

Preliminary Research on Water Supply, Drainage, and HVAC Equipment in Shanghai Historic Buildings During the Northern Warlord Period

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Abstract: During the Northern Warlord Period (1912–1928), the construction industry in Shanghai underwent robust development. As an integral element of buildings, equipment served both functional purposes and stood witness to the evolution of the economy and society, thus earning its place as part of the architectural heritage. However, due to various reasons, there are many loopholes in the protection of these building equipment. This paper examines the development of building equipment in Shanghai during the Northern Warlord Period, using water supply, drainage, and heating, ventilation, and air conditioning (HVAC) systems as examples. Through historical context analysis, it summarizes this development from a social-spatial perspective, infers the reasons behind it, and analyzes the importance of preserving such equipment, considering both past and present viewpoints. In this research, the importance of protecting historical building equipment is emphasized, which aims to give people a deeper understanding of their cultural value, and suggests that scholars conduct more practical research on their protection.

Keywords: Historic buildings; Water supply and drainage; HVAC; Protection

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1. Introduction

As one of the earliest treaty port cities in modern China, Shanghai was among the first to embrace new Western culture and ideas. Following the overthrow of the feudal monarchy in the Revolution of 1911, Shanghai entered the Northern Warlord Period (1912–1928), a time of political fragmentation led by Yuan Shikai. In its initial years, Shanghai's urban economic development leaned heavily on countries like the United States and Japan. However, with the end of World War I, the British and French forces reasserted their influence. The intervention of external forces directly catalyzed the construction and transformation of Shanghai. Meanwhile, during the decade following 1916, a myriad of ideological practices and innovative experiments emerged. As political forces waned, a trend of diversified development in thought, economy, and society emerged, greatly accelerating

urban construction in the realm of restless ideas ^[1]. In various districts, for instance, plans were formulated to rebuild or renovate buildings within the concessions, aligning them with urbanization, commercialization, and modernization efforts ^[2]. Despite the abandonment of numerous projects due to personnel shifts and political instability, many buildings successfully underwent suitable adaptations or reconstructions, with the Bund area standing out prominently. Significantly, the period of the Northern Warlord Government witnessed a transformation in architectural development, transitioning from Chinese Neoclassicism to the emergence of the International Style, underscoring Shanghai’s evolving architectural landscape.

Simultaneously, numerous advanced technologies were introduced during this era. These innovations not only accelerated Shanghai’s development but also solidified its position as a hub for modern architectural practices. In Shanghai, the introduction of these technologies often started within the concession and gradually expanded to the entire city ^[3]. Among them, building equipment, a pivotal facet of architectural engineering, also found its initial import and application in Shanghai before disseminating to other regions ^[4]. This pivotal role of building equipment in Shanghai transcends its mere functional impact on the establishment and evolution of municipal infrastructure; it also plays an integral role in shaping the city’s identity, especially catering to the new concept called “modernity.”

Common equipment includes water supply and drainage, air-conditioning, ventilation, lighting systems, etc. In the Northern Warlord Period, Shanghai’s building equipment had undergone tremendous changes and development, which could represent the glory and gloom of that era and have important value in historic context. However, looking back at the development of historical building equipment in Shanghai, there are great loopholes in its contextual tracing and protection. Historical building equipment is often overlooked in preservation efforts. Factors like neglect, damage, or the loss of their original appearance contribute to the demolition or renovation of many such equipment pieces, erasing the historical memories they once held. Based on the above status, and also due to the lack of relevant research during the Northern Warlord Period, this paper mainly introduces the development of water supply and drainage and air-conditioning systems in Shanghai during this period.

2. Contradiction: The birth of new water supply and drainage equipment and the dilemma faced by reality

Before the Northern Warlord Period, the water supply and drainage system depended on the Yangshupu Waterworks and other foreign-invested waterworks[5]. Only the Neidi water plant was totally built by Chinese and belonged to the public sector. After 1912, those water plants continued to play a role, and all the water from the water plants came from the Huangpu River region. The main waterworks in Shanghai during Northern Warlord Period are listed in Table 1.

Table 1. Overview of Shanghai waterworks in Northern Warlord Period

District	Water supply area (km ²)	Name	Operation mode
1	77.10	Neidi Water Plant	Privately operated (Chinese)
2	44.30	Shanghai Water Plant	Privately operated (UK)
3	–	–	Privately operated (UK)
4	–	French Water Plant	Privately operated (UK)

Despite water supply systems covering most densely populated areas in Shanghai, a significant number of low-income residents still depended on water workers to deliver water to their homes, mainly because of water scarcity and high prices. As a result, it was difficult to guarantee the quality of the water that was being delivered. The water usually came from nearby wells or rivers, which may contain pathogenic bacteria ^[6], and it was also susceptible to contamination during transportation.

Due to a scarcity of water and high prices, many low-income residents in Shanghai relied on water workers for their supply, despite water supply systems covering densely populated areas. Additionally, inadequate resident hygiene awareness and government oversight led to disorderly and secretive wastewater discharge. Furthermore, the absence of a modern water treatment system hindered water recovery and reuse, causing domestic water shortages and environmental pollution. These issues not only affected residents' lives but also sparked discontent among some concession leaders. Consequently, in 1917, they sought legal intervention on sewage matters, resulting in a court ruling that prompted the Industrial Engineering Department to construct sewage ditches and pipes. These projects were completed by 1923 and implemented in specific areas.

During this era, the civilian use of toilets and their equipment underwent various challenges. These conflicts stemmed from the inability to discharge domestic sewage into municipal sewers, a situation that also led to discontent among many affluent individuals ^[7].

After persistent negotiations with the consular court, certain affluent individuals were eventually permitted to install sanitary equipment connected to the sewer. It was not until July 1918 that the S.M.C. Public Works Department approved the use of toilets. Due to a high surcharge, toilets were available only in public buildings and wealthy families at that time. In the 1920s, certain Shanghai local gentry were dissatisfied with the significant disparities between the Chinese community and the foreign concessions. Utilizing the "Local Self-Government Legislation," they mobilized resources and funding, emulating advanced equipment from the concessions. As a result, numerous regular households gained access to actual toilets and related facilities. This movement has benefited thousands of families and greatly improved the living standards of Chinese residents.

In addition, in 1916 (before the toilet was officially put into use), the New Western Style Building Rules were promulgated ^[8]. It clearly stated the procedures for toilet installation application, defined the names and drawing requirements of equipment such as fecal and sewer pipes, explained the methods of sewage treatment, and stipulated the number and capacity of septic tanks. All these laid the foundation for the application of sanitary ware in the next few decades.

In addition to the application in the toilet, it is worth mentioning that the water supply and drainage system was also widely used in the field of fire protection in public buildings, especially with the development of high-rise buildings.

In line with Louis H. Sullivan's concept of multi-level functional zoning for high-rise buildings, architectural designs incorporated equipment floors. Pipes were flexibly arranged within the buildings, relying on unique patios and structural columns. Historical records reveal that no major fires occurred in the buildings equipped with automatic sprinkler systems during their existence, highlighting the pivotal role of equipment in ensuring safety. This was also attributed to the progress in building structures and materials at that time, particularly in high-rise buildings where steel frames and reinforced concrete proved more fire-resistant compared to the original ordinary brick and wood structures.

The introduction and development of water supply and drainage equipment was of great significance to the development of Shanghai's buildings and the quality of the citizens' lives. The main applications and development of water supply and drainage equipment during the Northern Warlord Period are shown in **Table 2**.

Table 2. Development of Shanghai building water supply & drainage system in Northern Warlord Period

Time	Event
1916	The New Western Style Building Rules was promulgated to regulate the installation of toilet equipment.
1917	Began to build sewage ditches and pipes.
1918	Toilets began to be used in some public buildings and wealthy families.
After the 1920s	A large number of civilian families began to have toilets and water supply and drainage equipment.

3. Progress: Application of HVAC equipment

Shanghai is cold in the winters and hot in the summers, making heating, ventilation, and air conditioning (HVAC) systems essential. During the Northern Warlord Period, most of HVAC systems were contracted by foreign firms. As a result, HVAC systems were primarily found in the concession areas.

The development of HVAC technology in Shanghai is closely intertwined with the growth of the electric power industry. As early as July 1882, Shanghai established the Shanghai Electric Light Company, marking the commencement of electrical supply. Its establishment was only seven years after the construction of the world's first power plant, the Gare de l'Est Power Station in Paris, and it was founded in the same year as Japan's first electric power company, the Tokyo Electric Light Company, preceding Edison's Pearl Street Station in New York by two months^[9].

The availability of fuel played a crucial role in the development of heating systems. In the early 20th century, as China produced more coal, Shanghai had a steady coal supply. During this time, due to the advanced foreign technology and strong demand in the local market, traditional stoves and braziers were gradually replaced by Western cast iron stoves, hot-water heating, and steam heating as the popular choices for heating systems. The earliest modern heating system in Shanghai was the steam heating in Astor Hotel in the early 20th century^[10]. The earliest hot water system in Shanghai was installed in 1910 in 40 suites on the second floor of the Shanghai Club^[11]. By the late 1910s, newly constructed buildings, such as office buildings in the Bund area, as well as upscale apartments and residences, began to install stoves and heating systems^[12]. By the 1920s, steam heating had become the dominant method of heating in Western-style architecture. These heating systems were more efficient and environmentally friendly compared to traditional methods, which is why they gained popularity among middle and high-income households^[12]. However, Shanghai did not have centralized heating systems like those in urban areas such as New York City in the United States. Instead, each building had its own boilers for hot water and steam supply, resulting in a decentralized heating approach. This arrangement offered high flexibility, ease of control, and minimized heat losses, making it well-suited for the practical conditions in Shanghai during that period. There were two reasons to this approach: firstly, Shanghai's winters were not as cold as those in New York, and snowfall was infrequent. Secondly, the key officials of the Public Works Department were from Britain, where centralized heating systems were not used. Furthermore, this approach was influenced by the relatively limited development of heavy industry in Shanghai during that era. However, for low-income families, the cost of purchasing and using this equipment remained prohibitively high. As a result, they often opted for traditional stoves or braziers, underscoring the significant wealth disparity in Shanghai's society at that time^[13].

In terms of cooling systems, traditional hand-pulled fans were used in bathrooms, barber shops and other small public places. They needed to be operated manually, and most of the workers were underage boys, which was inhumane. Fortunately, Willis H. Carrier designed the world's first scientific refrigeration system in 1902^[14], which marked the arrival of the industrialization era in the field of cooling systems. In 1913, a refrigeration

specialty was established in Shanghai ^[15]. Then, in 1923, HSBC Bank pioneered the use of air-conditioning systems. Following this, numerous buildings in Shanghai, including the Majestic Hotel, Kadoorie Marble Building, Pacific Hotel, Capitol Building, and others, adopted comfortable air-conditioning systems.

Air-conditioning systems found applications in the light industry as well. The New Chinese Building Rules ^[16], introduced in 1917, outlined ventilation requirements for ground floors, specified the window-to-floor ratio in rooms, set guidelines for food storage rooms, and provided details on the location and size of ventilation equipment, as well as the minimum net height of rooms. Since air-conditioning projects were monopolized by foreign companies, and pertinent laws and regulations had not been established, these ventilation requirements from the rules were carried over and applied in the field of light industry.

For instance, in 1923, a soda company established by Watson employed York's refrigeration unit to meet the cooling needs for beverages and staff ^[17]. With the maturity and development of technology, the first set of ammonia system refrigeration equipment appeared in Shaxun building. However, this system fell far behind the first ammonia refrigeration system in the West in terms of technology. Moreover, it was not until after liberation that China achieved its first domestically developed ammonia refrigeration compressor ^[18]. Meanwhile, many buildings from that era started using electric fans, thanks to Yang Jichuan's invention of the electric fan and the establishment of the Huasheng electric appliance factory ^[19]. Even today, mechanical fans are still commonly found in places without air conditioning.

At that time, Shanghai was gradually integrating with the world and catching up with the new era of air conditioning. The main application of air-conditioning system in Shanghai buildings during the Northern Warlord Period is shown in **Figure 1**.

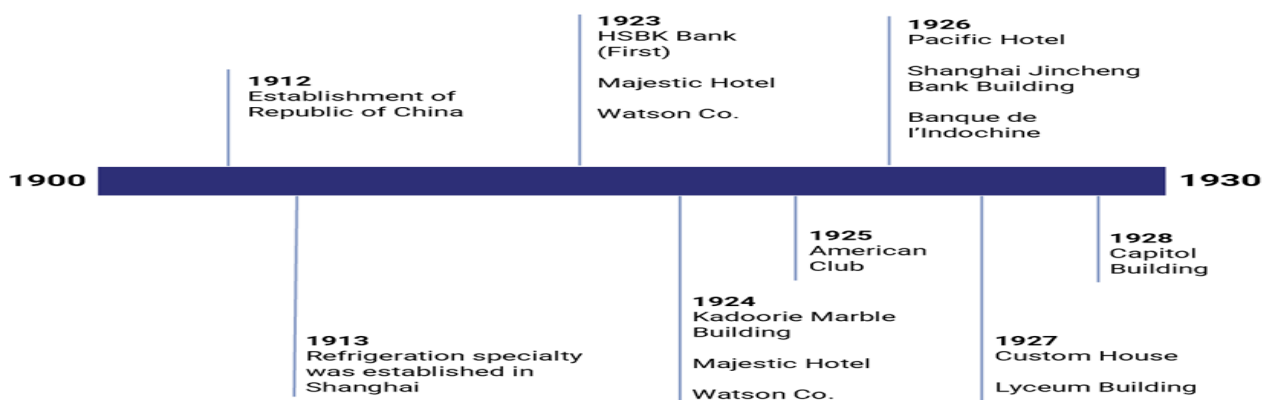


Figure 1. The typical application of air-conditioning system in Shanghai buildings during the Northern Warlord Period

4. Conclusion and prospect

Amidst the tumultuous backdrop of the Northern Warlord Period, Shanghai, a city characterized by its spirit of openness, witnessed a diverse array of transformations and advancements in the field of building equipment, particularly in water supply, drainage, and air-conditioning systems. During this era, driven by the intricate tapestry of historical circumstances, Shanghai's architectural apparatus underwent various changes, serving as a testament to the highs and lows of that age. A crucial facet contributing to Shanghai's rapid evolution from a humble fishing village to a bustling metropolis was the introduction and continuous refinement of advanced technologies, exemplified by the incorporation and ongoing enhancement of building equipment.

Historical building equipment can be seen as invaluable cultural heritage. Nevertheless, the current level

of attention and preservation efforts for certain historical building equipment within Shanghai's architecture is insufficient. Factors like disrepair, damaged appearance, and inadequacy for modern requirements have led to the replacement of numerous precious historical building equipment with contemporary alternatives, and some have even been demolished. Directly dismantling them is akin to removing a piece of the historical puzzle, leaving a particular period of history incomplete, which is undeniably a significant loss.

Therefore, we believe that the cultural value of historical building equipment must be taken seriously, and we must also take some measures to better protect them: (i) We must view historical building equipment through the lens of cultural heritage preservation and simultaneously enhance research efforts to delve deeper into their historical significance. (ii) We should bolster foundational tasks such as cataloging, selecting, and archiving historical building equipment. (iii) Leveraging advanced modern technology, we can also protect and restore these equipment pieces to maximize the historical memory encapsulated in Shanghai's building equipment. The protection of historical building equipment has a long way to go. Based on the points established in this paper, future research should focus on the following points:

- (i) Solving the safety problems of historical equipment, such as the issue of short circuit caused by the aging of some air ducts or heating systems.
- (ii) Allocation of funds in the protection of historical building equipment (daily maintenance, regular upgrading).
- (iii) Dealing with equipment that has lost its function and deciding which ones to keep or dismantle.
- (iv) Preserving the appearance of the original equipment while ensuring that it is coherent with the style of the reconstructed building.

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Disclosure statement

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References

- [1] Fairbank JK, 2002, *China: Tradition and Transformation*. Beijing: China World Knowledge Publishing House: 99.
- [2] Zhou YX, 2016, *Modernization of Chinese Interior Design Based on Modern Architectural Institution, 1845–1953*, Southeast University. 20–25.
- [3] Lai DL, 2016, *History of Chinese Modern Architecture*, China Architecture Publishing & Media Press, Beijing, 123.
- [4] Pu YJ, 2018, *Manifestation of Modernity on the Cultural Implications of Building Facilities in Modern Shanghai*. *Time + Architecture*, 2018(01): 162–166.
- [5] Gu ZN, Gu QX, 1984, *Development of Waterworks in China in recent 100 years*. *J. The Chinese Journal for the History of Science and Technology*, 1984(01): 88–93.
- [6] Ma CL, Liu AB, 2006, *Social Environment of Infectious Disease Prevention and Control in Shanghai during the Republic of China*. *J. Archives of the Republic of China*, 2006(01): 51–58.
- [7] Dong XJ, 1930, *Report on Investigating the Municipal Situation in Shanghai*. *Xinhankou*, 1930(12): 58–62.
- [8] Wang JY, 1934, *Shanghai Public Concession Housing Building Regulations*. *China Public Architecture Magazine*:

1-30.

- [9] Huang X, 2009, The Dissemination, Application, and Development of Electrical Lighting Technology in China, Inner Mongolia Normal University, 24–25.
- [10] He CX, 1912, Then and Now, A Comparison of Sixteen Years. *Journal of Society*, 1912(02): 177.
- [11] Hibbard P, 2007, *The Bund Shanghai: China Face West*. Hong Kong: Odyssey, 99.
- [12] Lai DL, 2016, *History of Chinese Modern Architecture*. China Architecture Publishing & Media Press, Beijing, 125.
- [13] Pu YJ, 2014, The Changed Custom: A History of Modern Building Heating System in Shanghai, 2014(07): 36–40.
- [14] Qiu ZY, 1984, Development History of World Air Conditioning. *J. Refrigeration technology*, 1941(03): 38–40.
- [15] Chen GF, 1948, Overview of China's Engineering in the Past 30 Years, Jinghua Publishing House, Beijing 20.
- [16] Chen YL, 1933, *Shanghai Real Estate*, Shanghai Real Estate Research Institute, 736–750.
- [17] Qi SF, 1923, New Factory Notes: Shanghai Newspaper, 6-7, April 4, 1923.
- [18] Yang YF, 2007, Application and Development of Ammonia Refrigeration Technology. *Journal of Refrigeration*, 2007(04): 12–18.
- [19] Shen Y, Wang Z, 2014, Trace and Research on the Design of Huasheng Brand Electric Fan. *Zhuangshi*, 2014(05): 58–61.

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