Iowa State University – Marston Hall Renovation

Supporting narrative for the 2018 ASHRAE Technology Awards

Marston Hall is the 60,000-square-foot historic home of the College of Engineering at Iowa State University (ISU) in Ames, Iowa. The original building, one of the oldest structures on campus, first opened in 1903 as the Division of Engineering, and was renamed in 1947 for the College of Engineering's first dean, Anson Marston. Over the past century the building was modified piecemeal, resulting in a warren of small, mostly administrative spaces replacing the original classroom learning areas and laboratories. Sections of the building were unused, and many other sections underused.

In 2016 ISU completed the first comprehensive renovation of Marston Hall, creating a 21st century learning environment within the 19th century structure to give the building another 100 years of life. The renovated building has achieved LEED Gold certification.

Energy Efficiency

With the University's goal of LEED Gold Certification, energy efficiency played a significant role in the design of the facility. The building is served by campus steam and chilled water from Iowa State's central power and cogeneration plant. As such, opportunities were not available to improve upon the production of heating and cooling efficiency within the building. Nor were opportunities available for on-site renewable energy. However, the following strategies were employed within the building to optimize its energy efficient operation:

1) The envelope loads were minimized by adding insulation to the exterior walls. The original masonry building structure did not include exterior wall insulation, and the original exterior wall R-Value was calculated as 2.7. Newly-added insulation increased the exterior wall R-Value to 15. The building's operable windows had been replaced just before the renovation, and are modern double pane insulated units.

2) The ventilation load was minimized by using a dedicated outside air system (DOAS). Ventilation is one of the largest loads that must be accommodated in facilities in Climate Zone 5A due to extreme winter and summer conditions, so the use of a DOAS ventilation system allowed the amount of ventilation air provided to the building to be the minimum required by ASHRAE 62.1-2010. With the amount of ventilation air minimized, the peak heating and cooling loads associated with the ventilation air were then further reduced by energy recovery wheels in the DOAS air handling unit. Fan-powered VAV boxes were used for meeting the chilled beam's minimum activation air when the minimum ventilation rate did not.

3) Ventilation air reheat and dehumidification was accommodated by using a desiccant dehumidification and energy recovery wheel in the DOAS unit. No steam energy is used for reheating ventilation air.
4) Ventilation air supply to the auditorium is controlled by carbon dioxide sensing.
5) Hydronic heating and cooling via active chilled beams and perimeter convectors were employed throughout a majority of the building to minimize air-based heating and cooling. Underfloor air distribution for cooling and ventilation was employed in the auditorium space, which has higher ceilings than practical for using chilled beams.
6) Lighting power density in the building was 27% less than code allowable. Design lighting power density was 0.86 W/SF. Code allowable was 1.19 W/SF. Lighting is also controlled by vacancy sensors in classrooms and office spaces.

The building EUI was 146 kBtu/SF/year average for the two years prior to renovation. LEED energy modeling analysis using Trane Trace showed the renovated building would consume approximately 53 kBtu/SF/year, a 64% reduction in EUI compared to pre-renovation. The modeled energy use was also a 33.5% reduction over the code allowable 86 kBtu/Sf/year - and $38,850/year less energy cost than what new code minimum would allow. Comparing actual use, the first year of data shows the building operated at 71 kBtu/SF/year. ISU and the design team executed the LEED M&V analysis credit to determine causes of the higher-than-anticipated energy consumption. The study identified multiple issues, with the most notable being a DOAS unit steam valve commanded open 100% at all times. This was negating energy recovery benefits, using unnecessary steam, and causing increased chilled water use. Correction of this issue saves as much as $24,000 a year in energy cost, and updated energy modeling based on actual use and occupancy showed the building to be operating within 10% of the updated modeled EUI.

Indoor Air Quality

The building is mechanically ventilated throughout via the dedicated outdoor air system. This type of direct ventilation system removes any doubt each space is receiving the code required outside air. The unit supplies 10,000 CFM of outside air filtered to MERV 13, which is an average of 0.16 CFM/SF over the entire building. Air is supplied directly to each space at the ASHRAE 62.1-2010 required flow rate, at least. In office and classroom spaces, the air is introduced via the active chilled beams to provide a zone air distribution effectiveness of Ez = 1.0.

In the auditorium space, ventilation air and cooling supply are both introduced through an underfloor air plenum, using displacement ventilation to cool and ventilate the space. The space is served with a high return, providing a zone air distribution effectiveness of Ez = 1.2.

The project design achieved LEED Credit IEQ 7.1 for thermal comfort, demonstrating compliance with ASHRAE 55-2010. Design temperature goals were 75°F/50% RH in the summer and 72°F/20% RH in the winter. The building is not actively humidified. Clo levels were assumed to be 0.66 in the spring and summer, and 0.70 in the fall and winter. Metabolic rate in offices and conference rooms was assumed to be 1.1, and 1.0 for classrooms. Design air speed for all spaces is below 40 fpm. There have not been significant comfort complaints.

Occupants in office and administrative spaces are also able to control natural space ventilation through the operable windows. Windows in spaces without permanent occupants, such as classrooms, are locked closed.

Innovation

This renovation provided the team with various opportunities to be innovative and still mindful of the building's history:

1) Fitting the New into the Old: A key challenge in the renovation of the facility was physically integrating 21st century systems within a facility that was not intended to house them – and still retain as much of the original building architecture as possible. The building structure was characterized by low floor-to-floor heights and an original masonry system that integrated air supply and relief shafts within thick corridor walls. A hot deck/cold deck tunnel (split top/bottom) ran under the ground floor central corridor that fed a series of vertical masonry shafts in corridor walls that served individual upper spaces. The original mechanical design was a pneumatically-controlled multizone system distributed in the structural walls of the building.

   To build the new systems into Marston Hall, a similar utility distribution strategy was employed. The hot deck/cold deck tunnel below the ground floor hallway was cleared out to create a walkable service/utility corridor. A majority of the MEP ducts, pipes, and associated services (which originate from central mechanical rooms in the basement) are distributed in this lower level to multiple vertical chase locations throughout the floor plate. This allowed the horizontal distribution on each occupied floor to be minimized and contained within small zones on each floor. This allowed ceiling heights to remain higher than if large utilities were piped and ducted across the floor plate on each occupied level. As noted earlier, the DOAS ventilation system was used to minimize the ventilation energy load. In addition to the energy benefits, providing only the code-required ventilation rate via the DOAS system also allowed the ventilation and exhaust duct mains to be as small as possible, easing routing through the building. However, in some cases the code-minimum ventilation air provided to certain zones was not enough to meet the chilled beam activation minimum air flow rate. For this reason, parallel fan-powered VAV boxes were used on the DOAS system. Ventilation air is provided via the VAV air valve through the chilled beams to the occupied spaces. When the chilled beams have a call for cooling, the parallel fan energizes, boosting the air flow to the chilled beams to the rate required for proper activation and cooling. This allowed the primary ventilation ducts to remain as small as possible to ease space constraints.

2) <u>Reliable Radiant Cooling in a Humid Climate</u>: This project demonstrates that using a chilled beam system for cooling in an older building in a humid climate can be successful if handled properly from a design, operation, and occupant education standpoint. The existing building lacked a vapor barrier to inhibit moisture transfer and it has operable windows, a combination that could create condensation and dripping if a space becomes too humid. Analysis was conducted early in design to determine the peak space latent loads, and to determine which source (permeation, infiltration, or occupants) was the dominant

load. By far, moisture from occupants was shown to be the dominant source of space latent load. To combat the risk of condensation on the chilled beams, the following strategies were employed:

a. The DOAS system with passive dehumidification wheel provides ventilation air to the building at the following conditions: 60°F db/51.2°F wb/44 grains/lb of moisture/44°F dew point. Typical 55°F saturated supply air (as may be used in a traditional VAV system) has a moisture content of 60-65 grains/lb with a dew point of 54-55°F. This dry ventilation air is required to absorb space latent loads and ensure the space dewpoint remains below 55°F, which is below the chilled beam loop set point temperature of 57°F.
b. The mechanical control system includes dew point sensors in each space that lock out the chilled beam cooling when a space's dew point reaches 57°F.
c. To ensure duct leakage was minimized and the dry ventilation air was supplied to the spaces, the DOAS supply ducts and associated VAV boxes were sealed to meet SMACNA Class A, plus sealed with heavy backed adhesive tape (UL 181A-P compliant) at all joints. The VAV box construction seams were all taped to reduce leakage, as these VAV boxes leak considerably as made.
d. Occupants and building operators were provided education by the design team and university staff on the mechanical system operation, and understand the potential issues caused by leaving windows open at the wrong times.

The DOAS and chilled beam system has operated successfully since the building opened in the summer of 2016.

Operation & Maintenance

The mechanical system is comprised of equipment that is familiar to Iowa State facilities staff, and only requires simple regular maintenance. The DOAS air handler, main mechanical pumps, and heat exchangers are located in an accessible mechanical space in the basement. Exterior access and interior elevator and stair access is provided to this mechanical space. Adequate space is provided for coil pulls, filter changes, and regular maintenance. The air handler serving the auditorium is located in a mechanical room adjacent to the auditorium, on floor level off of a central corridor. Fan-powered VAV boxes are located above accessible ceilings for filter changes. Chilled beams and perimeter radiant convectors only require periodic cleaning and are accessible throughout the building. During the construction of the project, the design team, contractors, and owner worked together to place and map isolation valves and control valves for optimized access and clearance. The isolation, control, and drain valves serving the perimeter heating system in the auditorium are located behind an access panel at floor level, as opposed to above the high auditorium ceiling.

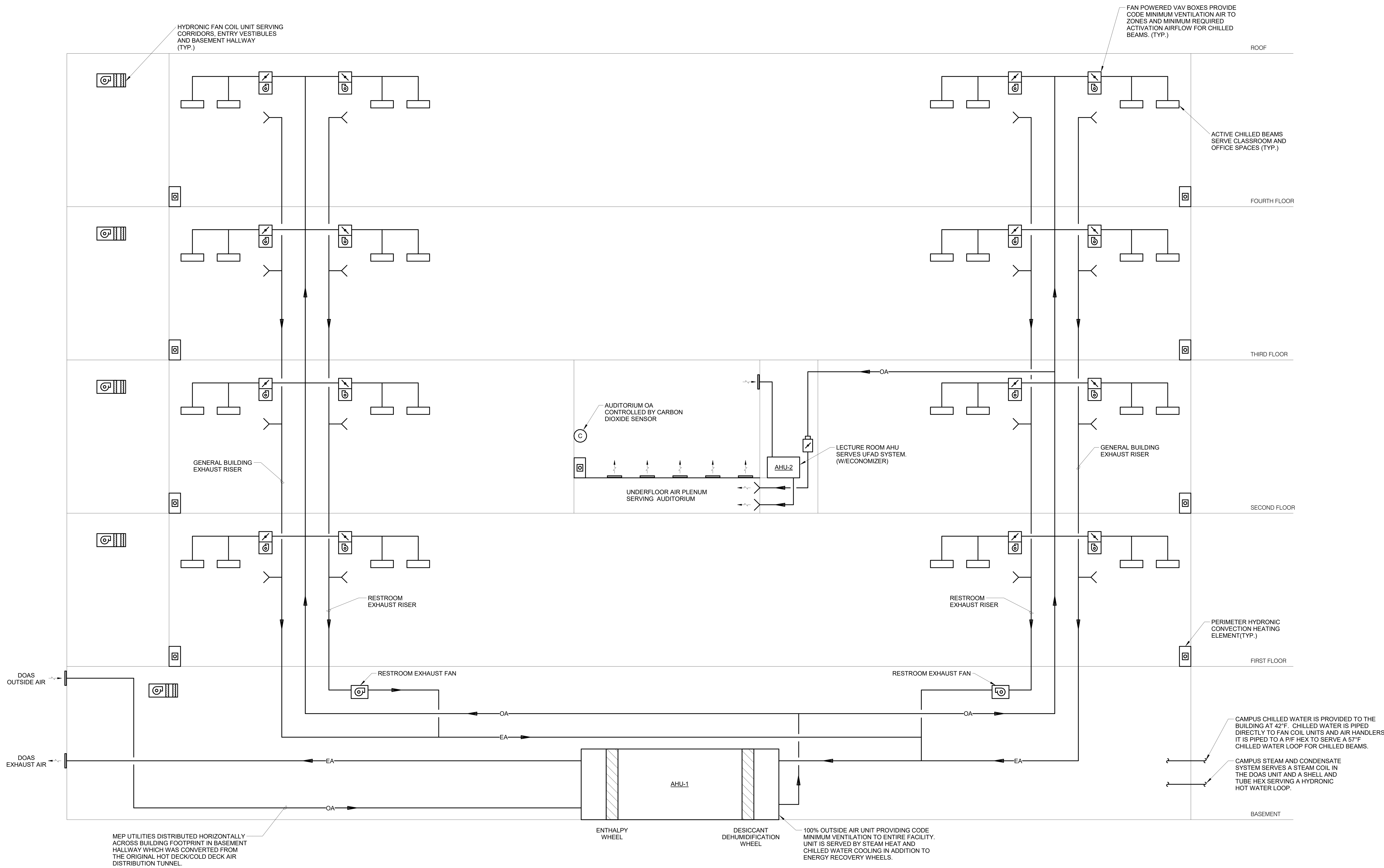
Cost Effectiveness

The project construction cost was $18.9 million, equating to a square foot cost of $315/SF. Considering the extensive renovation undertaken, asbestos abatement, tight construction site, and high performance MEP systems installed, the cost for the project compares favorably to similar State of Iowa Regents projects. Recent similar projects show construction costs between $350-400/SF for new construction. This project essentially provides ISU with a cost-effective and energy-efficient “new” facility for the next 50-plus years, while maintaining the architectural history of the campus and College of Engineering. The new system is currently saving $37,000 in annual energy costs compared to pre-renovation despite increased use and occupancy.

Environmental Impact

The design team analyzed multiple mechanical system options using energy modeling analysis to help optimize the MEP design. The building is currently using 50% less energy than it had prior to the renovations, even though its use and occupancy have increased significantly, with opportunities for improvement available through M&V analysis. Reuse and renovation of Marston Hall accomplished the additional environmental benefits in addition to energy use reduction:

1) No refrigerant based cooling is used within the building
2) The building underwent a complete asbestos abatement
3) Power, heating, and cooling sources are sourced from the campus power and cogeneration plant
4) 39.5% reduction in water use based on specified plumbing fixtures
5) 71% retention of the original structure
6) Diversion of 89% of the construction waste from the landfill
7) 18% of new materials sourced from the region
8) 26% of new materials manufactured using recycled materials
9) Enhanced acoustical performance was achieved for a LEED Innovation Credit



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