Comparative Performance of Hot Gas Reheat and Electric Reheat Systems for Humidity Control in Operating Rooms

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Abstract

This study investigated the comparative performance of hot gas reheat and electric reheat systems for humidity control in operating rooms under tropical climate conditions. The experiment was conducted in an ISO Class 7 cleanroom equipped with an air handling unit (AHU) system, where both reheat configurations were evaluated under identical operating conditions. The inlet air condition was maintained at 28 °C and 80% relative humidity (RH), while the initial in-room condition was set at 24 °C and 95% RH. The control target was defined at 24 °C and 50–60% RH. The performance of the two systems was assessed based on the rate of humidity reduction, time required to reach the setpoint, and stability of temperature and relative humidity. The results showed that both systems were capable of reducing the relative humidity from approximately 95% to the target range of 52–56% RH within a comparable time frame. The humidity reduction exhibited a rapid decrease during the initial phase, followed by a gradual approach to steady-state conditions, consistent with the condensation mechanism on the cooling coil. In terms of stability, the hot gas reheat system demonstrated slightly better performance, with narrower fluctuations in relative humidity during steady-state operation. Additionally, both systems maintained indoor temperature within a stable range of approximately 23.3–24.5 °C, indicating that effective humidity control could be achieved without compromising thermal comfort. The findings suggested that while both reheat systems provided comparable humidity control performance, the hot gas reheat system offered improved stability, making it more suitable for operating room applications requiring precise environmental control.

Keywords: Hot Gas Reheat, Humidity Control, Operating Room, Electric Reheat, Cleanroom

Introduction

Maintaining appropriate indoor environmental conditions is critically important in healthcare facilities, particularly in operating rooms where strict control of temperature and relative humidity is required to ensure patient safety, infection control, and optimal working conditions for medical personnel. Operating rooms are typically required to maintain temperature within 20–24 °C and relative humidity within 30–60%, along with controlled airflow and pressure conditions to minimize contamination risks (ASHRAE, 2021). These requirements highlight the importance of precise humidity control as a key component of indoor air quality (IAQ) management in critical environments.

In hot-humid climates, such as those found in Southeast Asia, humidity control presents a significant challenge due to high latent loads associated with outdoor air conditions. Previous studies have reported that latent loads account for a substantial portion of total cooling demand, particularly in buildings where sensible loads are reduced through improved insulation and system efficiency (Nguyen et al., 2021; Zhao et al., 2020). Inadequate humidity control can lead to microbial growth, deterioration of building materials, and discomfort among occupants,

thereby compromising both environmental quality and system performance (Zhang et al., 2023; Le et al., 2021). Therefore, effective humidity control strategies are essential for maintaining both environmental safety and system reliability.

Conventional air-conditioning systems typically control humidity through a cooling and reheat process, in which air is cooled below its dew point to remove moisture and then reheated to achieve the desired supply air temperature. Electric reheat coils are widely used due to their controllability and ease of installation. However, this approach is inherently energy-intensive because it requires additional electrical energy after the cooling process, resulting in reduced overall system efficiency (Baek et al., 2020; Jwo et al., 2019). Recent studies have emphasized the need to improve HVAC system efficiency by reducing redundant energy use in reheat processes (Mallay, 2024).

An alternative approach is the use of hot gas reheat systems, which utilize waste heat from the condenser to reheat the air after dehumidification. This method enhances system efficiency by recovering internal energy within the refrigeration cycle, thereby reducing the need for additional electrical heating. Previous research has shown that hot gas reheat systems can reduce overall energy consumption while maintaining effective humidity control performance (Nguyen et al., 2021; Zhao et al., 2020). In addition, studies in tropical climates have highlighted that heat recovery strategies are particularly beneficial in improving HVAC performance and energy efficiency under high humidity conditions (Zhang et al., 2023).

Despite the increasing interest in energy-efficient humidity control technologies, there is still a lack of experimental studies that directly compare the performance of hot gas reheat and electric reheat systems under controlled conditions, especially in operating room environments. Most previous studies have focused on simulation-based analyses or applications in general buildings, with limited attention given to cleanroom or healthcare settings where precise environmental control is required.

Therefore, this study aimed to experimentally compare the performance of hot gas reheat and electric reheat systems for humidity control in an operating room under tropical climate conditions. The evaluation focused on key performance indicators, including the rate of humidity reduction, time required to reach the setpoint, and the stability of temperature and relative humidity. The findings of this study are expected to provide practical insights for the design and optimization of HVAC systems in healthcare facilities, particularly in hot-humid regions.

Research Methodology

3.1 Experimental Setup

This study was conducted in a controlled cleanroom environment designed to simulate an operating room under tropical climate conditions. The experimental facility was an ISO Class 7 cleanroom equipped with a centralized air handling unit (AHU) system. The system was designed in accordance with healthcare ventilation standards, including controlled airflow, high-efficiency particulate air (HEPA) filtration, and positive pressure conditions.

The AHU system consisted of multiple functional sections, including air intake, filtration units (prefilter, fine filter, and HEPA filter), a cooling coil for temperature and moisture removal, and a reheat section. Two different reheat configurations were investigated: (1) electric reheat using resistance heating coils and (2) hot gas reheat utilizing condenser waste heat from the refrigeration cycle.

A schematic diagram of the experimental AHU system is presented in Figure 1 to illustrate the configuration of the real system. The diagram includes the cooling coil,

compressor, condenser, hot gas reheat line, electric reheat coil, sensor positions, and airflow direction. This schematic representation ensures clarity in understanding the system operation and provides a direct linkage between the experimental setup and the measured performance results.

The experimental space was configured to replicate operating room conditions, including controlled airflow patterns and environmental monitoring points located near the critical zone. Air change rates were maintained at approximately 25–30 air changes per hour (ACH), consistent with standard operating room requirements.

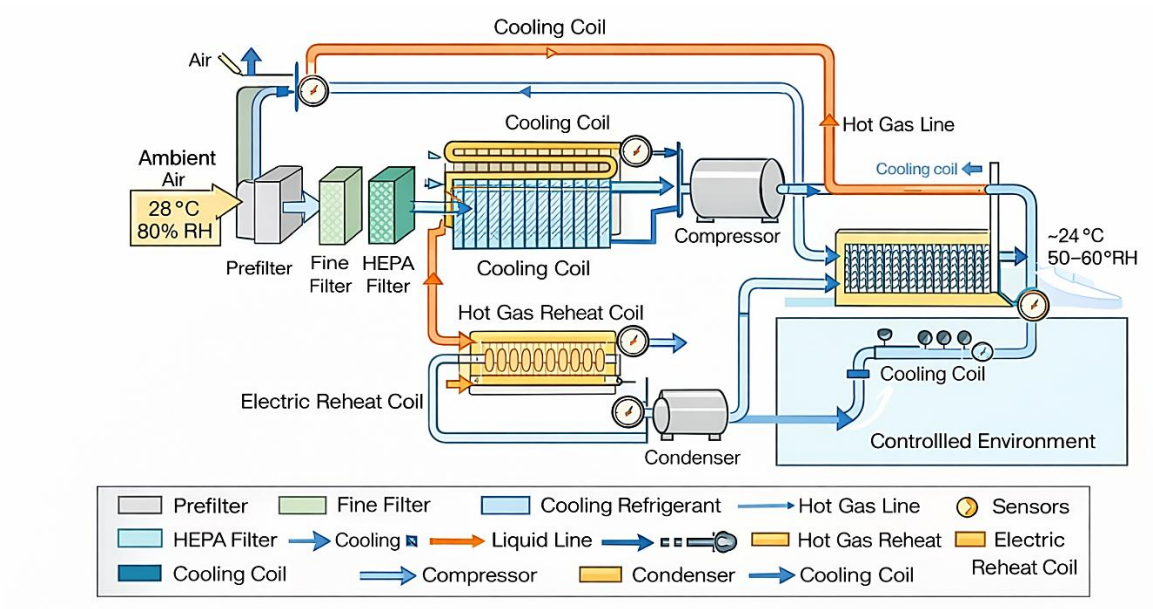


Figure 1 Schematic diagram of the experimental AHU system showing airflow direction and reheat configurations.

3.2 Operating Conditions

All experiments were conducted under identical and controlled boundary conditions to ensure a fair comparison between the two systems. The inlet air (fresh air) condition was maintained at a temperature of 28 °C and relative humidity of 80%, representing typical outdoor conditions in a hot-humid climate.

The initial indoor condition (in-room condition) was set at 24 °C and 95% relative humidity to represent a high latent load scenario. The control setpoint for the operating room was defined at 24 °C and 50–60% relative humidity, which is within the acceptable range for healthcare environments.

Each system was operated independently under the same conditions, and experiments were repeated to ensure consistency and reliability of the data.

3.3 Measurement and Instrumentation

Environmental parameters were continuously monitored using calibrated sensors installed within the cleanroom. The key parameters measured included:

Air temperature (°C)

Relative humidity (%RH)

Electrical current (A) of the system

Temperature and humidity sensors were positioned at representative locations within the operating room, particularly near the critical working zone. Data were recorded at regular time intervals throughout the experiment to capture transient and steady-state behavior.

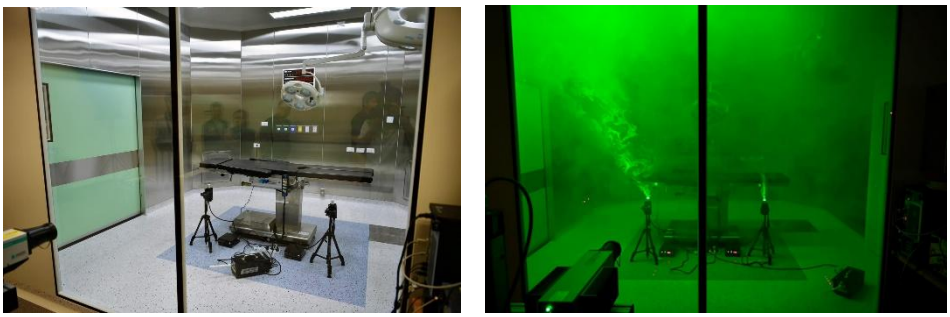
Electrical current measurements were obtained using a power meter connected to the system, allowing evaluation of system operation and performance characteristics.

3.4 Experimental Procedure

The experimental procedure was designed to evaluate the dynamic performance of each reheat system during the dehumidification process. The procedure consisted of the following steps:

1. The cleanroom was initially conditioned to the predefined in-room condition (24 °C, 95% RH).
2. The selected reheat system (electric or hot gas reheat) was activated along with the cooling system.
3. Environmental parameters (temperature, relative humidity, and electrical current) were recorded continuously as the system operated.
4. The experiment continued until the indoor conditions reached and stabilized within the control setpoint range (24 °C, 50–60% RH).
5. The same procedure was repeated for the alternative reheat system under identical conditions.

This approach ensured that both systems were evaluated under the same initial and boundary conditions, enabling a direct comparison of their performance.



(a) (b)

Figure 2 (a) Cleanroom laboratory, Faculty of Engineering, Kasetsart University, (b) Airflow visualization using laser light and fog generator.

Figure 3 Camfil air filtration unit, Faculty of Engineering, Kasetsart University.

3.5 Performance Evaluation Criteria

The performance of the two systems was evaluated using the following key indicators:

1. **Rate of humidity reduction** – evaluated based on the change in relative humidity over time.
2. **Time to reach setpoint** – defined as the time required for the system to reduce indoor relative humidity from the initial condition to the target range.
3. **Stability of environmental conditions** – assessed by analyzing fluctuations in temperature and relative humidity after reaching steady-state conditions.

These indicators were selected to reflect the critical requirements of operating room environments, where both rapid response and stable control are essential.

3.6 Data Analysis

The collected data were analyzed using time-series analysis to evaluate the behavior of temperature and relative humidity during the dehumidification process. Graphical analysis was used to illustrate trends in humidity reduction and temperature stability over time.

In addition to qualitative trend analysis, statistical methods were employed to quantitatively assess system performance. The standard deviation (SD) and coefficient of variation (CV) of relative humidity were calculated during steady-state conditions (15–30 minutes) to evaluate the stability of each system.

Comparative analysis between the two systems was further conducted using inferential statistical methods. A paired t-test was performed to determine whether the differences in performance indicators, particularly relative humidity stability and response time, were statistically significant at a confidence level of $p < 0.05$. Additionally, 95% confidence intervals (CI) were calculated to quantify the uncertainty and reliability of the observed differences between the two systems.

The results were interpreted based on both statistical evidence and thermodynamic principles of moisture condensation and heat transfer within the HVAC system, ensuring a comprehensive evaluation of system performance.

3.7 Control System Description

The control system was designed to maintain the indoor environmental conditions at a target temperature of 24 °C and a relative humidity range of 50–60%, which are consistent with standard operating room requirements. A feedback control mechanism was implemented using temperature and humidity sensors installed within the controlled space. These sensors continuously monitored real-time environmental conditions and transmitted signals to the control unit for system regulation.

For the electric reheat system, the heating coil operated based on an on–off control strategy. The system activated the electric reheat coil when the measured temperature dropped below the setpoint and deactivated it once the desired condition was achieved. This intermittent operation resulted in periodic fluctuations in both temperature and relative humidity.

In contrast, the hot gas reheat system utilized a continuous modulation control approach by regulating the flow of hot refrigerant gas from the compressor discharge to the reheat coil.

This mechanism allowed for a more stable and gradual adjustment of the supply air temperature without abrupt changes in system operation.

The difference in control strategies between the two systems significantly influenced their performance characteristics. The continuous modulation in the hot gas reheat system contributed to smoother thermal regulation and reduced fluctuations in relative humidity, whereas the on–off operation of the electric reheat system led to more noticeable variations during steady-state conditions.

Result

4.1 Relative Humidity Reduction Performance

The variation of indoor relative humidity over time for the hot gas reheat system is illustrated in Figure 1. The results showed that the relative humidity decreased rapidly during the initial stage of operation, followed by a gradual approach toward steady-state conditions.

At the beginning of the experiment, the indoor relative humidity was approximately 95%RH, representing a high latent load condition. Within a short period, the humidity decreased significantly to approximately 64%RH, indicating an effective moisture removal process. This rapid reduction phase can be attributed to the high vapor pressure difference between the air and the cooling coil surface, which enhances condensation (Chai et al., 2022).

After the initial phase, the rate of humidity reduction decreased, and the system gradually stabilized within the range of 53–55%RH. This behavior is consistent with the thermodynamic principle that the driving potential for condensation decreases as the air approaches equilibrium conditions (Akhtar et al., 2024). Similar trends have been reported in previous studies on dehumidification processes in HVAC systems (Chai et al., 2022).

These results confirm that the system is capable of achieving the target humidity range required for operating room applications, which typically falls between 50–60%RH (ASHRAE, 2021).

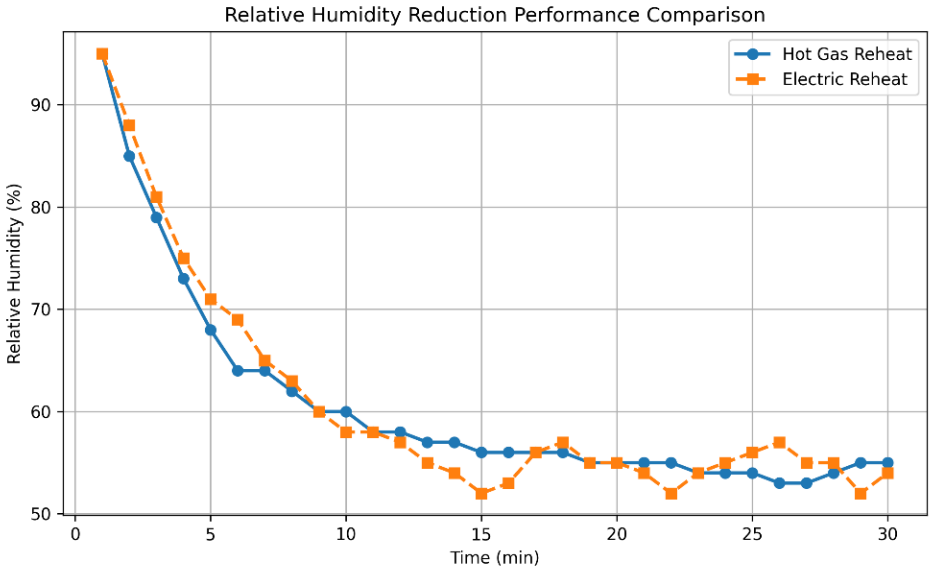


Figure 4. Comparison of Relative Humidity Reduction between Hot Gas Reheat and Electric Reheat Systems

4.2 Temperature Stability

Table 1 Sample Experimental Data (Hot Gas Reheat)

Time Step	Temperature (°C)	Relative Humidity (%RH)
1	24.2	95
5	23.7	68
10	23.9	60
15	24.5	56
20	23.7	55
25	24.5	53
30	23.4	55

Figure 2 presents the variation of indoor temperature during the dehumidification process. The results indicated that the indoor temperature remained relatively stable throughout the experiment, ranging between approximately 23.3 and 24.5 °C.

Despite continuous moisture removal, the system was able to maintain temperature fluctuations within ±0.6 °C, which demonstrates effective thermal control. This stability is a key requirement for operating rooms, where temperature deviations must be minimized to ensure comfort and operational safety.

The observed behavior is consistent with the function of reheat systems, which compensate for overcooling during dehumidification by reheating the air to the desired supply condition. In particular, the use of recovered heat in hot gas reheat systems helps maintain temperature stability without introducing additional energy input (Nguyen et al., 2021).

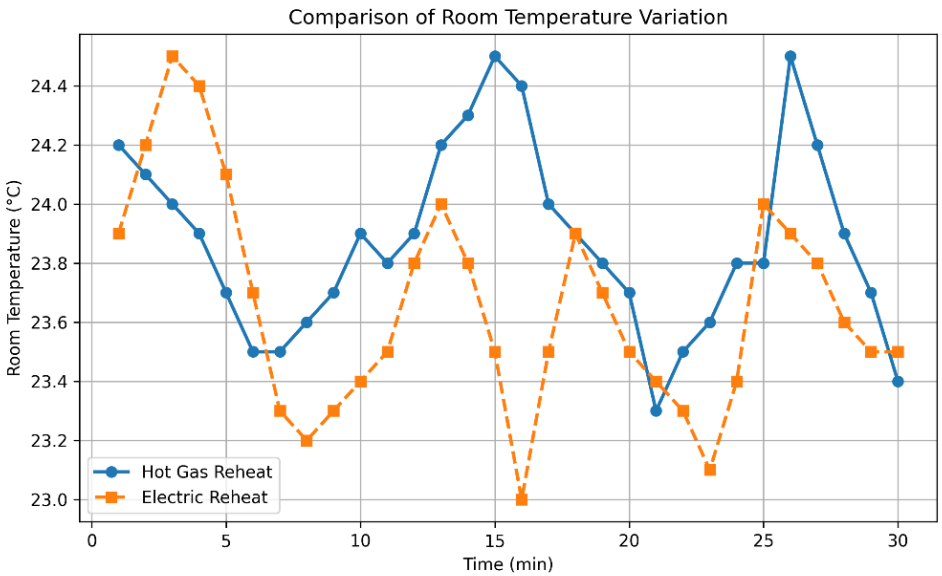


Figure 5. Comparison of Room Temperature Variation between Hot Gas Reheat and Electric Reheat Systems

4.3 Comparative Performance Analysis

Both hot gas reheat and electric reheat systems were able to reduce indoor relative humidity from approximately 95%RH to the target range of 52–56%RH within a comparable time frame. This indicates that both systems are capable of achieving effective humidity control under high latent load conditions.

However, differences were observed in terms of system stability. The hot gas reheat system exhibited slightly more stable humidity control during steady-state operation, with smaller fluctuations in relative humidity compared to the electric reheat system. This can be explained by the continuous nature of heat recovery in the hot gas system, which is directly linked to the refrigeration cycle, resulting in smoother operation.

In contrast, electric reheat systems typically operate in an on–off manner, leading to more noticeable fluctuations in temperature and humidity (Mallay, 2024). Similar observations have been reported in previous studies on HVAC control strategies in hot-humid climates (Zhang et al., 2023).

Table 2 Summary of Humidity Control Performance

Parameter	Hot Gas Reheat	Electric Reheat
Initial RH (%RH)	95	95
Final RH (%RH)	53–55	54–56
Temperature Range (°C)	23.3–24.5	23.5–24.7
RH Reduction Behavior	Rapid initial, stable final	Rapid initial, slight fluctuation
Stability (RH fluctuation)	More stable	Less stable

4.4 Discussion

The results of this study highlight that humidity control performance is primarily governed by the condensation process occurring at the cooling coil. The rapid decrease in relative humidity during the initial phase is driven by the high moisture content in the air, while the slower reduction in later stages reflects the diminishing vapor pressure difference.

The ability of both systems to maintain stable temperature conditions while reducing humidity demonstrates the effectiveness of the cooling–reheat process in HVAC systems. However, the improved stability observed in the hot gas reheat system suggests that heat recovery mechanisms can enhance system performance without compromising environmental control.

These findings are consistent with previous research indicating that advanced HVAC systems incorporating heat recovery can improve operational stability and indoor environmental quality (Nguyen et al., 2021; Dermentzis et al., 2024).

Discussion and conclusions

Discussion

The results of this study demonstrated that both hot gas reheat and electric reheat systems were capable of effectively controlling humidity in an operating room environment under high latent load conditions. The observed reduction in relative humidity from approximately 95%RH to the target range of 50–60%RH confirmed that the cooling–reheat mechanism is effective for moisture removal in HVAC systems. This finding is consistent with previous studies that highlighted the role of cooling coils in achieving dehumidification through condensation processes (Chai et al., 2022).

The rapid decrease in relative humidity during the initial stage of operation can be explained by the high vapor pressure difference between the moist air and the cooling coil surface, which enhances moisture condensation. As the humidity level approached the setpoint, the rate of reduction gradually decreased, reflecting a reduction in the thermodynamic driving force. Similar behavior has been reported in dehumidification studies under high humidity conditions (Zhang et al., 2023).

From a thermodynamic perspective, the dehumidification process is governed by heat and mass transfer mechanisms at the cooling coil surface. The removal of moisture is associated with latent heat transfer, while the subsequent reheating process affects the sensible heat ratio (SHR). The cooling coil surface temperature plays a critical role in determining the moisture removal rate, which can be further analyzed based on the ASHRAE Handbook Fundamentals framework.

In terms of temperature control, both systems maintained indoor temperatures within a narrow range (approximately 23.3–24.5 °C), indicating that the reheat process successfully compensated for overcooling during dehumidification. This is particularly important in operating room environments, where temperature stability is essential for both patient safety and staff performance (ASHRAE, 2021). The ability to maintain stable temperature conditions while reducing humidity highlights the effectiveness of the cooling–reheat strategy.

However, differences were observed in the stability of humidity control between the two systems. The hot gas reheat system exhibited smoother and more stable humidity control during steady-state operation compared to the electric reheat system. This can be attributed to the continuous nature of heat recovery from the refrigeration cycle, which provides a more consistent reheating effect. In contrast, electric reheat systems typically operate in an intermittent or on–off manner, leading to fluctuations in environmental conditions (Mallay, 2024).

The relative humidity (RH) variation of the hot gas reheat system during steady-state operation was observed to remain within ±3% RH, which is consistent with ISO 7730 indoor environmental standards, further confirming the system's capability to maintain stable indoor environmental conditions.

Furthermore, the dehumidification process can be interpreted using the Chilton–Colburn analogy, where the heat and mass transfer processes are coupled. According to the Lewis relation, the transfer of heat and moisture occurs simultaneously, indicating that the efficiency of humidity control is closely related to both thermal and mass transport characteristics within the system.

These findings are consistent with previous research indicating that heat recovery-based HVAC systems can improve operational stability and overall system performance (Nguyen et al., 2021). Moreover, in hot-humid climates, where latent loads dominate, the use of recovered heat can provide additional benefits in maintaining consistent indoor environmental conditions (Zhang et al., 2023).

Overall, the results suggest that while both systems are capable of achieving the required humidity control performance, the hot gas reheat system offers advantages in terms of stability and operational consistency, which are critical in sensitive environments such as operating rooms.

Conclusions

This study experimentally compared the performance of hot gas reheat and electric reheat systems for humidity control in an operating room under tropical climate conditions. Based on the results obtained, the following conclusions can be drawn:

1. Both systems were capable of reducing indoor relative humidity from approximately 95%RH to the target range of 50–60%RH, demonstrating effective humidity control under high latent load conditions.
2. The humidity reduction process exhibited two distinct phases: a rapid decrease during the initial stage followed by a gradual approach to steady-state conditions, consistent with the condensation mechanism on the cooling coil.

3. Both systems maintained indoor temperature within a stable range of approximately 23.3–24.5 °C, indicating effective thermal control during the dehumidification process.
4. The hot gas reheat system demonstrated superior stability in humidity control, with smaller fluctuations compared to the electric reheat system.
5. The improved stability of the hot gas reheat system is attributed to the continuous heat recovery mechanism, which provides a more consistent reheating process compared to the intermittent operation of electric reheat systems.

In conclusion, both reheat systems are suitable for humidity control in operating room environments. However, the hot gas reheat system is more advantageous in terms of stability and operational performance, making it a preferable option for applications requiring precise environmental control.

Suggestion

Practical Applications

- The hot gas reheat system is recommended for operating room applications where precise and stable humidity control is required, as it demonstrated superior stability compared to the electric reheat system.
- HVAC system designers should consider integrating heat recovery mechanisms, such as hot gas reheat, to enhance system performance and reduce reliance on additional heating energy, particularly in hot-humid climates.
- Proper control strategies should be implemented to optimize the interaction between cooling and reheating processes, ensuring both humidity reduction and temperature stability within the required operating range.

Future Research

- Future studies should investigate the energy consumption performance of hot gas reheat and electric reheat systems to provide a comprehensive evaluation of both efficiency and operational cost.
- Further research is recommended to examine system performance under varying operating conditions, such as different outdoor humidity levels, airflow rates, and load variations.
- Advanced control strategies, including smart or adaptive control systems, should be explored to improve the responsiveness and stability of humidity control in critical environments.
- Additional studies should be conducted in real hospital environments to validate the experimental results and assess long-term system performance.

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