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Inside An Energy-Efficient Upgrade for a Historical Army Band Hall

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ABSTRACT

This paper discusses the Heating, Ventilation, and Air Conditioning (HVAC) system designed as part of a major renovation project to the historical San Antonio building that serves as home to the U.S. Army Band known as "Fort Sam Houston's Own." The HVAC system design provides an innovative new heating and cooling system intended to save energy and give the facility a more sustainable long-term life. The facility is located in south Texas and was originally cooled by multiple two-pipe indoor air-handler units fed by an air-cooled chiller and gas-fired boiler. Outside air was provided to the air handlers from window louvers and roof vents. Such a ventilation approach is not recommended by the U.S. Department of Defense Unified Facilities Criteria (UFCs), the American Society of Heating, Refrigerating and Air-Conditioning (ASHRAE), or industry standards. The new system relies instead on a Dedicated Outside Air System (DOAS), Fan Coil Units (FCUs), and energy recovery wheels to bring the building up to modern standards.

1. BACKGROUND

Built as a barracks in 1891, Building 615 at Joint Base San Antonio, Texas; today is home to the 323rd Army Band, "Fort Sam's Own." Over the years, the facility has housed a dining hall, gym, surgery training center, and classrooms. Measuring 26,800-square-feet (2,490-square-meter) over two stories, the structure was converted into a band hall in 2008, but it soon needed upgrades to meet building codes and current needs. A priority upgrade was to replace the outdated ventilation system. Due to the building's historic nature, no roof vents or exterior wall penetrations could be added to bring in fresh air. Tight ceiling spaces were not originally designed for air conditioning and could not be expanded. Military restrictions on air systems limited design options as well.

To address these issues, an innovative approach was designed focusing on handling the envelope and ventilation loads separately while preconditioning air with energy recovery wheels and controlling indoor temperatures with dual-technology occupancy sensors. Design was completed in 2019, and the renovation is under way. When construction is completed, this energy-saving design should give the facility a more sustainable life over the long term.

2. DESIGN APPROACH

2.1 Overcoming Key Challenges

Building 615 was not designed for air condition 130 years ago. A new ventilation system needed to serve upgrades to offices and practice rooms, as well as a performance hall. Other than dual-temperature air handler units installed in 2013, the existing HVAC had exceeded its useful life. And the control system, although fairly new, relied on a manual switchover, causing poor temperature control and discomfort during temperate periods.

The building and its east and west wings were originally heated and cooled using a two-pipe, manual switchover system served by an air-cooled chiller and a gas-fired boiler, with zero energy recovery. An underground chilled water supply and return piping connected the chiller to the dual-temperature system. A single distribution pump delivered the chilled water and hot water to all air handler units. This setup violated the requirement for redundancy stipulated in UFC 3-410-01.

Additionally, outside air was provided to the indoor air handlers from repurposed antique window openings and unsightly roof vents — an approach no longer recommended by ASHRAE 90.1 or industry standards for spaces with high outside air loads. Some air conditioning equipment was located in open spaces in the building, posing a hazard.

2.2 Preserving History

The project aimed to respect as many historic elements as possible and to get approval from the Texas Historical Commission. For the ventilation makeover, that meant a design that uses techniques such as adapting antique attic vents to avoid new openings in the slate roof; minimizing the number of exterior wall penetrations; reclaiming antique window openings that were used for outside air on previous renovations; limiting equipment near the distinctive building exterior; and preserving unique elements such as a stained-glass inlay over a duct intake.

Figure 1: Building 615's historical attic vent and window to be restored. (Credit: Courtesy of Freese and Nichols)

When the existing HVAC system for Building 615 was installed, windows were destroyed to allow air in. The new design will instead use roof vents for air intake, allowing the windows to be reclaimed and the historic facade to be restored. While the restoration work includes sealing and insulating the entire attic, historical vent covers are being reused as outside air intakes and exhaust vents for the modern HVAC system.

2.3 Replacing the Existing HVAC System

The proposed design calls for the entire HVAC to be replaced with a four-pipe chilled water and hot water loop system, including new FCUs and DOAS with energy recovery. The DOAS, coupled with FCUs, handle the envelope and ventilation loads separately. FCUs provide heating and cooling, and DOAS condition outside air. Both use variable air volume boxes to precisely meet the demands while minimizing energy consumption. The DOAS and FCUs are fed by a four-pipe chilled water/hot water loop system. The new air-cooled chiller is served by two dedicated variable-speed primary pumps that are installed in parallel and operated in a lead/lag fashion based on run time to maintain full redundancy.

A new modulating condensing boiler has two redundant circulator pumps that deliver a constant flow to the boiler and modulate to maintain a water temperature of 140 degrees F (60 degrees C). Additionally, a set of two variable-speed hot water pumps are tapped into the closed circulating pump loop and modulate flow to the air-handling system based on downstream static pressure. All pumps are installed and operated similarly to the chilled water system.

The DOAS recover energy using enthalpy wheels, which allows for the removal of heat and moisture from outside air — an essential feature for muggy San Antonio summers.

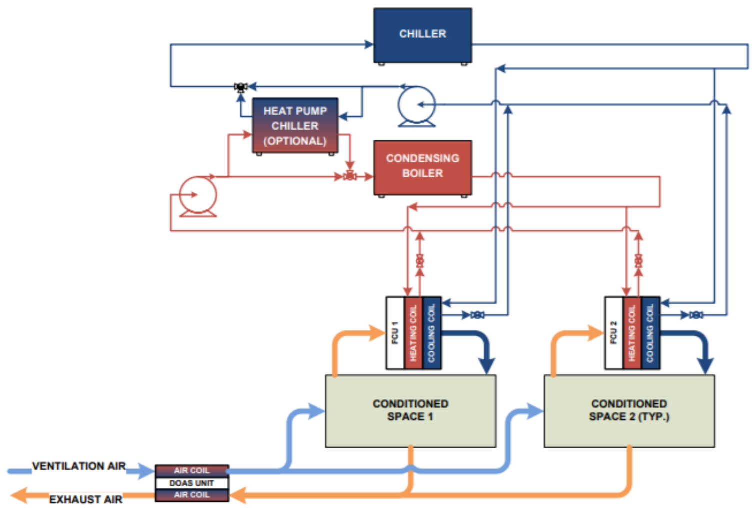

Figure 2: System Diagram (Credit: UFC 3-410-01Appendix F)

Figure 3 shows the system diagram with an outdoor chiller serving both indoor DOAS and FCUs. The common solution of direct expansion DOAS with hot gas reheating was ruled out because it requires outdoor equipment, is loud, and is not compatible with a chilled water system. The low ceilings and separate wings of Building 615 required creative use of space and equipment to make everything fit. To accommodate the historical architecture, chilled and hot water lines were run throughout the building rather than large ductwork, allowing for agile and precise implementation of technology.

2.4 Cooling the Performance Hall

A new, 3,100-square-foot (288-square-meter) performance hall has a 200-person capacity but is expected to be used by only a few people much of the time. Occupancy detection cannot rely on carbon dioxide concentration because UFC 3-410-01 Section 4-2.4.1 requires calculating ventilation for occupied spaces based on the ventilation rate procedure specified in ASHRAE Standard 62.1. But a system that is continuously cooled at 55 degrees F (12.8 degrees C) would require a high volume of outside air and thus a heavy cooling load, which would waste energy by overcooling the space when it's largely empty.

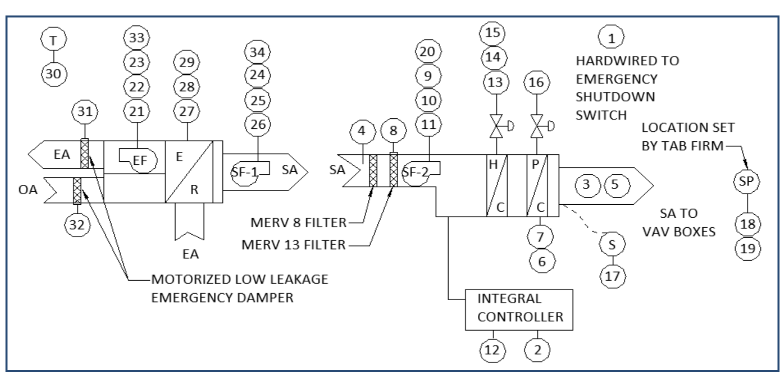

Figure 3: Performance Hall DOAS P&ID (Credit: Courtesy of Freese and Nichols)

To address this, the design calls for three zones in the performance hall to be monitored by a dual-technology occupancy sensor to detect movement and thermal projection. Figure 3 shows the control strategy used to minimize overcooling while maximizing energy saving. The DOAS unit modulates the amount of outside air brought in based on occupancy levels that the sensors detect. This solution creates a healthy environment when the room is fully occupied, saves energy when occupancy is sparse and improves occupants' comfort.

2.5 Meeting Musicians' Unique Needs

Mitigating the sound entering and exiting practice rooms was an important consideration, as was carefully controlling the humidity level for instrument storage. To provide precise humidity control between 47 and 49 percent, the design equips each instrument storage room with a dedicated dehumidifier that carries a relative humidity setpoint of 50 percent and a dedicated humidifier with a relative humidity setpoint of 47 percent. Temperature control is provided with an FCU.

To lessen sound transmission, the mechanical design team worked with the architects to separate the HVAC equipment and practice rooms. All practice room walls are rated STC-55, and each duct penetrating these walls applies an STC-55-rated double-wall silencer to a minimum of 6 ft (1.83 m) from both sides of the wall. The size of those duct segments was increased to accommodate the pressure drop resulting from the silencer.

2.6 Reducing HVAC Energy Use

Building 615 consumes a considerable level of energy because of the outside air required to ventilate the space and the location's inherent high humidity levels. Energy recovery using preconditioning with enthalpy wheels was incorporated to make the HVAC system sustainable. The rotary air-to-air enthalpy wheel in the design is made of a desiccant material and can transfer both sensible and latent energy with an effectiveness exceeding 70 percent. A compact configuration also provides a solution to space limitations.

Table 1: Energy Recovery Calculations

	OUTSIDE AIR			EXHAUSTING AIR			ENERGY RECOVERED
	AIR FLOW	ENTERING TEMP.	LEAVING TEMP.	AIR FLOW	ENTERING TEMP.	LEAVING TEMP.	
ER-1	1,465 cfm (2489 m^3/h)	99.3^{0}F (37.4^{0}C)	85.4 F (29.7^{0}C)	1,265 cfm (2149 m^3/h)	78^{0}F (25.6^{0}C)	94.1^{0}F (34.5^{0}C)	22,094 btu/h (6.5 kw)
ER-2	2,250 cfm (3823 m^3/h)		86.7 F (30.4^{0}C)	2,970 cfm (5046 m^3/h)		87.5^{0}F (30.8^{0}C)	30,760 btu/h (9.0kw)
ER-3	1,850 cfm (3143 m^3/h)		87.3 F (30.7^{0}C)	1,650 cfm (2803 m^3/h)		97.5^{0}F (36.4^{0}C)	24,087 btu/h (7.1kw)
TOTAL	**5,565 cfm (9455 m^3/h)**			**5,885 cfm (9999 m^3/h)**			**76,941 btu/h (22.5kw)**

Table 2: Life Cycle Cost Analysis (LCCA) Results

Cooling Energy Savings				
Item #	Building #	Baseline Cooling Energy [kWh]	Proposed Cooling Energy [kWh]	Energy Savings [kWh]
1	Building 615	62,433	43,611	18,822
Energy Savings %				30.1%
Heating Energy Savings				
Item #	Building #	Baseline Heating Energy [MCF]	Proposed Cooling Energy [MCF]	Energy Savings [MBh]
1	Building 615	331	311	20
Energy Savings %				5.9%

Table 1 summarizes the calculation results of the chosen energy recovery device. Outside air is precooled by energy recovery wheels with the heat transferred from exhausting air. The system can precool the total ventilation air from 99.3 degrees F (37.4 degrees C) to a minimum 86.7 degrees F (30.4 degrees C), which contributes to an energy recovering of 76,941 btu/h (22.5 kw). The chilled water valves were designed to modulate the DOAS to maintain 55 degrees F (12.8 degrees C) leaving coil temperature in cooling. While this approach deviated from UFC 3-410-01

Section 3-2, which requires neutral temperature air supply for DOAS units, it complies with ASHRAE 90.1 section 6.5.2.6 "Ventilation Air Heating Control" and is consistent with the most current industry practices. The energy savings of this design approach has been proven by the Life Cycle Cost Analysis in Table 2.

3. RESULTS AND CONCLUSIONS

Multiple partners have contributed to giving Building 615 new life. The ventilation system overhaul design provides significant benefits:

- The energy recovery approach reduced the size of the chiller required from 100-TR to 72-TR.
- The new HVAC system offers 30 percent cooling energy savings and 6 percent heating energy savings.
- The proposed design minimizes energy waste while meeting the ventilation requirements and maintaining a comfortable atmosphere.
- The system better controls humidity without the need for a manual changeover.

When the renovation is completed, Fort Sam's Own will be able to prepare for performances in comfort for the foreseeable future.

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