 | 12.28.11 12:15 AM | 0,1263 | 25,53 | 20,95 | 884,58 |
| 12.21.11 12:30 AM | 0,0106 | 23,81 | 28,92 | 473,21 | 12.28.11 12:30 AM | 0,0152 | 25,53 | 20,81 | 869,93 |
| 12.21.11 12:45 AM | -0,0030 | 23,79 | 28,75 | 446,35 | 12.28.11 12:45 AM | 0,0533 | 25,53 | 20,73 | 857,73 |
| 12.21.11 01:00 AM | -0,0030 | 23,74 | 28,27 | 431,09 | 12.28.11 01:00 AM | 0,0700 | 25,5 | 20,73 | 856,51 |
| 12.21.11 01:15 AM | 0,0106 | 23,64 | 27,75 | 413,39 | 12.28.11 01:15 AM | 0,0685 | 25,48 | 20,88 | 884,58 |
| 12.21.11 01:30 AM | 0,0000 | 23,59 | 27,34 | 409,12 | 12.28.11 01:30 AM | 0,0548 | 25,48 | 20,88 | 871,77 |
| 12.21.11 01:45 AM | 0,0000 | 23,55 | 26,86 | 396,91 | 12.28.11 01:45 AM | 0,1050 | 25,45 | 20,95 | 875,43 |
| 12.21.11 02:00 AM | -0,0030 | 23,4 | 26,24 | 367 | 12.28.11 02:00 AM | 0,0883 | 25,4 | 20,95 | 872,99 |

**Table A.02.** (Continued)

| Room 50 - location 'A' | | | | | Room 50 - location 'B' | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Date** | **m/s** | **°C** | **%** | **ppm** | **Date** | **m/s** | **°C** | **%** | **ppm** |
| 12.21.11 02:15 AM | -0,0030 | 23,3 | 26,07 | 357,24 | 12.28.11 02:15 AM | 0,0335 | 25,36 | 20,8 | 828,43 |
| 12.21.11 02:30 AM | -0,0030 | 23,23 | 26,09 | 355,41 | 12.28.11 02:30 AM | 0,0259 | 25,36 | 20,8 | 828,43 |
| 12.21.11 02:45 AM | 0,0046 | 23,16 | 26,26 | 352,97 | 12.28.11 02:45 AM | 0,0959 | 25,33 | 20,94 | 855,29 |
| 12.21.11 03:00 AM | 0,0015 | 22,99 | 26,42 | 347,47 | 12.28.11 03:00 AM | 0,0517 | 25,31 | 20,94 | 845,52 |
| 12.21.11 03:15 AM | -0,0030 | 22,82 | 26,47 | 347,47 | 12.28.11 03:15 AM | 0,0411 | 25,31 | 21,12 | 845,52 |
| 12.21.11 03:30 AM | 0,0411 | 22,61 | 26,66 | 342,59 | 12.28.11 03:30 AM | 0,0167 | 25,31 | 21,24 | 867,49 |
| 12.21.11 03:45 AM | 0,0015 | 22,49 | 26,95 | 337,71 | 12.28.11 03:45 AM | 0,0015 | 25,31 | 20,94 | 819,27 |
| 12.21.11 04:00 AM | 0,0122 | 22,42 | 27,25 | 332,82 | 12.28.11 04:00 AM | 0,0350 | 25,33 | 20,87 | 811,95 |
| 12.21.11 04:15 AM | 0,0152 | 22,39 | 27,59 | 332,21 | 12.28.11 04:15 AM | 0,0183 | 25,31 | 20,76 | 807,07 |
| 12.21.11 04:30 AM | 0,0183 | 22,42 | 28,4 | 335,88 | 12.28.11 04:30 AM | 0,0457 | 25,28 | 20,79 | 804,63 |
| 12.21.11 04:45 AM | 0,0000 | 22,37 | 28,74 | 332,82 | 12.28.11 04:45 AM | 0,0654 | 25,28 | 20,79 | 804,63 |
| 12.21.11 05:00 AM | 0,0578 | 22,27 | 28,73 | 334,66 | 12.28.11 05:00 AM | 0,0030 | 25,26 | 20,83 | 811,95 |
| 12.21.11 05:15 AM | -0,0030 | 22,15 | 28,38 | 335,88 | 12.28.11 05:15 AM | 0,1142 | 25,23 | 20,86 | 804,63 |
| 12.21.11 05:30 AM | -0,0020 | 22,11 | 28,18 | 337,71 | 12.28.11 05:30 AM | 0,0609 | 25,19 | 20,71 | 786,93 |
| 12.21.11 05:45 AM | -0,0030 | 22,03 | 28,03 | 337,71 | 12.28.11 05:45 AM | 0,1157 | 25,19 | 20,71 | 780,21 |
| 12.21.11 06:00 AM | 0,0106 | 21,99 | 27,96 | 337,71 | 12.28.11 06:00 AM | 0,0411 | 25,19 | 20,71 | 760,68 |
| 12.21.11 06:15 AM | -0,0030 | 21,99 | 27,9 | 337,71 | 12.28.11 06:15 AM | 0,0868 | 25,23 | 21,08 | 856,51 |
| 12.21.11 06:30 AM | 0,0122 | 22,01 | 27,9 | 347,47 | 12.28.11 06:30 AM | 0,0015 | 25,19 | 21,01 | 823,55 |
| 12.21.11 06:45 AM | -0,0020 | 22,01 | 27,83 | 345,03 | 12.28.11 06:45 AM | 0,0259 | 25,16 | 21,15 | 846,13 |
| 12.21.11 07:00 AM | -0,0020 | 22,03 | 27,83 | 349,3 | 12.28.11 07:00 AM | 0,0594 | 25,14 | 21,26 | 855,29 |
| 12.21.11 07:15 AM | 0,0046 | 22,13 | 27,7 | 345,03 | 12.28.11 07:15 AM | 0,0578 | 25,11 | 21,08 | 824,77 |
| 12.21.11 07:30 AM | 0,0000 | 22,13 | 27,3 | 343,2 | 12.28.11 07:30 AM | 0,0244 | 25,09 | 20,74 | 748,47 |
| 12.21.11 07:45 AM | -0,0030 | 22,03 | 26,68 | 345,03 | 12.28.11 07:45 AM | 0,0289 | 25,09 | 20,34 | 711,85 |
| 12.21.11 08:00 AM | -0,0030 | 21,99 | 26,58 | 352,36 | 12.28.11 08:00 AM | 0,0578 | 25,02 | 20,04 | 674,01 |
| 12.21.11 08:15 AM | 0,0030 | 21,96 | 26,1 | 357,24 | 12.28.11 08:15 AM | 0,0411 | 24,99 | 20,03 | 678,89 |
| 12.21.11 08:30 AM | 0,0091 | 21,99 | 25,93 | 354,8 | 12.28.11 08:30 AM | 0,0076 | 24,97 | 19,96 | 646,55 |
| 12.21.11 08:45 AM | -0,0030 | 22,01 | 24,98 | 352,36 | 12.28.11 08:45 AM | 0,0548 | 24,94 | 20,47 | 638 |
| 12.21.11 09:00 AM | 0,0030 | 21,99 | 24,44 | 350,52 | 12.28.11 09:00 AM | 0,0320 | 24,92 | 20,4 | 644,1 |
| 12.21.11 09:15 AM | 0,0061 | 21,94 | 24,03 | 349,91 | 12.28.11 09:15 AM | 0,0898 | 24,87 | 20,17 | 612,37 |
| 12.21.11 09:30 AM | 0,0076 | 21,94 | 24,09 | 349,3 | 12.28.11 09:30 AM | 0,0304 | 24,8 | 19,61 | 592,22 |
| 12.21.11 09:45 AM | 0,0213 | 22,03 | 24,58 | 421,33 | 12.28.11 09:45 AM | 0,0228 | 24,77 | 19,43 | 584,9 |
| 12.21.11 10:00 AM | 0,0152 | 22,13 | 24,58 | 461 | 12.28.11 10:00 AM | 0,0502 | 24,75 | 19,28 | 589,78 |
| 12.21.11 10:15 AM | -0,0030 | 22,15 | 24,59 | 465,27 | 12.28.11 10:15 AM | 0,0898 | 24,7 | 19,13 | 593,44 |
| 12.21.11 10:30 AM | 0,0076 | 22,2 | 24,59 | 480,53 | 12.28.11 10:30 AM | 0,0091 | 24,7 | 19,13 | 602,6 |
| 12.21.11 10:45 AM | 0,0015 | 22,25 | 24,53 | 485,41 | 12.28.11 10:45 AM | 0,0061 | 24,68 | 19,2 | 615,42 |
| 12.21.11 11:00 AM | -0,0030 | 22,32 | 24,16 | 457,95 | 12.28.11 11:00 AM | 0,0715 | 24,65 | 19,2 | 641,66 |

**Table A.02.** (Continued)

| Room 50 - location 'A' | | | | | Room 50 - location 'B' | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Date** | **m/s** | **°C** | **%** | **ppm** | **Date** | **m/s** | **°C** | **%** | **ppm** |
| 12.21.11 11:15 AM | 0,0228 | 22,3 | 23,78 | 438,42 | 12.28.11 11:15 AM | 0,0000 | 24,61 | 19,2 | 650,82 |
| 12.21.11 11:30 AM | 0,0015 | 22,32 | 23,98 | 456,12 | 12.28.11 11:30 AM | 0,0350 | 24,61 | 19,2 | 660,58 |
| 12.21.11 11:45 AM | -0,0030 | 22,39 | 24,19 | 481,75 | 12.28.11 11:45 AM | 0,0381 | 24,58 | 19,23 | 665,47 |
| 12.21.11 12:00 PM | 0,0000 | 22,44 | 24,06 | 504,94 | 12.28.11 12:00 PM | 0,0487 | 24,58 | 19,31 | 692,32 |
| 12.21.11 12:15 PM | 0,0106 | 22,51 | 24,68 | 583,68 | 12.28.11 12:15 PM | 0,0761 | 24,58 | 19,34 | 708,8 |
| 12.21.11 12:30 PM | 0,0000 | 22,61 | 24,62 | 603,21 | 12.28.11 12:30 PM | 0,0594 | 24,58 | 19,42 | 742,98 |
| 12.21.11 12:45 PM | -0,0020 | 22,66 | 25,92 | 661,8 | 12.28.11 12:45 PM | 0,0183 | 24,61 | 19,57 | 758,85 |
| 12.21.11 01:00 PM | -0,0020 | 22,73 | 26,74 | 722,84 | 12.28.11 01:00 PM | 0,0487 | 24,61 | 19,49 | 773,5 |
| 12.21.11 01:15 PM | -0,0030 | 22,87 | 27,63 | 811,95 | 12.28.11 01:15 PM | 0,0928 | 24,63 | 19,72 | 802,19 |
| 12.21.11 01:30 PM | 0,0076 | 23,06 | 28,66 | 921,81 | 12.28.11 01:30 PM | 0,0700 | 24,65 | 19,94 | 841,25 |
| 12.21.11 01:45 PM | -0,0030 | 23,26 | 29,14 | 1.023,13 | 12.28.11 01:45 PM | 0,0213 | 24,68 | 20,16 | 872,38 |
| 12.21.11 02:00 PM | -0,0030 | 23,33 | 29,01 | 1.012,76 | 12.28.11 02:00 PM | 0,0274 | 24,65 | 20,68 | 938,29 |
| 12.21.11 02:15 PM | -0,0030 | 23,4 | 29,59 | 1.073,79 | 12.28.11 02:15 PM | 0,0578 | 24,68 | 21,05 | 969,42 |
| 12.21.11 02:30 PM | -0,0020 | 23,62 | 30,32 | 1.201,35 | 12.28.11 02:30 PM | 0,0944 | 24,73 | 21,2 | 1.032,90 |
| 12.21.11 02:45 PM | 0,0030 | 23,79 | 31,14 | 1.309,39 | 12.28.11 02:45 PM | 0,0670 | 24,77 | 21,31 | 1.069,52 |
| 12.21.11 03:00 PM | 0,0061 | 23,91 | 31,69 | 1.402,77 | 12.28.11 03:00 PM | 0,0061 | 24,77 | 21,42 | 1.072,57 |
| 12.21.11 03:15 PM | 0,0015 | 23,98 | 31,63 | 1.281,92 | 12.28.11 03:15 PM | 0,0335 | 24,8 | 21,79 | 1.142,15 |
| 12.21.11 03:30 PM | -0,0020 | 24,05 | 31,77 | 1.287,41 | 12.28.11 03:30 PM | 0,0198 | 24,82 | 22,45 | 1.234,92 |
| 12.21.11 03:45 PM | 0,0015 | 24,12 | 31,47 | 1.225,77 | 12.28.11 03:45 PM | 0,0792 | 24,87 | 22,49 | 1.240,42 |
| 12.21.11 04:00 PM | -0,0020 | 24,17 | 31,44 | 1.223,94 | 12.28.11 04:00 PM | 0,0244 | 24,97 | 23,49 | 1.394,23 |
| 12.21.11 04:15 PM | 0,0061 | 24,15 | 31,17 | 1.122,62 | 12.28.11 04:15 PM | 0,0015 | 24,97 | 23,16 | 1.281,92 |
| 12.21.11 04:30 PM | -0,0030 | 24,15 | 30,97 | 1.078,67 | 12.28.11 04:30 PM | 0,0213 | 24,94 | 23,27 | 1.301,45 |
| 12.21.11 04:45 PM | -0,0030 | 24,12 | 30,6 | 1.015,20 | 12.28.11 04:45 PM | 0,0046 | 24,92 | 23,38 | 1.312,44 |
| 12.21.11 05:00 PM | 0,0015 | 24,1 | 30,02 | 885,8 | 12.28.11 05:00 PM | 0,0426 | 24,92 | 23,56 | 1.325,26 |
| 12.21.11 05:15 PM | 0,0122 | 24,07 | 29,24 | 804,63 | 12.28.11 05:15 PM | 0,0441 | 24,94 | 23,71 | 1.320,37 |
| 12.21.11 05:30 PM | 0,0000 | 24,1 | 29,35 | 826,6 | 12.28.11 05:30 PM | 0,0167 | 24,97 | 23,71 | 1.369,20 |
| 12.21.11 05:45 PM | -0,0030 | 24,12 | 28,71 | 778,38 | 12.28.11 05:45 PM | 0,0228 | 25,09 | 24,08 | 1.393,62 |
| 12.21.11 06:00 PM | -0,0030 | 24,07 | 28,13 | 672,18 | 12.28.11 06:00 PM | 0,0106 | 25,09 | 23,75 | 1.349,06 |
| 12.21.11 06:15 PM | -0,0030 | 24,03 | 28,19 | 652,65 | 12.28.11 06:15 PM | 0,0274 | 25,07 | 23,2 | 1.237,98 |
| 12.21.11 06:30 PM | 0,0015 | 24 | 28,05 | 652,04 | 12.28.11 06:30 PM | 0,0152 | 25,07 | 23,49 | 1.258,73 |
| 12.21.11 06:45 PM | 0,0030 | 24 | 27,85 | 627,62 | 12.28.11 06:45 PM | 0,0304 | 25,02 | 22,98 | 1.176,94 |
| 12.21.11 07:00 PM | 0,0061 | 23,98 | 28,02 | 659,36 | 12.28.11 07:00 PM | 0,0289 | 24,97 | 23,05 | 1.139,71 |
| 12.21.11 07:15 PM | 0,0167 | 23,98 | 27,78 | 640,44 | 12.28.11 07:15 PM | 0,0091 | 24,92 | 22,53 | 1.076,84 |
| 12.21.11 07:30 PM | 0,0030 | 23,95 | 27,37 | 605,65 | 12.28.11 07:30 PM | 0,0654 | 24,87 | 22,53 | 1.050,60 |
| 12.21.11 07:45 PM | -0,0030 | 23,95 | 27,17 | 597,72 | 12.28.11 07:45 PM | -0,0020 | 24,82 | 21,94 | 970,03 |
| 12.21.11 08:00 PM | -0,0030 | 23,93 | 26,93 | 585,51 | 12.28.11 08:00 PM | 0,0106 | 24,8 | 22,01 | 979,19 |

**Table A.02.** (Continued)

| Room 50 - location 'A' | | | | | Room 50 - location 'B' | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Date** | **m/s** | **°C** | **%** | **ppm** | **Date** | **m/s** | **°C** | **%** | **ppm** |
| 12.21.11 08:15 PM | -0,0030 | 23,91 | 26,96 | 578,8 | 12.28.11 08:15 PM | 0,0654 | 24,8 | 21,68 | 929,14 |
| 12.21.11 08:30 PM | -0,0030 | 23,91 | 27,03 | 595,89 | 12.28.11 08:30 PM | 0,0152 | 24,75 | 21,24 | 871,77 |
| 12.21.11 08:45 PM | -0,0030 | 23,91 | 26,69 | 569,03 | 12.28.11 08:45 PM | 0,0289 | 24,73 | 20,9 | 824,16 |
| 12.21.11 09:00 PM | -0,0030 | 23,91 | 26,69 | 581,24 | 12.28.11 09:00 PM | 0,0228 | 24,75 | 21,05 | 890,08 |
| 12.21.11 09:15 PM | -0,0030 | 23,91 | 26,55 | 563,54 | 12.28.11 09:15 PM | 0,0015 | 24,8 | 21,2 | 851,01 |
| 12.21.11 09:30 PM | -0,0030 | 23,91 | 26,55 | 566,59 | 12.28.11 09:30 PM | 0,0030 | 24,8 | 21,72 | 930,36 |
| 12.21.11 09:45 PM | -0,0030 | 23,91 | 26,52 | 565,98 | 12.28.11 09:45 PM | -0,0030 | 24,8 | 21,13 | 816,83 |
| 12.21.11 10:00 PM | 0,0000 | 23,88 | 26,28 | 539,12 | 12.28.11 10:00 PM | 0,0061 | 24,77 | 20,69 | 765,56 |
| 12.21.11 10:15 PM | -0,0030 | 23,91 | 25,94 | 517,15 | 12.28.11 10:15 PM | 0,0198 | 24,77 | 20,43 | 764,95 |
| 12.21.11 10:30 PM | -0,0030 | 23,88 | 25,83 | 502,5 | 12.28.11 10:30 PM | 0,0091 | 24,75 | 20,32 | 742,98 |
| 12.21.11 10:45 PM | -0,0030 | 23,86 | 25,59 | 470,15 | 12.28.11 10:45 PM | 0,0122 | 24,77 | 20,8 | 829,65 |
| 12.21.11 11:00 PM | -0,0030 | 23,83 | 25,46 | 455,51 | 12.28.11 11:00 PM | 0,0046 | 24,8 | 21,06 | 889,47 |
| 12.21.11 11:15 PM | -0,0030 | 23,83 | 25,32 | 446,35 | 12.28.11 11:15 PM | 0,0304 | 24,8 | 20,61 | 818,66 |
| 12.21.11 11:30 PM | -0,0030 | 23,83 | 25,25 | 443,91 | 12.28.11 11:30 PM | 0,0167 | 24,75 | 20,83 | 845,52 |
| 12.21.11 11:45 PM | -0,0030 | 23,81 | 25,22 | 445,74 | 12.28.11 11:45 PM | 0,0000 | 24,75 | 20,76 | 865,66 |
| 12.22.11 12:00 AM | -0,0020 | 23,81 | 25,11 | 438,42 | 12.29.11 12:00 AM | 0,0335 | 24,75 | 20,87 | 860,78 |
| 12.22.11 12:15 AM | -0,0030 | 23,79 | 25,04 | 440,86 | 12.29.11 12:15 AM | 0,0076 | 24,8 | 21,42 | 947,45 |
| 12.22.11 12:30 AM | -0,0020 | 23,76 | 24,87 | 438,42 | 12.29.11 12:30 AM | 0,0304 | 24,77 | 21,13 | 874,82 |
| 12.22.11 12:45 AM | -0,0020 | 23,74 | 24,83 | 438,42 | 12.29.11 12:45 AM | 0,0137 | 24,77 | 20,69 | 872,38 |
| 12.22.11 01:00 AM | 0,0000 | 23,74 | 24,77 | 435,97 | 12.29.11 01:00 AM | -0,0020 | 24,75 | 20,91 | 888,85 |
| 12.22.11 01:15 AM | -0,0030 | 23,71 | 24,63 | 431,09 | 12.29.11 01:15 AM | 0,0228 | 24,73 | 20,9 | 926,7 |
| 12.22.11 01:30 AM | -0,0030 | 23,69 | 24,69 | 433,53 | 12.29.11 01:30 AM | 0,0076 | 24,73 | 20,76 | 858,95 |
| 12.22.11 01:45 AM | -0,0030 | 23,69 | 24,63 | 428,65 | 12.29.11 01:45 AM | 0,0091 | 24,7 | 20,61 | 816,83 |
| 12.22.11 02:00 AM | 0,0030 | 23,67 | 24,49 | 426,21 | 12.29.11 02:00 AM | 0,0000 | 24,68 | 20,68 | 811,95 |
| 12.22.11 02:15 AM | -0,0030 | 23,67 | 24,56 | 428,04 | 12.29.11 02:15 AM | 0,0411 | 24,7 | 20,98 | 877,26 |
| 12.22.11 02:30 AM | -0,0030 | 23,64 | 24,45 | 425,6 | 12.29.11 02:30 AM | 0,0259 | 24,7 | 20,61 | 811,95 |
| 12.22.11 02:45 AM | -0,0030 | 23,64 | 24,42 | 431,09 | 12.29.11 02:45 AM | 0,0091 | 24,68 | 20,61 | 799,74 |
| 12.22.11 03:00 AM | 0,0015 | 23,64 | 24,35 | 423,77 | 12.29.11 03:00 AM | 0,0715 | 24,61 | 20,38 | 770,45 |
| 12.22.11 03:15 AM | -0,0030 | 23,62 | 24,35 | 428,04 | 12.29.11 03:15 AM | 0,0183 | 24,61 | 20,27 | 763,73 |
| 12.22.11 03:30 AM | 0,0015 | 23,62 | 24,31 | 421,33 | 12.29.11 03:30 AM | 0,0289 | 24,61 | 20,01 | 725,28 |
| 12.22.11 03:45 AM | -0,0030 | 23,59 | 24,35 | 423,16 | 12.29.11 03:45 AM | 0,0320 | 24,61 | 19,86 | 711,85 |
| 12.22.11 04:00 AM | -0,0020 | 23,59 | 24,31 | 420,72 | 12.29.11 04:00 AM | 0,0746 | 24,58 | 19,71 | 696,59 |
| 12.22.11 04:15 AM | 0,0000 | 23,57 | 24,28 | 418,88 | 12.29.11 04:15 AM | 0,0244 | 24,56 | 19,64 | 694,15 |
| 12.22.11 04:30 AM | 0,0015 | 23,55 | 24,21 | 410,95 | 12.29.11 04:30 AM | 0,0335 | 24,53 | 19,56 | 696,59 |
| 12.22.11 04:45 AM | -0,0020 | 23,55 | 24,27 | 411,56 | 12.29.11 04:45 AM | 0,0122 | 24,51 | 19,56 | 690,49 |
| 12.22.11 05:00 AM | -0,0020 | 23,52 | 24,2 | 411,56 | 12.29.11 05:00 AM | 0,0533 | 24,48 | 19,49 | 672,79 |

**Table A.02.** (Continued)

| Room 50 - location 'A' | | | | | Room 50 - location 'B' | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Date** | **m/s** | **°C** | **%** | **ppm** | **Date** | **m/s** | **°C** | **%** | **ppm** |
| 12.22.11 05:15 AM | -0,0030 | 23,5 | 24,2 | 414 | 12.29.11 05:15 AM | 0,0441 | 24,41 | 19,33 | 653,26 |
| 12.22.11 05:30 AM | 0,0000 | 23,5 | 24,2 | 413,39 | 12.29.11 05:30 AM | 0,0883 | 24,39 | 19,26 | 648,38 |
| 12.22.11 05:45 AM | 0,0061 | 23,5 | 24,34 | 421,33 | 12.29.11 05:45 AM | 0,0700 | 24,39 | 19,18 | 631,29 |
| 12.22.11 06:00 AM | 0,0152 | 23,5 | 24,27 | 423,77 | 12.29.11 06:00 AM | 0,0654 | 24,39 | 19,07 | 625,79 |
| 12.22.11 06:15 AM | 0,0091 | 23,5 | 24,41 | 423,77 | 12.29.11 06:15 AM | 0,0533 | 24,36 | 18,81 | 597,72 |
| 12.22.11 06:30 AM | 0,0137 | 23,5 | 24,61 | 430,48 | 12.29.11 06:30 AM | 0,0000 | 24,32 | 18,73 | 582,46 |
| 12.22.11 06:45 AM | -0,0030 | 23,52 | 24,75 | 441,47 | 12.29.11 06:45 AM | 0,0320 | 24,29 | 18,58 | 561,1 |
| 12.22.11 07:00 AM | 0,0030 | 23,52 | 24,72 | 445,74 | 12.29.11 07:00 AM | 0,0289 | 24,29 | 18,43 | 551,33 |
| 12.22.11 07:15 AM | -0,0030 | 23,52 | 24,68 | 443,3 | 12.29.11 07:15 AM | 0,0624 | 24,29 | 18,36 | 550,72 |
| 12.22.11 07:30 AM | -0,0030 | 23,55 | 24,72 | 448,18 | 12.29.11 07:30 AM | 0,0304 | 24,22 | 18,28 | 531,19 |
| 12.22.11 07:45 AM | -0,0020 | 23,55 | 24,68 | 450,62 | 12.29.11 07:45 AM | 0,0106 | 24,22 | 18,36 | 526,92 |
| 12.22.11 08:00 AM | 0,0137 | 23,59 | 24,76 | 450,62 | 12.29.11 08:00 AM | 0,0411 | 24,2 | 18,28 | 509,83 |
| 12.22.11 08:15 AM | 0,0046 | 23,62 | 24,89 | 470,15 | 12.29.11 08:15 AM | 0,0015 | 24,2 | 18,13 | 494,57 |
| 12.22.11 08:30 AM | 0,0015 | 23,67 | 25,17 | 482,97 | 12.29.11 08:30 AM | 0,0350 | 24,2 | 18,21 | 495,18 |
| 12.22.11 08:45 AM | 0,0091 | 23,71 | 25,45 | 502,5 | 12.29.11 08:45 AM | 0,0137 | 24,2 | 19,84 | 504,33 |
| 12.22.11 09:00 AM | 0,0411 | 23,76 | 25,62 | 531,8 | 12.29.11 09:00 AM | 0,0137 | 24,2 | 19,62 | 497,01 |
| 12.22.11 09:15 AM | 0,0137 | 23,83 | 25,93 | 581,24 | 12.29.11 09:15 AM | 0,0152 | 24,15 | 19,02 | 493,35 |
| 12.22.11 09:30 AM | 0,0015 | 23,88 | 26,14 | 613,59 | 12.29.11 09:30 AM | 0,0517 | 24,15 | 18,72 | 495,18 |
| 12.22.11 09:45 AM | -0,0020 | 23,93 | 26,42 | 639,83 | 12.29.11 09:45 AM | 0,0304 | 24,12 | 18,54 | 502,5 |
| 12.22.11 10:00 AM | -0,0020 | 23,98 | 26,66 | 656,92 | 12.29.11 10:00 AM | 0,0776 | 24,12 | 18,42 | 515,32 |
| 12.22.11 10:15 AM | -0,0030 | 24,03 | 27 | 686,83 | 12.29.11 10:15 AM | 0,0381 | 24,1 | 18,27 | 509,83 |
| 12.22.11 10:30 AM | -0,0030 | 24,05 | 26,97 | 677,06 | 12.29.11 10:30 AM | 0,0517 | 24,07 | 18,35 | 529,97 |
| 12.22.11 10:45 AM | -0,0030 | 24,1 | 27,25 | 696,59 | 12.29.11 10:45 AM | 0,0852 | 24,07 | 18,27 | 532,41 |
| 12.22.11 11:00 AM | -0,0030 | 24,15 | 27,25 | 708,19 | 12.29.11 11:00 AM | 0,0274 | 24,07 | 18,09 | 526,31 |
| 12.22.11 11:15 AM | 0,0320 | 24,2 | 27,66 | 763,12 | 12.29.11 11:15 AM | 0,0441 | 24,03 | 18,01 | 529,36 |
| 12.22.11 11:30 AM | -0,0030 | 24,24 | 27,73 | 819,27 | 12.29.11 11:30 AM | 0,0441 | 24,03 | 18,12 | 541,56 |
| 12.22.11 11:45 AM | 0,0000 | 24,27 | 27,57 | 755,8 | 12.29.11 11:45 AM | 0,0517 | 24,03 | 18,16 | 548,89 |
| 12.22.11 12:00 PM | -0,0030 | 24,27 | 27,4 | 733,22 | 12.29.11 12:00 PM | 0,0761 | 24,03 | 18,2 | 558,65 |
| 12.22.11 12:15 PM | 0,0076 | 24,29 | 27,23 | 686,83 | 12.29.11 12:15 PM | 0,0639 | 24,05 | 18,35 | 580,02 |
| 12.22.11 12:30 PM | -0,0030 | 24,32 | 27,13 | 662,41 | 12.29.11 12:30 PM | 0,1004 | 24,1 | 18,35 | 595,28 |
| 12.22.11 12:45 PM | -0,0030 | 24,32 | 27,06 | 642,88 | 12.29.11 12:45 PM | 0,0411 | 24,1 | 18,35 | 597,11 |
| 12.22.11 01:00 PM | 0,0030 | 24,36 | 26,89 | 611,15 | 12.29.11 01:00 PM | 0,0274 | 24,12 | 18,65 | 628,85 |
| 12.22.11 01:15 PM | -0,0030 | 24,39 | 26,72 | 593,44 | 12.29.11 01:15 PM | 0,1385 | 24,17 | 18,58 | 653,26 |
| 12.22.11 01:30 PM | 0,0076 | 24,39 | 26,66 | 583,07 | 12.29.11 01:30 PM | 0,0654 | 24,1 | 18,5 | 641,66 |
| 12.22.11 01:45 PM | -0,0030 | 24,39 | 26,45 | 573,91 | 12.29.11 01:45 PM | 0,0061 | 23,98 | 18,83 | 657,53 |
| 12.22.11 02:00 PM | 0,0000 | 24,41 | 26,52 | 603,21 | 12.29.11 02:00 PM | -0,0020 | 23,88 | 19,23 | 697,81 |

**Table A.02.** (Continued)

| Room 50 - location 'A' | | | | | Room 50 - location 'B' | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Date** | **m/s** | **°C** | **%** | **ppm** | **Date** | **m/s** | **°C** | **%** | **ppm** |
| 12.22.11 02:15 PM | -0,0030 | 24,39 | 26,83 | 639,83 | 12.29.11 02:15 PM | 0,0076 | 23,79 | 19,41 | 714,29 |
| 12.22.11 02:30 PM | -0,0030 | 24,36 | 26,99 | 669,13 | 12.29.11 02:30 PM | 0,0441 | 23,81 | 19,82 | 750,92 |
| 12.22.11 02:45 PM | -0,0030 | 24,36 | 27,61 | 735,66 | 12.29.11 02:45 PM | 0,0274 | 23,93 | 19,82 | 761,29 |
| 12.22.11 03:00 PM | 0,0046 | 24,36 | 27,54 | 742,98 | 12.29.11 03:00 PM | 0,0061 | 24,05 | 19,68 | 775,33 |
| 12.22.11 03:15 PM | 0,0046 | 24,36 | 27,4 | 711,24 | 12.29.11 03:15 PM | 0,0304 | 24,2 | 19,88 | 806,46 |
| 12.22.11 03:30 PM | 0,0015 | 24,34 | 26,99 | 671,57 | 12.29.11 03:30 PM | 0,0533 | 24,29 | 20,07 | 833,31 |
| 12.22.11 03:45 PM | 0,0030 | 24,29 | 26,58 | 627,01 | 12.29.11 03:45 PM | 0,0320 | 24,34 | 20,14 | 879,7 |
| 12.22.11 04:00 PM | 0,0000 | 24,27 | 26,31 | 602,6 | 12.29.11 04:00 PM | 0,0396 | 24,34 | 20,29 | 860,17 |
| 12.22.11 04:15 PM | -0,0030 | 24,24 | 25,96 | 583,07 | 12.29.11 04:15 PM | 0,0304 | 24,34 | 20,44 | 887,02 |
| 12.22.11 04:30 PM | -0,0030 | 24,24 | 25,83 | 571,47 | 12.29.11 04:30 PM | 0,0198 | 24,34 | 20,22 | 874,82 |
| 12.22.11 04:45 PM | 0,0000 | 24,22 | 25,72 | 562,93 | 12.29.11 04:45 PM | 0,0244 | 24,34 | 20,36 | 882,14 |
| 12.22.11 05:00 PM | 0,0228 | 24,22 | 25,69 | 570,86 | 12.29.11 05:00 PM | 0,0426 | 24,36 | 20,51 | 879,7 |
| 12.22.11 05:15 PM | 0,0000 | 24,22 | 25,62 | 564,15 | 12.29.11 05:15 PM | 0,0137 | 24,34 | 20,59 | 883,36 |
| 12.22.11 05:30 PM | -0,0030 | 24,22 | 25,55 | 558,65 | 12.29.11 05:30 PM | 0,0244 | 24,36 | 20,73 | 894,35 |
| 12.22.11 05:45 PM | 0,0106 | 24,2 | 25,62 | 563,54 | 12.29.11 05:45 PM | 0,0030 | 24,39 | 20,96 | 906,56 |
| 12.22.11 06:00 PM | 0,0076 | 24,2 | 25,62 | 569,03 | 12.29.11 06:00 PM | 0,0228 | 24,36 | 20,7 | 884,58 |
| 12.22.11 06:15 PM | 0,0076 | 24,22 | 25,72 | 588,56 | 12.29.11 06:15 PM | 0,0533 | 24,39 | 20,81 | 902,28 |
| 12.22.11 06:30 PM | -0,0020 | 24,24 | 26,13 | 666,69 | 12.29.11 06:30 PM | 0,0000 | 24,41 | 20,18 | 840,64 |
| 12.22.11 06:45 PM | -0,0020 | 24,24 | 25,9 | 605,65 | 12.29.11 06:45 PM | 0,0137 | 24,41 | 20,37 | 872,99 |
| 12.22.11 07:00 PM | -0,0030 | 24,27 | 25,97 | 617,86 | 12.29.11 07:00 PM | 0,0213 | 24,44 | 20,44 | 889,47 |
| 12.22.11 07:15 PM | -0,0020 | 24,27 | 26,1 | 632,51 | 12.29.11 07:15 PM | 0,0076 | 24,44 | 20,15 | 874,82 |
| 12.22.11 07:30 PM | 0,0000 | 24,29 | 26,04 | 627,62 | 12.29.11 07:30 PM | 0,0472 | 24,46 | 20,15 | 872,38 |
| 12.22.11 07:45 PM | 0,0030 | 24,29 | 26,27 | 642,27 | 12.29.11 07:45 PM | 0,0441 | 24,41 | 19,85 | 841,25 |
| 12.22.11 08:00 PM | -0,0030 | 24,32 | 26,55 | 657,53 | 12.29.11 08:00 PM | 0,0304 | 24,39 | 19,7 | 816,83 |
| 12.22.11 08:15 PM | -0,0030 | 24,32 | 26,51 | 637,39 | 12.29.11 08:15 PM | 0,0015 | 24,41 | 19,78 | 821,72 |
| 12.22.11 08:30 PM | -0,0030 | 24,34 | 26,79 | 671,57 | 12.29.11 08:30 PM | 0,0472 | 24,41 | 20 | 857,12 |
| 12.22.11 08:45 PM | 0,0076 | 24,36 | 26,79 | 659,97 | 12.29.11 08:45 PM | -0,0030 | 24,41 | 20,18 | 894,35 |
| 12.22.11 09:00 PM | -0,0020 | 24,36 | 26,79 | 659,36 | 12.29.11 09:00 PM | 0,0061 | 24,41 | 20,33 | 895,57 |
| 12.22.11 09:15 PM | -0,0030 | 24,41 | 26,96 | 700,87 | 12.29.11 09:15 PM | 0,0076 | 24,39 | 20,22 | 882,14 |
| 12.22.11 09:30 PM | -0,0030 | 24,41 | 26,79 | 664,25 | 12.29.11 09:30 PM | 0,0137 | 24,36 | 20,29 | 893,74 |
| 12.22.11 09:45 PM | 0,0030 | 24,41 | 26,86 | 649,6 | 12.29.11 09:45 PM | 0,0289 | 24,34 | 19,92 | 843,08 |
| 12.22.11 10:00 PM | -0,0030 | 24,44 | 26,93 | 667,3 | 12.29.11 10:00 PM | 0,0061 | 24,34 | 20,51 | 899,23 |
| 12.22.11 10:15 PM | 0,0000 | 24,44 | 27 | 655,09 | 12.29.11 10:15 PM | 0,0228 | 24,39 | 20,66 | 910,22 |
| 12.22.11 10:30 PM | 0,0015 | 24,46 | 27,07 | 644,71 | 12.29.11 10:30 PM | 0,0046 | 24,44 | 20,67 | 923,65 |
| 12.22.11 10:45 PM | -0,0030 | 24,46 | 27,04 | 620,3 | 12.29.11 10:45 PM | 0,0472 | 24,44 | 20,59 | 914,49 |
| 12.22.11 11:00 PM | -0,0030 | 24,48 | 27,21 | 620,3 | 12.29.11 11:00 PM | 0,0061 | 24,48 | 20,67 | 924,26 |

**Table A.02.** (Continued)

| Room 50 - location 'A' | | | | | Room 50 - location 'B' | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Date** | **m/s** | **°C** | **%** | **ppm** | **Date** | **m/s** | **°C** | **%** | **ppm** |
| 12.22.11 11:15 PM | 0,0000 | 24,48 | 27,55 | 620,3 | 12.29.11 11:15 PM | 0,0381 | 24,48 | 20,74 | 932,8 |
| 12.22.11 11:30 PM | 0,0061 | 24,48 | 27,72 | 564,15 | 12.29.11 11:30 PM | 0,0213 | 24,51 | 20,89 | 950,5 |
| 12.22.11 11:45 PM | -0,0030 | 24,48 | 28,02 | 575,74 | 12.29.11 11:45 PM | 0,0259 | 24,56 | 21,19 | 979,19 |
| 12.23.11 12:00 AM | -0,0030 | 24,48 | 28,53 | 588,56 | 12.30.11 12:00 AM | 0,0624 | 24,58 | 21,26 | 992 |
| 12.23.11 12:15 AM | -0,0030 | 24,48 | 28,7 | 587,95 | 12.30.11 12:15 AM | 0,0548 | 24,56 | 21,26 | 994,45 |
| 12.23.11 12:30 AM | 0,0046 | 24,44 | 28,49 | 526,31 | 12.30.11 12:30 AM | 0,0320 | 24,48 | 20,74 | 921,2 |
| 12.23.11 12:45 AM | -0,0030 | 24,44 | 28,83 | 558,65 | 12.30.11 12:45 AM | 0,0715 | 24,46 | 20,96 | 962,71 |
| 12.23.11 01:00 AM | -0,0030 | 24,46 | 28,87 | 571,47 | 12.30.11 01:00 AM | 0,0198 | 24,46 | 21,04 | 952,33 |
| 12.23.11 01:15 AM | 0,0000 | 24,46 | 28,9 | 561,1 | 12.30.11 01:15 AM | 0,0198 | 24,46 | 21,15 | 992 |
| 12.23.11 01:30 AM | -0,0030 | 24,44 | 28,63 | 514,71 | 12.30.11 01:30 AM | 0,0137 | 24,46 | 21,18 | 972,47 |
| 12.23.11 01:45 AM | 0,0046 | 24,41 | 28,56 | 475,04 | 12.30.11 01:45 AM | 0,0015 | 24,48 | 21,33 | 996,89 |
| 12.23.11 02:00 AM | -0,0020 | 24,41 | 29,58 | 606,26 | 12.30.11 02:00 AM | -0,0020 | 24,44 | 21,4 | 996,89 |
| 12.23.11 02:15 AM | 0,0015 | 24,41 | 29,44 | 563,54 | 12.30.11 02:15 AM | 0,0213 | 24,44 | 21,25 | 989,56 |
| 12.23.11 02:30 AM | 0,0000 | 24,41 | 29,34 | 516,54 | 12.30.11 02:30 AM | 0,0426 | 24,46 | 21,33 | 967,59 |
| 12.23.11 02:45 AM | -0,0030 | 24,39 | 28,76 | 487,24 | 12.30.11 02:45 AM | 0,0106 | 24,46 | 20,96 | 927,92 |
| 12.23.11 03:00 AM | -0,0030 | 24,34 | 28,55 | 479,92 | 12.30.11 03:00 AM | -0,0030 | 24,41 | 20,96 | 954,77 |
| 12.23.11 03:15 AM | 0,0183 | 24,34 | 28,42 | 450,62 | 12.30.11 03:15 AM | 0,0213 | 24,41 | 21 | 947,45 |
| 12.23.11 03:30 AM | 0,0046 | 24,29 | 28,21 | 443,91 | 12.30.11 03:30 AM | -0,0020 | 24,39 | 21,03 | 916,32 |
| 12.23.11 03:45 AM | 0,0061 | 24,29 | 28,21 | 442,69 | 12.30.11 03:45 AM | 0,0259 | 24,39 | 20,85 | 912,05 |
| 12.23.11 04:00 AM | 0,0030 | 24,27 | 28,07 | 443,91 | 12.30.11 04:00 AM | 0,0259 | 24,34 | 20,73 | 914,49 |
| 12.23.11 04:15 AM | -0,0030 | 24,27 | 27,94 | 443,3 | 12.30.11 04:15 AM | 0,0472 | 24,29 | 20,73 | 910,22 |
| 12.23.11 04:30 AM | 0,0030 | 24,24 | 27,8 | 438,42 | 12.30.11 04:30 AM | 0,0091 | 24,24 | 20,99 | 959,66 |
| 12.23.11 04:45 AM | -0,0030 | 24,24 | 27,73 | 441,47 | 12.30.11 04:45 AM | 0,0563 | 24,22 | 20,91 | 916,32 |
| 12.23.11 05:00 AM | -0,0030 | 24,22 | 27,6 | 437,81 | 12.30.11 05:00 AM | 0,0396 | 24,22 | 20,8 | 916,93 |
| 12.23.11 05:15 AM | -0,0030 | 24,22 | 27,53 | 458,56 | 12.30.11 05:15 AM | -0,0020 | 24,22 | 20,73 | 901,67 |
| 12.23.11 05:30 AM | -0,0030 | 24,2 | 27,53 | 432,92 | 12.30.11 05:30 AM | 0,0365 | 24,17 | 20,69 | 883,97 |
| 12.23.11 05:45 AM | -0,0030 | 24,24 | 27,87 | 536,07 | 12.30.11 05:45 AM | 0,0198 | 24,12 | 20,57 | 872,99 |
| 12.23.11 06:00 AM | 0,0061 | 24,32 | 27,87 | 472,6 | 12.30.11 06:00 AM | 0,0304 | 24,05 | 20,64 | 847,96 |
| 12.23.11 06:15 AM | -0,0030 | 24,34 | 28,15 | 465,27 | 12.30.11 06:15 AM | 0,0517 | 24,03 | 20,64 | 841,25 |
| 12.23.11 06:30 AM | -0,0030 | 24,36 | 28,01 | 497,01 | 12.30.11 06:30 AM | 0,0213 | 24 | 20,42 | 816,83 |
| 12.23.11 06:45 AM | -0,0030 | 24,36 | 28,22 | 514,1 | 12.30.11 06:45 AM | 0,0533 | 23,98 | 20,27 | 789,98 |
| 12.23.11 07:00 AM | -0,0030 | 24,41 | 28,63 | 492,13 | 12.30.11 07:00 AM | 0,0365 | 23,95 | 20,27 | 802,19 |
| 12.23.11 07:15 AM | 0,0076 | 24,41 | 28,02 | 482,36 | 12.30.11 07:15 AM | 0,0167 | 23,93 | 20,01 | 763,73 |
| 12.23.11 07:30 AM | -0,0030 | 24,44 | 28,22 | 514,1 | 12.30.11 07:30 AM | 0,0517 | 23,91 | 19,78 | 723,45 |
| 12.23.11 07:45 AM | -0,0030 | 24,41 | 27,54 | 443,91 | 12.30.11 07:45 AM | 0,0259 | 23,83 | 19,67 | 699,04 |
| 12.23.11 08:00 AM | -0,0030 | 24,39 | 27,61 | 468,32 | 12.30.11 08:00 AM | 0,0046 | 23,81 | 19,59 | 680,11 |

**Table A.02.** (Continued)

| Room 50 - location 'A' | | | | | Room 50 - location 'B' | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Date** | **m/s** | **°C** | **%** | **ppm** | **Date** | **m/s** | **°C** | **%** | **ppm** |
| 12.23.11 08:15 AM | 0,0015 | 24,39 | 27,74 | 478,09 | 12.30.11 08:15 AM | 0,0183 | 23,79 | 19,59 | 680,11 |
| 12.23.11 08:30 AM | -0,0030 | 24,39 | 27,74 | 477,48 | 12.30.11 08:30 AM | 0,0335 | 23,74 | 19,66 | 675,23 |
| 12.23.11 08:45 AM | 0,0076 | 24,39 | 27,81 | 495,18 | 12.30.11 08:45 AM | 0,0548 | 23,64 | 20,03 | 658,14 |
| 12.23.11 09:00 AM | 0,0015 | 24,39 | 27,88 | 526,92 | 12.30.11 09:00 AM | 0,0030 | 23,62 | 19,91 | 641,05 |
| 12.23.11 09:15 AM | 0,0030 | 24,39 | 28,08 | 561,1 | 12.30.11 09:15 AM | 0,0411 | 23,57 | 19,88 | 645,94 |
| 12.23.11 09:30 AM | -0,0030 | 24,36 | 28,35 | 591 | 12.30.11 09:30 AM | 0,0152 | 23,55 | 19,73 | 636,17 |
| 12.23.11 09:45 AM | -0,0030 | 24,39 | 28,56 | 632,51 | 12.30.11 09:45 AM | 0,0761 | 23,55 | 20,02 | 662,41 |
| 12.23.11 10:00 AM | -0,0030 | 24,39 | 28,76 | 657,53 | 12.30.11 10:00 AM | -0,0030 | 23,55 | 20,17 | 686,83 |
| 12.23.11 10:15 AM | -0,0030 | 24,39 | 29,1 | 684,39 | 12.30.11 10:15 AM | 0,0578 | 23,52 | 20,17 | 677,06 |
| 12.23.11 10:30 AM | -0,0030 | 24,41 | 29,07 | 694,15 | 12.30.11 10:30 AM | 0,0183 | 23,47 | 20,28 | 706,97 |
| 12.23.11 10:45 AM | -0,0030 | 24,41 | 28,9 | 691,1 | 12.30.11 10:45 AM | 0,0259 | 23,5 | 20,24 | 705,14 |
| 12.23.11 11:00 AM | -0,0030 | 24,41 | 29,31 | 780,82 | 12.30.11 11:00 AM | 0,0365 | 23,45 | 20,31 | 712,46 |
| 12.23.11 11:15 AM | -0,0030 | 24,46 | 29,44 | 760,68 | 12.30.11 11:15 AM | 0,0259 | 23,42 | 20,31 | 724,06 |
| 12.23.11 11:30 AM | -0,0020 | 24,53 | 29,45 | 772,89 | 12.30.11 11:30 AM | 0,0517 | 23,45 | 20,38 | 738,71 |
| 12.23.11 11:45 AM | -0,0030 | 24,56 | 29,79 | 816,83 | 12.30.11 11:45 AM | 0,0046 | 23,47 | 20,46 | 757,02 |
| 12.23.11 12:00 PM | -0,0030 | 24,56 | 30,09 | 865,66 | 12.30.11 12:00 PM | 0,0913 | 23,52 | 20,68 | 793,03 |
| 12.23.11 12:15 PM | -0,0030 | 24,56 | 30,53 | 861,39 | 12.30.11 12:15 PM | 0,0989 | 23,57 | 20,65 | 802,8 |
| 12.23.11 12:30 PM | -0,0030 | 24,58 | 31,21 | 1.007,87 | 12.30.11 12:30 PM | 0,0594 | 23,59 | 20,47 | 780,82 |
| 12.23.11 12:45 PM | -0,0030 | 24,63 | 31,62 | 1.015,20 | 12.30.11 12:45 PM | 0,0563 | 23,64 | 20,54 | 799,74 |
| 12.23.11 01:00 PM | 0,0000 | 24,73 | 32,43 | 1.088,44 | 12.30.11 01:00 PM | 0,0396 | 23,69 | 20,55 | 792,42 |
| 12.23.11 01:15 PM | 0,0000 | 24,77 | 33,27 | 1.171,45 | 12.30.11 01:15 PM | 0,0411 | 23,74 | 20,77 | 829,65 |
| 12.23.11 01:30 PM | -0,0030 | 24,87 | 33,92 | 1.260,56 | 12.30.11 01:30 PM | 0,0061 | 23,76 | 20,85 | 846,13 |
| 12.23.11 01:45 PM | -0,0030 | 24,92 | 33,59 | 1.194,03 | 12.30.11 01:45 PM | 0,0654 | 23,79 | 20,96 | 855,9 |
| 12.23.11 02:00 PM | -0,0020 | 24,97 | 34,29 | 1.321,59 | 12.30.11 02:00 PM | 0,0548 | 23,83 | 21,14 | 890,08 |
| 12.23.11 02:15 PM | -0,0030 | 25,02 | 34,73 | 1.314,27 | 12.30.11 02:15 PM | 0,0609 | 23,83 | 21,22 | 888,85 |
| 12.23.11 02:30 PM | 0,0106 | 25,07 | 34,67 | 1.250,18 | 12.30.11 02:30 PM | 0,0746 | 23,88 | 21,51 | 928,53 |
| 12.23.11 02:45 PM | -0,0030 | 25,09 | 33,8 | 1.208,68 | 12.30.11 02:45 PM | 0,0259 | 23,93 | 21,74 | 960,27 |
| 12.23.11 03:00 PM | -0,0020 | 25,09 | 34 | 1.142,15 | 12.30.11 03:00 PM | 0,0639 | 23,93 | 22,18 | 1.008,48 |
| 12.23.11 03:15 PM | 0,0076 | 25,11 | 34,01 | 1.073,79 | 12.30.11 03:15 PM | 0,0350 | 24 | 22,29 | 1.018,25 |
| 12.23.11 03:30 PM | 0,0076 | 25,11 | 34,07 | 1.093,93 | 12.30.11 03:30 PM | 0,0411 | 24 | 23,2 | 1.107,97 |
| 12.23.11 03:45 PM | 0,0259 | 25,14 | 35,08 | 1.129,94 | 12.30.11 03:45 PM | 0,0015 | 24,1 | 23,5 | 1.145,20 |
| 12.23.11 04:00 PM | -0,0020 | 25,14 | 35,14 | 1.054,87 | 12.30.11 04:00 PM | 0,0091 | 24,12 | 23,21 | 1.133,00 |
| 12.23.11 04:15 PM | 0,0457 | 25,14 | 34,64 | 1.049,38 | 12.30.11 04:15 PM | 0,0304 | 24,2 | 23,18 | 1.106,14 |
| 12.23.11 04:30 PM | -0,0030 | 25,14 | 33,81 | 917,54 | 12.30.11 04:30 PM | 0,0548 | 24,29 | 23,44 | 1.127,50 |
| 12.23.11 04:45 PM | -0,0030 | 25,09 | 34 | 836,36 | 12.30.11 04:45 PM | 0,0244 | 24,32 | 23,7 | 1.150,09 |
| 12.23.11 05:00 PM | -0,0020 | 25,04 | 32,73 | 721,01 | 12.30.11 05:00 PM | 0,0411 | 24,39 | 23,56 | 1.137,27 |

**Table A.02.** (Continued)

| Room 50 - location 'A' | | | | | Room 50 - location 'B' | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Date** | **m/s** | **°C** | **%** | **ppm** | **Date** | **m/s** | **°C** | **%** | **ppm** |
| 12.23.11 05:15 PM | 0,0106 | 24,94 | 32,05 | 638 | 12.30.11 05:15 PM | 0,0183 | 24,41 | 23,6 | 1.154,97 |
| 12.23.11 05:30 PM | -0,0030 | 24,85 | 31,63 | 578,19 | 12.30.11 05:30 PM | 0,0076 | 24,46 | 23,45 | 1.120,79 |
| 12.23.11 05:45 PM | -0,0020 | 24,77 | 31,29 | 524,48 | 12.30.11 05:45 PM | 0,0091 | 24,44 | 23,42 | 1.099,43 |
| 12.23.11 06:00 PM | -0,0030 | 24,68 | 31,08 | 495,18 | 12.30.11 06:00 PM | 0,0365 | 24,48 | 23,67 | 1.150,09 |
| 12.23.11 06:15 PM | 0,0106 | 24,58 | 30,97 | 478,7 | 12.30.11 06:15 PM | 0,0350 | 24,51 | 23,82 | 1.148,25 |
| 12.23.11 06:30 PM | -0,0030 | 24,48 | 30,86 | 465,27 | 12.30.11 06:30 PM | 0,0046 | 24,51 | 23,46 | 1.098,82 |
| 12.23.11 06:45 PM | 0,0183 | 24,44 | 30,96 | 457,95 | 12.30.11 06:45 PM | 0,0122 | 24,51 | 23,68 | 1.095,76 |
| 12.23.11 07:00 PM | 0,0046 | 24,41 | 30,86 | 457,95 | 12.30.11 07:00 PM | 0,0076 | 24,48 | 23,6 | 1.088,44 |
| 12.23.11 07:15 PM | -0,0030 | 24,41 | 30,96 | 477,48 | 12.30.11 07:15 PM | -0,0020 | 24,39 | 23,52 | 1.068,30 |
| 12.23.11 07:30 PM | 0,0030 | 24,39 | 30,99 | 485,41 | 12.30.11 07:30 PM | 0,0259 | 24,36 | 23,52 | 1.023,13 |
| 12.23.11 07:45 PM | 0,0030 | 24,36 | 30,99 | 487,85 | 12.30.11 07:45 PM | 0,0289 | 24,34 | 23,23 | 987,12 |
| 12.23.11 08:00 PM | 0,0076 | 24,34 | 30,95 | 489,69 | 12.30.11 08:00 PM | 0,0731 | 24,34 | 23,15 | 964,54 |
| 12.23.11 08:15 PM | -0,0030 | 24,32 | 30,98 | 487,24 | 12.30.11 08:15 PM | 0,0167 | 24,36 | 22,94 | 945,62 |
| 12.23.11 08:30 PM | 0,0046 | 24,32 | 31,02 | 492,74 | 12.30.11 08:30 PM | 0,1157 | 24,36 | 22,57 | 901,06 |
| 12.23.11 08:45 PM | -0,0020 | 24,29 | 31,05 | 497,62 | 12.30.11 08:45 PM | 0,0578 | 24,36 | 22,2 | 844,3 |
| 12.23.11 09:00 PM | -0,0030 | 24,29 | 31,05 | 494,57 | 12.30.11 09:00 PM | 0,0259 | 24,36 | 22,02 | 831,48 |
| 12.23.11 09:15 PM | -0,0030 | 24,27 | 31,05 | 487,85 | 12.30.11 09:15 PM | 0,0289 | 24,39 | 21,84 | 816,22 |
| 12.23.11 09:30 PM | -0,0030 | 24,27 | 30,98 | 484,8 | 12.30.11 09:30 PM | 0,0030 | 24,36 | 21,54 | 768,62 |
| 12.23.11 09:45 PM | -0,0030 | 24,24 | 30,91 | 487,24 | 12.30.11 09:45 PM | 0,0289 | 24,34 | 21,47 | 763,12 |
| 12.23.11 10:00 PM | -0,0030 | 24,22 | 30,87 | 482,97 | 12.30.11 10:00 PM | 0,0122 | 24,34 | 21,29 | 738,1 |
| 12.23.11 10:15 PM | -0,0030 | 24,22 | 30,84 | 482,97 | 12.30.11 10:15 PM | 0,0609 | 24,34 | 21,4 | 771,06 |
| 12.23.11 10:30 PM | -0,0030 | 24,2 | 30,7 | 482,36 | 12.30.11 10:30 PM | 0,0244 | 24,32 | 21,47 | 767,4 |
| 12.23.11 10:45 PM | 0,0015 | 24,2 | 30,64 | 475,65 | 12.30.11 10:45 PM | 0,0213 | 24,32 | 21,69 | 811,95 |
| 12.23.11 11:00 PM | -0,0020 | 24,2 | 30,57 | 470,15 | 12.30.11 11:00 PM | 0,0274 | 24,34 | 21,91 | 838,2 |
| 12.23.11 11:15 PM | -0,0030 | 24,17 | 30,5 | 468,32 | 12.30.11 11:15 PM | 0,0563 | 24,34 | 21,84 | 811,34 |
| 12.23.11 11:30 PM | -0,0030 | 24,17 | 30,47 | 462,83 | 12.30.11 11:30 PM | 0,0883 | 24,32 | 21,69 | 785,1 |
| 12.23.11 11:45 PM | -0,0030 | 24,17 | 30,47 | 465,27 | 12.30.11 11:45 PM | 0,0502 | 24,34 | 21,69 | 780,82 |

## APPENDIX B

## MECHANICAL DRAWINGS OF ROOM 28 AND ROOM 50

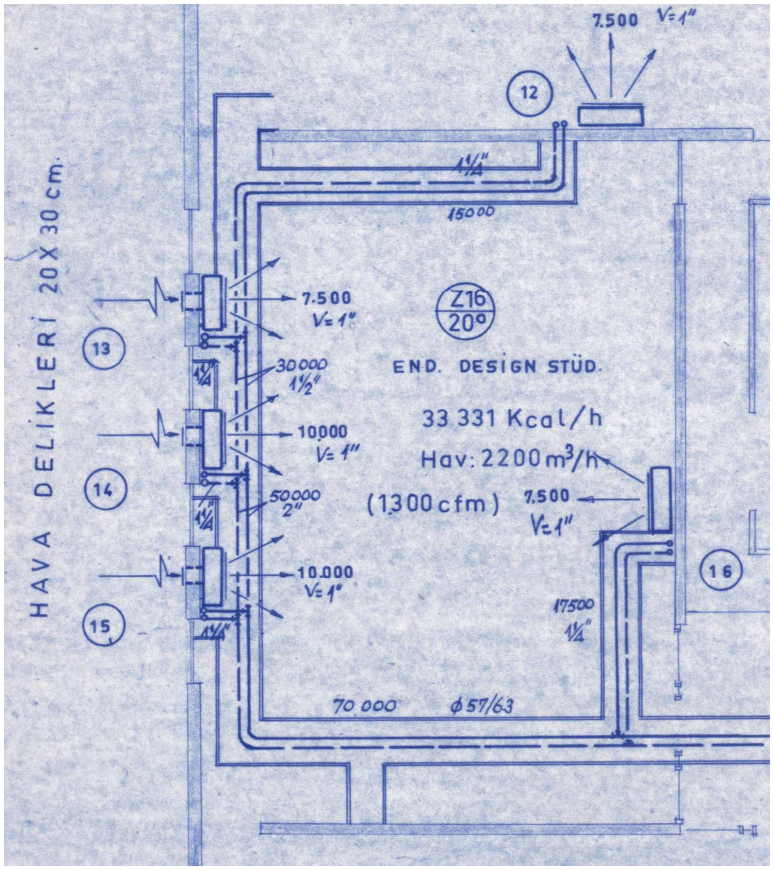


**Figure B.01.** Ground floor plan of Room 28

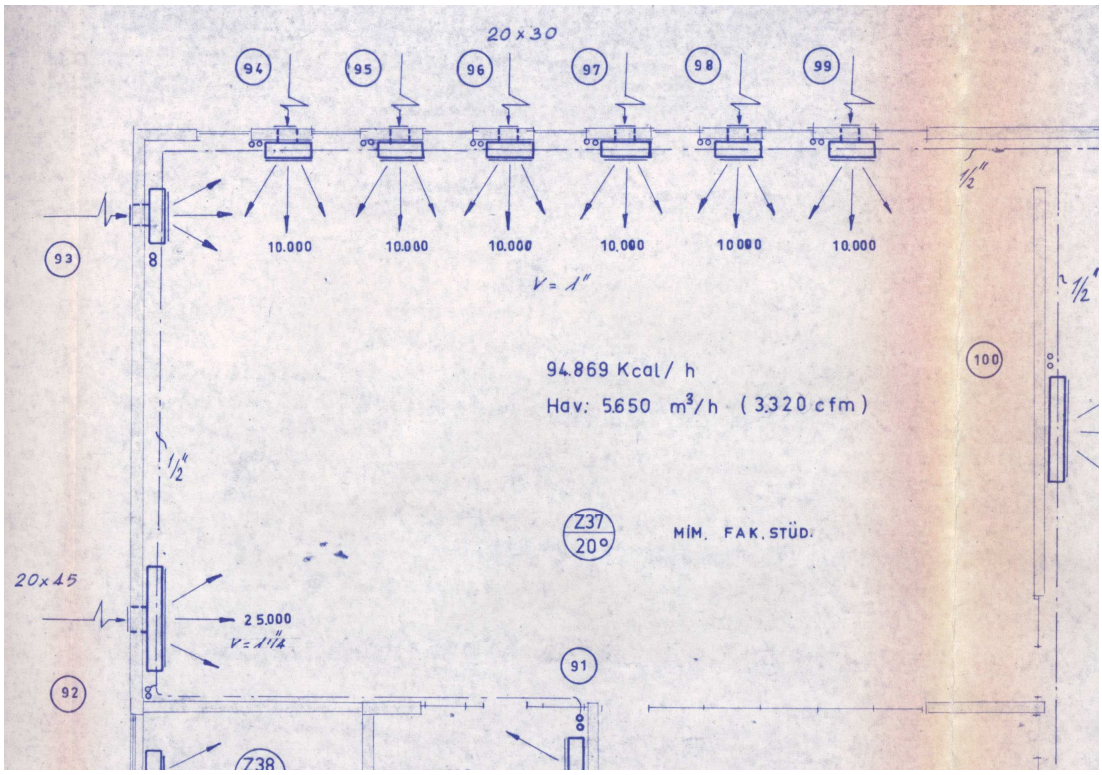


**Figure B.02.** Ground floor plan of Room 50