Demand Control Ventilation Retrofit Options Assessment

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THE NEW YORK CITY
SCHOOL CONSTRUCTION AUTHORITY
Long Island City, NY

Report Prepared by

OLA CONSULTING ENGINEERS, PC

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1 Executive Summary

Consulting Engineers (OLA) was requested by the New York City School Construction Authority to investigate options to implement Demand Control Ventilation (DCV) strategies as a retrofit application. A public school in Queens, NY was used as a sample building for this study. OLA investigated the feasibility and cost of retrofitting the controls of related HVAC components, to allow for demand control ventilation savings.

The objective of this assessment is to provide SCA with findings on demand control ventilation (DCV) strategies through retrofit measures to determine if the cost and energy savings would be favorable. SCA is interested in analyzing these options to determine if the majority of DCV energy savings achieved from a full HVAC controls project can be captured from a simpler DCV retrofit project (i.e. partial controls modification specifically for DCV implementation). This study explores this simpler controls option to explore a potential cost-effective way to maximizing energy, carbon and installation cost savings.

The efforts of this study helped determine that it is feasible to retrofit a school to have DCV and the carbon savings are significant, greater than 80 tCO_2e.

It is anticipated that every school will have varying results when explored for this DCV simpler modification, as the infrastructure needs and opportunities are different. This study can serve as an order of magnitude indicator of the potential to reduce carbon emissions by implementing DCV strategies in existing schools where it does not exist and allow for some initial high-level comparison of this measure against other investments as SCA strategizes to reduce carbon emissions.

2 Building Conditions/Existing Conditions

2.1 Existing Building Conditions

The public school is located in Queens, New York. The total area of the building is approximately 120,000 sq. ft. and consists of 3 floors plus a cellar floor and a mechanical penthouse. This study focused on seven (7) of the nine (9) air handling units (AHUs), located in the three (3) air handler rooms, which provide conditioning and ventilation to the spaces throughout the building. The steam heating coils within the AHUs are served by two (2) steam boilers in the cellar. The chilled water coils within the AHUs are served by two (2) air-cooled chillers in the mechanical penthouse.

2.2 Existing Airside Systems

Of the nine (9) AHUs, three (3) of these units serve multiple zones and the other six (6) units are single zone AHUs. Currently, BMS controls are installed on all the AHUs. Outside air is provided to all the AHUs, but there is not complete modulating control of outside air, with one of the two outside air dampers being two (2) position only. There is a minimum outside air damper which would be set up by a balancer to provide code minimum ventilation air and a separate economizer damper. These outside air dampers do not have associated outside air flow measuring stations, which would be needed to properly reconfigure the controls for demand control ventilation (DCV) operation.

2.2.1 AHUs Serving Multiple Zones

The AHUs, which serve the 1st, 2nd and 3rd floor classrooms and offices, are the unit types that serve multiple zones. The school is served by three (3) of these units, AHU-6, AHU-7, and AHU-8 (AHU-7 is shown in Photo 1 below). These units were installed in 2002 and are noted to be in fair condition based on a mechanical assessment report performed in December 2020. The supply airflow from these units is distributed to variable air volume (VAV) boxes, one dedicated for each space/zone. The supply airflow from the AHUs consists of mixed return/outside air, with outside air percentages ranging from 38% during non-economizer operation up to 100% in economizer. The outside air dampers are located external to the AHUs and are connected to the main AHU controls. Figure 1 below shows the controls schematic diagram for this AHU.

Photo 1: AHU-7

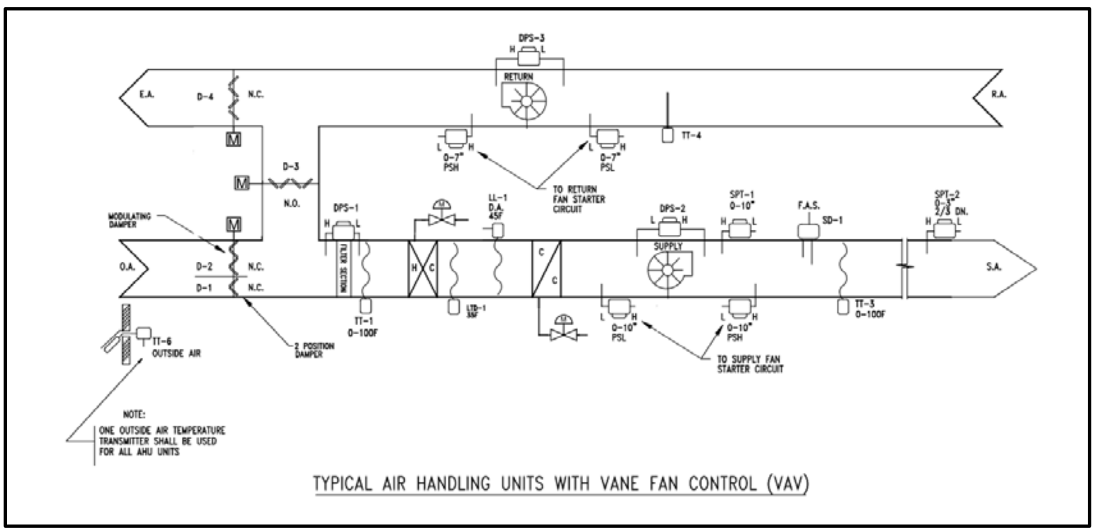

Figure 1. Typical Existing AHU Serving Multiple Zones - Control Schematic Diagram

2.2.2 Single Zone AHUs

The AHUs which serve the large open spaces throughout the building (gym, cafeteria, hallways, and auditorium) are single zone AHUs. The school is served by six (6) of these units, AHU-1, AHU-2, AHU-3, AHU-4, AHU-5, and AHU-9 (AHU-1 is shown in Photo 2 below). These units were installed in 2002 and are noted to be fair condition based on a mechanical assessment performed in December 2020. These units bring in a certain percentage of outside air, heat or cool the supply air depending on the determined setpoint and distribute this air to the space. The outside airflow is controlled by external outside air dampers to the unit, which are connected to the system via DDC controls. Figure 2 below shows the controls schematic diagram for this unit.

Photo 2: AHU-1

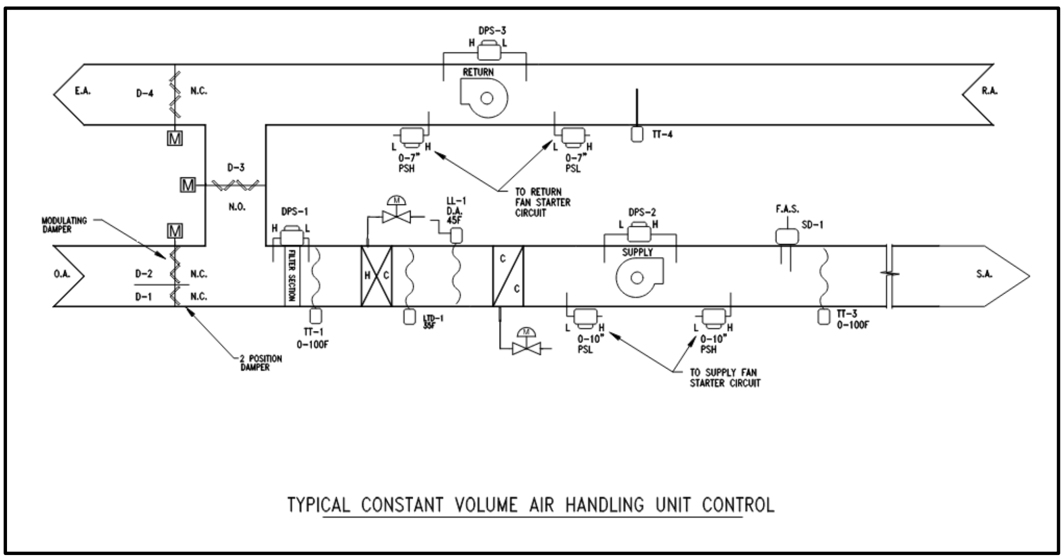

Figure 2. Typical Existing Single Zone AHU Control Schematic Diagram

2.3 Existing Building HVAC Controls System

The AHUs are monitored and controlled by a central controls system, for points including return air temperature, discharge air temperature, mixed air temperature, and static pressure. Alarms for supply fan status, freeze-stat status, dirty filter, and return fan status are also included in the controls. Table 1 below includes each AHU with respective number of temperature control zones.

Table 1. AHU Breakdown			
Unit	**Total CM**	**Service**	**Number of Zones**
AHU-1	7,545	Assembly Area	1
AHU-2	10,800	Gym	1
AHU-3	8,600	Cafeteria	1
AHU-4	4,400	Library	1
AHU-5	8,500	Corridor	1
AHU-6	24,500	Floor 1, 2 and 3 Classrooms	16
AHU-7	13,000	Floor 1, 2 and 3 Classrooms	15
AHU-8	17,000	Floor 1, 2 and 3 Classrooms	15
AHU-9	4,425	Kitchen	1

2.4 Existing AHU Outdoor Air Controls

The AHUs at the school have limited operating controls and it was noted by the school custodial staff that all systems at the school are currently manually operated. It was also found that there is an existing CO_2 sensor tied to a modulating outside air damper of AHU-1 (both the sensor and damper can be seen in Photos 3 and 4 below). For the purposes of this study, it was assumed that all applicable AHUs per SCA standards, including AHU-1, would require DCV controls.

Photo 3: AHU-1 CO_2 Monitor

Photo 4: AHU-1 Modulating OA Dampers

3 Potential Options / Recommendations

3.1 AHU DCV Scope

Following a review of the drawings and a site survey performed by OLA and the controls contractor of the installed controls at the school, the scope and costing required to include DCV as a retrofit on the AHU systems were determined.

The requirements for adding DCV to an existing single-zone AHU are similar to installing DCV on an existing AHU serving multiple zones, with the exception of zone DCV controls. AHU level DCV controls upgrades include furnishing, mounting, and wiring a modulating control damper and actuator for each unit and installing a new IOM (input output module) for the additional control capacity required for the additional points required for DCV. Single Zone AHUs will typically only require one (1) space CO_2 sensor for the space that these serve. AHUs serving multiple zones will require a space CO_2 sensor for each VAV box zone that these serve. The AHUs serving multiple zones will also require the installation of a VFD on the supply and return fans to allow for zone/VAV level DCV control. The supply fan modulation sequence would need to be integrated within the existing DDC network.

Due to the outside air damper arrangement in the existing airside systems, an outside air flow measuring station (OAFMS) is recommended within the outdoor air duct section for DCV to operate optimally. Since the speed of the AHU supply fans modulate based on the demand from the connected loads, the upstream resistance changes will have an effect on the amount of outside air being pulled in. Outside air damper positions must modulate to account for this change in supply fan speed and resistance changes such as dirty filters can affect outside airflow control. With an outdoor air flow measuring station for control (versus damper position control), the outside air dampers can maintain a certain airflow value and adjust to account for the varying supply fan speed and dirty filters. A thermal dispersion type OAFMS is being recommended due to its reliability and accuracy and has been included as part of the controls contractor proposal.

A static pressure sensor is required for multiple zone AHUs to allow the AHU supply fans to modulate for zone/VAV level DCV control – however, these were already found to be installed at the AHUs so only programming would be needed to ensure AHU VAV operation to maintain static pressure setpoint, as determined by a balancer. The static pressure setpoint could also be programmed to be reset based on the damper position of the connected VAV boxes, which would allow the AHU fans to modulate down further and provide further fan energy savings.

SCA standards do not require CO_2 sensors in kitchens or corridors. Based on the AHU zoning at the school, AHU-5, which serves the corridors, and AHU-9, which serves the kitchen, were excluded from DCV implementation. With new SCA schools, the corridors and kitchens may be part of other AHUs (Classroom AHU and Cafeteria/Kitchen AHU, respectively), and these zones typically would not have a CO_2 sensor due to the function/requirements of these spaces and per SCA standards.

Controls scope to implement DCV controls would also include controls engineering, CAD wiring diagrams, submittal and programming, checkout and start-up, commissioning support, and operations and maintenance manuals. A two (2) year warranty has also been provided as required by SCA. These items have been included in the scope for this case study project.

4 Energy and Cost Assessment

4.1 Energy and Cost Savings

DCV has numerous benefits, the greatest being energy savings. Without DCV, the outside air provided to the spaces will be a constant airflow at the design value, even when the building occupancy is below design or even unoccupied. Providing DCV control allows the AHUs, and associated outside air dampers, to modulate appropriately, saving fan energy, heating, and cooling energy.

Due to the existing AHUs being constant volume and not having variable frequency drives, the fan energy savings would be lower if VFDs were not included in the scope to implement DCV. Fan speed reduction and outside airflow reduction were calculated based on SCA occupancy schedules taken from the current standards, assuming that both VAV box airflows and outside airflows would be reduced during lower occupancy periods. The hours that the AHUs are running in occupied mode were provided by the building operators and would occur through the occupied/unoccupied scheduler at the DDC controller. The associated outside air temperatures at each occupied hour were obtained using hourly BIN data. Consideration was made for high heating and cooling load times when temperature control may override zone level DCV control. Using the existing efficiencies of the air-cooled chiller and steam boiler plants, cooling electricity savings and heating fuel (oil) savings were calculated for each AHU with DCV controls.

Shown in Table 2 below is the overall energy, cost and emissions savings to implementing DCV for the existing AHU systems at the school. These results show that it is feasible to retrofit a school to have DCV with significant carbon savings.

Table 2. DCV Implementation Cost and Savings

Annual Electricity Savings (kWh)	Annual Oil Savings (gal)	Energy Savings (kBtu/sf)	GHG Emissions Savings (metric tons of CO_2e)	Annual Avoided Cost
63,141	6,844	9.8	87	\$20,000 - \$25,000

An additional controls energy measure for the AHUs serving multiple zones would be to include static pressure reset controls for fan speed modulation along with the DCV controls programming. With the duct static pressure sensors already included in the AHU systems, this additional programming controls would not increase the capital cost of the DCV retrofit project and would provide control to reset the static pressure setpoint of the AHU system based on damper position of the connected VAV boxes, allowing the AHU fans to modulate down further and provide additional fan energy savings to that of the DCV energy measure. This can be reviewed further with SCA if there is a desire to investigate the potential energy and carbon savings of this static pressure reset energy measure further.