# REAL-TIME MEASUREMENTS OF RELATIVE HUMIDITY AND TEMPERATURE IN HOSPITAL OPERATING ROOM

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**Abstract** - This paper investigates a series of real-time measurements of relative humidity and temperature in an operating room at a private hospital located in Selangor, Malaysia. The measurements were logged for 24 hours, at 5 minute intervals, under the actual operating conditions. The time-averaged temperature and relative humidity during the surgical procedures were recorded to be 20.5 °C and 73.9 % respectively. The air temperature fulfilled the ASHRAE Standard 170 requirements, but the humidity level slightly fell out of the proposed range. The door openings and heavy traffic were found to disrupt the stability of the air temperature and humidity distributions in the operating room. The cleaning and disinfecting procedures significantly increased the humidity level by 14 %; whereas the frequent opening of the door elevated the air temperature by 2.5 °C. These two scenarios can potentially increase the growth and activities of bacteria, which may in turn increase the risk of patients suffering from surgical site infections.

**Keywords** - onsite measurement, operating room, relative humidity, temperature

## I. INTRODUCTION

Maintaining a proper temperature and humidity distribution in the operating room, a healthcare facility for surgical procedures, could enhance infection control and the occupant's comfort [1]. However, it has been reported that engineers struggle to fulfil indoor environmental conditions which satisfy occupants [2]. In general, a low-temperature distribution could result in health risks for the patient. To avoid hypothermia in patients, a temperature between 24 °C to 26 °C is preferable [3]. However, a temperature above 23 °C is hardly supportable by surgeons [4]. Surgeons demand the temperature to be in the range of 17 °C to 18 °C, while anesthesiologists and nurses prefer warmer conditions [1, 2]. In Romania, the supply air temperature usually falls within the range of 18 °C to 24 °C [3]. The Spanish and Turkish norms recommended a higher temperature range, from 22 °C to 26 °C; and 19 °C to 26 °C respectively [5]. In the UK, the proposed range is significantly wider, from 18 °C to 28 °C [3]. However, during paediatric surgery, the temperature can reach 27 °C [3]. For cardiac surgery, the air temperature should be maintained at 17 °C [6]. For special situations such as patients with polyarticular rheumatism or are highly burned, the air temperature should be kept between 30 °C to 32 °C. Yang et al. [7] and Forstot [8] reported that up to 50 % to 70 % of surgical patients developed mild hypothermia in the perioperative period. Table 1 tabulated the humidity level and temperature as recommended by the three international standards for the practice in the operating room. The overall humidity level should be maintained at an acceptable range. Low humidity levels favour blood coagulation and will cause problems associated with static electricity on medical equipment and surfaces [6]. A high moisture content promotes the growth and transfer of bacteria that can easily become airborne on water molecules and cause thermal discomfort [6]. In terms of European operating room practice, the humidity level should below 50 % [3]. ASHRAE and AIA standards, however, limit the humidity level to fall within 30 % to 60 %. For a patient with a certain health condition, such as polyarticular rheumatism, the humidity level of 30 % to 35 % is preferable. Nevertheless, a 60 % to 85 % moisture level is recommended for a highly burned patient.

| | *Temperature (°C/F)* | *Relative humidity (%)* |
|---|---|---|
| DIN 1946-4 [5] | 16- 26/ 61- 79 | 30- 60 |
| ASHRAE 170 [9] | 20- 24/ 68- 75 | 30- 60 |
| AIA [10] | 20- 23/ 68- 73 | 30- 60 |

**Table 1: Air temperature and humidity for operating room**

In recent years, similar studies have been reported by Uścinowicz et al. [11], Kamar et al. [12], and Tan et al. [13]. Their measurement studies, however, focused on the unoccupied and steady state conditions. The field measurement of humidity and temperature under the utilised scenario has not been investigated so far. The objective of the present study is to assess the humidity level and temperature condition under both actual usage and rest conditions.

## II. METHODOLOGY

### A. Operating Room Description

The operating room is located in a private hospital in Selangor, Malaysia, and was categorised as an ISO Class 7 cleanroom . The room was mainly used for general and orthopaedic surgeries. The dimensions of

the room are 8.5 m (W) × 3.0 m (H) ×4.2 m (L).

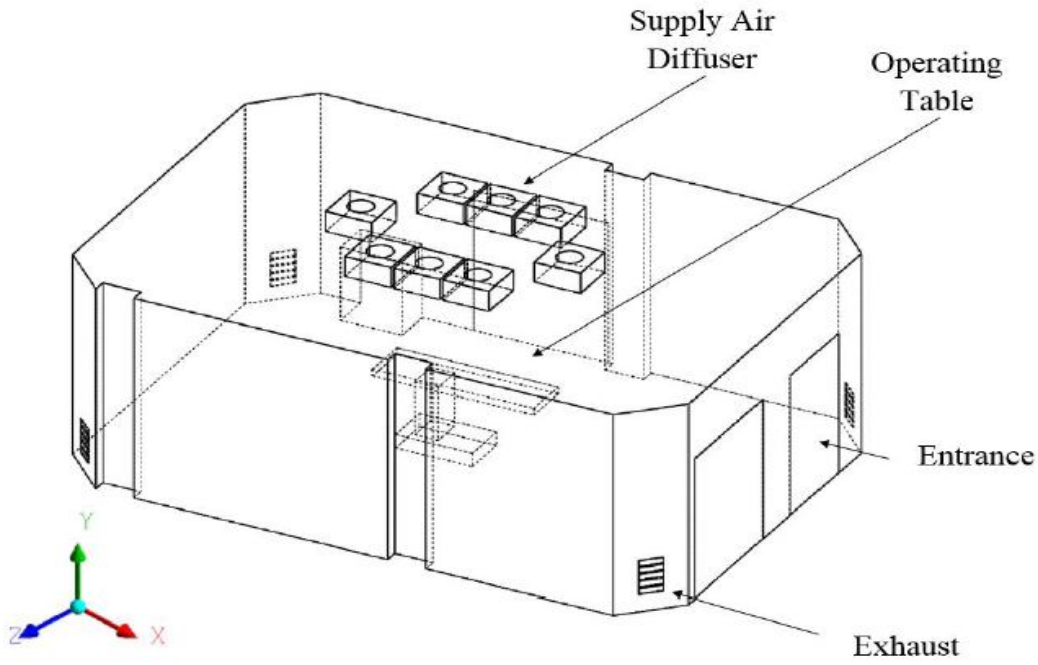



**Figure 1: Schematic diagram of an actual operating room in Selangor, Malaysia**

The air was supplied to the room via eight supply air diffusers mounted on the ceiling with a velocity of 0.44 m/s +/- 0.02 m/s. The air exits through the four exhausts placed at a height of 0.4 m above the floor level. High-efficiency particulate air (HEPA) filter

s were equipped at each supply air diffuser to trap particles larger than 0.3 µm. About 80 % of the supply air consists of recirculating air, whereas the remaining 20 % is obtained from the outside. A detailed description of the room is tabulated in Table 2.

| *Description of operating room* | |
|---|---|
| Operating system | Cleanroom system |
| Standard | ISO- Class 7 |
| Types of airflow | Unidirectional |
| Room dimensions | 8.5 m (W) × 3.0 m (H) × 4.2 m (L) |
| Entrance | 1.3 m (W) × 2.1 m (H) |
| Supply air diffusers | 0.6 m(W) × 0.6 m (L) |
| Exhaust | 0.22 m(W) × 0.46 m (H) |

**W: width; H: height; L: length

**Table 2: Operating room description**

## B. Humidity and Temperature Measurement Procedure

A field measurement was carried out on August 1, 2016 under normal operating conditions between 12.00am and 12.55pm. The data were logged at five minute intervals. The instrument was mounted on a support stand at the height of 1.1 m. It was then placed at one of the corners of the room, as shown in Figure 2. Such positioning ensures the surgical procedures could run safely and smoothly. The similar location was also considered by Gormley et al. [14] during particle measurement. The air conditioning system was switched on for at least 24 hours prior to the measurement. During the measurement, surgical procedures and other activities were conducted as usual.



**Figure 2: Placement of the instrument in the operating room**

## C. Instrumental Setup

A Testo 174 H (Testo Inc., Lenzkirch, Germany) was used to measure relative humidity and air temperature. The instrument was well calibrated before use. The instrumental specification is shown in Table 2.

| *Measured Variable* | *Instrument* | *Accuracy* | *Resolution* |
|---|---|---|---|
| Relative Humidity | Testo 174 H | +/- 3% | 0.1 % |
| Air Temperature | Testo 174 H | +/- 0.5 °C | 0.1 °C |

**Table 2: Instrumental specification**

### D. Limitations

There were several limitations in this study which should be noted. First, our measurements were monitored at a single point. Due to health privacy and ethical considerations, we were unable to perform the measurements at multiple locations. However, the deviations of humidity level and air temperature on the same height within a room were found to be insignificant [12]. Additionally, the duration of measurement was limited to one day. We are unable to monitor the fluctuation of parameters for one week. However, the fluctuation was expected to be the same, and this will mainly depend on the types of activities.

## RESULTS AND DISCUSSIONS

During the field measurement, the air-conditioning units operated in accordance with ASHRAE Standard 170. The surgical lamps were only switched on during the surgical procedures. The minimum and maximum occupants present in the room during the surgical procedures are 6 and 9 individuals respectively. All the medical staff were equipped with the standard cleanroom apparel. The measured data for both the humidity and temperature plotted against time are shown in Figure 3. The time-averaged relative humidity and temperature were measured at 63.3 % and 18.3 °C respectively.

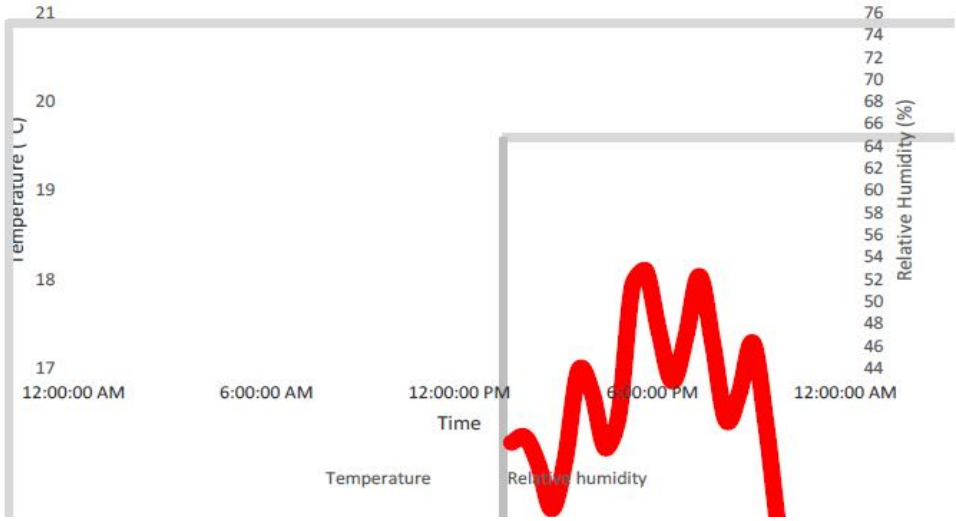



**Figure 3: Temperature and humidity measurements for 24 hours**

According to Figure 3, the humidity level demonstrates a directly proportional relationship with the temperature for two zones, which are: 12 am to 12 pm, and 6 pm to 12 am. Throughout this duration, the room was either kept unoccupied or had low traffic usage. A total of 11 door openings were recorded within the 12 hour duration. From 6 am onwards, there was an increment in humidity and temperature, due to the cleaning and disinfecting of the operating room. These two parameters were well controlled and kept stabled after the cleaning and disinfecting process. From 12 pm to 6 pm, however, both the temperature and humidity fluctuated dramatically. A door opening frequency of 32 was recorded within the 6 hour duration. This disrupted the airflow systems and thus limited the effectiveness of the air-conditioning to maintain the temperature and humidity distributions. During the heavy traffic and door opening conditions, the temperature and relative humidity were increased to 20.5 °C and 73.9 % respectively. The temperature remained within the recommended range, while the humidity was found to exceed the recommended humidity level by 14 %. Such moisture content will aggravate microbial activities [15]. In this study, the main contributions of the increment in humidity and temperature are due to the door openings and exhalation by occupants. Wong et al. [16] reported that the moisture released from the mouth and nose of a human is around 85 % to 90 %, and 83 % to 90 %, respectively. While, the exhalation temperature from the mouth and nose is 33 °C and 31.5 °C respectively.

## CONCLUSIONS

Under an unoccupied or low traffic condition, the air temperature and humidity level remained stable. The cleaning and disinfecting procedures, however, significantly increased the humidity level by 14 %. The frequent door openings also elevated the air temperature by 2.5 °C. These two scenarios could increase the growth and activities of bacteria, which may enhance the potential of a patient obtaining a surgical site infection.

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