The Golden Age of Cooling

Historic Theaters and Their Impact on Air Conditioning Today

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The performing arts have been an integral part of the history and culture of society. Access to performance evolved significantly starting in the late 19th century, inextricably tied to developments in the conditioning of performance spaces. Overheated theaters had been a concern for centuries, with the cheapest seats often up higher and exposed to even higher temperatures. A theater presented significant challenges for comfort and wellness, given they were often windowless, ornate, and most of all, packed with both performers and audience members. In an era before electric lighting, gas jets were used, often pushing temperatures past 100°F (38°C).[1]

First Innovations

Most theaters in New York City had no choice but to halve performances during the summer. One of the first noted evolutions occurred at the Madison Square Theater (*Figure 1*), newly renovated in 1880, and featuring a 650-seat house. The theater incorporated a ventilation system for the first time, developed specifically for comfort. The system as envisioned by Steele MacKaye, an actor/playwright/producer, is described as costing $10,000[1] and consisting of a 50 ft (15 m) high intake shaft on top of the theater's roof with a 3 ft (0.9 m) wide rotary fan. Outdoor air was drawn past a bag-shaped cheesecloth filter, washed once a week, forced through a chamber with racks of ice, then distributed through a network of smaller "pipes" emerging throughout the auditorium. This system was noted by Mr. MacKaye as being able to keep butter solid.

This system received a significant amount of coverage from the press but did not drive market transformation. The labor-intensive system used fans powered by steam engines, and ice had to be replenished at a rate of two to four tons per performance. In 1885, two additional Broadway theaters incorporated similar systems to the MacKaye concept—a low percentage of adoption. Reliability was a major concern, and *The Evening World* even noted that a theater cooling system is "heard a great deal more than it is felt." Even if a system was able to reduce air temperature a few degrees below the

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outside temperature, the novelty of systems attracted more scrutiny than if a theater had no system at all.

20th Century Experimentation

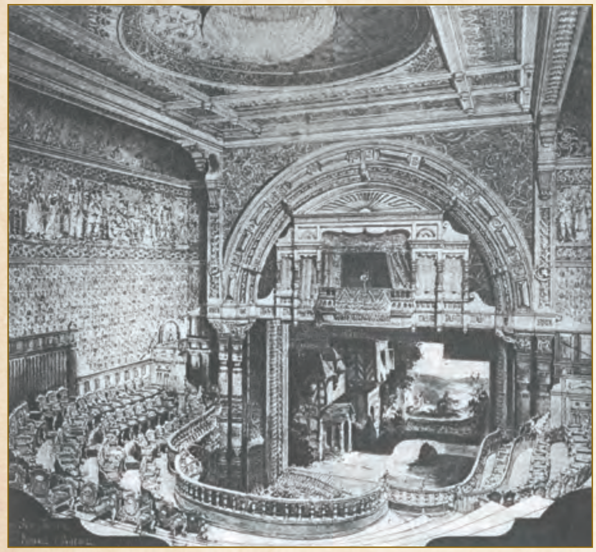
Through the remainder of the 19th century, emerging into the 20th century, experimentation continued with cooling systems but was seen through the lens of fascination rather than pure necessity. A greater fascination occurred starting in 1882, when Thomas Edison first made electricity available to consumers.[1] Two-bladed ceiling fans and tabletop fans became available, developed by Schuyler Skaats Wheeler. These electric fans were considered high-ticket items, costing up to $500 in today's dollars. In 1895, the Chicago Telephone Company developed a custom ventilation system using an "air washer," prior to the much fuller understanding of air properties that would later come with psychrometrics. Humidity was not well understood, and an air washer system on its own was also unreliable.

In 1880, Alfred Wolff, at the age of 21, set up a business as a "Steam Engineer." In a decade, he became known as a heating-and-ventilation expert, with clients such as St. Patrick's Cathedral and Carnegie Hall. Although ice production had become more well-known by this time, Wolff knew using ice for cooling was limited in its potential. In 1899, he received a commission from Cornell University to develop a ventilation system for its Medical College, as well as a refrigerating system for its dissecting rooms.[1] This led to the development of another commission for the New York Stock Exchange, which opened in 1903, considered the first high-profile application of a cooling system specifically for comfort, rather than textiles, manufacturing or food storage. Wolff would go on to develop systems for Columbia University, the New York Public Library, and the Metropolitan Museum of Art, which interestingly noted the benefit of constant humidity for preservation of art. When Wolff died in 1909, the stage was set for broader adoption of comfort cooling systems, not only for those with means, but for all.

Comfort Cooling Evolution

At the beginning of the 20th century, Alexander Bell was associated with the telephone and Thomas Edison with electricity, but comfort cooling still did not have a single champion. Willis Haviland Carrier, a graduate of Cornell University in 1901, set up Buffalo Forge's Department of Experimental Engineering in 1902. Carrier first developed a system for the Sackett-Wilhems Lithographic and Publishing Company. Printing in color on paper was highly sensitive to humidity; Carrier used a steam coil as a chilled water coil, and coupled with control of a fan and water temperature, was able to see excess humidity condensing on the coil. This initial system evolved over a decade of scientific exploration and experimentation, resulting in the 1911 publication of work known as the "Rational Psychrometric Formulae."[1]

Figure 1 Madison Square Theater. Source: *Cool: How Air-Conditioning Changed Everything* [New York Public Library, Billy Rose Theater Division]



By 1919, when Carrier published "The Story of Manufactured Weather," increasing acceptance of cooling technology for manufacturers was well underway, but comfort cooling was still not widely embraced. It noted, "the non-industrial applications—residences, schools, churches, theatres, office buildings, etc.—have been comparatively few, because the Average Man is a peculiar animal in the way he dissociates the principles he employs in his business and those he uses in the conduct of his home, his church, or even his amusements." And again, the stage was set for the significant impact of Hollywood on exposing an entire generation to comfort cooling.

In 1896, the first Vitascope showing occurred, an invention of Thomas Edison. Tiny movie theaters started to show up, and at 5 cents, the cost of admission was significantly less than for Broadway theater, or about one-fifth the cost! In 1905,[1] a Pittsburgh theater operator co-opted the name of a Boston music facility, The Nickelodeon, for a movie theater.[1] By 1908, there was estimated to be 8,000 theaters across the United States, with millions of attendees. The unintended consequence of this success was a generation exposed to the oppressiveness of spaces with no windows or ventilation in highly occupied spaces for hours at a time. Odor and stale air were associated with these nickelodeons and were initially masked with perfume!

Movie production houses saw the future of entertainment at their feet but also saw that the conditions would limit the middle and upper class from seeing movies unless interior conditions improved. Higher income streams were the way to further develop higher quality feature-length films. By the 1910s, movie theaters became more and more opulent. In 1915, the Rivoli in New York City (*Figure 2*) opened, the flagship of the Paramount Pictures chain. These theaters utilized two primary types of ventilation without mechanical cooling:

- Exhaust-driven. Fans were used to drive air from a space, relying on make-up air to enter as possible. Often these theaters had to keep their lobby doors open, resulting in discomfort for patrons at the rear of the theater. Very rarely were purpose-built makeup air openings provided.
- Plenum system. In this case, outdoor air was actively delivered to the space, but without exhaust fans. The concept was that the supply pressure would be enough to force out hot, stale air. The Typhoon Fan company specialized in this type of system, which was used initially at the Rivoli. The challenge with these systems was air delivery. A simple system would introduce air by fans into the theater, while others utilized mushroom-type ventilators at the floor. Both systems created discomfort, either due to too much or too little air movement.

Eventually, movie theater operators realized that mechanical ventilation alone would not be enough for comfort. The air needed to be cooled, but there was a reluctance to embrace ammonia-based refrigeration systems. In 1912, the Isis Theatre in Houston installed an air washer, and ice continued to be used at several other theaters,[1] either to cool water or air directly; outcomes were inconsistent.

Figure 2 Rivoli Theater. The theater's refrigeration plant was prominently featured on opening day on Memorial Day in 1925. Source: *Cool: How Air-Conditioning Changed Everything* [Carrier]

Figure 3 Balaban and Katz Theater Poster. Advertisements for movie theaters in the 1910s and 1920s used air conditioning as a major feature, often emphasizing temperatures cooler than in today's ASHRAE thermal comfort zone. Source: *Air-Conditioning America/Chicago Daily Tribune*, 23 June 1919

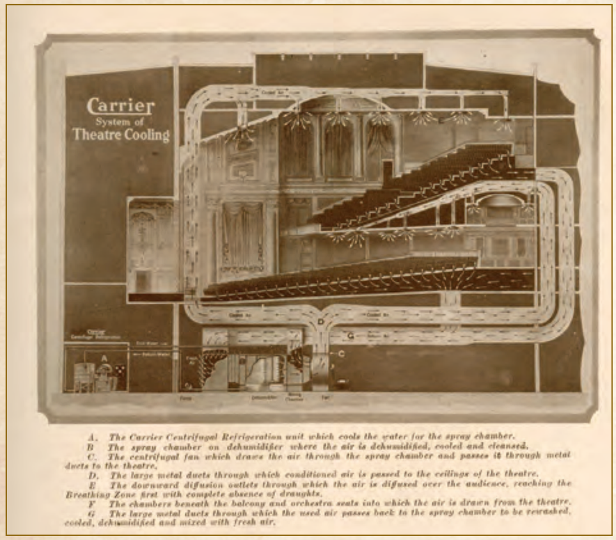
In 1917, the New Empire Theater in Alabama installed a 6 ton (21 kW) vertical single-acting belt driven enclosed type refrigerating machine, becoming the first known air-conditioned movie theater. There was little press coverage of this, as much of the attention on motion pictures was occurring back in larger cities like New York City and Chicago. At a similar time, Barney Balaban and Sam Katz opened the Central Park Theater in Chicago (*Figure 3*), with a goal of treating every patron, rich or poor, as royalty. Balaban had been working in the meat-packing trade and was exposed to mechanical cooling.[1] Frederick Wittenmeier, an engineer for the Kroeschell Brothers Ice Machine Company, had been developing a large-scale refrigeration system using carbon dioxide, rather than ammonia, as the refrigerant. The Central Park theater incorporated a Wittenmeier system and used it as a prominent feature in drawing audiences. The Central Park Theater was able to maintain 78°F (26°C) space temperatures, but there were still comfort complaints, due to use of floor-level distribution and "clammy" conditions.

Carrier entered the movie-palace market around the time of the Central Park Theater and studied the successes and failures of systems at many facilities. He noted, with his team, that air distribution needed to evolve. Carrier engineer L.L. Lewis introduced an overhead supply air distribution strategy using custom-engineered diffuser cones (*Figure 4*). Interestingly, theater designers were initially opposed to these, due to their impact on aesthetics. Over time, through integrated design between engineer and theater designer, overhead supply systems gained acceptance.

Overcoming Obstacles

There remained two major obstacles for comfort cooling in theaters: cost and space requirements. While a 3,000-seat movie palace could better absorb the cost of a $50,000 system within a basement, smaller facilities couldn't absorb this cost and could not rely on ammonia-based equipment, although smaller. Carrier solved this issue with the invention of the centrifugal compressor, using dielene as a refrigerant. The compressor was unveiled in 1922. A more refined version would later be installed at the Rivoli Theater in 1925. It is thought that the New York City inspector initially refused to issue a permit, due to a lack of familiarity with dielene and a concern that it was flammable.[1] The Rivoli opened with the Carrier system on Memorial Day, with box office receipts increasing by $5,000 a week. In the first summer, many other facilities took a wait-and-see approach, but quickly air conditioning became associated with the movie experience, something included with the price of admission. The Rivoli redoubled its investment in a $65,000 system in the first summer. Over the following five years, Carrier outfitted more than 300 theaters with refrigeration systems. It was not until 1927 that Broadway theaters started to adopt air conditioning, rather than going on hiatus during the summer. The Ziegfeld Theater was outfitted with a new system advertising it as the "Coolest Theater in the World." *The New York Times* reported, "There will be a cooling plant, capable of keeping the theater at 50 degrees if desired." Refrigeration and air-washer evaporative cooling systems co-existed for quite some time. Between 1925 and 1930, the Air Conditioning Corporation of Minneapolis installed 8,000 central-station evaporative-cooling systems.[2] In 1937, 11 out of 15 shows on Broadway were in air-conditioned theaters.[1]

Figure 4 Carrier Theater Cooling System. An early diagram of Carrier's system for air distribution for a theater. Source: Historictheaters.org



The chronology over 50 years—from 1880 and the Madison Square Theater to the air conditioning of Radio City Music Hall in 1932—is deeply tied to entrepreneurship, monumental changes in technology, an ever-evolving demographic, and the formation of critical engineering societies like ASHRAE, originally founded in 1894 as the American Society of Heating and Ventilating Engineers (ASHVE). In 1954, the organization changed its name to the American Society of Heating and Air-Conditioning Engineers (ASHAE) almost 30 years after the 1920s golden age of air conditioning in theaters.

Research and Development

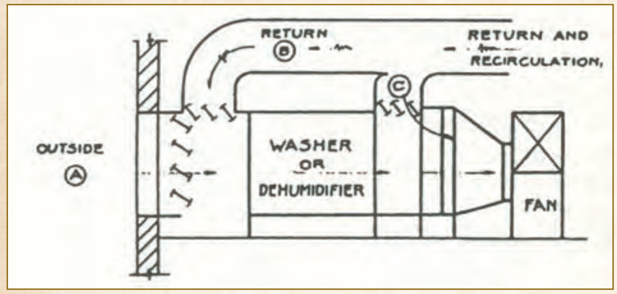
Through the brief chronology already presented, the industry experienced an intense demand for science and research to inform design. Movie exhibitors were bound by the same requirements for ventilation as public schools, but the exhibitors embraced air conditioning more quickly than in other markets. Outdoor air requirements of 30 cfm (14 L/s) per person presented a significant challenge for early air-conditioning systems. This 30 cfm (14 L/s) requirement was originally intended for mechanically ventilated spaces and published as a standard by ASHVE in 1914. Early system engineers found a need to recirculate a portion of air to achieve reasonable operating and first cost. At the same time, the engineering community was deeply focused on the importance of humidity control on human thermal comfort but found it hard to reconcile how operators wanted to run systems, versus what evolving comfort research was showing. Carrier noted, “art never achieves its full possibilities, regardless of the market, until the basic principles of its operation are thoroughly investigated and understood.”[2]

In the early 20th century, tension rose among those who were proponents of mechanical ventilation versus air conditioning versus natural ventilation. Experimental data largely came from the ASHVE Research Laboratory, established in 1919 at the U.S. Bureau of Mines in Pittsburgh, Penn. and led by F. Paul Anderson. This laboratory was first discussed by President Harry M. Hart at the 1917 ASHVE annual meeting. In 1922, the laboratory published its first findings, including a comfort chart, consisting of a graph of the combinations of temperature and humidity at which most people would find thermal comfort.

The historical record on July 4, 1919 for the Riviera Theater, a sister to the Central Park Theater, indicated an outdoor temperature of 94°F (34°C), while the inside condition was between 74°F and 78°F (23°C and 26°C) with 70% relative humidity.[2] At this time, comfort was considered qualitatively rather than quantitively. Wittenmeier was a proponent of an element of adaptive thermal comfort we see today, where the indoor temperature should be set to 15°F (–9°C) lower than the outdoor temperature.[2] Wittenmeier disregarded relative humidity compared to Carrier and thought an RH of 75% was acceptable, noting that while air could be sub-cooled to 50°F (10°C) and reheated, this required additional equipment and operating cost. Carrier’s experience with humidity control in industrial settings gave him valuable insights and a perspective that precision control of the indoor environment was important.

In 1919, Balaban and Katz turned to the Carrier Engineering Corporation (CEC) to address the “cold and clammy” environment of Wittenmeier’s system in an economical manner. A major challenge was Chicago’s ventilation requirement of 25 cfm (12 L/s) per person, lower than the 30 cfm (14 L/s) per person seen in New York City but still significantly higher than today’s requirement of 5 cfm (2 L/s) per person and 0.06 cfm/ft^2 (0.31 L/s/m^2). A tension continued to exist between proponents of mechanical ventilation alone versus air conditioning. CEC considered three options:[2]

Figure 5 Return Air Bypass. This diagram from 1928 showed a return air bypass strategy that became dominant in providing cost-effective humidity control in 90% of theaters during that era. Source: *Air-Conditioning America / Refrigeration Engineering,* 15, May 1928



- Option 1: Reheat chilled water downstream of an air washer. This was common to industrial systems but too expensive for comfort air conditioning.
- Option 2: Reduce airflow to 10 to 15 cfm (5 to 7 L/s) per person, but still at 100% outdoor air fraction, to better align with the temperature rise associated with occupant heat gain. This would require a variance from the Chicago Health Department.

Option 3: Provide 25 cfm (12 L/s) per person, but as a mixed air system, with 50% recirculated air. This was technically not compliant with the Chicago standards, which called for 25 cfm (12 L/s) of outdoor air.[2]

The relationship between health and ventilation was a significant topic of focus in the late 1910s through 1920s, driven by work at the ASHVE laboratory as well as the Harvard School of Public Health. At the 1923 ASHVE annual meeting, members voted to delete the term “fresh air” from its proposed ventilation standard, noting its imprecision and support of a perception that only non-recirculated air delivery systems were acceptable.

Carrier’s team focused heavily on providing humidity control efficiently and developed what we still know today as a return air bypass system (*Figure 5*). The early version of this system called for 75% of the return air to bypass an air washer while allowing the remaining 25% of outdoor air to enter the air washer. In 1921, the Metropolitan Theater in Los Angeles became the first to use a bypass arrangement. The air-conditioning system was estimated to cost $115,000. The system cost $500 per month to run during the winter and $2,200 per month during the summer. The bypass system allowed for an indoor temperature of 78° to 80°F (26° to 27°C) at a relative humidity of 45 to 55%. The Metropolitan Theater also incorporated an overhead supply air distribution system, even though it was still thought that a bottom-up approach was beneficial given the natural upward convection generated by body heat, a concept that would emerge again as displacement ventilation many years later.

The ASHVE laboratory produced a significant body of work supporting a thermal comfort envelope with basic characteristics not too different from those of today; yet, theater managers pushed back on the notion of a high-temperature/low-humidity environment. The early success of movie theaters was intertwined with the marketing of cold indoor temperatures, whether 70°F or 20°F (21°C or –7°C) less than the outdoor temperature. CEC hoped research findings would help convince operators to revise their views and not limit their focus to temperature. Marketing at the time used phrases like, “20 Degrees Cooler Inside,” “Never Over 70 Degrees,” “Arctic Breezes,” and “Siberian Zephyrs.”[2] Many theaters were designed with a positive pressure system. Theater managers left lobby doors open to allow exfiltration of cool air and draw in pedestrian traffic on hot days. It was not until the 1930s that operators finally started to move away from a focus on temperature alone. In 1925, ASHVE published “Minimum Requirements for Heating and Ventilation of Buildings” in the ASHVE Guide. Continued work by Yaglou, Hougton, Riley, Coggins and others led to a major update in 1938, resulting in a recommendation that 15 cfm (7 L/s) per person of ventilation was acceptable, considering multiple variables such as odor, volume of a space, occupant age, space conditions and the concept of air recirculation.

Revitalizing Historic Theaters for the Next Generation

Fast forward to the latter half of the 20th century, and many historic movie palaces fell into disrepair or abandonment due to suburbanization across America. Playhouse Square in Cleveland (*Figure 6*), the second largest performing arts district in the United States, was an example of a collection of five 1920s era theaters that experienced a rebirth. The first two theaters of the complex, the Ohio and the State, were designed by Thomas Lamb and opened in 1921. The last of the theaters to open was the Palace, designed by Rapp and Rapp, the same designers as the Central Park Theater in Chicago. This collection of theaters successfully showed theater, vaudeville shows and movies for 40 years.

Figure 6 Playhouse Square. This photo from 1928 is reminiscent of a different era, where theater palaces were the center of life for many major U.S. cities. Source: Playhouse Square Archive at Cleveland State University

The years following WWII, which included the rise of television, led to a decline of the Cleveland theaters, like many others across the United States. In the 1960s and 1970s, all but one of the Playhouse Square theaters were closed, with plans to demolish the two original theaters. Due to the committed efforts of a devoted group of community members, the Playhouse Square Foundation, founded in 1973, developed plans to revamp and renovate the theaters. In 1978, the district was added to the National Register of Historic Places.

Over the next 40 years, each theater was revitalized and became a key element for the rebirth of downtown Cleveland. Three of the most recent projects at Playhouse Square include work at the Allen Theater (*Figure 7*), the Hanna Theater (*Figure 8*) and the Ohio Theater lobby (*Figure 9*). These projects increased the flexibility for a variety of performances for greater financial sustainability. Rather than focusing on large seat counts, theaters were reconfigured with fewer seats but a greater variety of seating options. Finishes, HVAC systems, lighting, and technology systems support improved indoor air quality, reduced power demand, increased energy efficiency, and created greater flexibility to host all types of productions.

Figure 7 The Allen Theater at Playhouse Square. The original walls are covered by an acoustically and visually transparent material, allowing historical fabric to be augmented with modern lighting and technology systems. Source: DLR Group

The Allen Theater renovation included the reconfiguration of the 81,000 ft^2 (7527 m^2) historic theater into three venues, a 512-seat main stage proscenium theater, a 300-seat flexible theater, and a 150-seat black box theater.

The Hanna Theater renovation included the reconfiguration of a 32,000 ft^2 (2973 m^2) 1,400-seat theater into a 560-seat theater with a combination of traditional seats, loose club chairs, lounge seating, balcony boxes, historic boxes, banquette couches and bar stools. This diversity of seating allows for increased flexibility for different types of performances, while also adapting for a significantly changing demographic of theatergoers. This renovation was also the first theater within the complex to achieve LEED for Commercial Interiors certification.

The renovations of the Allen and Hanna Theaters support significant improvements in HVAC systems behind the scenes, while allowing for improved financial sustainability with reduced resource use costs, higher consistent revenue, and higher overall facility reliability.

The Ohio Theater lobby was destroyed by fire in 1964 and had undergone a modest renovation in the 1980s. The 7,500 ft^2 (697 m^2) theater was fully restored through a detailed research and analysis process. This included review of original architectural drawings, photo archives, and material analysis. The restoration included original paint colors, plaster ornamentation, and columns, while upgrading to current building codes. Sprinkler and air distribution systems were carefully integrated and hidden within the ceiling's ornamental plaster elements. As is often the case with historic theater renovations, phasing and construction staging to allow continued operations was needed.

Figure 8 The Hanna Theater at Playhouse Square. (Top) An example of the types of alternate seating provided in a recent renovation. Reducing seat count allows for an improved audience experience while also reducing ventilation requirements. (Bottom) A stage view of the restored Hanna Theater. The integration of modern elements within a historical context requires a fully integrated design process. While the technology demands for certain productions have increased, the use of LED lighting has helped reduce HVAC demand. Source: DLR Group

Economic Engines. Many historic theaters restored within the past 20 years have been catalysts for urban renewal. The Ulster Performing Arts Center (UPAC) (*Figure 10*), originally the Broadway Theater, was built in 1926 and is the largest proscenium theater between New York City and Albany, N.Y. The theater was added to the National Register of Historic Places in 1979, two years after it was closed due to declining attendance. In 2002, it reopened after a partial modernization. In 2017, the last phase of a multi-phase renovation was completed. UPAC was originally a movie theater but now hosts mainly musical performances due to its acoustic character. The work between 2002 and 2017 consisted of three

Figure 9 Ohio Theater Lobby. This series of photos shows the lobby (Top) in its original condition; (Center) after a later renovation; and (Bottom) after its recent historic restoration. Source: DLR Group

Figure 10 Ulster Performing Arts Center. This shows a typical condition in many early 20th century theaters, with plaster ceilings hung from metal strap hangers, making major changes often difficult to achieve without potential risk to historical finishes. Source: DLR Group

phases, including façade improvements, development of a multi-purpose room, and a major infrastructure and patron amenity upgrade.

Project work benefited from historical tax credit programs in New York state and the federal level, which recognize the difficulty in financing rehabilitation projects while acknowledging the significant broader direct and indirect economic impact of these facilities. The project required some reverse engineering, as no comprehensive HVAC, plumbing or electrical drawings were available. The renovation approach included rehabilitation of existing ductwork in place to minimize potential damage to historical plaster. An existing field-erected AHU was replaced with a semi-custom modular unit, and a secondary field-erected AHU was replaced with a dedicated outside air unit, set up to provide indirect conditioning to the existing historical lobby.

One of the major considerations addressed reliable summer season cooling, making the facility into a year-round community asset. The original cooling system was made of an individual indoor compressor, outdoor fluid cooler, AHU DX coil, and field-routed refrigerant piping. The indoor compressor created significant sound intrusion into the audience chamber, limiting the operation of the unit during an actual performance. New systems allow an NC-20 condition to be maintained while meeting ASHRAE Standard 90.1-2013 efficiency and ASHRAE Standard 62.1-2013 ventilation requirements. A new BACnet-compatible building automation system gives the facility team greater flexibility to operate equipment just in time for performances. Before this system, operators would have to manually start, stop, and adjust equipment locally. The facility is now able to

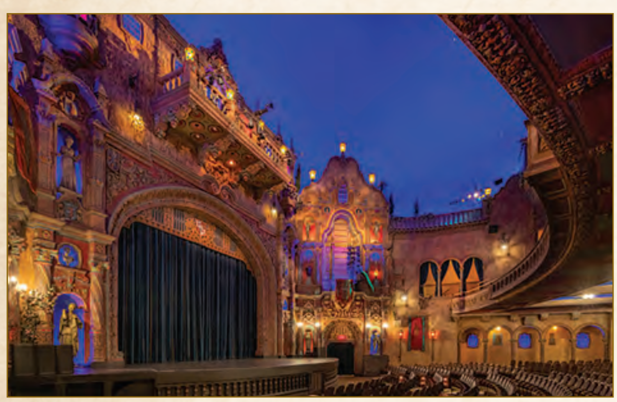
Secretary of the Interior's Standards for Rehabilitation[3]

1. A property shall be used for its historic purpose or be placed in a new use that requires minimal change to the defining characteristics of the building and its site and environment.
2. The historic character of a property shall be retained and preserved. The removal of historic materials or alteration of features and spaces that characterize a property shall be avoided.
3. Each property shall be recognized as a physical record of its time, place, and use. Changes that create a false sense of historical development, such as adding conjectural features or architectural elements from other buildings, shall not be undertaken.
4. Most properties change over time; those changes that have acquired historic significance in their own right shall be retained and preserved.
5. Distinctive features, finishes, and construction techniques or examples of craftsmanship that characterize a property shall be preserved.
6. Deteriorated historic features shall be repaired rather than replaced. Where the severity of deterioration requires replacement of a distinctive feature, the new feature shall match the old in design, color, texture, and other visual qualities and, where possible, materials. Replacement of missing features shall be substantiated by documentary, physical, or pictorial evidence.
7. Chemical or physical treatments, such as sandblasting, that cause damage to historic materials shall not be used. The surface cleaning of structures, if appropriate, shall be undertaken using the gentlest means possible.
8. Significant archeological resources affected by a project shall be protected and preserved. If such resources must be disturbed, mitigation measures shall be undertaken.
9. New additions, exterior alterations, or related new construction shall not destroy historic materials that characterize the property. The new work shall be differentiated from the old and shall be compatible with the massing, size, scale, and architectural features to protect the historic integrity of the property and its environment.
10. New additions and adjacent or related new construction shall be undertaken in such a manner that if removed in the future, the essential form and integrity of the historic property and its environment would be unimpaired.

operate year-round, supporting continued economic development in the region.

Design for Community Resiliency. The Tampa Theater (*Figure 11*), designed by John Eberson, was completed in 1926 in downtown Tampa, Fla. Eberson was well-known for developing movie palace designs in the atmospheric theater style. Rather than a traditional black box theater, the theater was designed to replicate a European courtyard or garden with a ceiling designed to mimic a sky, complete with painted clouds and pin-point lights to represent stars. The 1,250-seat theater was the first air-conditioned commercial building in Tampa. Like many other movie palaces from the 1920s, the theater faced demolition in 1973. City leaders reached a deal to assume ownership of the facility, and the county agreed to program the facility with films, concerts and other public events. The theater was added to the National Register in 1978 and became another example of a successful model for revitalization. The theater has also benefited from a phased modernization approach, with work in 2009, 2011–12, and 2017. The most recent work fully restored the main audience seating area and finishes, updated electrical systems and improved overall resiliency against major weather events.

FIGURE 11 Tampa Theater. (Top) The first air-conditioned commercial building in Tampa advertised its indoor environment as a Cool Vacationland. Source: Cinematreasures.org. (Bottom) The recently restored theater, including new seating, upgraded lighting and reconfigured return air distribution. The original installation utilized hundreds of floor-embedded mushroom return air devices. These often became difficult to maintain, if a drink was spilled on the floor. Source: DLR Group



Conclusions

This historical review of key milestones in theater system design shows deeply intertwined roots of ASHRAE with the public's first major introduction to air conditioning. Without the advent of film, the demand for research may have taken a different course. Yet today, we benefit from the incredible work of many on air distribution, refrigeration, psychrometrics, controls, thermal comfort, and ventilation in support of theaters across the United States.

The historic theater work described has significantly benefited from the work of ASHRAE over the past 125 years. Many of the questions asked in the late 19th and early 20th centuries continue to be topics of focus today, benefitting from a global network of professionals, technology, and research. The research and development driven by theaters led a generation of leaders to better understand thermal comfort, ventilation, architectural engineering integration, and early notions of the societal and economic impact of conditioned environments. ASHRAE's work and the "Secretary of the Interior's Standards for Rehabilitation"[3] complement each other and are a focus of the recently released ASHRAE Guideline 34-2019, *Energy Efficiency for Historic Buildings*.

The sensitivity required by the "Secretary's Standards"[3] has driven a demand for integrated design and construction, new products, and higher efficiency technologies that allow reductions in system size. The next century will see a new generation of buildings requiring our continued collective stewardship as we continue to improve wellness and address environmental sustainability and economic resilience.

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