INTI
International University
LAUREATE INTERNATIONAL UNIVERSITIES®

FACULTY OF SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATICS

BACHELOR OF ENGINEERING (HONS) IN MECHANICAL ENGINEERING

MEE4999 ENGINEERING DESIGN PROJECT

GROUP PROJECT REPORT

Name	Ker De Kuan, Samuel Ng ShenqJye, Seow Zhen Liang, Low ShuBoey
Matriculation No.	I11008249, I11008322, I11008048, I12001501
Programme	BMEGI
Session	AUG 2014 To MAY 2015
Course Code	MEE4999
Project Title	Resolution To Walls Surfaces Condensation &Mould Growth Issue In An 24-Hours Air Conditioned Room
Supervisor	Associate Professor Ramli

Declaration of Honesty in Academic Work

We declare that every assignment handed in is original except for source material explicitly acknowledged, and that the same or related material has not been previously submitted for another course. We also acknowledge that we are aware of University policy and regulations on honesty in academic work, and of the disciplinary guidelines and procedures applicable to breaches of such policy and regulations.

Date: 20/04/2015

Signature

Name: Low Shu Boey   Student ID: I12001501

Signature

Name: Ker De-Kuan   Student ID: I11008249

Signature

Name: Samuel Ng Sheng Jye   Student ID: I11008322

Signature

Name: Seow Zhen Liang   Student ID: I11008048

Table of Contents

1.0 INTRODUCTION

Engineering Design Project is about enabling students to develop a set of skills in order to solve and complete an engineering problem. The whole process is carried out on minimum supervision. There are a lot of factors in determining the success of the project, this include time management, having a clear objective, proposing multiple solutions, understanding the obtained results and many more. By getting hold of the objectives and as well as outcomes, a clear path of direction can be obtained. Both the skill to work as an individual as well as the skill to work as a group is put at stake. With the combination of both, a well-structured and complete project can be the output.

An operating theatre is where doctor and patients fought life battles. It has to be in a very favourable condition for surgeries to be carried out. The operating theatre department has to be separated into few zones so that procedures can be done simultaneously and in an orderly manner. Firstly, there is the protective zone; this is where the patients and staffs interact on normal basis with only normal hospital standards of cleanliness are applied. Next, there is the clean zone. A very strict cleaning routine is applied and everyone that enters this zone has to go through a system of transfer. This is followed by the aseptic zone, which is required to be as sterile as possible. All the staff that might handle operating equipment has to be scrubbed and properly gowned. The last and but not least, the disposable zone. All the exposed instruments, whether used or unused, have to be placed here for cleaning, sterilizing or any other necessary process. All the 4 zones basically sum up an operating department. A very strict control system is required to only allow certain individuals to pass through different zones.

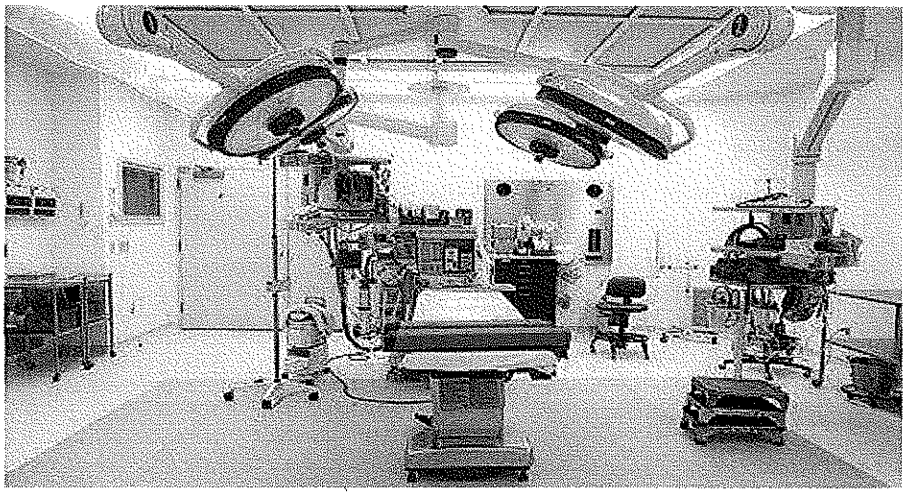

Figure 1: An operating theater [1]

An operating theatre requires a continuous 24 hours of air conditioning. Many mistakenly assumed that the cold condition of the room is to lower the risk of infection. This is very wrong as the risk of infection increases at low temperature. The body temperature of the patient decreases with the decrease in surrounding temperature, which directly increases the risk of infection. Long hours of standing in the operating room are very tiring for doctors as well as nurses. It is actually kept cold to create a comfortable condition for the surgeon and nurses.

According to a research found online [1], the wall finishes in operating rooms has to have several characteristics. It has to have a lifespan of at least 10 years. The wall is also supposed to be waterproof and also not susceptible to heat and steam. Other than that, the wall must be able to withstand damage from mobile equipment. These 3 features are slightly more important than the others as it will directly affect the condition of the room.

2.0 OBJECTIVE

The objective of this study is to prevent mould growth due the condensation from difference in temperature in the operation theatre in a hospital in a tropical country with an innovative insulation system on selected criteria which includes durability, but affordable and sustainability in the system. These conditions are as required in the sustainable development; essential for achieving the best solution in this design project. This report will present the analysis of different wall conditions, analyze different insulation material as well as installation method and evaluate their advantages and disadvantages according to the sustainable development criteria.

3.0 LITERATURE REVIEW

Insulation in any building is essential to govern heat transfer in and out of the building. Controlling the heat transfer rate is vital in preventing condensation which is at the point where air cools below its dew point (Evoltz 1999). Therefore, condensation usually occurs at the coolest surface with relative to its dew point temperature. In order to obtain heat transfer, prior knowledge regarding heat transfer has to be acquired before proceeding with analysis.

In an extensive study of A Hygrothermal Analysis of Various Exterior Wall Systems, Smegal & Straube (2010) pointed out that high-R value can increase the temperature gradient or in other words, reduce heat transfer across a boundary. This study is important to determine the suitable material for the insulation panel. Having high-R value insulation should also be cost effective, sustainable and also easily available. Not only that, it is also found that the corners and wall to wall edges are the most susceptible to condensation as this part of the room is experiencing 2 or 3 dimensional heat flux.

4.0 CUSTOMER'S REQUIREMENT

A customer approaches an engineer in order to solve a particular problem. It is assumed that the client has no knowledge on it at all and as an engineer, we are supposed to devise a step by step solution and explain it in simpler terms to the client. The customer's requirement is basically to solve the problem at an affordable cost. In this project, the problem given by the client is to solve the mold growth problem in an operating theater of a hospital. In the customer's point of view, an operating room requires a clean and sterile environment. The growth of mold may contaminate the surrounding condition which directly affects the success of an operation. The growth of mold has to be prevented at all cost. To analyze what causes the mold growth, it has to be a step by step procedure. By having a very clear understanding of the problem will eventually lead to the correct direction.

As the main concern of this project is on solving mold growth problem on the wall surfaces, all of the factors regarding it are researched on. Firstly, what kind of condition encourages mold growth? Mold is a type of fungus, or more commonly known as a decomposer. It feeds on dead organic material. Other than organic material, mold can possibly grow on synthetic materials such as adhesives and paints. Like any other living organism, mold requires food, water and warmth. Mold will grow if the conditions are favorable. Mold spores will reproduce in areas that are wet or damp. In just merely 48 hours, an environment that is moist with room temperature and as well as an organic food source will encourage mold growth. Areas that are wet or damp have a high relative humidity.

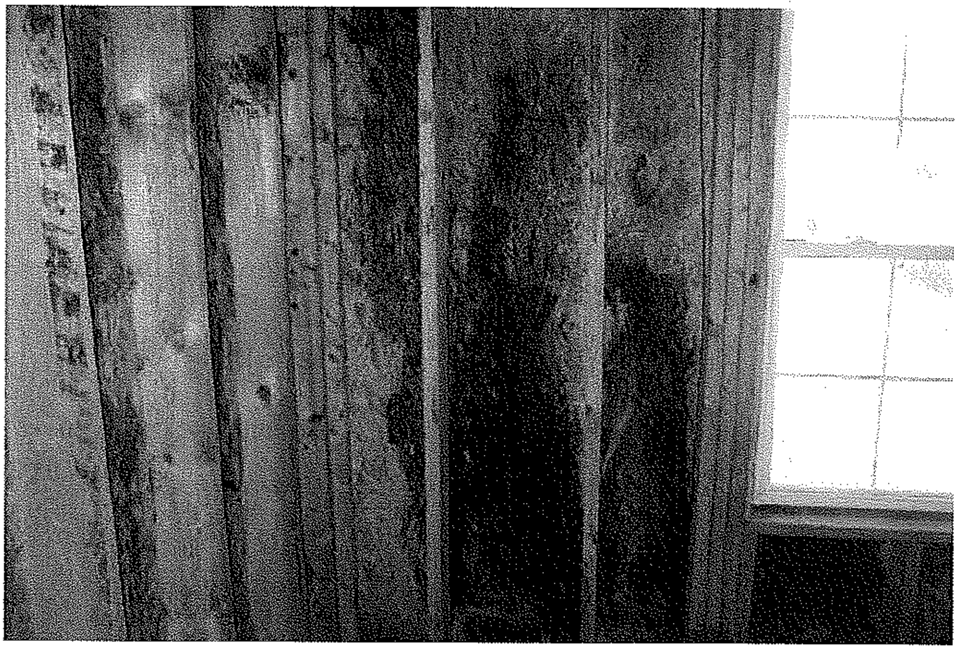

Figure 2: Mold growing on the wood studs and insulation inside the walls [2]

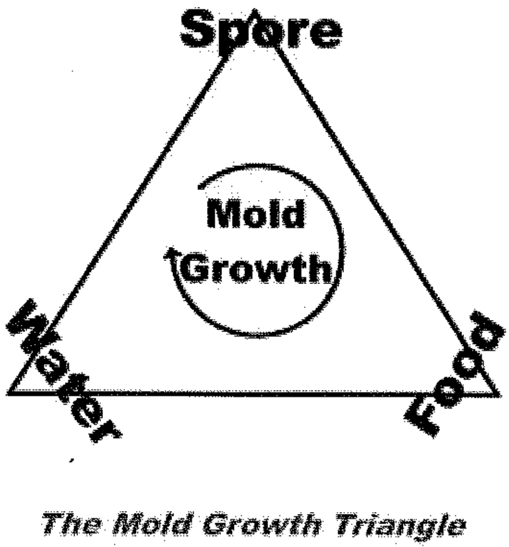

Figure 3: The Mold Growth Triangle [3]

5.0 ENGINEERING REQUIREMENT

The engineering approach to this problem would be first analyzing the problem properly and then devising the best solution for it through several hypothesis and trial and error. The mold growth cannot be tolerated in an environment that requires a very sterile condition, which in this case is the operating theater. This is because of the potential health effects that are associated with mold; this includes asthma and allergic reactions.

The operating room condition given has a relative humidity of 50%, with a temperature of 15 degree Celsius and with the present of biodegradable material. The operating room is normally not very bright as this favors the growth of mold because mold can't grow under ultraviolet light. All of the factors above favor the growth of the mold.

Now the problem lies at the presence of water condensation in the operating theater. Water vapor can form whenever cold air meets hot air. The air-conditioned operating room is very cool and this takes away the ability of air to hold water. The temperature of the wall is higher than the temperature of the air in the air-conditioned room. As a result, the excess water vapor condenses to form water droplets, for which this case is forming on the uninsulated wall surface of the operating room. Condensation normally forms first on glass windows, and then rapidly on wall surfaces. The presence of water droplets on the surface of the wall promotes the growth of mold.

Another factor that directly affects the success rate of the mold growth is the relative humidity. Relative humidity is related with moisture in the air. Relative humidity is the amount of moisture contained in the material at equilibrium with the environment. This is independent of temperature. At a higher relative humidity, there is more water in the material. As this indicates the moisture in the air, higher RH promotes a better growth of mold.

Temperature also plays a part in mold growth, but not as significant as the other factors. Temperature of the operating room is 15 degrees Celsius. Unfortunately, mold grows well at a wide range of temperature, even at temperature close to freezing point. With the increase in temperature, it favors the mold even more. It is not feasible to control mold growth by adjusting temperature.

By analyzing all the factors above, the cause of mold growth can be properly pin pointed. The primary approach to solving this problem would be by installing proper insulation panels in order to prevent water condensation. Through a series of calculation to determine all the needed variables, a suitable insulation material can be chosen. This is by listing a number of material candidates and weighing their pros and cons in terms of suitability, durability, cost and much more. To as what is required in this project, a secondary approach is needed too. The secondary approach can be any type of solution, provided that it must be able to solve the problem.

6.0 THEORY

6.1 Condensation

There are three fundamental factors [4] which causes condensation to occur, including:

- The presence of a temperature gradient in an object
- The presence of a source of moisture
- The temperature of the involved object is at or below the dew point temperature

The temperature gradient can be defined as a physical quantity that describes which direction and at what rate the temperature changes the most rapidly around a particular location. It is a dimensional quantity expressed in units of degrees per unit length with an SI unit of kelvin per meter (K/m) and is present in virtually all matter [5]. In our case, a temperature gradient is between in the ceiling, the floor and all four walls with the air of the operating theater.

Coupling with a source of moisture, the difference between the temperature between the air and the surfaces would cause condensation to occur on the surfaces. Moisture from the surroundings could come from human activities, plants and natural water vapor in the air. With the presence of sunlight and water, mold growth will start on the outer layer of the surfaces [6].

Condensation would also occur when the temperature of the surfaces is at or lower than the dew point temperature. The dew point temperature is the temperature where moisture condenses into liquid water at the same rate which it evaporates [7]. When the temperature reaches the dew point temperature, condensation will start to occur on the surfaces.

From the factors listed above, a conclusion can be made that condensation can be minimized if the heat transfer between the air and the room surfaces could be controlled. With an intervening device such as a heat insulator, heat transfer between the air and the surfaces could be reduced, decreasing condensation on the room surfaces thereby preventing mold growth.

6.2Thermal Conductivity

Thermal Conductivity is the ability of a material to transfer heat. Given two surfaces on either side of a material with a temperature difference between them, the thermal conductivity is the heat energy transferred per unit time and per unit surface area, divided by the temperature difference *[8].*

Thermal conductivity is a bulk property that describes the ability of a material to transfer heat. In the following equation, thermal conductivity is the proportionality factor *k*. The distance of heat transfer is defined as *x*, which is perpendicular to area *A*. The rate of heat transferred through the material is *Q*, from temperature T_1 to temperature T_2, when $T_1 > T_2$ [9].

$$k = \frac{Q\Delta x}{A(T_2 - T_1)}$$

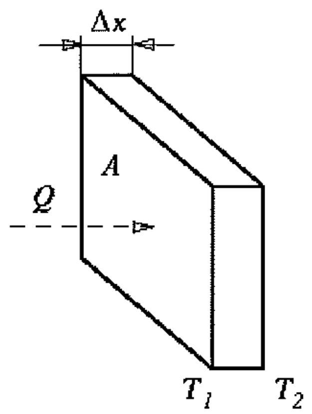

Figure 4: Conduction heat transfer process from $T_{1\text{-hot}}$ to cold $T_{2\text{-cold}}$ surfaces

Thermal conductivity can be affected by the changes in temperature of a material. When the temperature of the material increases, the internal particle velocity and thermal conductivity will increase. This behavior descried the Wiedemann-Franz law by correlating thermal and electrical conductivity to temperature. The effect of temperature on thermal conductivity is non-linear and hard to predict without prior research. The graphs below show the behavior of thermal conductivity over wide temperature ranges. Based on *[10]* and *[11],* both of the materials, aluminum nitride and silicon are used extensively in electronics

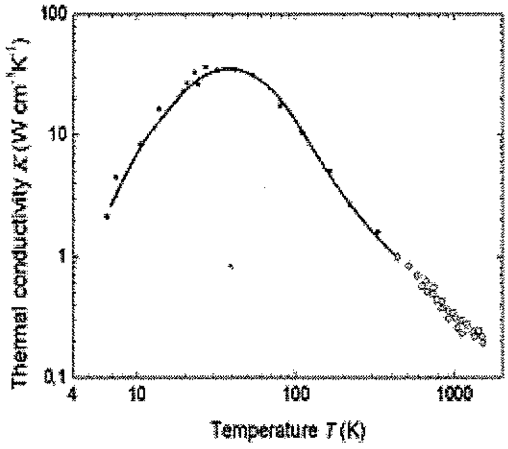

Figure 5: Thermal conductivity of aluminium nitride as a function of temperature. [10]

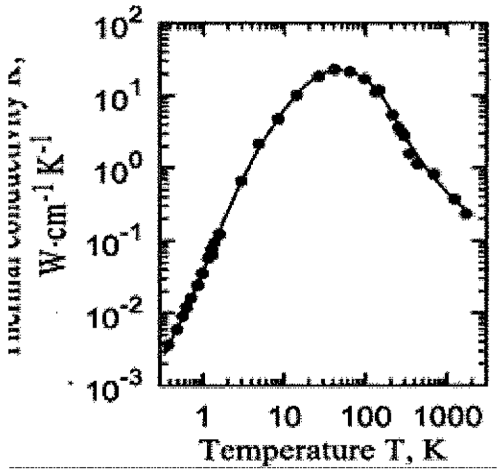

Figure 6: Thermal conductivity of silicon as a function of temperature. [11]

Below are the thermal conductivity, *k* values in this project:

Material	Thermal conductivity, *k* (W/(m•K))
Brick wall	0.75
Polyurethane foam	0.03
Fiberglass	0.04
Polystyrene, expanded styrofoam	0.03

Table 1: Thermal conductivity of materials

6.3 Newton's Law of Cooling for Forced and Natural Convection Heat Transfer

Convection heat transfer takes place when a fluid flows past a solid surface, with a difference in temperature between the fluid and the surface. If the fluid flow is due to an external force, like a pump, then it is forced convection. If the fluid flow is caused by density differences within the fluid due to internal fluid temperature differences, then it is natural convection, also known as free convection.

Below is the equation widely used for both forced and natural convection heat transfer Newton's Law of Cooling:

$$Q = h\,A\,\Delta T, \text{ where}$$

Q = rate of heat transfer between the fluid and the surface, (W)

A = area of the surface that is in contact with the fluid, (m^2)

ΔT = temperature difference between the fluid and the solid surface, (^oC or K)

h = convective heat transfer coefficient, (W/m^2-K) [12]

In this project, the newton's law of cooling is used to calculate the heat transfer from outside to inside the operation theatre room. The outside and inside of the operation theatre room is assumed to be only free convection.

6.4 Dimensionless Prandtl, Grashof, Rayleigh and Nusselt Numbers

The equations used to calculate natural convection heat transfer coefficients come from correlations of dimensionless numbers. The dimensionless numbers typically appearing in these correlations are the Nusselt number, the Prandtl number, the Grashof number, and Rayleigh number. The equations for the Nusselt, Prandtl, and Grashof numbers (Nu, Pr, and Gr) are shown below.

$$Nu = \frac{h\,D}{k} \qquad Pr = \frac{\mu\,C_p}{k}$$

$$Gr = \frac{D^3 \rho^2 g\,\Delta T\,\beta}{\mu^2}$$

Figure 7: Dimensional number used in Natural Convection Heat transfer coefficient [12]

Also, $Ra = Gr\,Pr$.

Below are the parameters that used in these dimensionless numbers:

D = characteristic length parameter (m)

ρ = density of the fluid (Kg/m^3)

μ = viscosity of the fluid ($N\text{-}s/m^2$)

k = thermal conductivity of the fluid (W/m-K)

C_p = heat capacity of the fluid (J/kg-K)

g = acceleration due to gravity (9.81 m/s^2)

β = coefficient of volume expansion of the fluid (K)

ΔT = temperature difference between the solid surface and the fluid, (^oC or K)

The purpose of using the Nusselt number formula in this project is to find the heat transfer coefficient, *h*. After that, the surface temperature of the wall can be found by using the heat transfer rate formula as shown below:

$Q = h\,A\,(T_{hot}\text{-}T_{cold})$