

EVALUATION OF THE VENTILATION SYSTEMS

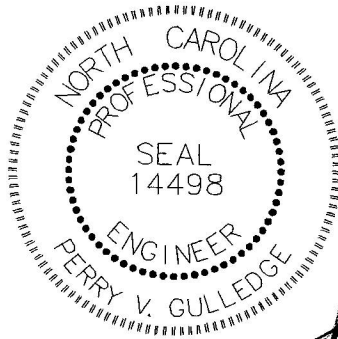
FOR

**OAK RIDGE ELEMENTARY SCHOOL
2050 Oak Ridge Rd.
Oak Ridge, NC 27310**

PROJECT #0926

PREPARED BY:

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5-28-09

May 28, 2009
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INTRODUCTION

Triad Engineering Consultants, Inc. was petitioned to evaluate the fresh air ventilation supply to Oak Ridge Elementary School in light of recent concerns regarding indoor air quality at the facility. A new fresh air treatment and delivery system was installed in the classroom wings and dehumidification sequences were added to heat pump units serving the media center last summer to address concerns about high humidity in the classroom wings and media center as well as actual delivery of fresh ventilation air to remote heat pump units in the classroom wings. Although monitoring and testing of the air over the last 9 months have not revealed indicators of air quality problems, persistent complaints of symptoms that have been attributed to the school environment by parents and school staff have prompted the administration to further investigate the facility for evidence of problems.

Using construction plans for the renovation and addition project that was completed in 2005, construction plans and balance reports from the HVAC Renovation project that was completed in August of 2008, areas of the school were examined and ventilation requirements at a system level were performed. These calculated values were compared to the scheduled ventilation air quantities in the 2005 renovation and addition plans and with the Test and Balance Report from the 2008 HVAC Renovation plan to determine if there were significant deficiencies in ventilation air quantities to the various areas.

SUMMARY

Most areas – including the classroom wings and administration wings were found to be adequately ventilated.

The Dining Room, Media Center Computer Lab, and Multipurpose Room were found to be significantly under-ventilated at peak occupancy levels. The PE offices as well as the library area of the media center were found to be slightly under-ventilated but not significantly so.

Two administrative office areas were found to be significantly over-ventilated. The system serving the Principal, Assistant Principal, Conference Room, Admin Assistant, Reception and Secretary was over-ventilated by 61.9%. The system serving the Counselling and Lounge areas was over-ventilated by 29%,

Since it has been 4 years since many of the heat pump systems were started and balanced, I would recommend that the outside air supply quantity to each system be measured and adjusted to the scheduled values for units with the exception of units listed in the Recommendations section as needing increased or decreased ventilation air supply. These adjustments should be feasible to accomplish with adjustments to existing as part of a Test and Balance contract performed by a Certified Test and Balance Contractor with the appropriate equipment, personnel, and training.

CLASSROOM WINGS E, F, AND G

Construction plans for the 2008 HVAC Renovation by Triad Engineering Consultants, Inc. dated 10/29/07 and the Certified Test and Balance Report by Hahn Mason Air Systems, Inc dated 8/23/08 were used to determine the current operating condition of the systems for the Classroom Wings.

A classroom accommodates up to 29 students plus 2 instructors, the maximum total # of occupants per classroom is 31.

Resource Rms are classified as classrooms that accommodate 10 students and 2 instructors for a total # of occupants per Resource Rm of 12.

Planning Rms are classified as offices with 4 occupants.

CALCULATIONS FOR CLASSROOMS WINGS.

N.C. Mechanical Code requires a minimum ventilation rate of 7.5 CFM per person in a classroom and 20 CFM per person in an office. Applying these figures yields the following ventilation airflows:

Classroom	232.5 CFM per classroom
Resource Rm	82.5 CFM per Resource Rm.
Planning Rm	80 CFM per Planning Rm.

WING E (400 WING)

13 CLASSROOMS @ 232.5 =	3022 CFM
2,220 SF CORRIDOR @ 0.1 CFM/SF =	222 CFM
3 RESOURCE ROOMS @ 90	270 CFM
3 PLANNING ROOMS @ 80	240 CFM
WING TOTAL	3754 CFM

AHU-E WAS DESIGNED TO SUPPLY 4140 CFM.

PER THE TEST AND BALANCE REPORT, THIS UNIT WAS SUPPLYING 4225 CFM. THIS REPRESENTS 112% OF THE MINIMUM VENTILATION CALCULATED FOR THE AREA SERVED BY THE UNIT.

WING F (500 WING)

12 CLASSROOMS @ 232.5 =	2790 CFM
1,500 SF OF CORRIDOR @ 0.1 CFM/SF =	150 CFM
1 PLANNING ROOM @ 80	80 CFM
WING TOTAL	3020 CFM

AHU-F WAS DESIGNED TO SUPPLY 3240 CFM.

PER THE TEST AND BALANCE REPORT, THIS UNIT WAS SUPPLYING 3157 CFM.

THE FAN SPEED ON THIS UNIT WAS LATER INCREASED BY 20% DUE TO STAFF CONCERNS ABOUT CLASSROOMS AT THE END OF THE VENTILATION DUCT SYSTEM NOT RECEIVING ADEQUATE VENTILATION AIR. AN SPEED INCREASE OF 20% INCREASES THE DELIVERED AIRFLOW OF THIS SYSTEM PROPORTIONALLY TO 3,788 CFM. THIS REPRESENTS 125% OF THE MINIMUM VENTILATION CALCULATED FOR THE AREA SERVED BY THE UNIT.

WING G (600 WING)

13 CLASSROOMS @ 232.5 =	3022 CFM
2,750 SF CORRIDOR @ 0.1 CFM/SF =	275 CFM
1 RESOURCE RM @ 90	90 CFM
1 PLANNING RM @ 80	80 CFM

WING TOTAL 3467 CFM

AHU-G WAS DESIGNED TO SUPPLY 3490 CFM.

PER THE TEST AND BALANCE REPORT, THIS UNIT WAS SUPPLYING 3524 CFM. THIS REPRESENTS 100.7% OF THE MINIMUM VENTILATION CALCULATED FOR THE AREA SERVED BY THE UNIT.

ADDITIONAL INFORMATION RELATIVE TO WINGS E, F, & G

AHU E, AHU-F and AHU-G were installed last August in the HVAC Renovations Project as part of a fresh air treatment and delivery system to provide positive delivery of tempered, treated, filtered ventilation air to the heat pump units that serve the classrooms in the classroom wings. The systems also dehumidify the air when the moisture level of the air is high (above 45 grains per pound of air). This is the system that has commonly been referred to as the "dehumidifier system". It is important to note that the system does not dehumidify the air when the moisture level is not high (above 45 grains per pound of air). These air handling units obtain fresh air that is taken from outside the building, filter it, heat and/or cool it, and deliver it to the classroom heat pump units through the fresh air supply ductwork connected to each heat pump that serves classroom areas.

The temperature, humidity and CO2 levels in the classroom wings have been checked often subsequent to the installation of the fresh air treatment and delivery system. Since the fresh air treatment and delivery system has been installed, the humidity levels have been lowered in these wings during the warm humid months as intended. The positive delivery of ventilation air to the heat pump systems serving the classrooms has resulted in maintaining CO2 levels within the desired target range of 700 PPM above the outdoor CO2 levels with the exception of brief periods when equipment was malfunctioning. The outdoor CO2 levels for the area have ranged from 350-450 parts per million. This establishes our target range of CO2 at 1050-1150 parts per million to provide satisfactory dilution of the most common pollutants generated within the building – human bioeffluents. Each building occupant contributes effluents from his or her body as long as the occupant remains in the building. The most prevalent effluent is CO2 gas. CO2 gas can be easily detected and measured. Consequently, the CO2 concentration is used as a tracer gas for air quality. As long as there is sufficient ventilation air to dilute the CO2 levels to the target range, it is accepted that other known effluents will remain at harmlessly low concentrations. Temporary increases above our target range do not constitute a hazard to the building occupants. Consistent readings above the target range do signal the need to check the system equipment for proper operation and possibly the need for additional ventilation air supply if the equipment is found to be operating properly while the CO2 levels consistently exceed the target levels. The OSHA threshold concentration levels for long term exposure (8 hrs) to CO2 is 5,000 parts per million. The OSHA threshold concentration levels for short term exposure (15 minutes) is 30,000 parts per million. Although there have been questions raised as to whether these concentrations are valid for children in a learning environment - as opposed to adults in a working environment these references are cited in the ASHRAE ventilation standard appendix and I am not aware of any other authoritative published data. There have not been any reports of CO2 levels approaching these threshold levels at the site since the fresh air treatment and delivery system was installed. I am not aware of any reports of readings approaching these threshold levels at any time before the system was installed. All references that have been made by GCS personnel and contractors on the site to “high CO2 levels” since last August have been made in reference to our target CO2 concentration range – not to any safe limit or hazardous level. I qualify the time frame to last August, because that is when I became involved in the discussions and evaluations of CO2 and humidity levels after the new systems were installed and operational.

Unfortunately, the delivery of this ventilation air in the colder and dryer months has resulted in dry conditions in the classrooms through the winter months when the outdoor air was cold and dry. This dry condition has been the result of the physical properties of air and the quantity of ventilation air delivered to the classrooms. It is not the result of dehumidification action by the fresh air treatment and delivery system. The dehumidification action of the system works only when the outdoor ambient dewpoint temperature is above 45 degrees Fahrenheit - which corresponds to a moisture content of 45 grains per pound of air. During the winter heating season, the outdoor dewpoint temperature rarely rises to 45F even on a warm 70 degree day.

Ventilation for the remaining areas of the building are assumed to be unchanged from the values scheduled on the plans for the 2005 renovation and addition project. All calculations and room use categories are taken from the construction plans produced by Clinton Gravely AIA Architect and Associates dated June 2003. The ventilation air quantities introduced by the heat pump units serving the respective areas are taken from the scheduled values on sheet M-1 of these plans. These calculations are performed at the system level to determine if there is a significant deficit of ventilation air scheduled when compared to the calculated requirements for a system. Actual ventilation air flow rates are unknown without a current test and balance report for each unit.

MEDIA CENTER

The N.C. Code requires 15 CFM per person for a Library and a default occupant density of 20 people per 1000 SF. The Media Center is area 3833 SF. The default occupancy for this area is 77 people.

CALCULATIONS FOR MEDIA CENTER LIBRARY

77 Occupants @ 15 CFM = 1155 CFM (NC)

The Media Center Library is served by HP 22 and HP-23 which were scheduled for 200 and 400 CFM respectively for a total of 600 CFM. This represents 52% of the calculated ventilation rate for the area.

600 CFM would be the correct ventilation for 40 people using these criteria.

Later versions of the ASHRAE ventilation standard define a Library as having an occupant density of 10 people per 1000 SF and a ventilation requirement of 0.12 CFM/SF plus 5 cfm per occupant. Using these parameters, the default occupancy is 38 people.

3833 SF @ 0.12 CFM/SF = 460 CFM

38 people @ 5 cfm each = 190 CFM

Total 650 CFM (ASHRAE)

600 CFM represents 92.3% of the calculated ventilation rate for the area under these criteria.

600 CFM would be the correct ventilation for 28 people using these criteria.

The heat pump units serving the Media Center and associated offices were modified last summer to add a dehumidification cycle by adding condenser water source reheat coils and controls to the units. The amount of ventilation air delivered by the systems serving the Media Center and Media Center offices were not modified during this project. The only change made to these systems was to add monitoring and control of humidity in the area (dehumidification only). This was the only other area outside of the classroom wings that received HVAC modifications in the 2008 HVAC Renovations project to reduce humidity in the building.

MULTIPURPOSE (GYMNASIUM/AUDITORIUM)

The N.C. Code requires 15 CFM per person for an auditorium and a default occupant density of 150 people per 1000 SF. The Multipurpose Rm area is 8230 SF. The default occupancy for this area is 1235 people.

CALCULATIONS FOR MULTIPURPOSE ROOM

1235 Occupants @ 15 CFM each = 18,525 CFM. Note that this occupancy and quantity of fresh air are unrealistic and unmanageable quantities for an 8230 SF area with conventional HVAC equipment.

Later versions of the ASHRAE ventilation standard define a Multi-use Assembly room as having an occupant density of 100 people per 1000 SF and a ventilation requirement of 0.06 CFM per SF plus 7.5 cfm per occupant. Using these parameters, the default occupancy is 823.

8230 SF @ 0.06 CFM/SF =	494 CFM
823 Occupants @ 7.5 CFM each =	6172 CFM
Total	6666 CFM

The Multipurpose Room is served by HP-2, HP-3, HP-4 and HP-5 which are scheduled to provide 600, 600, 1000, and 1000 CFM respectively for a total of 3,200 CFM. This ventilation rate is quite adequate for use as a gym, but approximately 48% of the appropriate rate for extended use as an auditorium.

DINING RM

The N.C. Code requires 20 CFM per person for a Dining room and a default occupant density of 70 people per 1000 SF. The Dining Rm area is 3950 SF. The default occupancy for this area is 277 people, but the room is limited to 244 occupant by the Fire Marshall.

CALCULATIONS FOR DINING ROOM

244 Occupants @ 20 CFM each = 4880 CFM. Note that this occupancy and quantity of fresh air are unrealistic and unmanageable figures.

Later versions of the ASHRAE ventilation standard define a Dining Room as having an occupant density of 70 people per 1000 SF and a ventilation requirement of 0.18 CFM per SF plus 7.5 CFM per occupant. Using these parameters and the maximum occupancy of 244:

3950 SF @ 0.18 CFM/SF =	711 CFM
244 Occupants @ 7.5 CFM each =	1830 CFM
Total	2541 CFM

The Dining Room is served by HP-8, HP-9 which are scheduled to provide 1000, CFM each for a total of 2000 CFM. This represents 78.7% of the calculated ventilation rate. This ventilation airflow would be correct for 172 occupants.

PE OFFICES

The N.C. Code requires 20 CFM per person for an office and a default occupancy of 7 people per 1000 SF. These offices are assumed to be individual offices (one person per office). The corridor requires 0.1 CFM per square foot.

CALCULATIONS FOR PE OFFICES

2 Occupants @ 20 CFM each =	40 CFM
Corridor is 800 SF @ 0.1 CFM/SF =	80 CFM
Total for Office System	120 CFM

Later versions of the ASHRAE ventilation standard require 0.05 CFM per SF for corridor and 0.06 CFM per SF plus 5 CFM per person for the offices. Using these parameters, the ventilation requirement is:

Office	855 SF @ 0.06 CFM/SF plus 2 Occupants @ 5 CFM/Occupant =	61.3 CFM
Corridor	800 SF @ 0.06 CFM/SF =	48
Total for Office System		109 CFM

The PE Offices and corridor is served by HP-11 which was scheduled for 100 CFM. This represents 91.7% of the calculated rate under the ASHRAE criteria

ADMINISTRATION AREA OFFICES

The N.C. Code requires the following ventilation rates for various areas

20 CFM per person for an office and a default occupant density of 7 people per 1000 SF.

15 CFM per person for reception areas and a default occupant density of 60 people per 1000 SF.

20 CFM per person for conference rooms and a default occupant density of 50 people per 1000 SF.

25 CFM per person for a patient room and a default occupant density of 10 people per 1000 SF

Storage rooms require 0.05 cfm per square foot.

The corridors require 0.1 CFM per square foot.

The following areas are grouped based on the heat pump (HP) unit that serves the rooms. The last three numbers in the line are the area ventilation rate, the occupant ventilation rate, and the combined area plus occupant ventilation rate calculated from the later ASHRAE ventilation standard. The two numbers in the "Total" line are total ventilation requirements calculated by the N.C. Code and the ASHRAE ventilation standard respectively.

Principal, Asst. Principal, Conf, Adm Assistant, Reception/Secretary

Office Area	1030 SF	7 Occupants	140 CFM	62	35	97
Conference Area	272 SF	14 Occupants	280 CFM	16	70	86
Reception Area	190 SF	11 Occupants	165 CFM	11	30	41
Corridor Area	382 SF		38 CFM	23	0	23

Total

(NC) 623 CFM

(ASHRAE) 247 CFM

These areas are served by HP-12 which was scheduled for 400 CFM. This represents 161.9% of the calculated ventilation rate under the ASHRAE criteria.

Office Core (Workrooms, Records, Storage, Testing, Health)

Conf Area	373 SF	19 Occupants	380 CFM	22	95	117
Storage Area	664 SF	0 Occupants	66 CFM	40	0	40
Workroom Area	700 SF	14 Occupants	280 CFM	42	20	62
Patient Rm	553 SF	2 Occupants	50 CFM	100	20	120

Total (NC) **776 CFM** (ASHRAE) **339 CFM**

These areas are served by HP-14 which was scheduled for 400 CFM. This represents 118% of the calculated ventilation rate under the ASHRAE criteria.

Lounge, Counselling, Corridor

Office Area	388 SF	8 Occupants	160 CFM	23	40	63
Break Rm	593 SF	36 Occupants	540 CFM	36	180	216
Corridor Area	506 SF	0 Occupants	51 CFM	30	0	30

Total (NC) **623 CFM** (ASHRAE) **309 CFM**

These areas are served by HP-15 which was scheduled for 400 CFM. This represents 129% of the calculated ventilation rate under the ASHRAE criteria.

IT Offices, Corridor

Office Area	423 SF	4 Occupants	80 CFM	25	20	45
Corridor Area	304 SF	0 Occupants	30 CFM	18	0	18
Storage	367 SF	0 Occupants	18 CFM	22	0	22

Total (NC) **128 CFM** (ASHRAE) **85 CFM**

These areas are served by HP-18 which was scheduled for 250 CFM. This represents 294% of the calculated ventilation rate under the ASHRAE criteria.

Computer Lab

Lab Area	1008 SF	25 Occupants	188 CFM	120	250	370
Corridor Area	186 SF	0 Occupants	19 CFM	11	0	11

Total (NC) **206 CFM** (ASHRAE) **381 CFM**

These areas are served by HP-17 which was scheduled for 300 CFM. This represents 79% of the calculated ventilation rate under the ASHRAE criteria. The ASHRAE criteria were selected for this application since there is a specific category for computer labs. There was no category for computer labs in the N.C. Code

Media Center Office, Workroom, Speech Rm

Office Area	279 SF	2 Occupants	40 CFM	17	10	27
Speech Rm	311 SF	16 Occupants	320 CFM	19	80	99
Workroom Area	431 SF	9 Occupants	180 CFM	42	20	62
Total			(NC) 540 CFM			(ASHRAE) 188 CFM

These areas are served by HP-21 which was scheduled for 250 CFM. This represents 133% of the calculated ventilation rate under the ASHRAE criteria.

BUILDING PRESSURIZATION ISSUES.

The overall ventilation air supply and exhaust quantities for the building were calculated to determine whether the building should be in a positive, neutral or negative pressure condition with all systems operating. The sum of all supply air quantities into the building is approximately 24,850 CFM. The sum of all the exhaust air quantities out of the building is 10,258 CFM which indicates the building is positively pressurized by 14,592 CFM. One would normally expect to see a significant positive pressure at the exterior doors created by this quantity of air. Due to the type of construction of this facility, it is likely that the air is transferring through the ceiling tiles, into the attic, then out of the building at various construction gaps and seams throughout the building.

CONCLUSIONS

Our conclusions are based on the figures cited above and using the lower calculated ventilation requirements for each area. The lower of the calculated values are used due to the evolving nature of the ventilation requirements over time. The ventilation rates in the North Carolina Mechanical Code are based on the 1989 ASHRAE 62.1 Ventilation Standard. The local code authorities required compliance with the N.C. version at the time this building was constructed even though later versions of the ASHRAE standards were developed that changed the ventilation rates. In many cases recent modifications to the current industry standard for ventilation – ASHRAE Standard 62.1 - have reduced the ventilation air quantities required for many spaces including offices, auditoriums, conference rooms, etc. Since higher ventilation airflows impose higher operating costs and additional treatment requirements (such as removing excess moisture) the current ASHRAE requirements are considered for applications that appear questionable or problematic by the basic N.C. Code requirements. Once the required ventilation rate has been determined, the introduction of additional outside air imposes higher operating costs and a tendency towards higher humidity during the warm dry periods and lower humidity in cold dry periods.

The classroom wings and administration office areas were found to be adequately ventilated for expected occupancy.

The media center library area was found to be slightly under-ventilated depending on the actual number of occupants in the library during the same time period.

The media center office and class areas were found to be slightly over-ventilated for expected occupancy.

The computer lab adjacent to the media center was found to be slightly under-ventilated as a computer lab under the current ASHRAE standard. It would have been classified as a classroom under the N.C. Code and would have been found to be over-ventilated by that requirement. The ASHRAE standard criteria were used due to the specific category of computer lab in the standard.

The dining room was found to be slightly under-ventilated depending on the actual number of occupants in the room during the same time period.

The multipurpose room was found to under-ventilated for extended use as an auditorium, but adequately ventilated for use as a gymnasium.

RECOMMENDATIONS

Slight under-ventilation or over-ventilation of areas should not present a concern for use of specific areas. Although the calculations are quite specific, they are typically based on continuous occupancy at full capacity. Activities such as class changes, lunch breaks, etc allow the dilution of contaminants to catch up when the area is vacant since the ventilation supply remains constant. I would categorize an area that has 90% or more of the calculated ventilation airflow as satisfactorily ventilated. Areas with less than 90% I would categorize as significantly under-ventilated. Areas with more than 120% I would categorize as over-ventilated. Areas that are significantly under-ventilated should either be monitored for possible air quality issues or their HVAC systems should be modified to allow higher ventilation rates. Caution should be exercised when increasing the ventilation rates to insure that the rates are not increased more than recommended. Higher ventilation rates will result in higher humidity in the cooling periods and lower humidity in the heating periods.

Based on these parameters, the areas listed below are categorized as significantly under-ventilated:

Multi Purpose Room:

Dining Room

Media Center Computer Lab

The Multi Purpose Room is under-ventilated only when used as an auditorium. If the use of this area is primarily as a Gym with occasional use for short time periods as an auditorium, I would not recommend increasing the ventilation supply to this room. The ventilation supply would need to be doubled to meet an occasional use function of the room. This additional ventilation would require additional equipment to treat the air in order to avoid significant humidity problems associated with the higher outside air quantities in the cooling periods and low humidity problems in the heating periods.

The Dining Room heat pump systems should be adjusted to provide additional ventilation supply. This can be accomplished by balancing the outside air dampers to HP-8 and HP-9 to increase the ventilation air supply from 1000 CFM each to 1270 CFM each. This increase should not require additional cooling equipment be added for the room.

The Media Center Computer Lab heat pump system (HP-17) should be modified to increase the ventilation air supply from 300 CFM to 380 CFM. This increase should be achievable with existing equipment and should not require additional cooling equipment be added for the room unless the room is already short on cooling capacity.

The Administration Offices heat pump system (HP-12) should be modified to decrease the ventilation air supply from 400 CFM to 250 CFM due to the existing significant over-ventilation condition. This should help to reduce humidity in the area also.

The Lounge, Counselling Offices heat pump system (HP-15) should be modified to decrease the ventilation air supply from 400 CFM to 310 CFM due to the existing significant over-ventilation condition.

The IT Offices heat pump system (HP-18) should be modified to decrease the ventilation air supply from 250 CFM to 100 CFM due to the existing significant over-ventilation condition.