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Upgrading the Wyoming State Capitol's Mechanical System: A Case Study

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Updating heating, ventilation and air conditioning (e.g., 'mechanical') systems in historic buildings represent a major component of building restoration projects. Mechanical system retrofits can be challenging since the new system must be designed to fit within the constraints of an existing building while also meeting current codes and standards that are written for new construction. Substantial time investment and in-depth planning are required when historically significant building features will be retained or recreated through the project. The Wyoming State Capitol Building provides a unique case study demonstrating the planning and installation of modern mechanical systems within a nationally designated historic structure. This study provides insight and creative solutions for installing mechanical systems while retaining and restoring the building's historic fabric and significance. Discussions herein outlines several challenges encountered and the strategies utilized by the state of Wyoming and its design and construction partners to incorporate a modern mechanical system within the State Capitol Building. This case study highlights the careful planning and commitment necessary to maintain historically important buildings for future generations, while addressing the critical goal of bringing a building up to current comfort and safety standards.

Key Words: historic preservation, HVAC, mechanical, capitol, restoration, Wyoming

Introduction and Background

The built environment in the Western United States is still relatively young when compared to the Mid-Atlantic Region. As buildings reach and surpass 100 years of age, their use, function, and relevance is often questioned. Some buildings, however, are iconic public symbols and discontinuing their use or replacing them with new construction is a sensitive and often disputed option. The Wyoming State Capitol is recognized as "the state's most significant building" and was originally constructed in 1888 with two later additions (1890, 1917) (State of Wyoming Legislative Services Office, 2016, p. 4). The building was showing its age by the early 2000s after years of modifications, systems had reached the end of their functional life, and state government offices had outgrown the historic spaces that had been partitioned over time. The Wyoming State Capitol building is nearing the end of a 3-year, $219 million project that restored and recreated historic features that were covered or lost throughout the 130-year history (State of Wyoming Legislative Services Office, 2016). The project includes a substantial overhaul to the building's mechanical systems to improve human comfort and life safety. The Wyoming State Capitol Building serves as a case study for successfully integrating modern mechanical systems with significant historic spaces.

Building History and Significance

Neoclassical state capitol buildings typically borrow their architectural style from the United States Capitol building. Generally, capitol building layouts comprise mirrored wings containing offices and legislative chambers on either side of a central rotunda. While building details change from one state to the next, often bringing in regional influences, the form remains constant. There are 33 state capitol buildings that fall under the neoclassical architectural style; the oldest completed in the mid-nineteenth century and the most recent during the Great Depression. All of these buildings have been updated and modified to some extent to meet the demand for additional space to address occupant comfort and modern building code.

Ohio native David W. Gibbes designed the 1888 Wyoming Capitol building and 1890 addition (see figure 1). Construction firm Adam Feick & Bro., also of Ohio, constructed the 1888 building for $131, 275.13. The Territorial

Assembly recognized the government would need more space and allocated an additional $125,000 for expansion in 1888. Cheyenne contractor Moses P. Keefe won the bid at $117,504. The State awarded the third and final addition to John Howard of Cheyenne for a price of $140,790 (Miller, 1987). The building was listed in the National Register of Historic Places in 1973 and designated a National Historic Landmark in 1987. The Wyoming Capitol Building is nationally significant under Criterion A for government and political history and regionally significant under Criterion C for architecture. The building is three stories with a garden level basement, attic, and dome. The enclosure is limestone quarried in Rawlins, Wyoming; the quarry reopened for this project so exterior repairs could be perfectly matched.

US Capitol Buildings

The Secretary of the Interior designated the Wyoming State Capitol Building a National Historic Landmark in 1987, one of only 20 state capitol buildings with the designation. The Wyoming Capitol Square Project is a unique study for a major public building restoration: the project was 100% state-funded and therefore not subject to Section 106 of the National Historic Preservation Act of 1966 regarding federal undertakings or the Secretary of the Interior's Standards for the Treatment of Historic Properties.

Figure 1: Wyoming State Capitol Construction, circa 1890, *National Park Service.*

Case Study and Stakeholders

This case study explores how a contractor acts on restoring a building's historic character while discretely installing modern mechanical systems. J.E. Dunn served as the general contractor on the Wyoming Capitol Square Project (J.E. Dunn, 2018). The Wyoming Capitol Square Project includes the Capitol building rehabilitation and restoration, the Central Utility Plan Replacement, the Connecting Tunnel remodel and expansion, and the Herschler Building remodel and expansion. The scope of this paper is the Capitol Building and aspects related to the Central Utility Plant. J.E. Dunn was hired at-risk under a guaranteed maximum price contract for the entire Capitol Square Project scope, with approximately $110 million budgeted for Capitol restoration. J.E. Dunn is emerging as an expert for state capitol restoration projects; recently completing Kansas (2014) and Minnesota (2018), with Oklahoma and Oregon currently underway (Scott and Boyse, 2018). Loring Consulting Engineers was the mechanical engineer and has worked on other state and federal government neoclassical buildings (Loring Consulting Engineers, 2018). Mechanical Systems, Incorporated based in Cheyenne was the mechanical contractor (Mechanical Systems, Incorporated, 2018).

Case Study Significance

The project team embarked on the monumental task of restoring the building to its 1917 appearance, while simultaneously outfitting the capitol and supporting state offices with modern mechanical, electrical, and plumbing systems. This task was completed within the challenging constraints of meeting desired efficiency standards, needed life safety codes and providing human comfort in a building that was not designed to accommodate these systems. While chosen systems and installation methods may not be appropriate for other state capitol restoration projects, this case study can stand as a model for other state capitol buildings that will likely require similar mechanical and life safety upgrades as they age. Specifically, this study provides insight regarding methods for making such upgrades while retaining the historic material and character of an iconic building.

Restoration Planning

Restoration projects can be challenging for contractors due to unknown scopes of work, unforeseen building conditions and the need to remediate prior, sometimes historically insensitive, interventions. This issue can quickly escalate projected costs and the associated paperwork required for change orders. The State of Wyoming considered restoration a high priority to showcase the building as a piece of Wyoming history and to create a destination for Wyoming students and Cheyenne visitors (State of Wyoming Legislative Services Office, 2016). Project planning began in the early 2000s. The Legislature opened a project savings account and created an oversight committee involving the Governor, President of the Wyoming Senate, Speaker of the Wyoming House, the majority and minority floor leaders of the Senate and House, a member selected by the Senate President, and a member selected by the Speaker of the House (State of Wyoming Legislative Services Office, 2016). Early planning and investigation allowed capitol maintenance staff, designers, and other project stakeholders to understand the existing building conditions and assess what areas within the building had the most flexibility for change. This early design process established four preservation zones and permissible restoration interventions that would be appropriate (HDR, 2014).

J.E. Dunn and Loring Consulting Engineers came well equipped, having spearheaded other major neoclassical building restorations in recent years. Mechanical planning began in 2013 and the team undertook selective demolition to "better understand shafts, foundations, structural materials, structural framing systems, utility routings" (Galway, 2018) and wall thickness to better understand the building and try to anticipate any unusual conditions. These investigations allowed the design team to make changes during the design phase rather than during the construction phase. The Wyoming Capitol Building has withstood 130 years of constant use and technological upgrades, and since modern mechanical systems have an average lifespan of 20-30 years, "historic buildings should not be greatly altered or otherwise sacrificed in an effort to meet short-term systems objectives" (Park, 1991, p. 2). Research for this case study was collected through site visits and in person and virtual interviews with the general contractor, mechanical contractor, mechanical engineer, and architect to understand the construction changes. Publically available State documentation was analyzed to understand the Capitol Building's condition and State restoration priorities.

Existing Mechanical Systems and Upgrades over Time

Wood burning fireplaces and operable double-hung sash windows provided the earliest heating and ventilation in the original Capitol Building core. Gas and electric lighting were later installed. Two Advance Boilers from the American Boiler Company supplied the Capitol Building with a hydronic heating system by 1899, located in the garden level, approximately where the State Auditor and State Treasurer offices are proposed today (S.J.W., 1899). Radiant heating apparatuses were installed in individual offices on the first through third floors and on the main level of both the House and Senate Chambers. Air conditioning was installed in select areas in the 1960s with later window air conditioning units and electric baseboard heating (HDR, 2014). Additional changes were made throughout the 20th century to improve life-safety and human comfort within the building; the double hung wood widows were replaced with aluminum sash, original gas and electric lighting features were stripped, decorative painting was painted over and original 10-15 foot ceilings were dropped, covering historic skylights and laylights to accommodate mechanical piping and ductwork (Loring Consulting Engineers, February 2014; Miller, 1987).

Previous systems in the Wyoming State Capitol Building were modified and replaced over the building's life. The most recent large-scale efforts were in the 1970's and 1980's, when some alterations were made that would be considered inappropriate today from a historic preservation standpoint. For example, sheet metal details were replaced with acoustical tile, woodwork was stripped and stained, precast plaster cornices were replaced with stamped sheet metal, the walls and rotunda ceilings were repainted, florescent lights replaced the original incandescent fixtures, and bronze windows and basement entrance doors replaced the original wood (Miller, 1987). The building was modified to fit the systems rather than truly designing systems to respect the building at the cost of losing historic features.

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The complex gained a Central Utility Plant (CUP) with the Herschler Building construction in 1985. This was advantageous for the Capitol Building because large systems could be installed close by, but without further encroaching on historic interior spaces. The CUP is located in the Herschler east basement and was expanded from approximately 11,000 square feet to 18,000 square feet (State of Wyoming Legislative Services Office, 2016) as a separate component of the current project. The existing building systems were studied in full in the planning phase to determine where inefficiencies existed and where modern systems could be installed that would not detract from the historic aspects prioritized for restoration. The building had 165, 4-pipe fan coil units that were well maintained and working, but beyond their useful life prior to the current restoration (Loring Consulting Engineers, February 2014). 27% of the building remained with no HVAC systems and ventilation was accommodated largely through aluminum sash windows (not original to the building) (Loring Consulting Engineers, February 2014).

It was no small task to redistribute these systems within the existing building to regain the historic proportions and corridors as they previously existed. Careful planning allowed for minimal invasion while fully outfitting the entire building with modern HVAC systems. The current restoration project and mechanical updates uncovered building details that had been lost with previous mechanical installations. The original 10, 12, and 14-foot ceilings had been dropped to accommodate ductwork and mechanical piping, obscuring the full window height, hiding arched doorways, and covering Corinthian columns and coffered ceilings. Details such as doors and vaults were hidden behind framed walls that were likely installed as a place to run electrical wiring and other modern building systems.

Previous System/Deficiency	Historic Implication	Intervention
Building lacked fire suppression system.	Building was not designed with adequate egress and fire could quickly spread through open corridors causing fire and smoke damage.	Smoke exhaust system installed in central rotunda with makeup air unit in garden level; building fully sprinkled; additional egress stairs installed from garden level to third floor in east and west wings.
Only 27% of building air conditioned.	No negative implications for building’s historic nature.	4-pipe fan coil units installed throughout the buildings with regulated in individual offices. Windows remain operable.
Ductwork installed utilizing a dropped ceiling.	Original ceiling heights were lowered, covering character-defining features including Corinthian columns and arched openings.	Mechanical piping and ductwork installed below the garden-level slab and through vertical chases created in new shear walls and repurposed fireplace flues to restore ceilings to original heights.
Elevators installed in primary corridors.	Obscured views and monumental corridor spaces.	Elevators moved out of corridors in east and west wings to recapture original corridor spaces.
Fan coil units had exceeded their expected lifespan.	Potential for leaks damaging historic fabric.	All fan coil units replaced and housed in decorative woodwork to match historic character of interior spaces.
CUP lacked adequate servicing space.	Cooling towers remained outside with condensation deteriorating the Capitol’s sandstone façade.	CUP expanded to provide additional equipment, offices, and servicing space. Cooling towers moved to Herschler Building roof.

Integrating Modern Mechanical Systems

Significant research has been conducted regarding the energy and thermal retrofit of historic buildings; however, the suggested interventions have not always been the best practice (in preservation terms) to protect the historic fabric. There has been little documented research on appropriate methods that have recorded long-term success. This can be partly attributed to the fact that there is not a universal solution that is appropriate for each historic building. Lubbehusen and Thornsbury (2012) and Baggio et al. (2017) present case studies about retrofitting historic buildings at Indiana Tech (United States) and A.Canova High School (Italy), respectively. Both case studies present building interventions that reach the goal of making the building high performance or designing a renovation based off of the

LEED rating system. However, both studies present options that are irreversible and therefore not preservation best practices. Some of their solutions included adding spray foam insulation on the interior of a historic brick wall and replacing windows. Kay (1996) and Lubbehusen & Thornsbury (2012) stress properties will have physical limitations for installing modern mechanical systems, and Azarbayjani, Nemeth, and Sliwinsky (2011, p. 537) argue that at some point, energy costs will rise to such a level that retrofitting historic building materials may "become economically attractive." Regardless, "poor installations in older buildings have economic implications because they adversely affect the cost of repair, maintenance, and operation" (Kay, 1996, p. 248) since they could be damaging significant historic materials around them or are not conveniently accessed.

Updating the mechanical systems within the Capitol building falls within components one and two of the project scope: Capitol Rehabilitation and Restoration and Central Utility Plant Replacement. The State wanted a new system that would "blend into the architectural design and the historic fabric of the structure and function in harmony with the programmatic aspects of the facility, and are consistent with the operational intent of the owner" (Loring Consulting Engineers, February 2014, p. N.1). Restoration and mechanical upgrades were weighed as equal State priorities (Galway, 2018).

The mechanical design was carefully coordinated with the structural engineering and architectural teams to accommodate required structural improvements while disguising mechanical systems and retaining and recreating historic features. Two of the largest structural interventions included rebuilding four shear walls from the original 1880 core and drilling 450 micropiles into bedrock below the entire Capitol Building. Mechanical systems were designed around these interventions (see figure 2). Garden level ductwork and hydronic piping runs below the slab and all MEP components had to be designed around the new micropiles since they were specifically placed for structural loads. The garden level had to be excavated six additional feet below the top of the slab to install the mechanical systems (Foder, 2018).

Figure 2: Below-slab micropile installation, ductwork and piping, March 2018

Structural improvements also required rebuilding four shear walls in the 1888 core; the building was shored and walls were replaced one at a time to prevent sudden failure. The new CMU shear walls provided vertical chases to connect mechanical piping below the slab with the mechanical equipment in the attic (Foder, 2018). The historic fireplace flues were repurposed as another avenue to channel piping to the attic. While losing some historic fireplaces detracts from the historic character, it allowed the team to recapture other historic features like open corridors and historic ceiling heights. It was a creative way to hide a modern system in an historic building with little adverse impact. Using these paths also freed up space to restore the original ceiling heights which left approximately six inches of room between the ceiling and floor above to accommodate modern MEP. The State of Wyoming Legislative Services office argued, "restoring the original ceiling heights is actually a cost savings. By adopting a fan coil heating and cooling system, ceiling-mounted ductwork and stepped ceilings are avoided, lowering construction costs" (State of Wyoming Legislative Services Office, 2016, p. 26).

The majority of horizontal ductwork and mechanical piping is encased below the slab under the garden level and in the attic, leaving the historically significant spaces free from intrusion. The new piping placed below the slab is not accessible. The mechanical engineering team insisted that the system must be jacketed and should therefore "have a lifespan adequate to prevent its deterioration and required replacement until the next major renovation" (Galway, 2018). The attic is a purely utilitarian space and not publicly accessible. Additional air handling units and the smoke exhaust fans are arranged around the dome. The attic space is not conditioned. The design team planned four mechanical rooms in the garden level adjacent to the rebuilt shear walls to house air handling units. The mechanical rooms are isolated from office spaces, reducing their noise impact on people working in nearby offices. Visible mechanical system components are generally mirrored on either side of the rotunda.

The new system utilizes steam for heating and chilled water for cooling and has 181 fan coil units in individual offices. The fan coils are individually regulated constant volume units (Galway, 2018) that were disguised in smaller offices and meeting rooms within decorative built-in woodwork to enhance the building's character and protect the equipment (figure 3).

Figure 3: Fan coil units framed for built-in decorative woodwork.

Central Utility Plant

The Wyoming Capitol complex had an existing central utility plant that serviced the Wyoming Capitol Building, Herschler Building, Supreme Court Building, Hathaway Building, and Barrett Building. The project Oversight Group identified replacing the Central Utility Plant as one of four primary components of the project scope. Systems in the CUP had reached the end of their functional life and the existing footprint did not leave adequate space for servicing equipment. An additional 7,000 square feet was proposed, bringing the total facility to approximately 18,000 square feet. Cooling towers were moved from the plaza on the north side of the Capitol Building to the Herschler Building. These changes not only improved efficiency, safety, and function, but the changes and relocations also allow a continuous plaza between the Capitol Building and Herschler Building (State of Wyoming Legislative Services Office, 2016). Creating a continuous plaza between the buildings is desirable from a historic preservation standpoint, as it strengthens the Capitol Building's historic integrity by restoring the grounds' setting and feeling.

The expanded CUP now houses the boiler plant, cooling system, electric services and emergency generators. These systems are monitored and controlled directly from the CUP. The expansion was positive for the restoration project because it moved the large components to a central serviceable area, protected historic spaces that were restored within the Capitol Building itself, and removed unwanted noise. The CUP expansion was accomplished without losing any working time in the three other office buildings it supplies. The new CUP supplied HVAC functions to the Supreme Court, Hathaway, Barrett and Herschler Buildings for two weeks to detect any operational rooms prior to removing the old system. Connections to the new equipment and neighboring state office buildings were made after hours to avoid interrupting any state government working days. The old CUP was removed approximately one month after the new facility was entirely up and running (Foder, 2018).

Fire Suppression

The Capitol Building lacked an adequate fire notification system and lacked a fire suppression system entirely. The building will be fully sprinkled upon completion. The alarm system does not have zones, as many modern large buildings do, and will instead ring throughout the Capitol Building if triggered. The 30-ft diameter central rotunda is used as an asset in case of fire; four new exhaust fans in the attic pull smoke upward to pool in the rotunda to prevent seepage into the axial corridors. A makeup air unit and the garden-level windows work in conjunction with the exhaust fans; windows open when smoke is detected in the rotunda and a makeup air unit located beneath the south front stairs pulls new air in as smoke is exhausted up through the rotunda. The makeup air supplies the rotunda with “approximately 80% of the exhaust air quantity, reducing the pressure differential across egress doors” (Galway, 2018). Analysis determined that this kind of system was required for the Capitol Building because of the large central space in the rotunda and open corridors. Similar systems are in place at the Tweed Courthouse in New York City and at the Minnesota State Capitol Building (Bjornberg, 2014; Waite & Rankin, 2004), among others. This approach follows a softening in strict building code application when historic buildings are rehabilitated or restored; opting for performance based approaches that meet the code intent rather than strict interpretation. State capitol buildings are one such type that could greatly benefit from a performance-based approach.

Conclusion

The restored Wyoming State Capitol Building stands proud as a symbol of state government and the American West. The mechanical designers started with a blank canvas for mechanical system options, but had to work within the bounds of a historically designated building shell. Integrating modern mechanical systems into historic buildings will likely increase as older buildings continue to be retrofitted for new uses and historic city cores are revitalized. The careful planning and coordination with stakeholders and designers allowed for a complete overhaul of the building’s mechanical systems while reaching the State’s goal to restore the building and maintain its historic character. Placing ductwork and mechanical piping below the garden level slab allowed for minimal ductwork in the historic corridors, exposure of the original ceiling height and, recreation of interior details that had been obscured for decades. Coordinated mechanical and structural improvements created chases in the rebuilt shear walls to run mechanical piping to the attic. Historic fireplace chases were repurposed as an additional avenue in order to maintain arched openings throughout the corridors. The individual office fan coil units are neatly housed in built-in woodwork as a modern convenience that compliments the building’s historic aesthetic.

The Wyoming State Capitol Building provides an important example for the integration of a full, new, energy-efficient, mechanical system as compared to piecemeal system retrofits. Capitol buildings are typically designated as historically significant at the state and/or national level, making the standards for preservation more stringent. Future historic restoration projects can greatly benefit from studying recently completed, and on-going, capitol building restorations. Studying these past projects can help develop new options and understandings how mechanical systems have been successfully integrated into historic buildings while maintaining important historic building fabric. New possibilities should also be explored to creatively install modern systems while best preserving the building-specific historic character.

References

Azarbayjani, M., Nemeth, R., & Sliwinsky, B. (2011). *Energy refurbishment of mies vanderohe residential buildings.* Paper presented at the 27th International Conference on Passive and Low Energy Architecture: Architecture and Sustainable Development, PLEA 2011, July 13, 2011 - July 15, 2011, Louvain-la-Neuve, Belgium.

Baggio, M., Tinterri, C., Mora, T. D., Righi, A., Peron, F., & Romagnoni, P. (2017). *Sustainability of a Historical Building Renovation Design through the Application of LEED Rating System.* Paper presented at the International Scientific Conference Environmental and Climate Technologies, CONECT 2016, October 12, 2016 - October 14, 2016, Riga, Latvia.

Bjornberg, M. j. (2014). *The Minnesota State Capitol: Historic Structures Report* Retrieved from Minnesota: https://mn.gov/admin/assets/3.2-Historic-Struct-Vol3-Full_tcm36-225160.pdf

Foder, L. (2018, August 17, 2018) *CSU Historic Research/Interviewer: A. Simpkins*.

Galway, M. (2018, October 3, 2018) *Wyoming Capitol Project Mechanical Engineering/Interviewer: A. Simpkins*.

HDR. (2014). *Wyoming State Capitol Renovation & Restoration: Level I Reconnaissance & Level II Feasibility Study*. Retrieved from Cheyenne, Wyoming: https://static1.squarespace.com/static/553d78dbe4b0786b41e0e2ca/t/5750c98f20c6475fb76e08cb/1464912304931/2014-Level-I-II-Vol-I-pgs-1-22.pdf

J.E. Dunn. (2018). Wyoming State Capitol. Retrieved September 01, 2018, from https://www.jedunn.com/projects/wyoming-state-capitol.

Kay, G. N. (1996). *Repairing, retrofitting, and maintaining mechanical/electrical systems in pre-1940 structures.* Paper presented at the Proceedings of the 1993 Symposium on Standards for Preservation and Rehabilitation, October 10, 1993 - October 11, 1993, Dallas, TX, USA.

Loring Consulting Engineers. (2018). Wyoming State Capitol Complex. Retrieved September 15, 2018, from https://www.loringengineers.com/project/wyoming-state-capitol-complex/.

Loring Consulting Engineers. (February 2014). *Wyoming State Capitol Renovation & Restoration: Level I Reconnaissance & Level II Feasibility Study*. Retrieved from https://static1.squarespace.com/static/553d78dbe4b0786b41e0e2ca/t/5751bf687c65e4555a900cdd/1464975280263/2014-Level-I-II-Vol-3-pgs-103-166.pdf.

Lubbehusen, M., & Thornsbury, T. (2012). *How to make a 155 year old building a high performance building.* Paper presented at the 2012 ASHRAE Winter Conference, January 21, 2012 - January 25, 2012, Chicago, IL, United states.

Mechanical Systems, Incorporated. (2018). Wyoming State Capitol Renovation. Retrieved August 15, 2017, from https://www.mechanicalsystemswyo.com/msi-project/wyoming-state-capitol-renovation/.

Miller, P. P. (1987). *National Register of Historic Places Inventory - Nomination Form*. Washington, D.C.: National Park Service.

Park, S. C. (1991). *Heating, Ventilating, and Cooling Historic Buildings--Problems and Recommended Approaches*. Washington, D.C: National Park Service: Technical Preservation Services.

Scott, L. and Boyse, L. (2018). Analyzing the Restoration of the Oklahoma State Capitol from the Perspective of the Design Build Process - A Descriptive Case Study. Proceeding of the 54th annual conference of the Associated Schools of Construction. Minneapolis, MN. April 17-21, 2018. Retrieved 10/12/2018 from: http://ascpro0.ascweb.org/archives/cd/2018/paper/CPGT147002018.pdf

S.J.W. (1899). Wyoming Capitol Building, Cheyenne, Wyoming. In. Cheyenne, Wyoming: J.E. Dunn.

State of Wyoming Legislative Services Office. (2016). *Capitol Square Project History and Status: Summary Report of the Oversight Group on the Capitol Rehabilitation and Restoration*. Retrieved from Cheyenne, Wyoming: https://static1.squarespace.com/static/553d78dbe4b0786b41e0e2ca/t/57f4e2abe4fcb541f80d1a86/1475666646291/2016-0202-CapitolSquareProjectHistoryandStatusReport.pdf

Waite, J. G., & Rankin, N. A. (2004). Tweed Courthouse: New Approach to Life-Safety Management in a Landmark Public Building. *APT Bulletin: The Journal of Preservation Technology, 35*(1), 15-21.