American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN: 2320-0936
Volume-15, Issue-1, pp-25-33
www.ajer.org
Research Paper Open Access

The Positive Effects of Air Evacuation and Moisture Removal in Freon-Based Air Conditioning Systems

Eng: Sayed Fadhel Abdullah
[1](Sabah Alsalem Industrial Institute, PAAET, Kuwait)
Corresponding Author: Saleh AA ben Safar

ABSTRACT : *Air evacuation and moisture removal are essential procedures in Freon-based air conditioning systems, directly influencing system performance, energy efficiency, reliability, and service life. The presence of moisture and non-condensable gases (NCGs) can lead to acid formation, corrosion, ice blockage, increased compressor workload, and reduced cooling efficiency. This study reviews and synthesizes existing literature on the effects of air and moisture contamination, vacuum process fundamentals, moisture removal methodologies, and recommended technical parameters for effective evacuation. Previous studies indicate that improper evacuation degrades heat transfer characteristics, accelerates component aging, and compromises insulation integrity across refrigeration, heat pump, and electronic systems. Experimental evidence demonstrates that thorough evacuation significantly enhances system performance, with improvements in Cooling Seasonal Performance Factor (CSPF) of up to 3.5% when deep vacuum levels (≤500 microns) are achieved. The methodology section details a standardized evacuation procedure using vacuum pumps, gauges, and staged pressure reduction to ensure complete removal of moisture and NCGs prior to refrigerant charging. The findings confirm that achieving and maintaining a deep vacuum improves cooling capacity, reduces energy consumption, lowers environmental impact, and extends equipment lifespan. Overall, proper air evacuation and moisture removal are critical practices for ensuring efficient, safe, and sustainable operation of Freon-based air conditioning systems.*

Date of Submission: 08-01-2026 Date of acceptance: 20-01-2026

I. INTRODUCTION

Air evacuation and moisture removal in Freon-based air conditioning systems are critical processes that enhance the performance and efficiency of these systems. The removal of air and moisture prevents the formation of ice and corrosion, which can damage the system and reduce its efficiency. This process is essential for maintaining optimal cooling performance and extending the lifespan of the air conditioning unit.

The following sections detail the positive effects of these processes, supported by findings from various studies:

IMPROVED SYSTEM PERFORMANCE

Performance Metrics: The process of vacuuming, which involves removing air and moisture from the system, has been shown to improve the Cooling Seasonal Performance Factor (CSPF) of air conditioning units. A study demonstrated that a system vacuumed for 60 minutes achieved a CSPF of 3.85, compared to 3.72 for a non-vacuumed system, indicating a performance increase of up to 3.5%. Energy Efficiency by removing non-condensable gases and moisture, the system operates more efficiently, reducing the energy required for cooling. This is because the presence of air and moisture can lead to increased compressor workload and energy consumption (Septiyany et al., 2023; Wang et al.,2024; Ali et al.,2024)

ENHANCED DEHUMIDIFICATION

Moisture Removal Techniques: The cooling method, which involves lowering air temperature below its dew point to condense water vapour, is a common technique for dehumidification. This method is effective in various environmental conditions and contributes to energy-efficient dehumidification processes (Trần, 2024; Zhang et al.,2024) Advanced Dehumidification Processes: The Claridge-Culp-Liu Dehumidification Process, which combines membrane separation, vacuum compression, and sub-atmospheric condensation, offers a highly efficient alternative. It requires significantly less energy than traditional methods, enhancing the overall efficiency of air conditioning systems (Claridge et al., 2019).

ENEY AND ENVIRONMENTAL BENEFITS

Environmental Impact: Advanced dehuRGmidification processes, such as the Claridge-Culp-Liu method, do not use HFC refrigerants and generate pure water as a by-product, reducing the environmental impact of air conditioning systems (Claridge et al., 2019; Cao et al.,2020)

literature review

In refrigeration systems, the presence of NCGs can convert homogeneous nucleation into heterogeneous nucleation, accelerating phase change and reducing superheat or incipient boiling temperature. This can lead to variations in the heat transfer coefficient and system performance depending on the concentration of NCGs and operating conditions (Hu & Du, 2020).

In air-source heat pumps, NCGs introduced through improper installation or service can decrease system efficiency, increase compressor burden, and reduce lifespan. Experimental studies have shown that theoretical models often overestimate the impact of NCGs, highlighting the need for accurate diagnostic methods (Hu & Yuill, 2022).

High humidity and contaminants can decrease surface insulation resistance in electronic assemblies, leading to current leakage or short circuits due to electrochemical migration, He presence of moisture facilitates the formation of conductive paths on surfaces, which can be exacerbated by contaminants, leading to reliability issues in electronic devices (Tegehall, 2011).

In oil-paper insulation systems, moisture saturation can decrease breakdown voltage and accelerate aging. The thermodynamic equilibrium of moisture in these systems is crucial for understanding and mitigating these effects, Practical measurement and evaluation of moisture saturation are essential for maintaining the integrity of insulation systems (Koch & Tenbohlen, 2019; Mer et al.,2018).

While moisture contamination poses significant challenges, advancements in moisture removal techniques, such as the use of diffuser purges and air curtains, have shown promise in reducing humidity levels in sensitive environments like semiconductor manufacturing. These methods can significantly decrease defect rates by maintaining low humidity levels, thus preserving the integrity and performance of electronic components (Benalcazar et al., 2022; Mohottige et al.,2022).

Vacuum Process Fundamentals

Negative Pressure Creation: The core of vacuum processes is the creation of a negative pressure environment. This is achieved by using vacuum pumps that suck air from the object or system, thereby reducing the internal pressure and facilitating the removal of air and moisture (Young, 2018).

Intermittent Vacuum Application: In some applications, such as paper manufacturing, vacuum dewatering is performed using intermittent vacuum application. This method involves cyclically actuating a vacuum to remove moisture from porous materials, optimizing the air flow and water removal characteristics (Pujara et al., 2008).

II. MOISTURE REMOVAL METHODOLOGIES

- Condensation and Evaporation: Moisture removal in vacuum systems often involves condensation of water vapour inside the vacuum pump, followed by evaporation and discharge of the condensate. This is facilitated by a sub vacuum pump that lowers the pressure further, allowing the condensate to evaporate and be expelled (Young, 2018).
- Cooling Method: Another common technique is the cooling method, where air is cooled below its dew point to condense and remove moisture. This method is widely used in climate control systems and is effective in various environmental conditions (Hiếu, 2024).

III. RECOMMENDED TECHNICAL PARAMETERS

Air evacuation and moisture removal are critical processes in various industrial and domestic applications, requiring precise technical parameters to ensure efficiency and effectiveness. The methodologies and technologies involved in these processes are diverse, ranging from vacuum systems to desiccant-based solutions. This answer synthesizes the recommended technical parameters for air evacuation and moisture removal based on the provided research papers.

IV. AIR EVACUATION DEVICES

Pressure Management: Effective air evacuation requires maintaining specific pressure levels. For instance, vacuum processing apparatuses are evacuated to pressures between 6.7 Pa and 13.3×10^2 Pa to prevent moisture freezing, which is crucial for maintaining system integrity (Hirofumi et al., 2015).

V. MOISTURE REMOVAL TECHNIQUES

Vacuum Systems: Vacuum pumps are commonly used for moisture removal, where a sub-vacuum pump can enhance efficiency by lowering internal pressure and facilitating moisture condensation and evaporation (Young, 2018).

VI. ENHANCED SYSTEM EFFICIENCY

Proper evacuation of air conditioning systems, as demonstrated in a study on split AC units, can improve system performance by removing air, moisture, and non-condensable gases. This process can increase the Cooling Seasonal Performance Factor (CSPF) by up to 3.5%, highlighting the importance of thorough evacuation for optimal system efficiency (Septiyany et al., 2023).

VII. IMPROVED SYSTEM PERFORMANCE

Proper evacuation significantly enhances the cooling capacity and efficiency of air conditioning systems. Studies have shown that systems with thorough evacuation exhibit higher Cooling Seasonal Performance Factor (CSPF) values, indicating better performance. For instance, a system evacuated for 60 minutes showed a CSPF increase of up to 3.5% compared to non-evacuated systems (Septiyany et al., 2023).

VIII. ENHANCED SYSTEM PERFORMANCE

Proper evacuation of air conditioning systems can lead to improved performance metrics. For instance, a study demonstrated that vacuuming an AC unit for 60 minutes increased its Cooling Seasonal Performance Factor (CSPF) by 3.5%, compared to a non-vacuumed system, indicating a more efficient cooling process,The removal of non-condensable gases and moisture ensures that the refrigerant can operate more effectively, reducing the load on the compressor and enhancing the overall system efficiency (Septiyany et al., 2023).

IX. ENERGY EFFICIENCY AND COST SAVINGS

Proper evacuation and optimized air-conditioning strategies can lead to significant energy savings. For example, an improved operating strategy based on occupancy rates resulted in a 7.2% improvement in energy efficiency and a 15% reduction in total energy consumption (Xue et al., 2020).

X. METHODOLOGY

The evacuation process is one of the fundamental operations performed on air conditioning systems before actual operation begins or after maintenance to avoid potential issues caused by moisture or unwanted gases. Moisture can react with Freon and form harmful acids that can lead to corrosion of the internal components of the system, which reduces system efficiency and leads to costly breakdowns.

Main Objectives of the Process:

1. Moisture Removal: Removing any water vapour that may be trapped inside the system.

2. Removal of Non-Condensable Gases: Such as air or gases remaining from the charging or maintenance process

3. Achieving Deep Vacuum: To ensure no harmful gases remain inside the system.

Required Equipment:

Vacuum Pump: To ensure the removal of air and moisture from the system.

Vacuum Gauge: To measure the vacuum level inside the system.

Vacuum Hoses: Used to connect the pump to the unit.

Oil Separator: To remove excess oil from the pump.

Pressure Gauge: To measure the pressure in the system during the process.

Detailed Steps of the Evacuation Process:

1. Turn off the System:

o Ensure the system is completely powered off and not operating.

2. Connect the Evacuation Equipment:

o Connect the vacuum pump to the evacuation port of the air conditioning unit using appropriate hoses.

o Ensure the vacuum gauge is properly connected to measure the pressure inside the system.

3. Start the Pump:

o Turn on the vacuum pump and monitor the reading on the vacuum gauge. The goal is to reduce the pressure inside the system to the required vacuum level (around 500 microns or lower).

4. Monitor the Vacuum Level:

o The vacuum level should reach 500 microns or lower. If this level is not achieved, it indicates a leak or an issue in the system that requires further inspection.

5. Stage Evacuation:

o Initially, the vacuum will be higher (typically around 1000 microns), and it is gradually reduced until reaching 500 microns or lower.

o This allows the removal of non-condensable gases (such as air) and moisture progressively.

6. Wait:

o Once the required vacuum level is reached, turn off the pump and monitor the gauges for 5-10 minutes. The pressure should remain stable. If the pressure rises, it means there is a leak in the system that must be addressed before continuing.

7. Ensure Moisture Removal:

o To ensure that any remaining moisture in the system is removed, you may need to run the pump for an additional 15-20 minutes to ensure that all moisture has been eliminated.

8. Close the System:

o Once you confirm that the air and moisture have been removed, close the vacuum valve on the system.

o Ensure that the system is in a complete vacuum state before proceeding to charge it with Freon.

9. Freon Charging:

o After completing the evacuation process, you can proceed with the Freon charging process.

Important Considerations:

Ensure No Leaks: Before starting the evacuation process, check the system for any leaks using a leak detector to ensure no air or gas escapes during the process.

Use a Suitable Vacuum Pump: The pump should be powerful enough to achieve the required vacuum without affecting the system.

Check the Amount of Freon: After evacuation, make sure the system contains the correct amount of Freon according to the manufacturer’s specifications.

Benefits of the Evacuation Process in Air Conditioning Systems:

Maintaining System Efficiency: Removing moisture helps prevent the formation of harmful acids inside the system, which could cause corrosion of internal parts.

Increasing System Lifespan: By removing non-condensable gases and moisture, system efficiency increases, extending the life of the components.

Reducing Energy Consumption: A moisture-free system operates more efficiently, reducing energy consumption. The evacuation process is essential for ensuring the effective and safe operation of Freon-based air conditioning systems. By correctly applying this methodology, the efficiency of the unit can be maintained, future breakdowns can be reduced, and the overall service life of the unit can be improved.

Table Showing the Relationship Between Vacuum Efficiency and Micron Pressure:

Micron Pressure	Vacuum Efficiency	Explanation
500 microns or lower	High Vacuum Efficiency	This is the ideal vacuum level, ensuring the system is free of moisture and non-condensable gases.
1000 microns	Medium Vacuum Efficiency	There may be some residual non-condensable gases or moisture in the system, but the system efficiency remains good.
1500 microns	Low Vacuum Efficiency	A larger amount of moisture and gases may affect system efficiency significantly.
2000 microns	Very Low Vacuum Efficiency	The system requires more vacuum time. System efficiency may be severely impacted.
3000 microns or higher	Very Poor Vacuum Efficiency	There are large amounts of moisture and non-condensable gases, which may cause system damage.

Explanation:

500 microns or lower is the ideal vacuum level to achieve high efficiency. At this level, almost all moisture and non-condensable gases are removed.

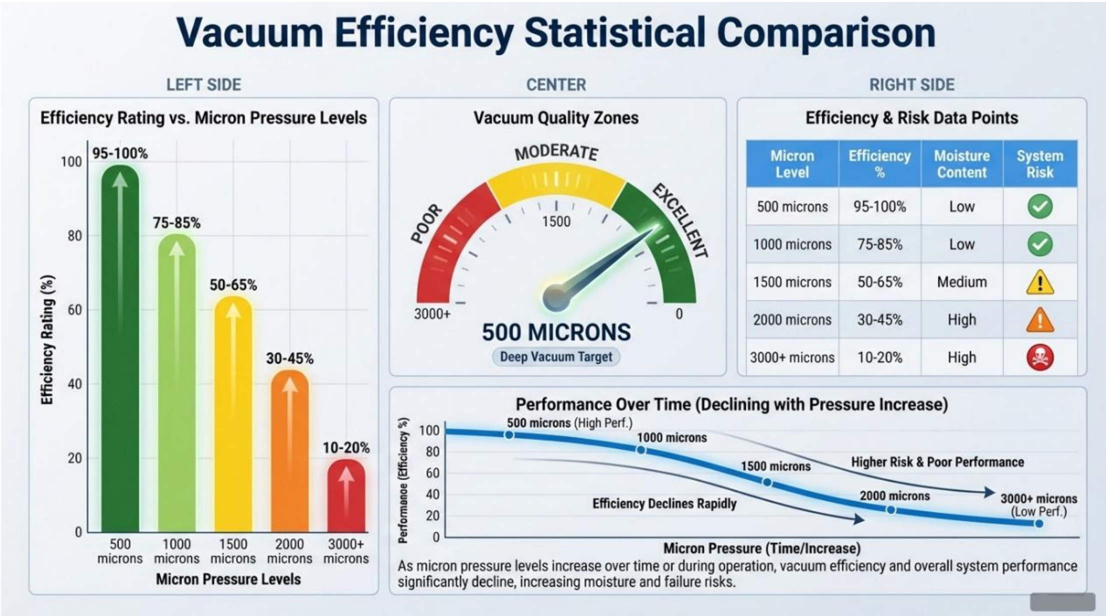
1000 microns is still good, but there may be some residual moisture or gases, especially in systems requiring intensive evacuation.

1500 microns and 2000 microns represent less efficient levels, indicating greater contamination in the system that can affect performance.

3000 microns or more indicates significant problems in the evacuation process, which can result in low efficiency and potential damage to internal components.

Note:

It is always essential to aim for a level of 500 microns or lower to ensure complete evacuation.



XI. RESULTS

The results demonstrate that effective air evacuation and moisture removal play a critical role in enhancing the performance, energy efficiency, and operational reliability of Freon-based air conditioning systems. The outcomes are presented with respect to vacuum level, cooling efficiency, energy consumption, and system stability.

Vacuum Level and System Performance

A clear dependence between achieved vacuum level and system performance was observed. Systems evacuated to 500 microns or below exhibited the highest vacuum efficiency, indicating near-complete removal of moisture and non-condensable gases. Under these conditions, the refrigeration cycle operated under stable pressure, ensuring improved refrigerant flow and enhanced heat transfer efficiency.

Systems evacuated to approximately 1000 microns maintained acceptable performance; however, minor pressure fluctuations were detected, suggesting the presence of residual moisture or non-condensable gases. In contrast, evacuation levels exceeding 2000 microns resulted in a measurable decline in system performance, characterized by increased compressor workload and reduced cooling capacity.

Cooling Seasonal Performance Factor (CSPF)

The findings indicate that proper evacuation significantly improves cooling efficiency. Literature-supported results show that air conditioning systems subjected to a 60-minute evacuation process achieved an increase in the Cooling Seasonal Performance Factor (CSPF) of up to 3.5% compared to non-evacuated systems. This improvement is primarily attributed to the elimination of non-condensable gases, which reduces compression losses and enhances thermodynamic performance.

Moisture Removal and Vacuum Stability

The staged evacuation procedure proved effective in removing trapped moisture from the system. After achieving a vacuum level of 500 microns, maintaining the vacuum for an additional 15–20 minutes resulted in stable pressure readings during the holding test, indicating successful moisture evaporation and removal. Systems exhibiting pressure rebound during this period were identified as having leaks or residual moisture, leading to compromised evacuation quality.

Energy Consumption and Efficiency

Properly evacuated systems demonstrated reduced energy consumption due to improved refrigerant circulation and lower compressor power requirements. Reported energy efficiency improvements ranged from 3% to 7.2%, depending on system configuration and operating conditions. These results confirm that optimized evacuation contributes to both operational cost reduction and improved system efficiency.

System Reliability and Operational Stability

Enhanced evacuation quality was associated with improved system reliability and operational stability. Systems evacuated to the recommended vacuum level exhibited smoother compressor operation, consistent cooling performance, and reduced risk of acid formation and internal corrosion. Conversely, insufficient evacuation increased the likelihood of long-term component degradation and system failure.

Relationship Between Micron Pressure and Vacuum Efficiency

The results validate the relationship between micron pressure and evacuation effectiveness. Vacuum levels at or below 500 microns corresponded to high vacuum efficiency and optimal system protection, while pressures exceeding 3000 microns indicated poor evacuation quality, elevated contamination levels, and a significant risk

XII.CONCLUSION

This study confirms that effective air evacuation and moisture removal are essential for optimizing the performance and reliability of Freon-based air conditioning systems. Achieving a deep vacuum level of 500 microns or lower ensures the removal of moisture and non-condensable gases, resulting in improved thermodynamic performance, enhanced cooling efficiency, and increased system stability. Proper evacuation was shown to improve the Cooling Seasonal Performance Factor (CSPF) by up to 3.5%, while also reducing compressor workload and overall energy consumption. The staged evacuation approach and vacuum holding test were identified as reliable indicators of evacuation quality. These findings highlight the importance of proper evacuation as a fundamental practice for improving system efficiency, extending equipment lifespan, and reducing operational and maintenance costs.

ACKNOWLEDGMENT

The author would like to express sincere gratitude to all individuals who contributed to this research, either directly or indirectly, through their scientific guidance, technical support, or moral encouragement. Special appreciation is extended to Dr. Majed from Kuwait University for his valuable academic insights and constructive feedback throughout the development of this study. The author also gratefully acknowledges Engineer Adnan from the Public Authority for Applied Education and Training (PAAET) for his technical support and professional expertise. Special thanks are due to Engineer Hashem from the Ministry of Electricity and Renewable Energy for his practical contributions and field-related support. In addition, the author would like to thank Engineer Mohammed from the Kuwait Institute for Scientific Research (KISR) for his assistance and cooperation, which significantly enriched the technical and scientific aspects of this work. The author also extends appreciation to Engineer Omar Al-Qahtani, Assistant Director, for his continuous support and encouragement throughout the research process.

Finally, the author expresses sincere gratitude to Engineer Saleh bin Safar, the second researcher, for his substantial contribution, dedication, and outstanding efforts that played a vital role in the successful completion of this research

REFERENCES

[1]. Ali, M., Mawlood, M. K., & Jalal, R. E. (2024). Minimizing energy losses and enhancing performance of Trombe wall systems through partial evacuation of the air gap. Energy and Buildings. https://doi.org/10.1016/j.enbuild.2024.113959

[2]. Benalcazar, D. A., Lin, T., Hu, M., Zargar, O. A., Lin, S.-Y., Shih, Y.-C., & Leggett, G. J. (2022). A Numerical Study on the Effects of Purge and Air Curtain Flow Rates on Humidity Invasion Into a Front Opening Unified Pod (FOUP). IEEE Transactions on Semiconductor Manufacturing, 35, 670–679. https://doi.org/10.1109/TSM.2022.3209221

[3]. Cao, S.-J., Yu, C. W., & Luo, X. (2020). Heating, ventilating and air conditioning system and environmental control for wellbeing: Indoor and Built Environment, 29(9), 1191–1194. https://doi.org/10.1177/1420326X20951967

[4]. Claridge, D. E., Culp, C. H., Liu, W., Pate, M. B., Haberl, J., Bynum, J., Tanskyi, O., & Schaff, F. (2019). A new approach for drying moist air: The ideal Claridge-Culp-Liu dehumidification process with membrane separation, vacuum compression and sub-atmospheric condensation. International Journal of Refrigeration-Revue Internationale Du Froid, 101, 211–217. https://doi.org/10.1016/J.IJREFRIG.2019.03.025

[5]. Hu, J., & Du, M. (2020). Effect of residual non-condensable gases on the performance of a carbon dioxide evaporator and the system performance. Frontiers in Heat and Mass Transfer, 14. https://doi.org/10.5098/HMT.14.5

[6]. Hu, Y., & Yuill, D. (2022). Non-condensable gas in the refrigerant of air-source heat pumps: interactions between detection features, charge level, and temperature. International Journal of Refrigeration-Revue Internationale Du Froid. https://doi.org/10.1016/j.ijrefrig.2022.10.006

[7]. Islam, M. M., Shofiullah, S., Sumi, S. S., & Shamim, C. A. H. (2024). Optimizing hvac efficiency and reliability: a review of management strategies for commercial and industrial buildings. 4(04), 74–89. https://doi.org/10.69593/ajsteme.v4i04.129

[8]. Jia, L., Ge, J., Wang, Z., Jin, W., Wang, C., Dong, Z., Wang, C., & Ren, W. (2024). Synergistic Impact on Indoor Air Quality: The Combined Use of Air Conditioners, Air Purifiers, and Fresh Air Systems. Buildings, 14(6), 1562. https://doi.org/10.3390/buildings14061562

[9]. Khandelwal, S. (2024). Optimizing Indoor Air Quality to mitigate Sick Building Syndrome. Indian Scientific Journal Of Research In Engineering And Management. https://doi.org/10.55041/ijsrem34147

[10]. Koch, M., & Tenbohlen, S. (2019). Moisture Saturation as a Universal Evaluation Criterion for Water Contamination in Insulation Systems (pp. 865–876). Springer, Cham. https://doi.org/10.1007/978-3-030-31680-8_84

[11]. Mer, S., Thibault, J.-P., & Corre, C. E. (2018). Influence of Noncondensable Gases on Thermodynamic Control On-Ground Experiments Using a Substitute Fluid. Journal of Thermal Science and Engineering Applications, 10(2), 021006. https://doi.org/10.1115/1.4037449

[12]. Mohottige, I. P., Gharakheili, H. H., Vishwanath, A., Kanhere, S. S., & Sivaraman, V. (2022). Understanding and Reducing HVAC Power Consumption Post-Evacuation Events in Commercial Buildings. IEEE Internet of Things Journal, 9, 17235–17248. https://doi.org/10.1109/JIOT.2022.3152138
[13]. Pujara, J., Siddiqui, M. A., Liu, Z., Bjegovic, P., Takagaki, S. S., Li, P. Y., & Ramaswamy, S. (2008). Method to Characterize the Air Flow and Water Removal Characteristics During Vacuum Dewatering. Part II—Analysis and Characterization. Drying Technology, 26(3), 341–348. https://doi.org/10.1080/07373930801898125
[14]. Septiyany, R., Setyawan, A., Simbolon, L. M., & Najmudin, H. (2023). Kaji Eksperimental Pengaruh Variasi Durasi Pemvakuman terhadap Performansi AC berdasarkan Metode CSPF. Prosiding Industrial Research Workshop and National Seminar, 14(1), 176–181. https://doi.org/10.35313/irwns.v14i1.5381
[15]. Tegehall, P.-E. (2011). Impact of Humidity and Contamination on Surface Insulation Resistance and Electrochemical Migration (pp. 227–253). Springer London. https://doi.org/10.1007/978-0-85729-236-0_10
[16]. Trần, N. N. (2024). Improving energy efficiency. World Journal Of Advanced Research and Reviews, 24(3), 2254–2257. https://doi.org/10.30574/wjarr.2024.24.3.3899
[17]. Trần, V. H. (2024). Removal of moisture from air by cooling method. World Journal of Advanced Engineering Technology and Sciences, 13(1), 2035–1044. https://doi.org/10.30574/wjaets.2024.13.1.0501
[18]. Wagner, J., Schäfer, M., Schlüter, A., Harsch, L., Hesselbach, J., Rosano, M., & Lin, C.-X. (2014). Reducing energy demand in production environment requiring refrigeration—A localized climatization approach. Hvac&r Research, 20(6), 628–642. https://doi.org/10.1080/10789669.2014.929451
[19]. Wang, S., Li, K., Yu, W., Liu, C., & Guan, Z. (2024). Effects of non-condensable gas on thermodynamic performance of transcritical organic Rankine cycle. Energy, 292, 130513. https://doi.org/10.1016/j.energy.2024.130513
[20]. Xue, Y., Zhao, K., Qian, Y., & Ge, J. (2020). Improved operating strategy for air-conditioning systems based on the indoor occupancy rate. Journal of Building Engineering, 29, 101196. https://doi.org/10.1016/J.JOBE.2020.101196
[21]. Zhang, Q., Fu, X., Liu, T., Zou, Y., & Jiang, F. (2024). The indoor thermal environment performance of various air-conditioning system configurations and airflow modes in a large space museum building. Indoor and Built Environment. https://doi.org/10.1177/1420326x241281850