

**A TECHNICAL REPORT ON DESIGN OF INNOVATIVE AND AUTOMATED RESPIRATORY BUILDINGS FOR PATIENTS AND HEALTH WORKERS AGAINST CORONAVIRUS DISEASE OUTBREAK**

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**CERTIFICATION**

This is to certify that the project is written by **IBE CHIBUNNA ELVIS** with matriculation number **17/ENG06/039** in the department of Mechanical Engineering, College of Engineering Afe - Babalola University, Ado Ekiti (ABUAD) during the 2019/2020 academic session under my supervision.

Student`s Signature / Date Lecturer`s Signature / Date

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**DEDICATION**

I dedicate this project to God Almighty my creator, my strong pillar, my source of inspiration, wisdom, knowledge and understanding.

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**ACKNOWLEGDEMENT**

My deepest gratitude goes to God who has provided all that was needed to complete this project and the program for which it was undertaken for. There was never lack or want. Throughout this entire study, He took care of everything that would have stopped me in my tracks and strengthened me through my most difficult times.

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**ABSTRACT**

The study focused on design of innovative and automated respiratory buildings for patients and health workers against coronavirus disease outbreak. In the present situation of the world highly affected by the Coronavirus (COVID-19) pandemic, all professions are putting all hands on deck to bring an end to this pandemic. This study highlights the need for proper ventilation in controlling this Coronavirus (COVID-19) infection in health-care settings and proposes innovative designs that will aid in achieving it.

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**CHAPTER ONE**

**INTRODUCTION**

The purpose of this study is threefold:

* to promote proper ventilation design for the Corona virus(COVID-19) control in health-care settings.
* to describe the basic principles of how to design, construct, operate and maintain an effective ventilation system for the Corona virus(COVID-19) infection control.
* to propose a concept for an automated ventilation system.

This study is primarily developed for engineers and architects who design or operate health-care facilities. The study is also useful for health-care workers, particularly infection-control professionals who work in health-care facilities. The study recognizes that the hospital designers, operators and health-care workers need to work together for effective infection control of the Corona virus. Naturally ventilated hospitals need to be designed properly for natural ventilation to provide the recommended ventilation rates, otherwise, factors such as the lack of directional control of airflow may lead to a potential for transmission of infection.

Naturally ventilated hospitals or airborne precaution rooms need to be designed properly for natural ventilation to provide the recommended ventilation rates, otherwise, factors such as the lack of directional control of airflow may lead to a potential for transmission of infection.

**LITERATURE REVIEW**

**Droplets:** Inspirable particles larger than 5 μm in diameter, which can be deposited on upper respiratory tract levels and mucosa.

**Exfiltration:** Outflow through unintended leakages in buildings.

**Hybrid ventilation**: Combination of both mechanical and natural ventilation (also called mixed mode ventilation).

**Infiltration:** Air flow through unintended leakages into buildings.

**Mixed-mode ventilation:** See hybrid ventilation.

**Natural ventilation:** Use of natural forces to introduce and distribute outdoor air into or out of a building. These natural forces can be wind pressures or pressure generated by the density difference between indoor and outdoor air.

**CHAPTER TWO**

**2.1 BRIEFING ON CORONA VIRUS(COVID-19)**

Corona virus disease(COVID-19) is an infectious disease caused by a newly discovered corona virus, Severe Acute Respiratory Syndrome Coronavirus2 (SARS-Cov-2).

The disease was first identified in December 2019 in Wuhan, the capital of China`s Hubei province, and has spread globally, resulting in the on-going 2019-20 corona virus pandemic. Common symptoms include fever, cough, and shortness of breath. Other symptoms may include fatigue, muscle pain, diarrhoea, sore throat, loss of smell, and abdominal pain.

Most people infected with the COVID-19 virus will experience mild to moderate respiratory illness and recover without requiring special treatment. Older people, and those with underlying medical problems like cardiovascular disease, diabetes, chronic respiratory disease, and cancer are more likely to develop serious illness.

The COVID-19 virus spreads primarily through droplets of saliva or discharge from the nose when an infected person talking, coughs or sneezes. These droplets are produced when breathing out, they usually fall to the ground or unto surfaces rather than being infectious over long distances. People may also become infected by touching a contaminated surface and their eyes, nose, or mouth. The virus can survive up to 72 hours.

**2.2 GENERAL PRINCIPLES OF INFECTION CONTROL**

**The concept of isolation precaution**: Isolation precaution is an important strategy in the practice of infection control. The spread of this infection can be impeded if infected patients are segregated from those who are not yet infected.

The first level of control is administrative controls, which are measures taken to ensure that the entire system is working effectively. These controls include:

* implementing proper procedures for triage of patients
* detecting infections early
* separating infectious patients from others
* transporting the patients
* educating the patients and staff
* designating responsibilities clearly and correctly
* communicating with all relevant partners.

The second level is “environmental and engineering controls”, including cleaning of the environment, spatial separation and the ventilation of spaces. The third level of control to further decrease the risk of transmission is personal protection, which is the provision of the proper personal protective equipment (PPE) (e.g. masks, respirators). When setting up an isolation system in the hospital, all levels of controls (administrative controls, environmental and engineering controls, and personal protection) must be given proper attention for the system to work effectively, and for the different levels to support each other.

**CHAPTER THREE**

**CONCEPTS AND TYPES OF VENTILATION**

**3.1 VENTILATION**

Ventilation moves outdoor air into a building or a room, and distributes the air within the building or room. The general purpose of ventilation in buildings is to provide healthy air for breathing by both diluting the pollutants originating in the building and removing the pollutants from it.

Building ventilation has three basic elements:

* ventilation rate: the amount of outdoor air that is provided into the space, and the quality of the outdoor air
* airflow direction: the overall airflow direction in a building, which should be from clean zones to dirty zones
* air distribution or airflow pattern: the external air should be delivered to each part of the space in an efficient manner and the airborne pollutants generated in each part of the space should also be removed in an efficient manner.

There are three methods that may be used to ventilate a building: natural, mechanical and hybrid (mixed-mode) ventilation.

**3.2 TYPES OF VENTILATION**

**3.2.1 NATURAL VENTILATION:** Natural forces (e.g. winds and thermal buoyancy force due to indoor and outdoor air density differences) drive outdoor air through purpose-built, building envelope openings. Purpose-built openings include windows, doors, solar chimneys, wind towers and trickle ventilators. This natural ventilation of buildings depends on climate, building design and human behaviour.

**3.2.2 MECHANICAL VENTILATION**: Mechanical fans drive mechanical ventilation. Fans can either be installed directly in windows or walls, or installed in air ducts for supplying air into, or exhausting air from, a room. The type of mechanical ventilation used depends on climate. For example, in warm and humid climates, infiltration may need to be minimized or prevented to reduce interstitial condensation (which occurs when warm, moist air from inside a building penetrates a wall, roof or floor and meets a cold surface). In these cases, a positive pressure mechanical ventilation system is often used. Conversely, in cold climates, exfiltration needs to be prevented to reduce interstitial condensation, and negative pressure ventilation is used. For a room with locally generated pollutants, such as a bathroom, toilet or kitchen, the negative pressure system is often used. In a positive pressure system, the room is in positive pressure and the room air is leaked out through envelope leakages or other openings. In a negative pressure system, the room is in negative pressure, and the room air is compensated by “sucking” air from outside. A balanced mechanical ventilation system refers to the system where air supplies and exhausts have been tested and adjusted to meet design specifications. The room pressure may be maintained at either slightly positive or negative pressure, which is achieved by using slightly unequal supply or exhaust ventilation rates. For example, a slight negative room pressure is achieved by exhausting 10% more air than the supply in a cold climate to minimize the possibility of interstitial condensation. In an airborne precaution room for infection control, a minimum negative pressure of 2.5 Pa is often maintained relative to the corridor.

**3.2.3 HYBRID/MIXED-MODE VENTILATION:** Hybrid (mixed-mode) ventilation relies on natural driving forces to provide the desired (design) flow rate. It uses mechanical ventilation when the natural ventilation flow rate is too low. When natural ventilation alone is not suitable, exhaust fans (with adequate pre-testing and planning) can be installed to increase ventilation rates in rooms housing patients with the infection. However, this simple type of hybrid (mixed-mode) ventilation needs to be used with care. The fans should be installed where room air can be exhausted directly to the outdoor environment through either a wall or the roof. The size and number of exhaust fans depends on the targeted ventilation rate, and must be measured and tested before use. Problems associated with the use of exhaust fans include installation difficulties (especially for large fans), noise (particularly from high-power fans), increased or decreased temperature in the room and the requirement for non-stop electricity supply. If the environment in the room causes thermal discomfort spot cooling or heating systems and ceiling fans may be added. Another possibility is the installation of whirlybirds (whirligigs or wind turbines) that do not require electricity and provide a roof-exhaust system increasing airflow in a building.

**CHAPTER FOUR**

**DESIGN FOR PROPER VENTILATION**

**4.1 IN NATURAL VENTILATION SYSTEMS**

As previously defined, natural ventilation is the use of natural forces to introduce and distribute outdoor air into or out of a building. These natural forces can be wind pressures or pressure generated by the density difference between indoor and outdoor air. There are four design methods available for natural ventilation systems:

* cross flow (no corridor): the simplest natural ventilation system with no obstacles on either side of the prevailing wind (i.e. windows of similar size and geometry open on opposite sides of the building)
* wind tower (wind catcher/wind extractor): the positive-pressure side of the wind tower acts as a wind catcher and the negative-pressure side of the wind tower acts as a wind extractor
* stack (or buoyancy), simple flue: a vertical stack from each room, without any interconnections goes through the roof; this allows for air movement based on density gradients
* stack (or buoyancy), solar atrium: a large stack that heats due to solar radiant loading, which induces air movement due to density (temperature) differentials; without radiant loading, the atrium provides minimal ventilation.

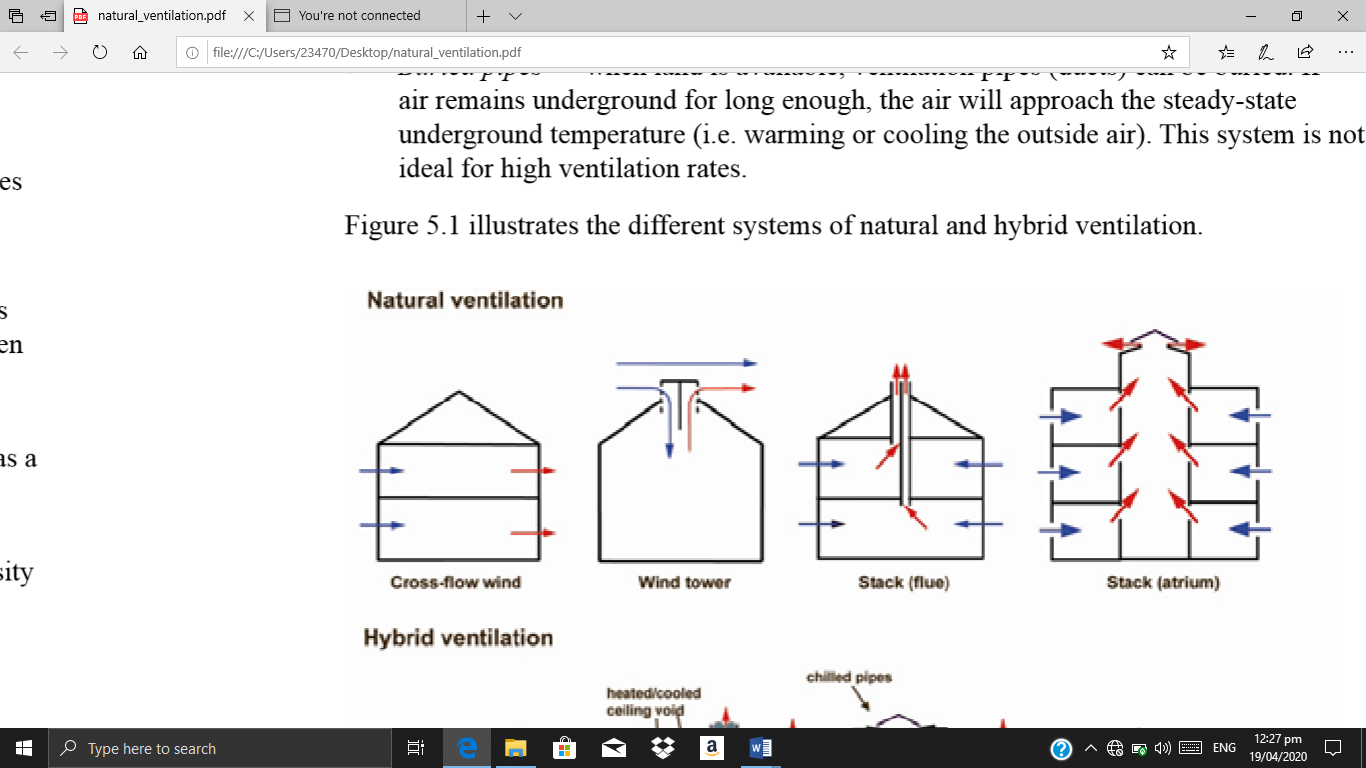


FIG.1 Diagram showing methods of natural ventilation

**4.2 IN HYBRID (MIXED-MODE) VENTILATION SYSTEM**

As previously defined, hybrid (mixed-mode) ventilation relies on natural driving forces to provide the desired (design) flow rate. It uses mechanical ventilation when the flow rate is lower than that required to produce natural ventilation.

Three design methods are available for hybrid ventilation systems.

* Fan-assisted stack: when there is insufficient solar radiant loading on the stack (i.e. evenings and inclement days) the ventilation rate is supplemented by extraction fans. Inlet air is heated and cooled to maintain comfort for building occupants.
* Top-down ventilation (fan-assisted stack plus a wind tower): when there is insufficient solar radiant loading on the stack (i.e. evenings and inclement days) the exhaust ventilation rate is supplemented by extraction fans while the supply ventilation rate is supplemented by the wind tower (wind scoop). Inlet air is heated and cooled to maintain comfort for building occupants.
* Buried pipes: when land is available, ventilation pipes (ducts) can be buried. If air remains underground for long enough, the air will approach the steady-state underground temperature (i.e. warming or cooling the outside air). This system is not ideal for high ventilation rates.

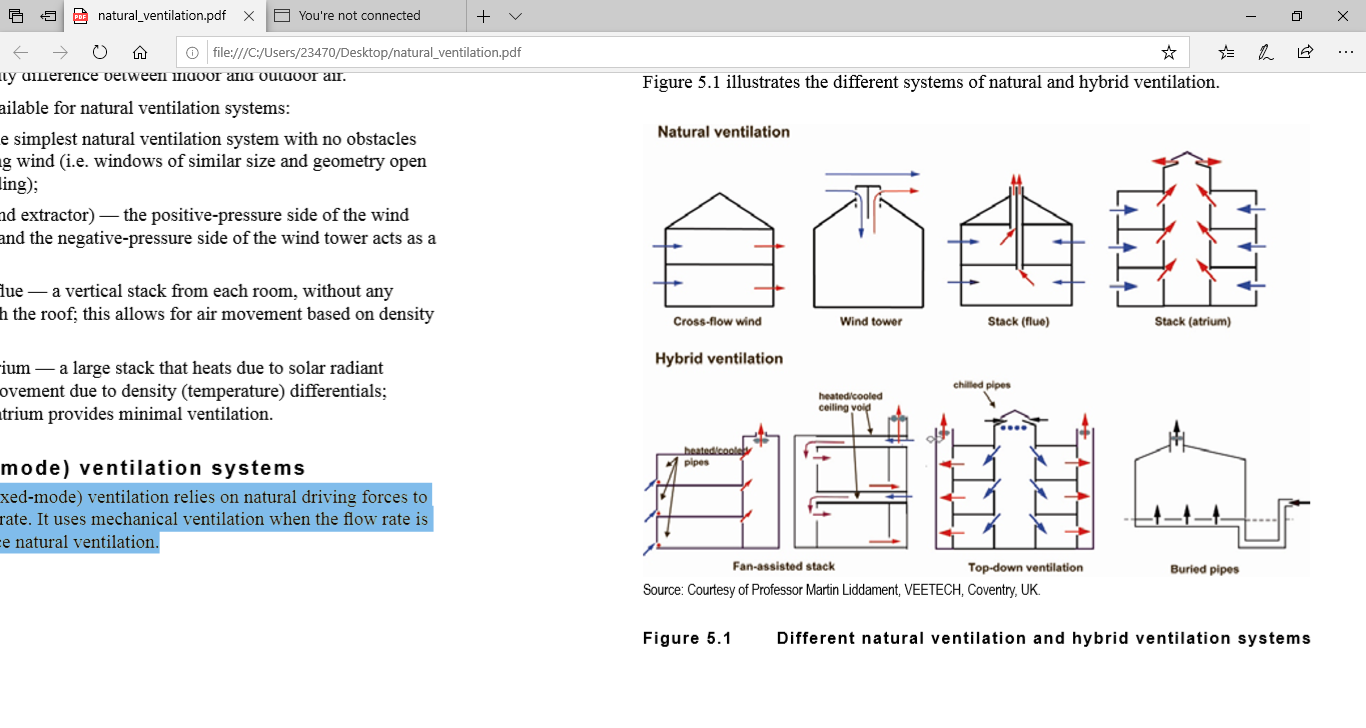


FIG.2 Diagram showing methods of hybrid ventilation

**4.3 CONSIDERATIONS IN VENTILATION DESIGN**

1. **Maintaining thermal comfort:** In temperate and warm climates and under good ambient air quality conditions, a higher ventilation rate is good for both thermal comfort and indoor air quality. However, this is not true for cold climates where outdoor air infiltration should be minimized for thermal comfort. When the ambient air temperature stays above 30 °C, the thermal conditions in a naturally ventilated ward may become intolerable. 5.3.4 Maintaining healthy indoor air quality With a higher air-change rate, the indoor air quality is more linked to the ambient air quality. The benefit is that the indoor air quality is less likely to be affected by the presence of common indoor pollutant sources, such as the off-gassing from common building materials.
2. **Managing ambient air pollution:** With the high air-change rate of untreated outdoor air, indoor air quality will be more affected by the ambient air pollution. In regions with severe ambient air pollution problems, the location of an infectious disease hospital should be chosen carefully. A hybrid (mixed-mode) ventilation design may be the only option. Solely relying on ordinary window openings will expose the occupants to a high ambient pollutants level.
3. **Humidity and mould growth:** Condensation can occur on ceilings, walls, floors and beddings for many reasons. For example, in buildings with a heavy structure and that use natural ventilation, a sudden change of weather with warm, moist ambient air may induce condensation when the surface temperature is lower than the dew-point temperature of the moist incoming air. While the conditions are a discomfort and annoyance during the condensation period, mould may also grow — which is a health hazard.
4. **Security and vector-borne disease spread:** Large openings in natural ventilation without any protection increase the risk of security breaches and the spread of vector-borne diseases. Purpose-designed barred windows and semi-transparent mosquito meshes can be used in these situations.

**CHAPTER FIVE**

**DESIGNING AN AUTOMATED SYSTEM**

To be able to achieve an automated system that can be able to switch between allowing pure natural ventilation and the hybrid ventilation (i.e. it will be able to control the appliances concerned with the mechanical ventilation and control over the opening of vents for the natural ventilation), the need for sensors cannot be neglected.

Some sensors that would be used may include;

1. Pressure sensors: These monitor rooms and filter for drops in pressure. Monitoring the pressure will be useful for optimizing air flow.
2. Occupancy sensors: These identify the presence of a person in a room. Occupancy sensors can help the patients and health workers save energy.
3. Sensors detecting Indoor Air quality(IAQ): The basic IAQ sensor is a carbon sensor, which detects carbon levels in air. Carbon levels are an indicator of air circulation, and poor air circulation increases the chances that other contaminants could be present.

Other devices needed may include;

1. Programmable thermostat: There would also be need for a programmable thermostat which is designed to adjust the temperature according to series of programmed settings that effect at the different times of the day. As this would help to maintain the overall room temperature to make it conducive for both the patients and health workers.
2. Automatic sliding window openers: this would also be programmed to take inputs from the various sensors and give its outputs as the way it opens the window the suit the desired condition and help prevent the spread of the Corona Virus infection in the respiratory building.
3. Automated ceiling fans: this as well would be programmed to take its input from the sensors to determine whether to operate or not and speed at which to operate during its operation.

To reduce much wiring of these various sensors to each appliance, considering a module in each room will be a better option. The sensors used would be connected to the module and the module could be connected in a wired or wireless network to the appliances, relaying the data from the sensors to the appliances to carryout appliances. This module which would be present in each room would be connected to a central module acting like a CPU (Central Processing Unit) to maintain the general condition of the respiratory building.

**CHAPTER SIX**

**CONCLUSION**

This study focused on designing an automated respiratory building for patients and health workers against coronavirus disease outbreak has been able to show how automated ventilation can be achieved with the use of sensors and other automated appliances connected with modules. This would be able to prevent the further spread of the Corona virus as the patients undergoing healing processes will not be re-infected and the health workers can be more focused on the medical recommendations in fighting the virus and will stand very little chance of being infected.

This automated respiratory building will help a lot since the infection considered which is the corona virus spreads through droplets of saliva or discharge from the nose, with the use of this automated system further spread of the virus caused as a result of an uninfected person being infected because he or she touched or came in contact with a material where the virus was present would be minimised.

Things like the window frames and fan regulators are very accessible by both the patients and the health workers, so we can see that having their operations automated will go along in protecting the health-care workers against the corona virus and combating the corona virus disease outbreak.

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