# A HISTORICAL ANALYSIS OF THERMAL COMFORT: THE EVOLUTION OF VENTILATION SYSTEMS AT THE ROYAL VICTORIA HOSPITAL, BELFAST

**Suci Farahdilla**
Universitas Muhammadiyah Aceh, email: suci.farahdilla@unmuha.ac.id

## ABSTRACT

*The Royal Victoria Hospital in Belfast, founded in the late 18th century, marks a pivotal moment in the evolution of hospital design and healthcare delivery. This paper traces the hospital's development from its origins as the General Dispensary to its transformation into a modern medical facility. Central to this evolution was the architectural vision of William Henman, who introduced the plenum system of mechanical ventilation—an innovative and pioneering approach at the time. This study investigates the impact of Henman's design on thermal comfort and air quality within the hospital, focusing on both the challenges and successes of implementing such a system in the early 20th century. Through the analysis of historical documents and architectural plans, this research offers insights into the relationship between hospital design, patient care, and environmental control. The findings highlight the critical role of thermal management strategies in healthcare architecture and offer lessons for contemporary hospital design in the pursuit of enhanced patient outcomes.*

***Keywords: healthcare architecture, mechanical ventilation, Royal Victoria Hospital Belfast, thermal comfort, William Henman***

---

***Info Artikel:***
*Dikirim: 24 September 2024; Revisi: 24 Oktober 2024; Diterima: 02 Januari 2025; Diterbitkan: 31 Maret 2025*



---

## 1. INTRODUCTION

The Royal Victoria Hospital in Belfast has a significant historical legacy, originating as the Belfast General Hospital in 1817. Initially designed to accommodate 100 beds, the hospital expanded in response to the increasing demand for surgical care, particularly due to industrial accidents prevalent in the region. The decision to construct a larger facility on the grounds of the Belfast Lunatic Asylum marked a pivotal moment in the evolution of healthcare infrastructure in Belfast. Architect William Henman, who gained recognition for his work on the Birmingham General Hospital, was appointed to design this new hospital. His innovative vision aimed to address the challenges of patient care in an era marked by rapid industrialization and the need for improved medical facilities [1].

The architectural design of hospitals has been a subject of extensive scholarly inquiry, particularly in the context of the transition from traditional pavilion plans to more modern, integrated designs. Previous studies have highlighted the significance of ventilation systems in hospital architecture, with a focus on how these systems impact patient recovery and comfort. Henman's work, particularly his application of the plenum system of ventilation, has been analysed in various architectural and medical journals, emphasizing the importance of air quality and thermal comfort in hospital settings. Critics, such as E.T. Hall, have raised concerns about the compact design of the Royal Victoria Hospital, suggesting that it may hinder patient recovery [2]. This body of literature provides a foundation for understanding the architectural innovations introduced by Henman and their implications for healthcare.

Despite the advancements in hospital design represented by the Royal Victoria Hospital, there remains a gap in understanding the long-term effects of Henman's architectural choices on patient outcomes and operational efficiency [3]. This research seeks to investigate the hypothesis that the integration of mechanical ventilation systems, as exemplified by the Royal Victoria Hospital, significantly enhances patient comfort and recovery compared to traditional pavilion designs. By examining historical data, patient records, and architectural evaluations, this study aims to provide insights into the effectiveness of Henman's design and its relevance to contemporary hospital architecture. Ultimately, the research will contribute to the ongoing discourse on how architectural innovations can improve healthcare delivery in modern settings.

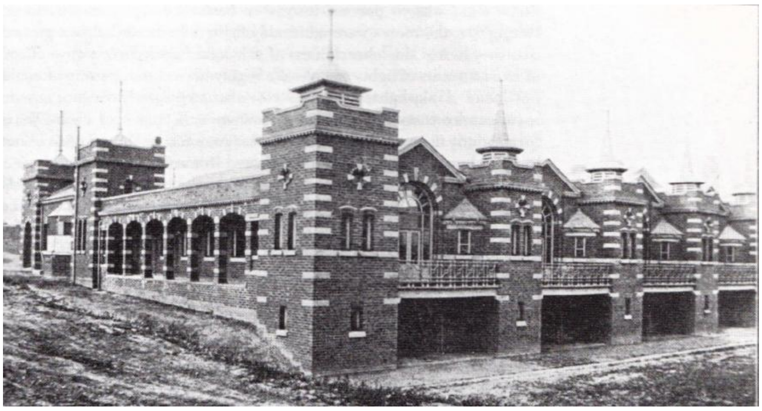


Figure 1. View of ward block from the South-East
Source: Adapted from [4]

## 2. RESEARCH METHODOLOGY

The research employs a historical analysis approach to investigate the design and development of the Royal Victoria Hospital in Belfast. Primary sources, including articles from the British Medical Journal and reports from the Ulster Medical Society, were utilized to gather firsthand information on the hospital's inception, construction, and early operational phases. These documents provided crucial insights into the architectural decisions and environmental systems implemented during the hospital's establishment. Additionally, a comparative analysis was conducted to juxtapose the Royal Victoria Hospital with the Birmingham General Hospital, focusing on the architectural and environmental systems. This comparison aimed to highlight the differences in design philosophies, particularly the implementation and effectiveness of the plenum ventilation system. Temperature data were analysed to assess the system's performance in maintaining indoor comfort levels relative to outdoor conditions.

The study also involved a detailed environmental analysis to evaluate the hospital's ventilation and heating systems. The research explored the plenum system's design, operation, and impact on patient comfort and recovery. This analysis involved a thorough review of contemporary critiques and reports, including those by Professor Byers and architect E.T. Hall, to understand the strengths and potential limitations of the compact design adopted by William Henman [5]. An architectural critique was included to assess the design's reception among contemporaries, with critiques from medical professionals and architects analysed to provide a balanced perspective on the hospital's architectural innovations and challenges. This critique was essential for understanding the broader implications of the hospital's design choices on hospital architecture during that period.

Various visual aids, such as historical photographs, floor plans, and architectural diagrams, were incorporated to support the textual analysis. These visual materials were crucial in illustrating the spatial arrangement and architectural features of the hospital, thereby enhancing the comprehension of the design elements discussed in the study. The research methodology relied on both primary and secondary sources for data collection. Primary sources, including historical documents, medical journals, society reports, and personal correspondence, provided direct evidence of the hospital's architectural and environmental design. Secondary sources, such as academic texts and historical analyses like Jeremy Taylor's comprehensive examination of hospital design, were used to contextualize the Royal Victoria Hospital within the broader evolution of hospital architecture [2]. These sources helped in framing the long-term significance and impact of the design choices made.

This multifaceted research methodology, combining historical, comparative, environmental, and architectural analyses, offers a comprehensive understanding of the Royal Victoria Hospital's design and its implications. By leveraging primary and secondary sources and employing various analytical techniques, this study provides valuable insights that contribute to the broader field of historical architectural research. The methodology ensures that the findings are robust, well-grounded in historical context, and replicable by future researchers.

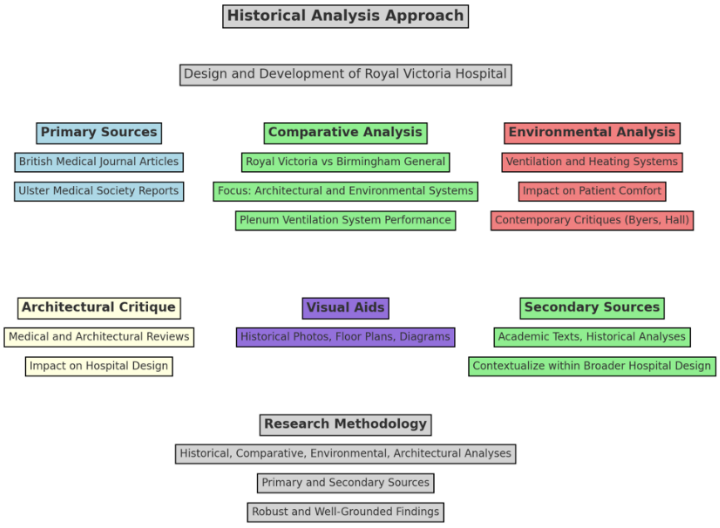



Figure 1. Research Methodology

## 3. RESULT AND DISCUSSION

### a. Hospital Type and System

The Royal Victoria Hospital was architecturally designed to function with mechanical ventilation, diverging from the traditional reliance on natural ventilation. In the nineteenth century, hospital architecture commonly adhered to the 'pavilion plan,' which facilitated optimal natural ventilation using separated pavilions equipped with multiple windows and openings. E.T. Hall critiqued Henman's innovative design for the Royal Victoria Hospital, arguing that it could potentially impede patient recovery. Henman's design featured closely spaced wards, separated only by walls, with 17 wards each containing a single large window and balcony, complemented by skylight windows to enhance natural lighting (Figure 3). Hall highlighted the therapeutic benefits of 'prospect, sunlight, trees, and gardens,' raising concerns that patients might experience depressive symptoms in rooms with limited window exposure.

The floor plan (Figure 3) and aerial view (Figure 4) reveal that Henman implemented a more compact layout for the Royal Victoria Hospital, with rooms positioned adjacent to one another and only separated by walls. This design choice was intentional, aiming to optimize the implementation of mechanical ventilation via the plenum system. Although Henman had previously applied this system successfully in the Birmingham General Hospital, the architectural approaches of the two hospitals differed significantly. The Birmingham General Hospital adhered to the traditional pavilion plan, whereas the Royal Victoria Hospital did not.

Henman's primary rationale for the distinct design of the Royal Victoria Hospital was to minimize heat loss from underground ducts connecting separated buildings by consolidating all accommodations within a single structural volume [8]. He referred to this concept as 'compactness,' which he argued would prevent heat wastage. Moreover, Henman asserted that the compact design was more suitable for the plenum ventilation system, resulting in enhanced ventilation efficiency.

Figure 3. Ward interior
Source: Adapted from [4]

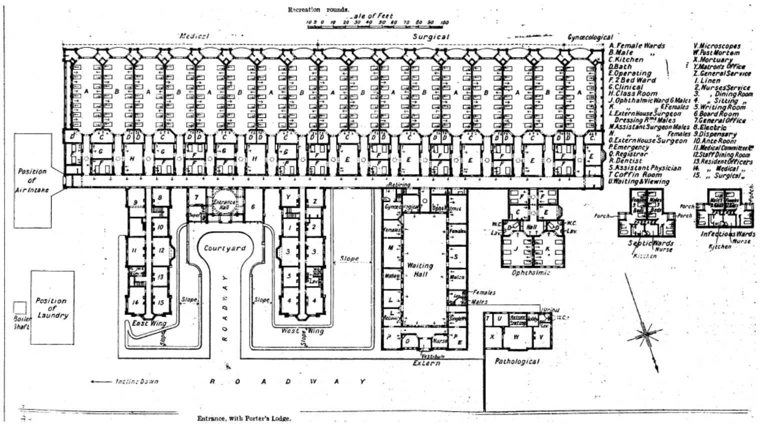



Figure 4. Plan at the Main Floor Level of The Royal Victoria Hospital, Belfast, 1903
Source: Adapted from [6]

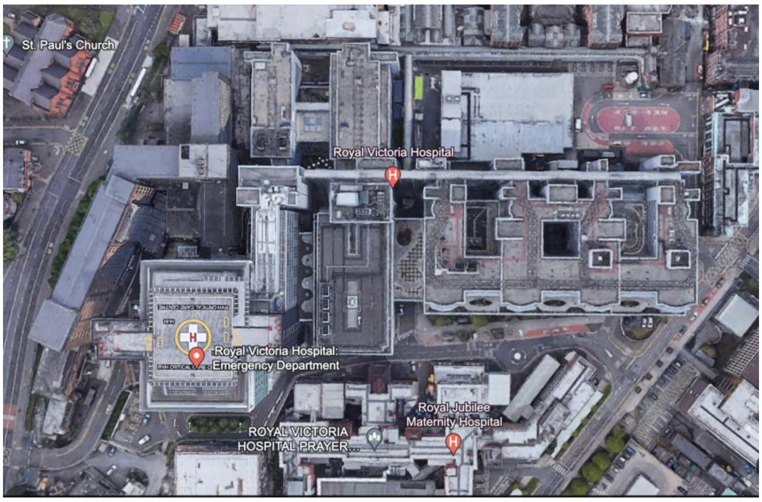



Figure 5. The Royal Victoria Hospital Belfast's View from Above
Source: Adapted from [7]

## b. Adoption of Plenum System Ventilation in Hospital Design

In the late nineteenth and early twentieth centuries, mechanical ventilation systems, such as the plenum chamber system, were not widely embraced in hospital architecture. The predominant preference among architects, engineers, and medical professionals was for natural ventilation. For instance, Surgeon-General Sir Thomas Crawford expressed doubts about the effectiveness of mechanical ventilation, arguing that forcing air into building was not beneficial. He believed that the safest and most reliable method for supplying air was to obtain it naturally from a pure source and allow it to flow freely [9].

The plenum system, a form of mechanical ventilation, operates by propelling air through a central chamber connected to a network of ducts. At the Royal Victoria Hospital, this system was implemented for both heating and cooling purposes. To maximize the system's efficiency, the building needed complete insulation. The primary air duct, constructed from brick with a concrete floor, extended over 500 meters beneath the main corridor. This tunnel-like duct varied in width from nine feet and in depth from twenty feet at the intake end to six feet at the downstream end [8]. The plenum system ventilated 703.000 cubic feet of air [4].

Air distribution throughout the hospital was achieved via two large axial flow fans, each nine feet in diameter, driven by steam engines. These engines, located in an engine house at the duct's intake end, utilized waste steam from the hospital laundry's boilers. A single fan capable of maintaining rate of seven air changes per hour throughout the hospital [4].

The main air duct fed into smaller subsidiary ducts made from concrete brick, which were situated under ancillary areas and along dividing walls. These ducts channeled fresh air to the wards and other rooms through risers in the walls, distributing air via openings positioned above head level. Each ward featured six air entry points, three on each side.

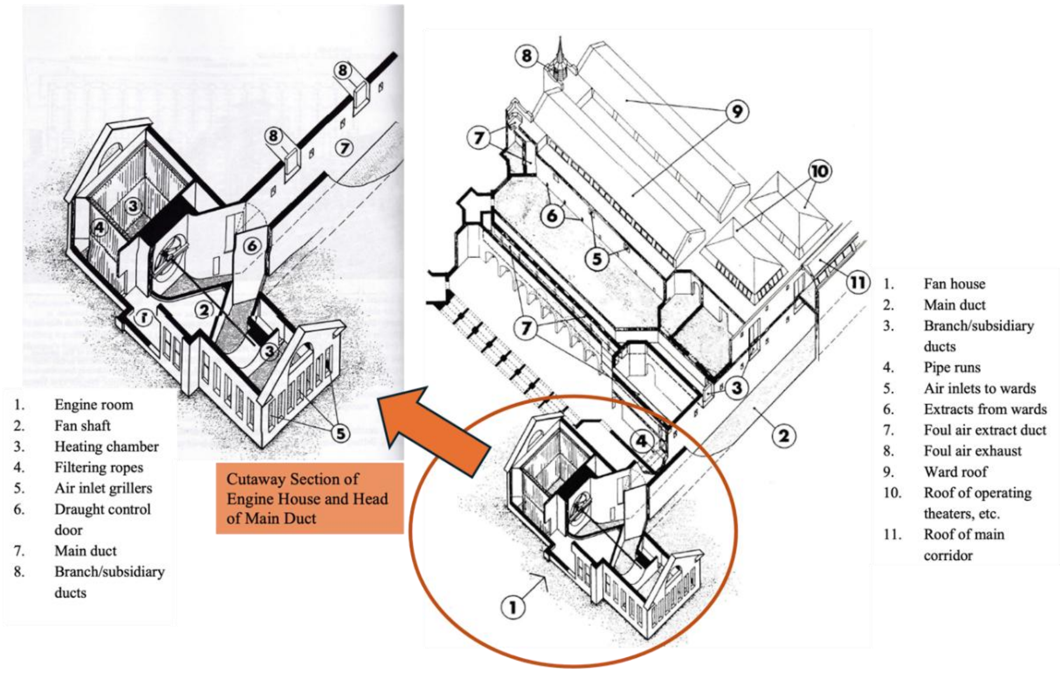



Figure 6. Ventilation system in the Royal Victoria Hospital, Belfast
Source: Adapted from [8]

Given the polluted atmosphere of late nineteenth-century Belfast, the air entering the system through the engine house openings was cleaned using coconut fiber rope curtains. To maintain humidity levels, sprinklers were installed on the roof of the filter chamber, with water heated in winter to prevent freezing. The cleaned air passed through heating-coils batteries before entering the fans and being distributed through the ducts. Additional heating coils at the entrance of each subsidiary duct prevented excessive temperature drops and provided further temperature control in winter.

Designed to supply warmed and purified air to all medical and surgical areas, the system also addressed seasonal variations in air quality and temperature. The sprinklers were particularly useful during winter when the outside air was dirtiest and the temperature differential between inside and outside was greatest. Air entering the system below freezing would exit at around 60 degrees Fahrenheit (15-16 degrees Celsius), reducing relative humidity [8].

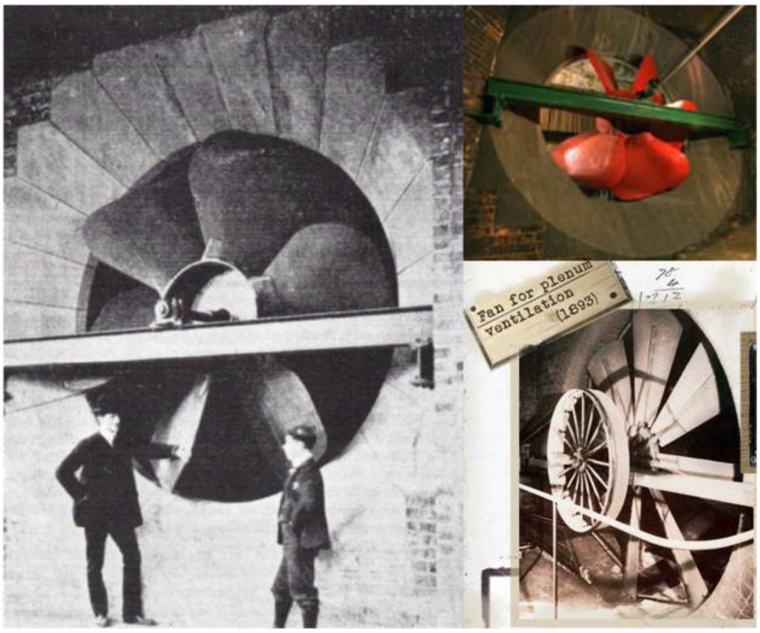



Figure 7. The 9 feet diameter fan in the Royal Victoria Hospital, Belfast
Source: Adapted from [4]

## c. Controversy and Acceptance of The Plenum System in Healthcare

The plenum system of ventilation faced considerable objection from many in the medical field. Professor Corfield, a Professor of Hygiene and Public Health at University College London, expressed his disapproval of artificial ventilation, stating that any method of ventilation relying on mechanical or artificial means is inherently unreliable and, therefore, not recommended [9].

Despite these objections, the plenum system proved highly effective from the patients' perspective at the Royal Victoria Hospital. Patients experienced notable improvements in both surgical and medical wards compared to those in the previous Royal Hospital. The nursing staff also displayed better health outcomes, which were attributed to the enhanced environmental conditions. Medical personnel, including doctors and surgeons, acknowledged the considerable advancements in heating and cooling within the operating theaters and wards, recognizing the system's positive impact on patient care and staff well-being [6].

In a demonstration of the hospital's innovations, from July 2nd to 4th, 1903, the Chairman of the Construction Committee, Mr. W. J. Pirrie, along with Mrs. Pirrie, hosted an afternoon reception at the hospital. The event was intended to showcase the hospital's performance to the subscribers of the building fund. Over 1,500 invitations were extended, attracting visitors not only from Belfast but also from across Ulster. The attendees expressed satisfaction with the freshness and brightness of the hospital's corridors and wards, and they were equally impressed with the evident administrative facilities [10].

The following day, a subsequent reception was held with an entrance fee, with proceeds donated to the hospital's endowment fund. On July 4th, 1903, the final day of the event, over a thousand working men subscribers were given the opportunity to inspect the building. Despite the large number of visitors, the hospital's ventilation system performed exceptionally, with no reports of stuffiness or discomfort. The success of the plenum system during these inspections solidified its effectiveness and garnered widespread approval.

## d. Data Analysis and Patient Outcomes

Due to the historical context and limitations in data availability from the early 20th century, comprehensive quantitative data on patient outcomes are scarce. However, valuable information from contemporary reports, such as those by Prof. Byers (1904) in the *British Medical Journal* and McMechan (1955) in the *Ulster Medical Journal*, provides specific data on indoor and outdoor temperatures, coal consumption, air exchange rates, and qualitative assessments of patient and staff experiences at the Royal Victoria Hospital. This section analyzes this data to evaluate the effectiveness of Henman's architectural design and the plenum ventilation system on patient outcomes and operational efficiency.

**1) Temperature Regulation and Environmental Control**

The plenum ventilation system at the Royal Victoria Hospital effectively maintained stable indoor temperatures throughout the year, despite significant fluctuations in outdoor conditions. During the winter months, the hospital sustained indoor temperatures between 59°F and 62°F (15°C to 16.7°C), even when outdoor temperatures dropped to as low as 22°F (-5.6°C). In the summer, the hospital kept indoor temperatures at 63°F to 65°F (17.2°C to 18.3°C), while outdoor temperatures reached highs of 125°F (51.7°C) in the sun and 80°F (26.7°C) in the shade [5].

Table 1. Comparison of Indoor and Outdoor Temperature at The Royal Victoria Hospital, Belfast

| Season | Outdoor Temperature | Indoor Temperature |
|---|---|---|
| Winter (1903 – 1904) | 22° F (-5.6° C) | 59-62°F (15-16.7° C) |
| Summer (1904) | 125° F (51.7° C) in the sun<br>80°F (26.7° C) in the shade | 63-65°F (17.2-18.3° C) |

Source: Adapted from [5]

The ability to maintain such stable indoor temperatures was crucial for patient comfort and recovery. Stable thermal environments reduce physiological stress on patients, particularly those who are vulnerable due to illness or surgery [11]. The hospital's temperature regulation exceeded contemporary standards, contributing to a therapeutic environment.

**2) Air Exchange Rates, Air Quality and Coal Consumption**

The plenum ventilation system was instrumental in maintaining optimal environmental conditions throughout the year. The system adjusted air exchange rates seasonally, which correlated with coal consumption and operational needs.

During the winter months, the hospital maintained an air exchange rate of 7 to 8 air changes per hour [5]. This rate was sufficient to supply fresh air to the wards while conserving heat, essential during colder periods. To achieve this, the hospital consumed approximately 45 tons of coal per week. The higher coal consumption in winter was necessary to generate steam for heating the incoming air, powering the ventilation fans, and providing steam for other hospital functions such as cooking, laundry, and sterilization.

In the summer months, the air exchange rate increased to 10 to 12 air changes per hour to maintain cooler indoor temperatures and ensure adequate ventilation during warmer weather [5]. Despite the increased ventilation rates, coal consumption decreased to approximately 18 to 20 tons per week. The reduced coal usage in summer was due to the diminished need for heating, as outdoor temperatures were higher.

Table 2. Seasonal Air Exchange Rates and Coal Consumption at The Royal Victoria Hospital, Belfast

| Season | Air Exchange Rate | Coal Consumption |
|---|---|---|
| Winter | 7 to 8 air changes/hour | 45 tons/week |
| Summer | 10 to 12 air changes/hour | 18 to 20 tons/week |

Source: Adapted from [5]

The efficient adjustment of air exchange rates according to seasonal demands demonstrates the operational effectiveness of the plenum system. By increasing air changes during the summer, the hospital ensured that indoor temperatures remained comfortable for patients and staff, maintaining temperatures between 63°F and 65°F (17.2°C to 18.3°C) even when outdoor temperatures soared. Conversely, in winter, the reduced air exchange rate minimized heat loss while still providing adequate ventilation, keeping indoor temperatures stable when outdoor temperatures dropped significantly.

### 3) Impact on Air Quality and Patient Outcomes

The plenum system not only regulated temperature but also significantly improved air quality within the hospital. Incoming air was filtered and humidified by passing over coir matting screens moistened with water, effectively removing impurities and adjusting humidity levels [5]. These screens were hosed every second day, and the main air duct was washed weekly, ensuring the air supplied to the wards was clean and fresh. Observations indicated that the wards maintained slightly higher humidity levels compared to the outside air during hot weather, contributing to patient comfort by preventing dryness and irritation of the respiratory tract. Prof. Byers noted:

"From the point of view of patients, nothing could be more perfect than the Plenum system of heating and ventilation as seen in the Royal Victoria Hospital, Belfast. Patients do better in both the surgical and medical wards than in the old Royal Hospital, and the nurses... are more healthy " [5].

Improved air quality and stable environmental conditions likely had a positive impact on patient outcomes. Historical surgical data supports these observations:

1. In 1893, only two abdominal operations were performed, both resulting in patient deaths, reflecting a 100% mortality rate [12].
2. By 1903, after the implementation of Henman's design and the plenum system, 39 intraperitoneal operations were conducted with 13 deaths, reducing the mortality rate to approximately 33% [12].
3. In 1904, 859 surgical operations were performed with 27 deaths, resulting in a mortality rate of approximately 3.1% [10].

The significant reduction in mortality rates and the increase in the number of surgical procedures performed indicate that the improved environmental conditions facilitated by the plenum system contributed to better patient outcomes. The stable temperatures and enhanced air quality reduced the risk of postoperative infections and created a more therapeutic environment for recovery.

### d. Staff Satisfaction and Operational Efficiency

The medical staff expressed high levels of satisfaction with the hospital's facilities and working conditions. Sir William Whitla, M.D., highlighted the staff's contentment during the annual meeting:

"It was the unanimous feeling of the medical and surgical staff that they had one of the best equipped hospitals in the United Kingdom, and one of the most perfect of its size" [10].

The efficient operation of the plenum system, which provided comfortable temperatures and clean air, likely contributed to improved staff well-being and productivity. The reduced incidence of illness among nurses and the enhanced comfort in wards and operating theatres facilitated better patient care.

## e. The Critical Role of Fresh Air in Hospital Environments

Maintaining clean and fresh air, free from harmful bacteria, is essential in a hospital setting. Florence Nightingale, a seminal figure in Victorian medicine, emphasized the importance of fresh air in her influential work, *Notes on Nursing*. She described the discomfort of being in a closed room, even if unoccupied, noting that such spaces would inevitably acquire a musty odor due to stale air, unpurified by sunlight [13].

Nightingale also observed that patients frequently yearn for fresh air above all else, asserting that they would fare better outside than in wards lacking it. She argued that keeping wards fresh is imperative for patient recovery, and she contended that artificial ventilation systems could not adequately achieve this goal. Instead, she advocated for the use of open windows, natural ventilation, and open fireplaces as the only effective means to provide the essential fresh air necessary for the convalescence of the sick [11].

A recent study in the United States has validated Florence Nightingale's views on the importance of fresh air in hospital rooms. Researchers compared bacterial populations in rooms with open versus closed windows, discovering that naturally ventilated wards harbored fewer harmful bacteria than those relying on artificial ventilation. Dr. Jack Gilbert, from the Argonne National Laboratory near Chicago, explained that allowing fresh air into wards increases the population of beneficial bacteria, which in turn helps to control the proliferation of harmful bacteria [14].

Nightingale also recommended that a hospital should have at least 1,500 cubic feet of air per hour per person [11]. The Royal Victoria Hospital, utilizing the plenum system, ventilated a total of 703,000 cubic feet per hour, equating to approximately 2,343 cubic feet per hour per person for its 300 patients, thereby exceeding Nightingale's standard. However, Nightingale also suggested that for certain diseases requiring more fresh air, the air supply should be increased to as much as 4,000 to 5,000 cubic feet per bed. Meeting this higher demand for fresh air might pose a challenge for the Royal Victoria Hospital.

The Royal Victoria Hospital maintained indoor temperatures between 15°C and 18°C during both winter and summer, although the National Institute for Health and Care Excellence recommends an optimal temperature of 21°C for operating theaters [15]. Despite the plenum system's effectiveness in regulating temperatures, concerns about hygiene persisted, particularly in hospital settings where air quality significantly impacts patient health. A study examining the benefits of air purification through mechanical ventilation found that fever patients exhale warmer air than healthy individuals, which tends to rise and could be inhaled by those near the patient's bed if not adequately ventilated. In contrast, naturally ventilated rooms effectively remove exhaled breath from patients, reducing the risk of contamination.

## f. Comparative Analysis: New System at Royal Victoria Hospital, Belfast, Versus Previous System at Birmingham General Hospital

### 1) Architectural Layout and Integration of Ventilation Systems

Both the Royal Victoria Hospital in Belfast and the Birmingham General Hospital implemented the plenum ventilation system, yet the effectiveness of the system varied significantly between the two institutions due to differences in architectural design and system integration.

The Royal Victoria Hospital was designed by William Henman with a compact architectural layout that optimized the efficiency of the plenum ventilation system. The hospital's design minimized the distance air needed to travel through ducts, reduced heat loss, and facilitated easier maintenance of environmental conditions [4]. The wards were arranged closely together, and the building's structure supported the seamless integration of mechanical systems within the architectural framework.

In contrast, the Birmingham General Hospital, also designed by Henman, adhered to a traditional pavilion layout, characterized by separate buildings or wings connected by corridors [16]. While this design was popular in the 19th century for its potential to reduce the spread of infections through segregation of patients, it posed challenges for the effective implementation of the plenum ventilation system. The extended distances between wards increased the length of ductwork required, leading to greater heat loss and reduced efficiency in maintaining stable environmental conditions [2].

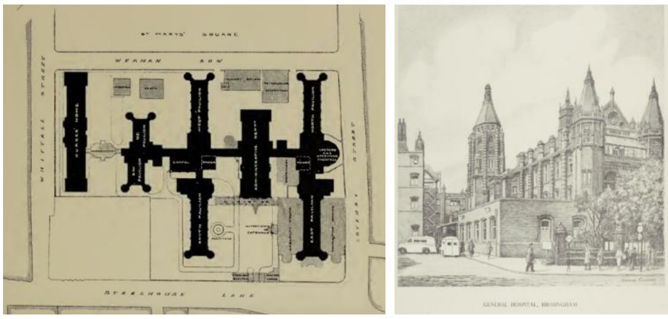


Figure 8. The Birmingham General Hospital Block Plan (left), Sketch of The Birmingham General Hospital (right)
Source: Adapted from [17] and [18]

**2) Temperature Regulation and Environmental Control**

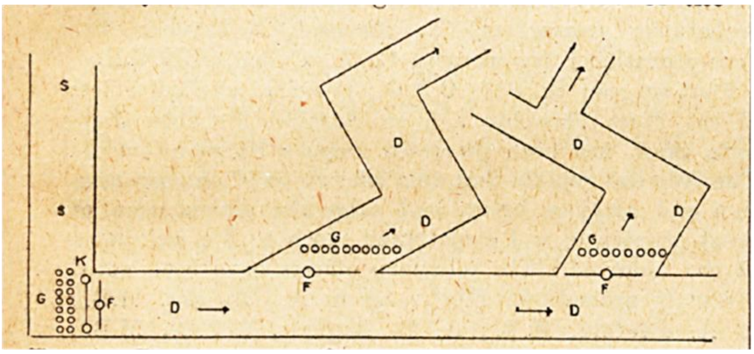
The differences in architectural design had a direct impact on the hospitals' ability to regulate indoor temperatures and air quality. At the Royal Victoria Hospital, the plenum system maintained stable indoor temperatures year-round (see Table 2). This stability was achieved despite extreme outdoor temperatures ranging from 22°F (-5.6°C) in winter to 80°F (26.7°C) in the shade and 125°F (51.7°C) in the sun during summer [5]. The compact design minimized heat loss, and the efficient air exchange rates ensured optimal air quality.

At the Birmingham General Hospital, temperature regulation was less effective (as seen in Table 2). The higher indoor temperatures during summer and the less consistent temperature control suggest that the pavilion layout hindered the plenum system's efficiency. The longer ductwork and increased exposure to external temperatures made it more challenging to maintain stable conditions.

Table 2 Indoor Temperature Comparison

| Season | Royal Victoria Hospital | Birmingham General Hospital |
|---|---|---|
| Winter | 59°F to 62°F (15°C to 16.7°C) | Maintained at approximately 59°F (15°C) |
| Summer | 63°F to 65°F (17.2°C to 18.3°C) | Reached up to 68°F (20°C) |

Source: Adapted from [4] and [16]




**S** : The shaft though which the air enters the building
**D** : The ducts through which the air is distributed to the different parts of the building
**K** : The kaiar screen
**F** : The fans delivering the air to the ducts
**G** : The grids of steam pipes arranged to warm the air

Figure 9. A diagram illustrating the setup for cleaning, warming, and distributing air in the wards of Birmingham General Hospital using the "Plenum" system
Source: Adapted from [19]

**3) Patient Outcomes, Staff Satisfaction, and Operational Efficiency**

The Royal Victoria Hospital made remarkable strides in improving patient outcomes and operational efficiency after adopting Henman’s design and the plenum ventilation system. Mortality rates for abdominal surgeries dropped significantly over time, falling from a staggering 100% in 1893 [12] to approximately 33% in 1903, and then further improving to just 3.1% in 1904, based on 859 surgical procedures performed that year [5]. Alongside this, the hospital’s capacity to handle more complex and varied surgeries also expanded, underscoring the impact of the improved facilities.

Staff at the hospital were equally impressed with the advancements. It was described as “one of the best-equipped hospitals in the United Kingdom, and one of the most perfect of its size” [5]. The carefully controlled indoor environment created by the plenum system likely played a significant role in this positive perception, providing both comfort and a more hygienic setting for patients and medical staff alike.

While specific data on air exchange rates and coal consumption for the Birmingham General Hospital is limited, it is reasonable to infer that the hospital faced higher operational costs and less efficient ventilation due to its architectural design. From an operational perspective, the hospital demonstrated a sophisticated approach to balancing energy use and patient care. During the colder months, ventilation rates were maintained at 7 to 8 air changes per hour, requiring 45 tons of coal per week. In the summer, this was increased to 10 to 12 air changes per hour, with coal consumption dropping to just 18 to 20 tons weekly [5]. These seasonal adjustments reflect an early awareness of resource efficiency and cost management.

In contrast, the Birmingham General Hospital faced more challenges. While it also employed a plenum system, its pavilion-style design likely limited its effectiveness. The fragmented layout may have made it harder to maintain consistent environmental conditions, potentially increasing operational costs and reducing staff morale. These differences emphasize how the Royal Victoria Hospital's integrated design not only set new standards for hospital architecture but also improved outcomes and working conditions in meaningful and measurable ways.

## 4. COMMENT AND CONCLUSION

### a. Comment

The Royal Victoria Hospital's integration of the plenum ventilation system, designed by William Henman, marked a pivotal moment in hospital design, significantly improving patient outcomes, staff satisfaction, and operational efficiency. The hospital's ability to maintain consistent indoor temperatures and air quality regardless of external weather conditions demonstrates the effectiveness of combining innovative mechanical systems with thoughtful architectural planning. Henman's design emphasized the importance of blending mechanical systems with the building's architecture. The compact layout minimized heat loss and reduced the distance air needed to travel, enhancing the efficiency of the plenum system. This integration ensured reliable environmental control, creating a stable and comfortable environment for both patients and staff.

In contrast, the Birmingham General Hospital's attempt to retrofit the plenum system into a traditional pavilion layout faced challenges. The inefficiencies in temperature regulation and the lower satisfaction among staff highlight the limitations of applying advanced mechanical systems to designs not originally conceived with such technologies in mind.

The improvements at the Royal Victoria Hospital were transformative. Surgical mortality rates fell dramatically, from 100% in abdominal surgeries in 1893 to 33% in 1903, and further to just 3.1% in 1904. Enhanced air quality and thermal stability likely played a key role in reducing postoperative infections and fostering recovery. Staff well-being also improved notably. Healthier nurses and satisfied medical professionals reported better working conditions, free from extreme temperatures and poor air quality. This positive environment likely contributed to more efficient and effective patient care.

Henman's design also showcased an early understanding of resource efficiency. By adjusting air exchange rates seasonally—lower rates in winter and higher in summer—the hospital optimized coal consumption while maintaining optimal indoor conditions. This approach balanced patient comfort with energy efficiency, demonstrating a forward-thinking approach to operational sustainability.

### b. Conclusion

William Henman's innovative approach to hospital design and his integration of the plenum ventilation system set a new standard for healthcare architecture in the early 20th century. By improving patient outcomes, enhancing staff well-being, and achieving operational efficiency, the Royal Victoria Hospital demonstrated how thoughtful design can address complex healthcare challenges. These advancements offer valuable lessons for modern hospital design:

1. Holistic Integration of Technology and Architecture: Designing hospitals with mechanical systems as integral components, rather than add-ons, ensures efficiency and effectiveness in environmental control.
2. Environmental Control for Patient Care: Stable indoor environments with consistent temperature, humidity, and air quality are critical for patient recovery and staff performance. Modern hospitals should prioritize advanced HVAC systems to achieve this balance.
3. Sustainability and Resource Efficiency: The hospital's early adoption of seasonal ventilation adjustments highlights the importance of energy-efficient designs that reduce operational costs while maintaining high care standards.
4. Staff Well-being: Recognizing the influence of physical environments on staff morale and performance is vital. Designing spaces that support health and satisfaction leads to better retention and improved patient care.

This analysis underscores the enduring importance of combining architectural innovation with environmental control systems to create effective healthcare facilities. Henman's work provides a blueprint for addressing contemporary challenges in hospital design, ensuring spaces that promote healing, support staff, and operate sustainably.

## *5.* BIBLIOGRAPHY

[1] R. Clarke, "Ulster medical society: Royal Victoria Hospital," in *The Royal Victoria Hospital, Belfast: A History 1797-1997*, 1997. Accessed: Jul. 30, 2024. [Online]. Available: https://www.ums.ac.uk/rvh.html

[2] J. Taylor, *The architect and the pavilion hospital: Dialogue and design creativity in England 1850-1914*. London: Leincester University Press, 1997.

[3] "1903 – Royal Victoria Infirmary, Belfast | Architecture @ Archiseek.com." Accessed: Jul. 31, 2024. [Online]. Available: https://www.archiseek.com/2009/1901-royal-victoria-infirmary-belfast/

[4] *Journal of the Royal Institute of British Architects 1903-12-19: Vol 11 Issue 4*. Royal Institute of British Architects, 1903. Accessed: Aug. 02, 2024. [Online]. Available: http://archive.org/details/sim_riba-journal_1903-12-19_11_4

[5] P. Byers, "Royal Victoria Hospital, Belfast: The practical working of the 'plenum' system of heating and ventilation," *Br. Med. J.*, vol. 2, no. 2281, pp. 697–698, 1904.

[6] "The New Royal Victoria Hospital, Belfast," *Br. Med. J.*, vol. 2, no. 2218, pp. 25–28, 1903.

[7] "Google Earth." Accessed: Aug. 02, 2024. [Online]. Available: https://earth.google.com/web/search/The+Royal+Victoria+Hospital+Belfast%27s/@54.59434691,-5.95409242,37.2175798a,326.59492678d,35y,17.99991058h,0t,0r/data=CigiJgokCeB2OTyqXjVAEd12OTyqXjXAGeEBjltsnkVAISqWZVUNFk7AOgMKATA

[8] R. Banham, *Architecture of the well-tempered environment*. University of Chicago Press, 2022. Accessed: Jul. 31, 2024. [Online]. Available: https://www.perlego.com/book/3568542/architecture-of-the-welltempered-environment-pdf

[9] L. (London) Robert Boyle & Son, *Natural and artificial methods of ventilation*. London: R. Boyle, 1899. Accessed: Aug. 04, 2024. [Online]. Available: http://archive.org/details/naturalartificia00robe

[10] B. M. J. P. Group, "Ireland," *Br Med J*, vol. 2, no. 2219, pp. 101–102, Jul. 1903, doi: 10.1136/bmj.2.2219.101.

[11] F. Nightingale, *Notes on hospitals*. London, Longman, Green, Longman, Roberts, and Green, 1863. Accessed: Jul. 31, 2024. [Online]. Available: http://archive.org/details/cu31924012356485

[12] E. MCMECHAN, "A tribute to our surgical pioneers: A history of surgery and surgeons of the Royal Victoria Hospital, Belfast, from 1792 to 1920," *Ulst. Med J*, vol. 24, no. 2, pp. 81–91, Nov. 1955.

[13] F. Nightingale, *Notes on nursing: What it is, and what it is not*. Philadelphia: J.B. Lippincott Company, 1946. Accessed: Aug. 04, 2024. [Online]. Available: https://archive.org/details/notesnursingwhat00nigh/page/n7/mode/2up

[14] M. Reporter, "Hospitals admit: Florence nightingale was right about fresh air," Metro. Accessed: Jul. 31, 2024. [Online]. Available: https://metro.co.uk/2012/02/19/florence-nightingale-was-right-about-fresh-air-hospitals-admit-324654/

[15] "Keeping patients warm before, during and after an operation." National Institute fo Health and Care Excelent, Apr. 01, 2008. Accessed: Aug. 06, 2024. [Online]. Available: https://www.nice.org.uk/guidance/cg65/resources/keeping-patients-warm-before-during-and-after-an-operation-pdf-255053003461

[16] *Journal of the Royal Institute of British Architects 1894-04-23: Vol 1 Iss 12*. Royal Institute of British Architects, 1894. Accessed: Aug. 06, 2024. [Online]. Available: http://archive.org/details/sim_riba-journal_1894-04-23_1_12

[17] *Sketches of new buildings: General Hospital, Birmingham opened on behalf of Her Majesty the Queen by H.R.H the Princess Christian July the 7th 1897*. [London] : [Produced at the British Architect offices], 1897. Accessed: Aug. 07, 2024. [Online]. Available: http://archive.org/details/b3055665x

[18] "Birmingham General Hospital | Science Museum Group Collection." Accessed: Aug. 07, 2024. [Online]. Available: https://collection.sciencemuseumgroup.org.uk/objects/co122187/birmingham-general-hospital-print

[19] "The Birmingham General Hospital," pp. 589–590, Sep. 1916.