



This paper has been developed to outline a suburban office complex fresh air supply system retrofit that was implemented based on the recommendation of a facility performance audit performed by BLDG Services Group Inc (BSG) in 2010. The fresh air system operation and configuration before and after the retrofit along with the design and actual performance of the system is discussed herein.

## Introduction

Many HVAC systems employ constant volume air handling units to meet the fresh air requirements of a building or facility. These systems use on/off controls and are typically operated on an occupancy schedule that is dictated by a time clock or a building management system scheduler.

In some cases where localized heating and cooling is provided through devices like heat pumps the air handling systems may use a 100% fresh air supply with no return air supply. The fresh air design requirement is based on maximum occupant load requirements. This type of implementation does not take into consideration that most commercial buildings operate below full load the majority of the time. Since the volume of fresh air is constant the energy consumed by the motors and fan sets supplying the fresh air is also constant regardless of the load on the heating and air conditioning system or the actual fresh air requirement. Additionally, the requirement to condition the volume of outside air in terms of temperature and humidity represent a significant amount of energy consumption and therefore cost, in particular when the systems in non temperate climates were extremes in temperature and humidity occur. As such, the energy to provide the volume of air and the energy used to condition that volume of air must be taken into account when considering the cost associated with the operation of such systems. The opportunity to take advantage of saving in the energy consumption as described occurs when the system can be retrofit to provide air volumes based on actual demand rather than maximum design criteria.

## The Facility



The facility is the Steppes Business Campus. The Steppes is located in Edmonton Alberta, Canada and incorporates approximately 75,000 square feet of office space in 2 buildings. The Steppes construction was completed in 2008 was based upon a sustainable building design. The Steppes is also operated with a focus on environmental friendly and sustainable principles that have resulted in its receiving the BOMABest - Level 4 green building operational award in 2011 and the BOMA Earth Award in 2012.

Additionally, the Steppes, has been found to have the lowest potable water consumptions of any surveyed office building in Canada based on the Realpac 2010 study of office building water consumption.

- White Paper -

Variable Volume Fresh Air Retrofit in an Office Building

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The office campus buildings share a common base heating and cooling system, but have independent fresh air supply systems.

The buildings above grade areas are heated and cooled with water-to-air zone based heat pumps that use a hybrid geothermal and low temperature boiler source water supply. The fresh air supply is provided via make up air handling units that produce the entire make up air volume with fresh air. These units are typically running for 12 hours a day on all working days.

The exhaust air system is comprised of several fans including; roof top exhaust fans on each building that are dedicated to ventilation of washrooms and utility rooms, transfer fans that remove the remainder of the exhaust air from the above grade areas to the sub grade parking area where the combined remaining exhaust air from the 2 buildings is evacuated by an exhaust fan that also acts in conjunction with a third make up air unit that is dedicated to controlling carbon monoxide levels in the parking area.

A facility performance audit is performed by the building management and operations company each year with the first study being performed in 2009. In the 2010 performance audit one of the resulting recommendations was to implement a variable volume fresh air supply system based on the actual fresh air volume requirements rather than the maximum design fresh air volume requirement. It was estimated that a reduction of 30% in fresh air supply volume could potentially be achieved by basing those volumes on actual carbon dioxide measurements of occupied areas and control of the air volume rates through the use of variable speed drives on the air handling devices. The economic justification for this recommendation included an estimated \$13,000.00 saving in energy cost and budgetary pricing of \$25,000.00 in implementation costs. This represented a simple return on investment of just less than 2 years, which was within the facilities retrofit for efficiency project program requirement of 2.5 years or less. Based upon the recommendation and the subsequent return on investment the project was approved for implementation in 2011 and a design was developed at in the first half of 2011.

## The Design

During design development it was concluded that the fresh air volumes related to the ventilation of washrooms and utility rooms could not be substantially reduced while maintaining adequate ventilation to maintain negative pressure and therefore contain odors. The small reduction in air flow that could be achieved did not justify the cost of retrofitting the motor controls of these ventilation fans with VSDs. As such, the retrofit of air handling devices to use VSD was limited to the 2 transfer fans, the 2 building dedicated make up air units and the sub grade primary exhaust fan. With this scope the design was developed to base control of fresh air supply on the actual carbon dioxide CO<sub>2</sub> levels in the building during occupied hours.

The control scheme was developed to consider the CO<sub>2</sub> levels on individual floors as well as the ambient outdoor air CO<sub>2</sub> levels. The highest CO<sub>2</sub> level in a building would dictate the air flow rates of the associated air handling devices for that building. Additionally, the outdoor ambient air carbon dioxide levels would be incorporated into the control scheme to prohibit increased fresh air supply to the buildings in the event that outdoor carbon dioxide levels were found to be at or higher than those found indoors.



The building specific make up air units would be configured to have a low speed limit to accommodate the exhaust air flow of the roof top exhaust fans and a slight positive pressuring of the above grade building areas. The high speed limit of these make up air units, and therefore fresh air flow high volume limit, was set to the original building design requirement or 100% of the design fan speed. The carbon dioxide high limit was decided to be 850 parts per million which is considered to be the maximum concentration level of a healthy building according to ASHRAE 62-1989 – Ventilation for Acceptable Indoor Air Quality. The low limit was set at 700 parts per million. Air volumes were calculated for each air handling unit and a linear speed ramp of the make up air units was to occur between the minimum and the maximum speed set points. In consideration of the fan types employed the reduction in speeds equates almost directly to a proportional reduction in air volumes. This meant that the air volume could be reduced by up to 45% of the initial designs fixed fresh air volumes. The combined air volume supplied to the sub grade level and to be evacuated by the primary exhaust fan was to be calculated in real time and the result used to modulate that exhaust fan speed between the minimum and the maximum speed to provide for adequate exhaust and a slight under pressurization of the sub grade parking area. In the event that a carbon monoxide level alarm was detected in the sub grade parking area by the building management system the fresh air system would revert to the maximum airflow volume design levels to ensure adequate and immediate evacuation of the sub grade parking area air and a positive pressure in the occupied areas.

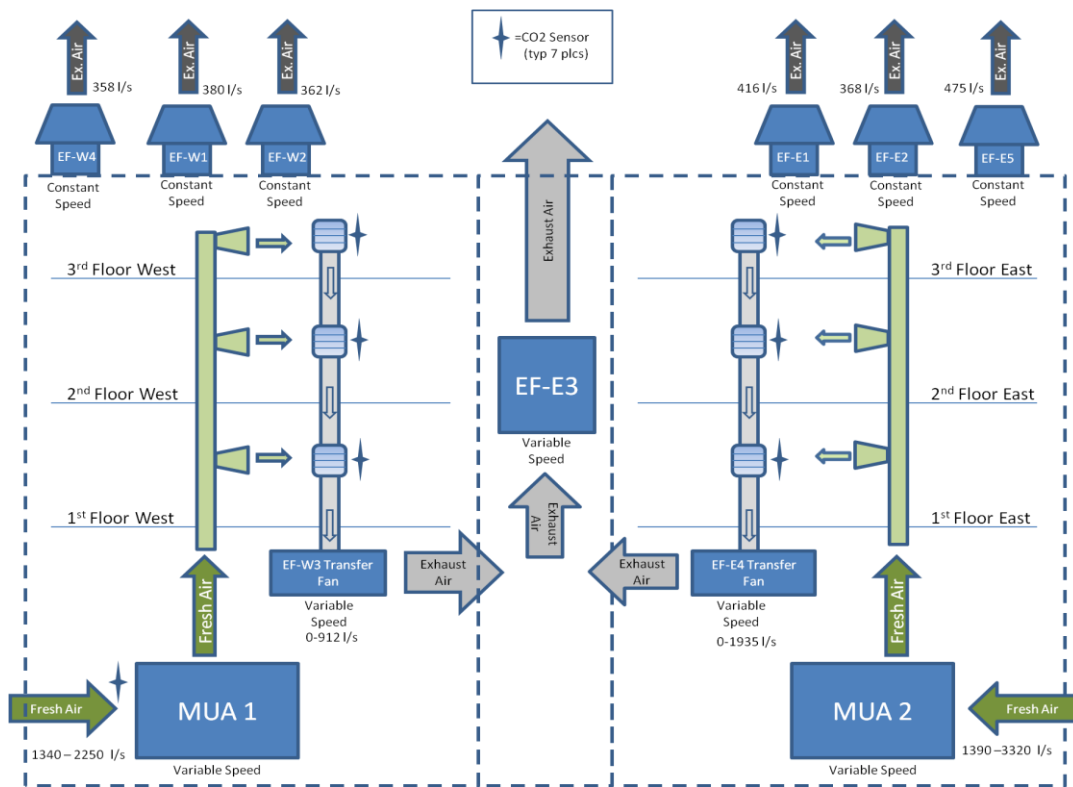


Figure 1 - System Design Schematic



## Implementation

Prior to the installation of the VSD and their integration into the existing controllers the CO2 sensors were installed and monitored by the building management system for approximately 2 months before the system implementation began. This provided settling time for the sensors and the collection of some empirical data to model the carbon dioxide concentration levels in consideration of building schedules and occupancy loads. During this period it was found through experimentation and review of the daily operating concentrations that the operating hours of the ventilation systems could be reduced by about 1.2 hours each day while still maintain carbon dioxide levels well below the lower design limits and adequate air quality.

The implementation of the VSD system required the replacement of the transfer fan motors as they would be run down to 10% of their rated full speed and as such required additional cooling as found with inverter duty type motors. The existing motors on the make up air units and primary exhaust fans were found to be inverter duty and therefore did not require replacement.

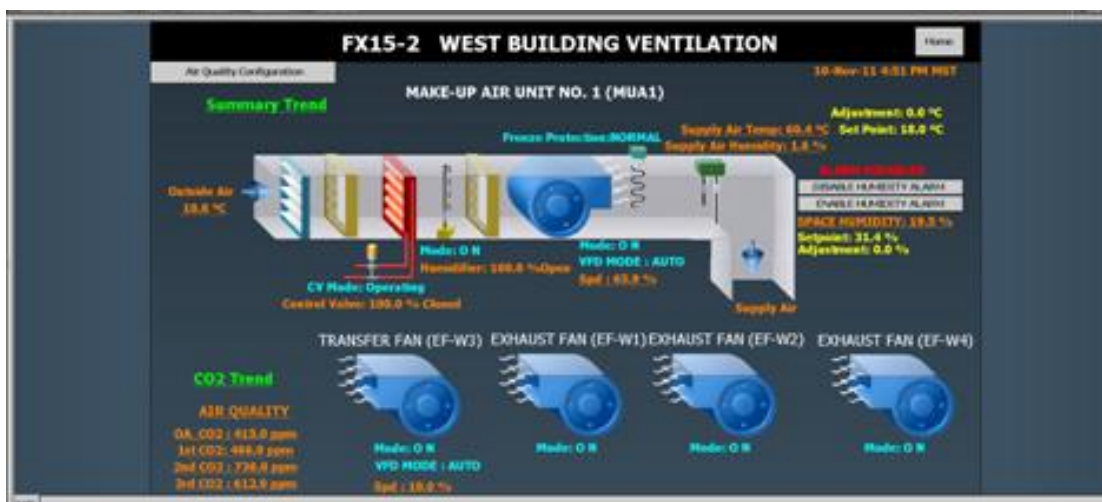


Figure 2 - BMS Graphic of Typical MUA

To simplify the commissioning process, and to allow for tuning of the system over time, a comprehensive configuration interface was developed. This configuration interface allows all parameters of the system to be controlled. This interface aided greatly in reducing commissioning time and provided excellent flexibility for the air balancing.

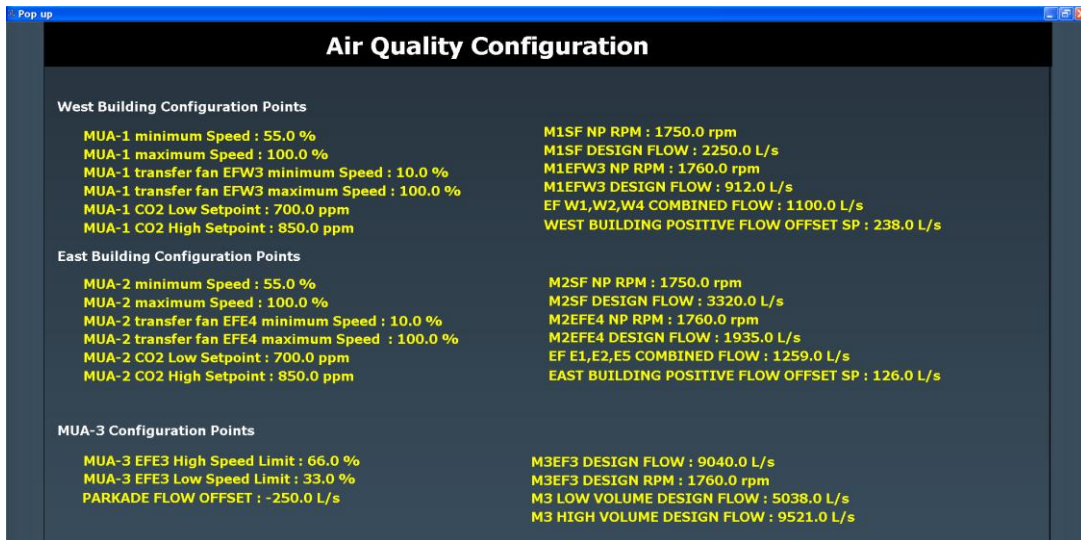


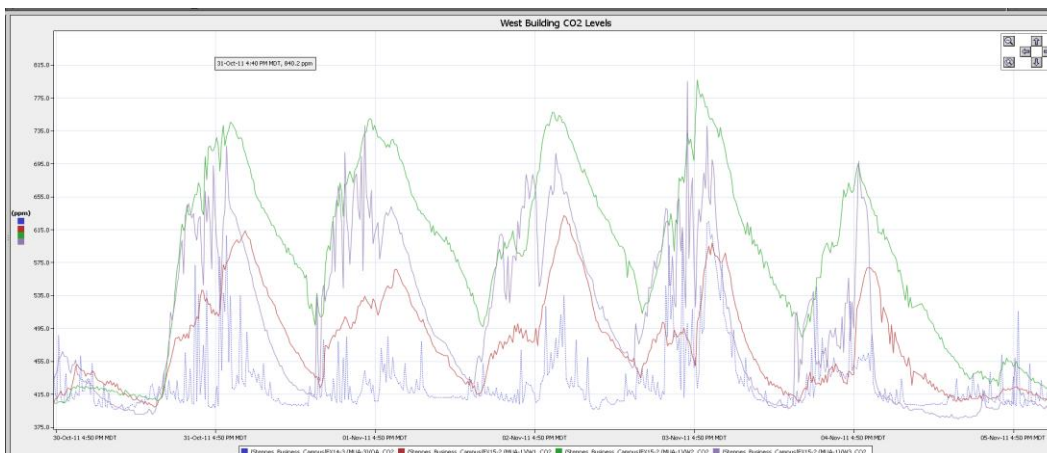
Figure 3 - System Configuration Interface

After installation and configuration of the system an air balance was conducted and the modified units VSD were tuned to provide air volumes to match the design volumes over the range of the VSD speeds. The system was then commissioned including calibration confirmation of the CO2 sensors with calibration gas. The implementation and commissioning was accomplished in approximately 55 man hours.

As a part of the commissioning process a post installation Indoor Air Quality (IAQ) audit was performed and during that audit process a number of deficiencies in tenant suites were found that related to design versus the as built condition of the ventilation system in those suites. These included fresh air dampers closed in tenant spaces, fresh air ducts supply ceiling plenum areas that were isolated from the tenant suite ceiling plenum areas, which are the primary means of distributing fresh air into these spaces, and a number of transfer ducts that were not installed. With a minimal effort on the building operations part many of these issues were addressed through damper settings and air quality specific to fresh air supply was provided to these tenant suites for the first time since their construction was completed.

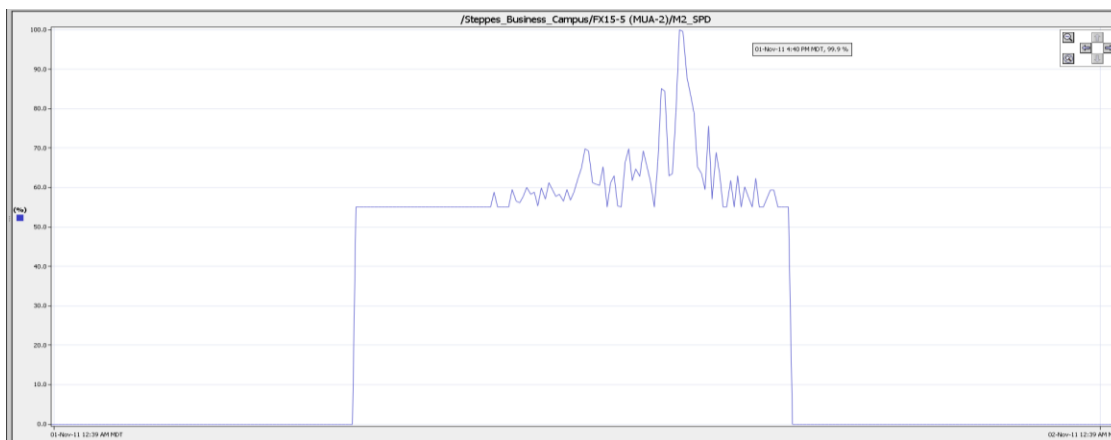
## Results

The commissioned system has effectively controlled the CO2 levels in the facility within the limits of design and with minor adjustments to the airflow system dampers.



**Figure 4 - CO2 Levels Over a Typical One Week Period**

The system was placed into service in August of 2011 and for the first 6 months of operation it consistently ran, on average, at less than 60% of the original design fresh air volumes.



**Figure 5 - Typical Daily Speed / Air Volume Variations**

Based upon this performance to date it is anticipated that the system will outperform the design expectations of a 30% reduction in fresh air volumes supplied. At the time of writing this paper an over 40% reduction in fresh air supply volumes had been achieved and the associated reduction in energy consumption was found to result in a cost savings of approximately \$17,000.00 yearly with a simple return on investment of 1.3 years based on the actual project cost of \$22,700.00.