

Continuous Commissioning[®] of Commercial Kitchen and Dining Facilities – Case Study

Hui Li, Chen Xu, Qiang Chen and Song Deng
Energy Systems Laboratory
Texas A&M University System

ABSTRACT

Commercial kitchens usually require a large amount of ventilation air and high ventilation rates. Today's typical kitchens and dining facilities are often equipped with Make-up Air Fans (MAF) or dedicated Make-up Air Units (MUA) to make up about 50% to 80% of the total exhaust air through range hoods. Comparing with 8:00 am to 5:00 pm operation of general office building, dining facilities have distinct schedules in which internal loads are much more condensed during specific occupied periods, i.e. breakfast, lunch, and dinner hours. This paper demonstrates the Continuous Commissioning[®] (CC[®])¹ process for commercial kitchens and dining facilities through two case studies on a university campus. It will discuss the problems encountered in the case study facilities and CC measures identified, as well as savings analysis and more generic lessons and CC practices on commercial kitchen and dining facilities.

KEYWORD

Continuous Commissioning, Commercial Kitchens, Dining Facilities, Makeup Air Unit, Outside Air Unit, Humidity Control

1 Introduction

Continuous commissioning is defined as an ongoing process to resolve operational problems, improve comfort, optimize energy use and identifying retrofits in existing commercial and institutional buildings and central plant facilities. It differs significantly from retro and new building commissioning since it focuses on optimizing the building for existing conditions and operations, not to original design conditions, and should be done on a continuing basis.

For the different building types and system characteristics, the CC process should be implemented through some special measures. For the

HVAC system of kitchen and dining facilities, there are three distinct characteristics:

- 1) Kitchens in general require large amounts of ventilation air. The centerpiece of almost any kitchen ventilation system is exhaust hoods, used primarily to remove effluent from kitchens. The volume of air exhausted must be replaced with uncontaminated air. The kitchen ventilation issue can result in HVAC systems with higher energy consumption comparing to other facilities of comparable sizes.
- 2) Dining facilities have distinct schedules in which internal loads are much more condensed during specific occupied periods, i.e. breakfast, lunch, and dinner hours.
- 3) Dining areas often have a high and large space, which is often served by more than one AHU. Additionally, Kitchen and Dining areas have higher latent loads during occupied time.

This paper demonstrates how the Continuous commissioning process has been applied to kitchen and dining facilities through two specific case studies. Problems discovered in the above three categories are described. The CC measures and the benefit analysis of the recommended measures are also presented.

2 Case Study 1

2.1 Project Overview

Building description: The case study building, located in a southern university campus, is a one-story building with a basement and a mezzanine level constructed in 1912's. The total floor area, excluding the non-conditioned area, is about 94,323 square feet, of which most is a large dining area and commercial style kitchen.

HVAC system description: The HVAC system has fifteen Direct Digital Controls (DDC) controlled single duct units and three DDC controlled outside air units. These OAHUs provide outside air for all single zone units. Additionally, only two single duct units serving two small office areas have terminal boxes. The total design maximum supply flow in the building is 105,180 cfm, of which the maximum

¹ Continuous Commissioning and CC are registered trademarks of the Texas Engineering Experiment Station (TEES), the Texas A&M University System, College Station, Texas. To improve readability, the symbol "®" will sometimes be omitted.

outside air is 32,500 cfm. All AHUs and OAHUs run 24 hours a day seven days a week.

The kitchen area has large volume, powered range hood exhausts with four make-up units providing total conditioned air of 15,120 cfm with the total 7 hp motors. The hood style is a double-island canopy, as shown in Figure 1. About 13,600 cfm, accounting for 90% of air flow of these make-up air units, AHU8-11, provides make-up air through short circuit hoods, and the rest of the air flow provides conditioned air through perforated perimeter diffusers. The type of MUA supply is shown in Figure 2. The ventilation system is manually on/off controlled.

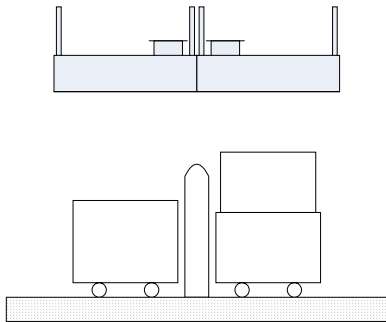


Figure 1. Hood style of double-island canopy

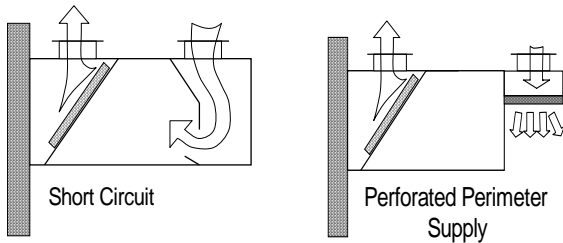


Figure 2. Types of MUA supply integrated with the hood

Occupied schedule: In generally, when classes are in session, the kitchen and dining area are occupied from 6:00 AM to about 8:30 PM Monday through Thursday and 6:00 AM to 2:30 PM on Fridays. Any of the areas may be open at other times for special events such as banquets at off site facilities.

2.2 CC & Retrofit measures

Based on the three characteristics of kitchen and dining facilities, major CC measures were recommended including: 1) optimize make-up air units control; 2) optimize AHU operation during un-occupied time and lightly occupied time; 3) optimize AHU control.

2.2.1 Optimize make-up air units control

Existing operation: The make-up air units (AHU8-11), interlocked with the corresponding exhaust fans, are controlled to maintain the space temperature set point of 74°F. The temperature sensors are installed in the kitchen wall near the corresponding MUA. Additionally, AHU6 serves the kitchen space to maintain the space temperature setpoint of 70°F based on another space temperature sensor. The control sequence results in fighting between the MUAs and AHU6 and simultaneous heating and cooling. It was noticed that the MUAs were in heating mode and the discharge air temperature was ranging from 95°F to 115°F, as shown in Figure 3; whereas the AHU6 was in cooling mode and CHW valve was fully open to maintain the space temperature setpoint, as shown in Figure 4. The situation of heating and cooling simultaneously results in unnecessary energy usage and thermal comfort problems in the kitchen area.

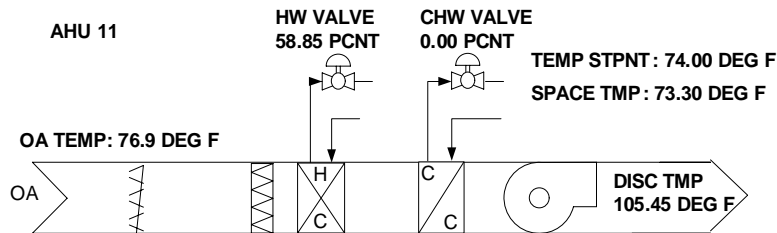


Figure 3. MUA (AHU11) operation sketch

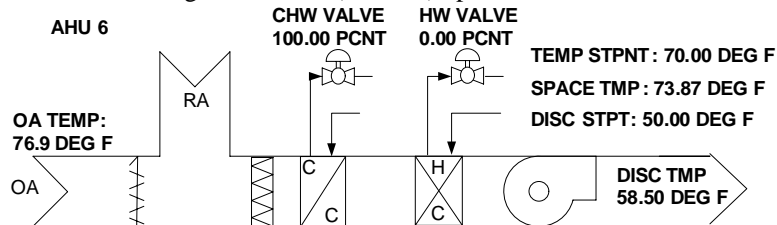


Figure 4. AHU6 operation sketch

CC measure: The International Mechanical Code (IMC) requires make-up air be conditioned to within 10°F of the kitchen space, except when introducing replacement air does not decrease kitchen comfort [1]. Instead of maintaining space temperature setpoint, it is recommended that MUAs (AHU8-11) CHW control valves should be controlled to maintain the discharge air temperature set point of 85°F, whereas and that the HHW control valves be modulated to maintain a discharge air temperature set point of 60°F.

2.2.2 AHU operation during un-occupied and lightly occupied time.

1) Implement AHU shut down and rotation schedules during un-occupied hours.

Existing operation: At the onset of commissioning, all AHUs run 24 hours a day seven days a week. Whereas the building is totally empty during about 13 weeks of break seasons and always un-occupied overnight.

CC measure: It is recommended to shut down all AHUs during all un-occupied time, including weekend and overnight, spring break, summer break and winter break etc. Moreover, an additional rotational schedule for AHUs is recommended to provide necessary air movement during long hours of shut down. If the duty AHU has not been running for 4 hours continuously, it can be turned on for 20 minutes.

Additionally, during unoccupied times, it was recommended that all outside air units (OAHUs 1, 2, and B1) be shut down. It was also suggested that for freeze control purposes, when the outside air dry bulb temperature is below 40°F, chilled water valve should be opened completely and the preheat valve should be modulated to assure the temperature of the air between the pre-heat coil and the cooling coil is not below 40°F.

2) Reduce discharge fans speed of dining area AHUs during lightly occupied time.

Existing operation: There are four single duct AHUs, constant speed discharge fans and total 52.5 hp, serving the dining area. Whereas the dining facilities have distinct schedules that during the meal hours internal loads are much more condensed. This makes it a large potential to save energy by reducing discharge fan speed.

Retrofit measure: It is recommended to reduce the discharge fans speed based on demand to save energy. There are two options which can be considered.

Option 1: Convert discharge fans motors to two-speed motors.

The high/low speed can be chosen based on the demand. Considering the occupancy level in the dining area has a strong correlation with time, a simple fan speed table schedule can be implemented. Addition to the savings due to the implementation of shut down schedules, the rough estimated annual savings for this measure are \$3,200 at the estimated cost of \$15,000.

Option 2: Install VFDs on dining area AHU.

It is a good option that VFDs be installed to control AHU discharge fans speed varying from 30% to 100%. An optimal VFD control strategy based on demand can be implemented. Addition to the savings due to the implementation of shut down schedules, the rough estimated annual savings for this measure are \$5,000 at the estimated cost of \$20,000.

2.2.3 Optimize AHU control.

1) Establish a temperature dead band between heating and cooling

Existing operation: AHU CHW/HHW control valves are controlled to maintain a fixed space temperature, such as 75°F. When the space temperature is higher than the space temperature set point, the AHU will attempt to cool air otherwise heat air. This control will result in the unnecessary energy usage. Additionally, the fluctuation of the space temperature also may cause alternative cooling/heating, as Figure 5 shows.

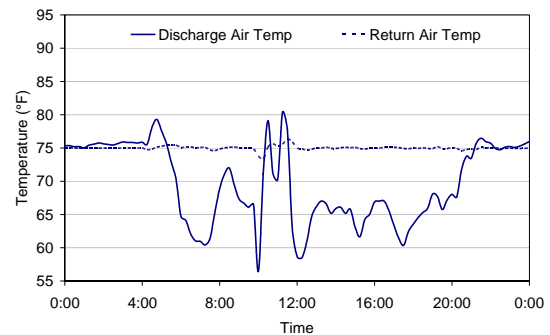


Figure 5. Single temperature setpoint control

CC measure: It is recommended that a temperature set point dead band be implemented to these units so that both CHW and HHW valves could stay closed until the space temperature exceeds the dead band. During occupied time, the temperature dead band for these units could be set at 75°F for cooling and 70°F for heating. However, during un-occupied time, when the space thermostat reading is above 85°F, the AHU will be started to cool until the corresponding space temperature falls to 80°F; whereas when the space

thermostat reading is below 60°F, the AHU will be started to heat until the space temperature rises to 65°F.

2) Optimize the OAHU discharge air temperature

Existing operation: OAHU1/2/B1 supplies outside air to other AHUs in the building. Currently, when in operation, the control strategy attempts to maintain the air temperature before the cooling coil above 45°F and the fixed discharge air temperature at 55°F. This is not an energy-efficient control consequence because the fixed discharge air temperature of 55°F may result in cooling in the OAHU as well as simultaneous reheat in the AHU even when there are no humidity issues.

CC measure: It is recommended that the OAHU should control to remove humidity from the incoming outside air if necessary, and to temper it only as needed for the units served. Since outside air dew point sensor was available in the field, consequently, when the outside air dew point temperature exceeds 55 °F, the discharge air temperature set point for the OAHU should not be allowed to exceed 57 °F. When the outside air dew point temperature is 55 °F or below, it is recommended that the CHW control valve of these units stay closed until the outside air temperature is higher than 75°F. Also, the pre-heat valve should be modulated to maintain a discharge air temperature setpoint of 40°F. The purpose of this measure is to shift as much of the cooling/heating load to the AHUs served as possible without overloading the systems to try to avoid overcooling or overheating at the outside air unit.

3) Optimize humidity control

Existing operation: These AHUs each have an on/off humidity control based on corresponding space humidity sensor readings. When the space relative humidity reading is above 55%, AHU DEHUM MODE will be activated and CHW valve should be maintained at 100% open to remove moisture until the space relative humidity reading is below 45%.

CC measure: It is recommended that an optimal PID humidity control strategy should be implemented to maintain the space relative humidity below 60% and reduce cooling/heating simultaneously. The corresponding control device, the CHW control valve or discharge fan speed, should be modulated based on the maximum valve position value of space temperature demand and dehumidification demand.

4) Relocate space temperature sensors optimally

Existing operation: It was noted the space temperature sensors are installed in unfavorable locations where they get little airflow and could not

represent the actual space temperature. This results in a significant difference, about 5°F~6°F, between the field measure space temperature and the temperature sensor reading. Consequently, the space is always overcooled or overheated due to the faulty thermostat reading.

CC measure: It is recommended to place the temperature sensor in the space where it can get a more representative temperature for controlling the AHU CHW/HHW valves.

2.3 CC & Retrofit Results

2.3.1 Savings analysis

Since no CC measures have been implemented at the time of submittal of this paper, a savings analysis involving measured pre-CC and post-CC data was not performed. However, based on simulation and engineering analysis, it is estimated that implementation of the recommended CC measures would result in savings somewhere in the range of 35% for cooling, 50% for heating, and 15% for electricity. The total annual savings of \$100,000 can be expected based on a rate of \$7.554/MMBtu for chilled water, \$9.936/MMBtu for hot water, and \$0.078/kWh for electricity.

2.3.2 Comfort improvements

Several comfort complaints in the building were brought up at the time of commissioning. The main issue was hot complaint from makeup units discharging hot air in the kitchen area. It was found to be related to the incorrect control strategy for the makeup air units (AHU 8 through 11) described previously. CC measure 2.2.1 addresses this issue, and should help eliminate these hot complaints. Additionally, cold complaints were received from some dining areas in the building. The recommendation of relocating space temperature sensors should help eliminate the discomfort in these areas.

3 Case Study 2

3.1 Project Overview

Building description: The building evaluated for this case study, also located in a southern university campus, is a one-story building with a full basement and a small mezzanine floor. It was originally constructed in the 1920's and last expanded in 1986. The total floor area, excluding the non-conditioned area, is about 67,500 square feet, of which most is two large dining areas, a commercial style kitchen and a separate bakery area.

HVAC system description: The HVAC system in the building consists of eight constant volume single zone systems and a commercial kitchen ventilation system. Five of the single zone systems have DDC controls and the other three have pneumatic controls. Four of the DDC controlled units serve the dining area. Each unit has a design of 4,500 cfm of outside air and a total of 18,000 cfm. Another DDC controlled unit serves the Bakery area with a design of 6,125 cfm of outside air and a total of 24,500 cfm. The other three pneumatic controlled units serve the kitchen area, dishwashing area and some small offices respectively. All AHUs run 24 hours a day seven days a week.

The kitchen ventilation system has 10 exhaust hoods with a total of 71,177 cfm. These are served by eight dedicated make-up air units with a total of 54,282 cfm un-conditioned air. The hood styles include double-island canopy and wall-mounted canopy, as shown in Figure 1 and Figure 6. The types of MUA supply include perforated-perimeter supply and face-discharge, as shown in Figure 2 and Figure 7. The ventilation system is manually on/off controlled.

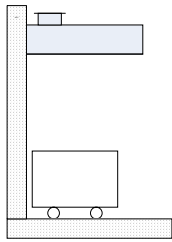


Figure 6. Hood style of wall-mounted canopy

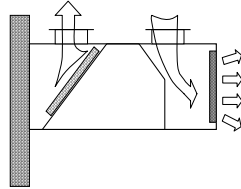


Figure 7. MUA supply type of face-discharge

Occupied schedule: The building occupied schedule is similar to case study 1.

3.2 CC & retrofit measures

3.2.1 Optimize make-up air units operation

Existing operation: According to the building design, if all kitchen hood exhaust fans and makeup air fans are running, 80% of the exhausted air, about 57,000 cfm, should come from make-up fans. The rest of the exhaust air is made up by the transfer air from Dining area and kitchen area AHUs.

However, because the make up air is not conditioned, kitchen staffs often leave the make-up air units off during hot or cold days. Under this circumstance, above 80% of the exhaust air, about 57,000 cfm, is estimated to be replaced by the conditioned air through the Dining area and kitchen area AHU, i.e. wasting energy. In the mean time, the building is very negatively pressurized resulting in significant infiltration.

CC & retrofit measure: According to the design, if the building proctor “mandates” kitchen staff to turn on the exhaust fan whenever the corresponding exhaust hood is turned on, it would be energy-efficient, but at the cost of the thermal comfort of the staff. If the makeup units were converted to air-conditioned system, as case study 1, thermal comfort problem would be resolved, but at the cost of long payback year. Based on the two extreme situations, there are two options which can be considered to save energy and relief thermal comfort problem with little retrofit.

Option 1: Convert make-up air fans to remote start/stop digital control

According to the International Mechanical Code 508.1.1, make-up air is required to be conditioned to within 10°F of the kitchen space, except when introducing replacement air does not decrease kitchen comfort. Therefore, a relief opportunity to consider consists of turning off make-up air unit only when outside air dry bulb temperature is above 85°F or below 60°F.

Consequently, it is recommended to convert make-up air fans to remote start/stop digital control. When outside air dry bulb temperature is between 60°F to 85°F, the individual make-up air units should be turned on when their respective exhaust hoods operate. Otherwise, it should be turned off. To assure the individual make-up air units operate when their respective exhaust hoods operate, it is also recommended that key controlled H-O-A switches be installed on the make-up air starter panels and left in the automatic position. The rough estimated annual savings for this measure are \$1,400.

Option 2: Reduce the kitchen make-up air to 50% of the respective exhaust cfm

Current Commercial Kitchen Ventilation (CKV) practice recommends the kitchen make-up air should be limited to below 60% of the exhaust hood cfm^[2] to improve the kitchen thermal comfort. Therefore an opportunity can be considered to reduce the make-up air cfm to below 60% of the respective exhaust fan cfm, e.g. 50%, and keep the MUA interlocked with respective exhaust fan. An annual savings of \$5,000 could be realized based on this measure.

3.2.2 AHU operation during un-occupied and lightly occupied time.

At the onset of commissioning, all AHUs run 24 hours a day seven days a week. However, the dining area is lightly occupied except during meal times. It is recommended to shutdown AHUs during un-occupied time and reduce discharge fans speed by

installing VFDs or two-speed motors during lightly occupied time as case study 1.

1) Reduce outside air flow during lightly occupied time

Existing operation: At the onset of commissioning, the four RTUs 1A/1B/1C/1D outside air dampers had been set manually at the fixed minimum outside air intake position. However, it was found that the outside air intake almost accounts for 35%~50% of the total airflow, which is about twice the design and excessive than the demand.

Retrofit measure: Therefore it is recommended to expand the dampers adjusting range firstly to assure the damper capacity will close completely. Then convert these outside air dampers to DDC control. Considering the occupancy level in the dining area has a strong correlation with time of the day, a simple damper position reset schedule based on time of the day can be implemented as Table 2 shows.

Table 2 Outside air intake reset schedule

Time (hour)	OA %
6:00-8:00, 11:00-13:00, 17:00-20:00	25%
8:00-9:00, 10:00-11:00, 13:00-14:00, 16:00-17:00	10%
9:00-10:00, 14:00-16:00, 20:00-0:00, 0:00-5:00	0%
Un-occupied time (break season, weekend etc)	0%

3.2.3 Optimize AHU control.

1) Establish a temperature dead band between heating and cooling and install space temperature sensors.

Existing operation: The four Dining area units, AHU1-4, operate to maintain the return air

temperature set point of 75°F. The return air temperature sensors used to control CHW/HHW valves are located at the entrances of the return air ducts up to the ceiling. Whereas the return air intake of each two AHUs serving the same large dining area are in very close proximity, as shown in Figure 8. So the two AHUs control operation almost is based on the same return air whereas different return air temperature sensor reading. And the temperature sensors reading have a hard time accordant completely even for the same air. The existing operation may result in one AHU cooling whereas the other AHU heating simultaneously as shown in Figure 9, which also cause thermal comfort problems in the dining area.

Also noted were significant differences, about 2°F~7°F, between the fields measured space temperature and the temperature sensor readings. The consequence is unfavorable temperature control because the control point could not accurately represent the actual space temperature.

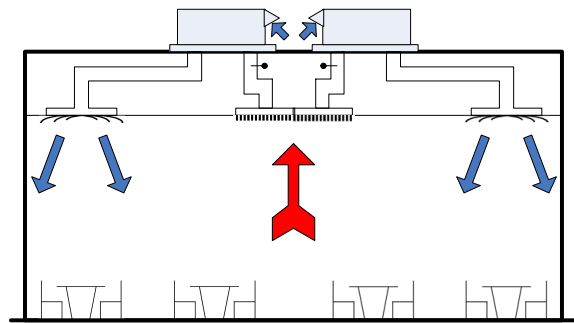


Figure 8. Dining area AHU system sketch

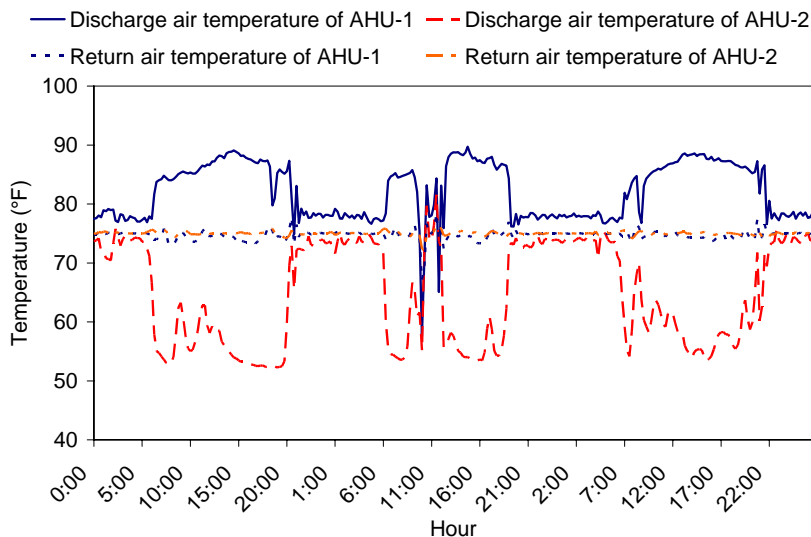


Figure 9. Temperature trend of two dining AHUs

CC measure: It is recommended that a temperature set point dead band be implemented as case study 1 so that both CHW and HHW valves could stay closed until the space temperature exceeds the dead band. During occupied time, the temperature dead band for these units could be set at 75°F for cooling and 70°F for heating.

It is also recommended that new temperature sensors be installed in the space and used to control their corresponding AHUs.

3.3 CC & Retrofit Results

3.3.1 Savings analysis

Since no CC measures have been implemented at the time of submittal of this paper, a savings analysis involving measured pre-CC and post-CC data was not performed. However, based on simulation and engineering analysis, it is estimated that implementation of the recommended CC measures would result in savings somewhere in the range of 30% for cooling, 15% for heating, and 10% for electricity. The total annual savings of \$28,000 can be expected based on the same rates as case study 1.

3.3.2 Comfort improvements

As noted, the main comfort issues that this building experienced before commissioning was dining areas staying cool and clammy. The cold complaints in the dining areas were found to be related to the return air temperature sensors location. The recommendation of installing the space temperature sensors should eliminate the cold complaints. The humidity issue in the dining area was found to be related to the fact that the heating coil was in the preheat position. The recommendation of installing VFD on the supply fans should help resolve the problem.

4 Conclusions

Based on the above two case studies, some main CC processes applied to the kitchen and dining facilities can be concluded as following:

- 1) If makeup air is not conditioned, it is recommended makeup air should be limited to below 60% of the exhaust hood cfm to improve the kitchen thermal comfort. If make up air is conditioned, the CHW/HHW control valves of makeup air units should be controlled to maintain the discharge air temperature setpoint rather than the space temperature setpoint. The makeup discharge air should be conditioned to within 10°F of the kitchen space, except when introducing replacement air does not decrease kitchen comfort. MUA should be interlocked with respective exhaust hood.
- 2) During un-occupied time, shutdown schedules should be implemented. During lightly occupied time, the discharge fans speed of dining AHUs should be reduced through VFD or two-speed motors. The outside air intake also should be reduced based on demand.
- 3) Temperature dead band should be established. OAHU should control to remove humidity from the incoming outside air if necessary, and to temper it only as needed for the units served. Additionally, the location selection of space temperature/humidity sensors is very important for the air conditioning system of a large space, such as a dining area.

Reference:

- [1] 2003 ASHRAE Applications Handbook, 31.10
- [2] CKV Lab in Chicago, Improving Commercial Kitchen Ventilation System Performance-Optimizing Makeup Air, <http://www.fishnick.com>