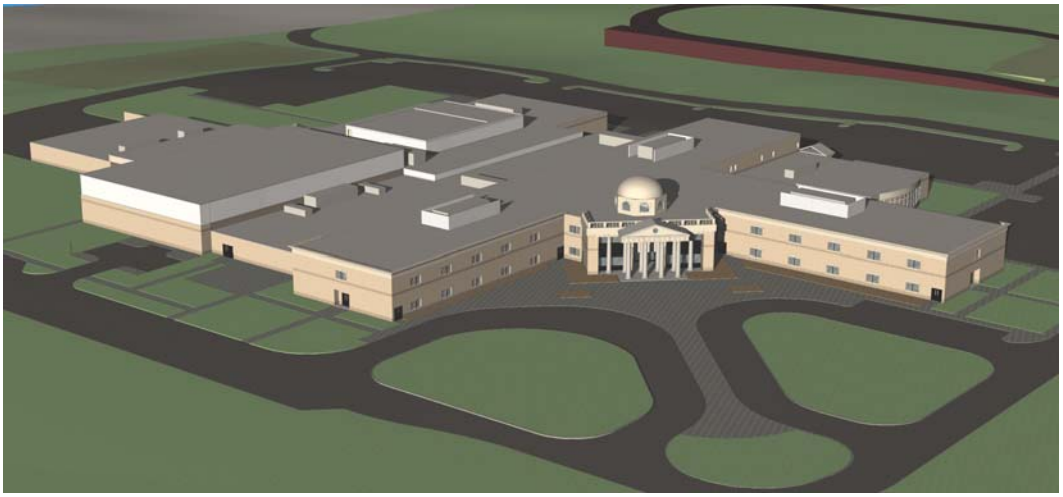
Technical Assignment 1

ASHRAE Standard 62.1 – 2004: Ventilation Report



South Jefferson High School

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Executive Summary:

This purpose of this report is to examine South Jefferson High School, a two story 230,000 s.f. facility, to verify its compliance with ASHRAE Standard 6.21-2004 minimum ventilation requirements at design conditions.

Supply air is delivered to the school by 14 roof top units (RTU), which range in size from 4,500 cfm to 25,500 cfm. The amount of minimum outside air to the 14 RTU's varies between 1,200 cfm and 14,000 cfm. The ventilation effectiveness is 1.0 based on the air distribution configuration with ceiling supply of cool air. A comprehensive summary of the building's HVAC systems' design is located in the Systems and Equipment Summary section.

As described in the Conclusions section, all 14 roof top units comply with Standard 62.1-2004. RTU-5 exceeds the minimum outdoor air quantity significantly by requiring the unit to supply 100% outside air. The remaining 13 roof top units closely follow the calculated outdoor air rates for ASHRAE Standard 62.1-2004.

Introduction:

The intended purpose of ASHRAE 62.1-2004 is to reduce potential for unfavorable health effects arise from poorly designed mechanical systems by specifying minimum ventilation rates and indoor air quality for occupied indoor or enclosed space. This standard is pertinent to all new building construction and renovations consisting of occupied indoor or enclosed space.

Systems and Equipment:

South Jefferson High School is broken into 8 separate zones. These areas are noted zone A through H. A list of what zones are served by its corresponding roof top unit is included in Appendix A.

The HVAC system serving classroom areas for South Jefferson High School consists primarily of variable air volume roof top units serving series-style fan powered boxes at classrooms. The classroom wings have a total of 5 rooftop units with ductwork chased down through rated shafts for outside air to a fan powered box located in the plenum space above the corridor outside of each classroom. The fan powered boxes are in serve ceiling mounted diffusers. A return plenum is used to building return air to the roof top units. The administrative offices are also served in this same method by RTU-3.

The science Rooms on the 2nd floor Zone G are served by RTU-5. This roof top unit supplies all of its 14,000 cfm as 100% OA in order to reduce the risk of volatile lab chemicals getting into the air. 4. Air distribution systems serving the Sciences Rooms are designed to maintain a negative pressure in the room with respect to the adjacent areas.

The locker room/athletic department of the school are located on the 1st floor Zone C. This are is served by RTU-12 a 12,000 cfm 100% outside air unit. The locker room areas are fully exhausted to maintain a negative pressure to adjacent spaces. This roof top unit serves as a make-up for 90% of the exhausted air.

The Gymnasium, Auditorium and Cafeteria are served with single-zone air handling units located on the roof. The Gymnasium and Auditorium both utilize 2 roof top units each, while the Cafeteria only requires a single RTU. All 5 roof top units incorporate demand-based ventilation controls in the form of CO2 sensors.

All sequences of controls for the entire building are performed by direct digital controls (DDC). This DDC system monitors all the sensors, and it is able to adjust all the set points and time delays for the equipment. The DDC system also provides start/stop, speed control, monitoring, and alarms for the variable frequency drives (VFD).

Assumptions:

- Every space was assumed to have perfect mixing for the purposes of these calculations.
- Contaminant concentrations were treated as uniform as well because there was no data to suggest otherwise.
- Regional outdoor air quality and Local outdoor air quality in the Charles Town area shall be assumed acceptable for ventilation during occupied hours. Documentation will be assumed to be taken care of.
- Exhaust stacks are sufficiently far from outdoor air intake to ensure acceptable ventilation air.
- Smoking is not permitted in South Jefferson High School.

Unlisted occupancies:

Note 6 from Table 6.1

- Any space without specific ventilation rates was calculated using values of a similar functionality.

Spaces that are not considered for ventilation include, but are not limited to:

- Most mechanical equipment rooms.
- Elevator shafts.
- All stairwells.
- Janitor closets and small storage closets.

Note: Transfer air from adjacent spaces will provide enough ventilation for these spaces.

Ventilation effectiveness:

Assuming cooling is the predominant conditioning of South Jefferson High School for most of the year and due to the prevailing weather in Charles Town and the function of the building.

- Ventilation effectiveness (Ez) = 1 for ceiling distribution of cool air.

Other Standard 62.1 Compliance Issues:

- The HVAC system does not utilize any natural ventilation.
- The ventilation system includes balancing capabilities.
- A plenum return is used for many of the roof top units.
- Design documents specified minimum requirements for air balance testing.
- The design documentation stated assumptions that were made in the design with respect to ventilation rates and air distribution.

Part I – Multiple-Zone Calculation:

Note: During the mechanical system design of South Jefferson High School, West Virginia code required the ventilation calculations be done using ASHRAE Standard 62.1 Addendum n – 2001 Appendix G Multiple-Zone Systems Procedure in order to benefit from potential reduction in outdoor air intake by taking advantage of recirculated unused outdoor air in the plenum space. In order to make a fair comparison of the design documents in this report, all multiple space ventilation calculations were done using the equivalent ASHRAE Standard 62.1-2004 Appendix A Multiple-Zone Systems Procedure. This procedure eliminates the zone primary outdoor air fraction (Zp) variable and replaces it with a more complex zone ventilation efficiency (Evz) variable.

Step One:

Determine the breathing zone outdoor airflow (Vbz) from the following equation:

$$Vbz = RpPz + RaAz \quad \text{(Equation 6.1)}$$

The outdoor airflow rate (Rp) required per person and outdoor airflow rate (Ra) required per zone floor area (Az) as determined from Table 6.1. The zone populations (Pz) for South Jefferson High School and are located in Appendix B.

Step Two:

Determine the primary airflow (Vpz) to zone from air handler (intake plus recirculated air, but not local recirculation such as at mixing boxes). In VAV systems, use the design value.

Step Three:

Determine the supply/discharge (Vdz) to zone including primary air (Vpz) and locally recirculated air. In VAV systems, use the design value.

Note: Zone supply air flows were increased during the design process, particularly to the critical zones requiring the highest fraction of outdoor air, and thereby reduced the system outdoor air intake requirement determined in the calculation.

Step Four:

Determine the minimum supply/discharge (Vdzm) to zone used to calculate (Ev).

In CAV systems, Vdzm = Vdz.

In VAV systems, Vdzm is the minimum expected value of Vdz.

Step Five:

Determine the outdoor air fraction required in air discharged to zone.

$$Zd = Voz/Vdzm$$

Step Six:

Determine the primary air fraction to zone (Ep),

$$Ep = Vpz/Vdz$$

Step Seven:

Determine the fraction of secondary recirculation to zone (Er) representative of system average, this variable only applies if Ep<1.

For plenum return Er <=1.
For duct return with local secondary recirc Er = 0.
For constant volume boxes Er = 0

Note: This variable was determined by assuming a percentage of system average of potentially usable unused outdoor air able to be recirculated by the spaces local VAV box. VAV boxes closer to the return duct opening in the plenum were assumed to have higher potential for unused outdoor air. While VAV boxes located farther from the return duct opening in the plenum were assumed to have no potential benefit from locally recirculated unused outdoor air.

Step Eight:

Determine the zone air distribution effectiveness (Ez) using Table 6.2.

For ceiling supply of cool air: Ez = 1.

Step Nine:

Determine the design zone outdoor airflow (Voz), i.e., the amount of outdoor air that must be provided.

$$Voz = Vbz/Ez \text{ (Equation 6.2)}$$

Step Ten:

Determine the fraction of supply air to zone from sources outside zone (Fa).

$$Fa = Ep + (1-Ep) * Er$$

Step Eleven:

Determine the fraction of supply air to zone from full mixed primary air (Fb).

$$Fb = Ep = Vpz/Vdz$$

Step Twelve:

Determine the fraction of outdoor air to zone from sources outside zone (Fc).

$$Fc = 1 - (1-Ez) * (1-Er) * (1-Ep)$$

Step Thirteen:

Determine the uncorrected outdoor air intake (Vou) from the following equation:

$$Vou = D \sum_{all\ zones} RpPz + \sum_{all\ zones} RaAz \quad \text{(Equation 6.6)}$$

The occupant diversity factor (D) takes variations in occupancy into consideration within the system.

$$D = Ps / \sum_{all\ zones} Pz$$

The system population (Ps) is the maximum simultaneous number of occupants in the area served by the system. The occupancy diversity (D) varies for each roof top unit. Differences between the system population (Ps) and the zone population (Pz) during operation were given by mechanical system designer. See Appendix B for diversity factor values.

Step Thirteen:

Determine the mixing ratio at primary air handler of uncorrected outdoor air intake to system primary flow (Xs).

$$Xs = Vou/Vps$$

Step Fourteen:

Determine the zone ventilation efficiency (Evz).

$$Evz = (Fa + Xs*Fb - Zd*Fc)/Fa$$

Note: The general case equation was used because of the systems use of fan-powered mixing boxes.

Step Fifteen:

Determine the system ventilation efficiency (Ev).

Using Appendix A: $Ev = (Evz)_{min}$

Step Sixteen:

Determine the design outdoor air intake flow (Vot).

$$Vot = Vou/Ev$$

Discussion of Ventilation Rate versus Indoor Air Quality Procedures:

The procedure outlined in Section 6 of Standard 62.1, known as the Ventilation Rate Procedure. The purpose of the Ventilation Rate Procedure is "to specify minimum ventilation rates and indoor air quality that will be acceptable to human occupants and are intended to minimize for adverse health effects." According to ASHRAE Standard 62.1 – 2004 (ASHRAE 2004), all buildings must provide the required ventilation rate to each space considering its type and occupancy. The required ventilation rates are based on general contaminant levels and requirements for cfm/person in spaces of that type. These ventilation rates also ensure the amount of ventilation air required to keep a majority of the occupants satisfied with a particular spaces air quality. This procedure uses a large number of equations and tables to determine the critical space in a building and the necessary outdoor air based on effectiveness of the system and size and occupancy of the room. It is a relatively fast method to calculate and does not require extensive knowledge of the space requirements. This allows the basic system to be designed before specific use and occupancy is ever determined allowing the design process to take less time. The major drawback is that the designed system may not be tailored to the specific need of all spaces. This could mean over – or under – heating or cooling, wasted energy, or contaminant levels exceeding recommended limits.

The first alternative procedure to the Ventilation Rate Procedure was introduced in 1981. The Indoor Air Quality Procedure is a performance-based procedure. Rather than prescribing rates based on occupancy category, rates are calculated based on contaminant source strengths and desired indoor concentrations. This procedure required the engineer to know the specific function of every space in the building. A design of this precision could be necessary in critical spaces or spaces with specialized functions such as hospital rooms, scientific research facilities, museums, or other spaces where there is a threat of contamination from known sources. Also, if outdoor air is found to be unacceptable for general ventilation, the IAQ Procedure should be considered instead of the Ventilation Rate Procedure. This could lessen the impact of outdoor air contaminants on building occupants and may reduce both the amount of ventilation air required and the concentration of contaminants by use of an appropriate air cleaning device. Still, contaminant information is not always known and in these situations ventilation design based on this procedure seems impossible. The Indoor Air Quality Procedure also eliminates flexibility in the design. The system is specific for each space therefore any alterations would require the system to be modified. In comparison, the Ventilation Rate Procedure is able to absorb some changes in space characteristics as the procedure only uses generalized requirements.

Conclusion:

After following the multiple zone calculation procedure outlined in ASHRAE Standard 62.1-2004 section 6.2.2 and Appendix A, it was determined that all roof top units at South Jefferson High School are compliant with ASHRAE 62.1-2004 ventilation requirements. In total they require approximately 89,555 cfm and have a capacity of 101,770 cfm. The difference can be accounted for by the desire to be conservative, varying assumptions, rounding to reasonable balancing values, and other design considerations.

Roof top units 1, 2, 3, 4, 6, 7, 8, and 10 supply ventilation rates that closely resemble the values acquired from the ASHRAE Standard 62.1-2004 calculations. The difference between design outdoor air cfm and calculated Standard 62.1 values differ by a total of only 1,241 cfm.

The use of RTU's 5 and 12 as 100% outdoor air/ make-up units is completely acceptable considering that code requires full exhaust of these areas.

Roof top units 13 and 14 are used for the gymnasium. Two separate units were used because of the use of a roll-away divider separating the gymnasium into two zones. The design outdoor air value for these units is more than double that required for one zone of the gymnasium. This will provide the capability for only one RTU to supply the entire gymnasium when the divider is retracted and the heat loads are not too high in the space.

Roof top unit 9 supplying the auditorium has a design value greater than the required minimum. This is most likely to improve indoor air quality in such a densely populated area.

Roof top unit 11 is used for Kitchen area supply and make-up. The design outdoor air rate is higher for this system in order to account for outdoor air lost from exhausting these spaces.

APPENDIX A:

ROOF TOP UNIT SUMMARY

Symbol	Supply Air (CFM)	Design Outdoor Air (CFM)	Variable or Constant Volume	Serves	Standard 62.1 Ventilation Values (CFM)
RTU-1	22,000	9,600	VV	Zone A - 1st and Second Floor	9,563
RTU-2	25,500	10,600	VV	Zone B - 1st and Second Floor	10,485
RTU-3	13,000	3,600	VV	Administration	3,515
RTU-4	24,000	10,500	VV	Zone G - 1st Floor	10,432
RTU-5	14,000	14,000	CV	Zone G - 2nd Floor	14,000
RTU-6	12,000	2,700	VV	Zone H - 1st Floor	2,380
RTU-7	15,000	6,400	VV	Zone F - 1st Floor	6,342
RTU-8	4,500	1,200	CV	Auditorium Stage	957
RTU-9	9,000	8,000	CV	Auditorium	6,844
RTU-10	13,000	7,500	CV	Cafeteria	7,155
RTU-11	6,000	4,670	CV	Zone E - 1st Floor	1,554
RTU-12	12,000	12,000	CV	Zone C - 1st Floor	12,000
RTU-13	9,500	5,500	CV	Gymnasium	2,164
RTU-14	9,500	5,500	CV	Gymnasium	2,164
Totals:	189,000	101,770			89,555

APPENDIX B:

RTU-1

RESULTS		
Vot	**Minimum outdoor air intake, Vou/Ev, cfm**	**9563**
	Percent outdoor air intake, Vot/Vps	**48%**
Ev	**System ventilation efficiency**	**0.74**

ZONE LEVEL

	Zones served by system	**LD CLASS**	**LANG ART**	**LANG ART**	**LANG ART**	**FOR LANG**	**LANG ART**	**LANG ART**	**JOURNAL A104**	**JOURNAL A103**	**PROMENT IMP**
	Space type (select from pull-down list)	Classroom	Classroom	Classroom	Classroom	Classroom	Classroom	Classroom	Classroom	Classroom	Classrooms
Az	Floor area of zone, ft2	738	750	750	750	868	750	750	750	344	915
Pz	Zone population, largest # of people expected to occupy zone	28	28	28	28	28	28	28	28	10	12
Rp	People outdoor air rate from Table 6.1, cfm/person	10	10	10	10	10	10	10	10	10	10
Ra	Area outdoor air rate from Table 6.1, cfm/ft2	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Pz*Rp		280	280	280	280	280	280	280	280	100	120
Az*Ra		88.56	90	90	90	104.16	90	90	90	41.28	109.8
Voz	Outdoor airflow to the zone corrected for zone air distribution effectiveness, (Pz*Rp + Az*Ra)/Ez, cfm	368.56	370	370	370	384.16	370	370	370	141.28	229.8
Vpz	Primary airflow to zone from air handler (intake plus recirculated air, but not local recirculation such as at mixing boxes), cfm. **In VAV systems, use the design**	450	400	400	370	475	400	400	400	200	300
Vdz	Supply/discharge to zone including primary air Vpz and locally recirculated air, cfm. **In VAV systems, use the design value.**	1200	1200	1200	1200	1200	1200	1200	1200	400	1200
Vdzm	Minimum supply/discharge to zone used to calculate Ev, cfm. **In CAV systems, Vdzm = Vdz. In VAV systems, Vdzm is the minimum expected value of Vdz.**	1200	1200	1200	1200	1200	1200	1200	1200	400	1200
Zd	Outdoor air fraction required in air discharged to zone, = Voz/Vdzm	0.31	0.31	0.31	0.31	0.32	0.31	0.31	0.31	0.35	0.19
Ep	Primary air fraction to zone, = Vpz/Vdz (=1 for single duct and single zone systems)	0.38	0.33	0.33	0.31	0.40	0.33	0.33	0.33	0.50	0.25
Er	Fraction of secondary recirc to zone representative of system average, only applies if Ep<1. For plenum return <=1. For duct return with local secondary recirc =0.	0.50	0.70	0.90	1.00	0.50	0.70	1.00	1.00	0.90	0.50
Ez	Zone air distribution effectiveness, Table 6.2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fa	Fraction of supply air to zone from sources outside zone, = Ep + (1-Ep)*Er	0.69	0.80	0.93	1.00	0.70	0.80	1.00	1.00	0.95	0.63
Fb	Fraction of supply air to zone from full mixed primary air, = Ep = Vpz/Vdz	0.38	0.33	0.33	0.31	0.40	0.33	0.33	0.33	0.50	0.25
Fc	Fraction of outdoor air to zone from sources outside zone, = 1 - (1-Ez) * (1-Er) * (1-Ep)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

SYSTEM LEVEL

Ps	System population, maximum simultaneous # of occupants of space served by system	530	
D	Occupant diversity, ratio of system peak occupancy to sum of space peak occupancies, = Ps/ΣPz	0.90	
Vou	Uncorrected outdoor air intake, = D*ΣRp*Pz + ΣRa*Az, cfm	7103	
Vps	Total system primary flow to all zones, Σ Vpz, cfm	20000	**Note: In VAV systems, Vps is equal to the fan airflow, and the formula in cell c40 needs to be replaced by this value.**
Xs	Mixing ratio at primary air handler of uncorrected outdoor air intake to system primary flow, = Vou/Vps	0.36	

SYSTEM EFFICIENCY

Evz	Zone ventilation efficiency, (Fa +Xs*Fb - Zd*Fc)/Fa	0.75	0.76	0.80	0.80	0.74	0.76	0.81	0.81	0.82	0.84
Ev	System ventilation efficiency, min(Evz)	0.74									

			Percent outdoor air intake	
Vot	**Minimum outdoor air intake, Vou/Ev, cfm**	**9563**	**48%**	= Vot/Vps

APPENDIX B:

RTU-1 (Continued)

	SOC STDY	SOC STDY	SOC STDY	MATH A215	MATH A216	CMP LAB A210	SOC STDY	LD CLASS	MATH A203	MATH A202	HEALTH A201	CORR A132	CORR A2__	LOUNGE A118A	FAC PLAN A118	WORKRM A112
	Classroom	Classroom	Classroom	Classroo	Classroom	Computer	Classroom	Classroom	Classroom	Classroom	Classroom	Corridors	Corridors	Lobbies	Conference	Storage roor
Az	726	737	737	737	728	1079	737	734	737	737	709	2255	2255	239	449	239
Pz	28	28	28	28	28	28	28	28	28	28	28	0	0	11	16	9
Rp	10	10	10	10	10	10	10	10	10	10	10	0	0	5	5	0
Ra	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.06	0.06	0.06	0.06	0.12
Pz*Rp	280	280	280	280	280	280	280	280	280	280	280	0	0	55	80	0
Az*Ra	87.12	88.44	88.44	88.44	87.36	129.48	88.44	88.08	88.44	88.44	85.08	135.3	135.3	14.34	26.94	28.68
Voz	367.12	368.44	368.44	368.44	367.36	409.48	368.44	368.08	368.44	368.44	365.08	135.3	135.3	69.34	106.94	28.68
Vpz	450	400	400	400	400	425	400	400	400	400	450	225	225	125	200	50
Vdz	1200	1200	1200	1200	1200	1600	1200	1200	1200	1200	1200	400	400	475	450	300
Vdzm	1200	1200	1200	1200	1200	1600	1200	1200	1200	1200	1200	400	400	475	450	300
Zd	0.31	0.31	0.31	0.31	0.31	0.26	0.31	0.31	0.31	0.31	0.30	0.34	0.34	0.15	0.24	0.10
Ep	0.38	0.33	0.33	0.33	0.33	0.27	0.33	0.33	0.33	0.33	0.38	0.56	0.56	0.26	0.44	0.17
Er	0.50	0.60	0.80	1.00	1.00	0.50	0.70	1.00	1.00	0.70	0.50	0.00	0.00	0.00	0.00	0.00
Ez	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fa	0.69	0.73	0.87	1.00	1.00	0.63	0.80	1.00	1.00	0.80	0.69	0.56	0.56	0.26	0.44	0.17
Fb	0.38	0.33	0.33	0.33	0.33	0.27	0.33	0.33	0.33	0.33	0.38	0.56	0.56	0.26	0.44	0.17
Fc	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Evz	0.75	0.74	0.78	0.81	0.81	0.74	0.76	0.81	0.81	0.76	0.75	0.75	0.75	0.80	0.82	0.78

APPENDIX B:

RTU-2

RESULTS		
Vot	**Minimum outdoor air intake, Vou/Ev, cfm**	**10485**
	Percent outdoor air intake, Vot/Vps	**52%**
Ev	**System ventilation efficiency**	**0.81**

ZONE LEVEL

	Zones served by system	**WORKRM B120**	**LD CLASS**	**LANG ART**	**LANG ART**	**MOD MENT**	**FOR LANG**	**FOR LANG**	**LANG ART**	**LANG ART**	**BD CLASS B130**	**CORR B133**
	Space type (select from pull-down list)	Office spa	Classroom	Classroom	Classroom	Classrooms	Classroom	Classroom	Classroom	Classroom	Classrooms	Corridors
Az	Floor area of zone, ft2	239	746	750	750	750	868	750	747	750	799	1120
Pz	Zone population, largest # of people expected to occupy zone	9	28	28	28	28	30	28	28	28	22	0
Rp	People outdoor air rate from Table 6.1, cfm/person	10	10	10	10	10	10	10	10	10	10	0
Ra	Area outdoor air rate from Table 6.1, cfm/ft2	0.06	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.06
Pz*Rp		90	280	280	280	280	300	280	280	280	220	0
Az*Ra		14.34	89.52	90	90	90	104.16	90	89.64	90	95.88	67.2
Voz	Outdoor airflow to the zone corrected for zone air distribution effectiveness, (Pz*Rp + Az*Ra)/Ez, cfm	104.34	369.52	370	370	370	404.16	370	369.64	370	315.88	67.2
Vpz	Primary airflow to zone from air handler (intake plus recirculated air, but not local recirculation such as at mixing boxes), cfm. **In VAV systems, use the design**	170	500	450	400	400	550	450	400	450	400	125
Vdz	Supply/discharge to zone including primary air Vpz and locally recirculated air, cfm. **In VAV systems, use the design value.**	350	1200	1200	1200	1200	1400	1200	1200	1200	1200	250
Vdzm	Minimum supply/discharge to zone used to calculate Ev, cfm. **In CAV systems, Vdzm = Vdz. In VAV systems, Vdzm is the minimum expected value of Vdz.**	350	1200	1200	1200	1200	1400	1200	1200	1200	1200	250
Zd	Outdoor air fraction required in air discharged to zone, = Voz/Vdzm	0.30	0.31	0.31	0.31	0.31	0.29	0.31	0.31	0.31	0.26	0.27
Ep	Primary air fraction to zone, = Vpz/Vdz (=1 for single duct and single zone systems)	0.49	0.42	0.38	0.33	0.33	0.39	0.38	0.33	0.38	0.33	0.50
Er	Fraction of secondary recirc to zone representative of system average, only applies if Ep<1. For plenum return <=1. For duct return with local secondary recirc =0.	0.00	0.50	0.70	0.90	1.00	0.50	0.70	0.90	0.70	0.50	0.00
Ez	Zone air distribution effectiveness, Table 6.2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fa	Fraction of supply air to zone from sources outside zone, = Ep + (1-Ep)*Er	0.49	0.71	0.81	0.93	1.00	0.70	0.81	0.93	0.81	0.67	0.50
Fb	Fraction of supply air to zone from full mixed primary air, = Ep = Vpz/Vdz	0.49	0.42	0.38	0.33	0.33	0.39	0.38	0.33	0.38	0.33	0.50
Fc	Fraction of outdoor air to zone from sources outside zone, = 1 - (1-Ez) * (1-Er) * (1-Ep)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

SYSTEM LEVEL

Ps	System population, maximum simultaneous # of occupants of space served by system	600	
D	Occupant diversity, ratio of system peak occupancy to sum of space peak occupancies, = Ps/ΣPz	0.90	
Vou	Uncorrected outdoor air intake, = D*ΣRp*Pz +ΣRa*Az, cfm	8465	
Vps	Total system primary flow to all zones, Σ Vpz, cfm	20100	**Note: In VAV systems, Vps is equal to the fan airflow, and the formula in cell c40 needs to be replaced by this value.**
Xs	Mixing ratio at primary air handler of uncorrected outdoor air intake to system primary flow, = Vou/Vps	0.42	

SYSTEM EFFICIENCY

Evz	Zone ventilation efficiency, (Fa +Xs*Fb - Zd*Fc)/Fa	0.81	0.81	0.81	0.82	0.83	0.82	0.81	0.82	0.81	0.82	0.88
Ev	System ventilation efficiency, min(Evz)	0.81										

			Percent outdoor air intake	
Vot	**Minimum outdoor air intake, Vou/Ev, cfm**	**10485**	**52%**	= Vot/Vps

APPENDIX B:

RTU-2 (Continued)

	COMP LAB B215	SOC STDY	LD CLASS	MATH B222	MATH B223	HEALTH B224	SOC STDY	SOC STDY	SOC STDY	MATH B210	MATH B209	FACS CL B202	FAC PLAN	FACS LAB B225	LOUNGE B203	CORR B225	CORR B226
	Computer L	Classroom:	Classroom	Classroom	Classroom	Classroom:	Classroom:	Classroom:	Classroom:	Classroom	Classroom	Classroom	Classroom	Classroom:	Lobbies/pr	Corridors	Corridors
Az	1077	734	731	737	737	711	726	737	737	737	728	785	490	1839	206	2255	775
Pz	28	28	28	28	28	28	28	28	28	28	28	28	16	48	9	0	0
Rp	10	10	10	10	10	10	10	10	10	10	10	10	10	10	7.5	0	0
Ra	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.06	0.06	0.06
Pz*Rp	280	280	280	280	280	280	280	280	280	280	280	280	160	480	67.5	0	0
Az*Ra	129.24	88.08	87.72	88.44	88.44	85.32	87.12	88.44	88.44	88.44	87.36	94.2	58.8	220.68	12.36	135.3	46.5
Voz	409.24	368.08	367.72	368.44	368.44	365.32	367.12	368.44	368.44	368.44	367.36	374.2	218.8	700.68	79.86	135.3	46.5
Vpz	500	450	400	400	400	450	500	450	400	400	400	400	275	950	150	250	100
Vdz	1750	1200	1200	1200	1200	1200	1300	1200	1200	1200	1200	2400	2900	3400	300	500	250
Vdzm	1750	1200	1200	1200	1200	1200	1300	1200	1200	1200	1200	2400	2900	3400	300	500	250
Zd	0.23	0.31	0.31	0.31	0.31	0.30	0.28	0.31	0.31	0.31	0.31	0.16	0.08	0.21	0.27	0.27	0.19
Ep	0.29	0.38	0.33	0.33	0.33	0.38	0.38	0.38	0.33	0.33	0.33	0.17	0.09	0.28	0.50	0.50	0.40
Er	0.50	0.70	0.90	1.00	0.90	0.70	0.50	0.70	0.90	1.00	1.00	0.50	0.50	0.30	0.00	0.00	0.00
Ez	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fa	0.64	0.81	0.93	1.00	0.93	0.81	0.69	0.81	0.93	1.00	1.00	0.58	0.55	0.50	0.50	0.50	0.40
Fb	0.29	0.38	0.33	0.33	0.33	0.38	0.38	0.38	0.33	0.33	0.33	0.17	0.09	0.28	0.50	0.50	0.40
Fc	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Evz	0.82	0.82	0.82	0.83	0.82	0.82	0.83	0.82	0.82	0.83	0.83	0.85	0.94	0.82	0.89	0.88	0.96

APPENDIX B:

RTU-3

RESULTS		
Vot	Minimum outdoor air intake, Vou/Ev, cfm	3515
	Percent outdoor air intake, Vot/Vps	28%
Ev	System ventilation efficiency	0.50

ZONE LEVEL

	Zones served by system	GUIDANCE A124	GUIDANCE A125	GUIDANCE A126	GUIDANCE A122	GUIDANCE A123	CONF RM A127	WAIT CAR LAB	RECORDS A121	WORK RM A120	INTIN OFF A129	HEALTH CLIN	VICE PRIN
	Space type (select from pull-down list)	Office spac	Office spac	Office spac	Office spac	Office spac	Conferenc	Lobbies	Storage ro	Office spac	Office spac	Office spac	Office spac
Az	Floor area of zone, ft2	139	116	135	110	113	212	412	120	111	150	393	110
Pz	Zone population, largest # of people expected to occupy zone	4	4	4	4	4	6	11	0	2	4	8	4
Rp	People outdoor air rate from Table 6.1, cfm/person	10	5	5	5	5	5	5	0	5	5	5	5
Ra	Area outdoor air rate from Table 6.1, cfm/ft2	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.12	0.06	0.06	0.06	0.06
Pz*Rp		40	20	20	20	20	30	55	0	10	20	40	20
Az*Ra		8.34	6.96	8.1	6.6	6.78	12.72	24.72	14.4	6.66	9	23.58	6.6
Voz	Outdoor airflow to the zone corrected for zone air distribution effectiveness, (Pz*Rp + Az*Ra)/Ez, cfm	48.34	26.96	28.1	26.6	26.78	42.72	79.72	14.4	16.66	29	63.58	26.6
Vpz	Primary airflow to zone from air handler (intake plus recirculated air, but not local recirculation such as at mixing boxes), cfm. **In VAV systems, use the design**	100	100	100	50	50	75	125	50	50	50	100	250
Vdz	Supply/discharge to zone including primary air Vpz and locally recirculated air, cfm. **In VAV systems, use the design value.**	375	675	725	175	175	175	250	75	225	125	225	800
Vdzm	Minimum supply/discharge to zone used to calculate Ev, cfm. **In CAV systems, Vdzm = Vdz. In VAV systems, Vdzm is the minimum expected value of Vdz.**	375	675	725	175	175	175	250	75	225	125	225	800
Zd	Outdoor air fraction required in air discharged to zone, = Voz/Vdzm	0.13	0.04	0.04	0.15	0.15	0.24	0.32	0.19	0.07	0.23	0.28	0.03
Ep	Primary air fraction to zone, = Vpz/Vdz (=1 for single duct and single zone systems)	0.27	0.15	0.14	0.29	0.29	0.43	0.50	0.67	0.22	0.40	0.44	0.31
Er	Fraction of secondary recirc to zone representative of system average, only applies if Ep<1. For plenum return <=1. For duct return with local secondary recirc =0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ez	Zone air distribution effectiveness, Table 6.2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fa	Fraction of supply air to zone from sources outside zone, = Ep + (1-Ep)*Er	0.27	0.15	0.14	0.29	0.29	0.43	0.50	0.67	0.22	0.40	0.44	0.31
Fb	Fraction of supply air to zone from full mixed primary air, = Ep = Vpz/Vdz	0.27	0.15	0.14	0.29	0.29	0.43	0.50	0.67	0.22	0.40	0.44	0.31
Fc	Fraction of outdoor air to zone from sources outside zone, = 1 - (1-Ez) * (1-Er) * (1-Ep)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

SYSTEM LEVEL

Ps	System population, maximum simultaneous # of occupants of space served by system	140
D	Occupant diversity, ratio of system peak occupancy to sum of space peak occupancies, = Ps/ΣPz	0.92
Vou	Uncorrected outdoor air intake, = D*ΣRp*Pz +ΣRa*Az, cfm	1754
Vps	Total system primary flow to all zones, Σ Vpz, cfm	12585
Xs	Mixing ratio at primary air handler of uncorrected outdoor air intake to system primary flow, = Vou/Vps	0.14

Note: In VAV systems, Vps is equal to the fan airflow, and the formula in cell c40 needs to be replaced by this value.

SYSTEM EFFICIENCY

Evz	Zone ventilation efficiency, (Fa +Xs*Fb - Zd*Fc)/Fa	0.66	0.87	0.86	0.61	0.60	0.57	0.50	0.85	0.81	0.56	0.50	1.03
Ev	System ventilation efficiency, min(Evz)	0.50											

			Percent outdoor air intake	
Vot	**Minimum outdoor air intake, Vou/Ev, cfm**	**3515**	**28%**	= Vot/Vps

APPENDIX B:

RTU-3 (Continued)

	PRINCIPAL B106	FIN OFFICE	GEN OFFICE	ATTEN OFF	WORK RM	CONF B103A	RECEPT B103C	SPL ED CONF	SPL ED OFF	VICE PRIN	VICE PRIN	LOUNGE B114A	FAC PLAN	CORR B133	CORR B134	CORR D102	LOBBY B101	CORR H112
	Office spac	Office spac	Office space	Office spac	Office spac	Conference	Reception a	Conference	Office spa	Office spa	Office spa	Lobbies	Office spac	Corridors	Corridors	Corridors	Main entry	Corridors
Az	217	71	334	110	138	272	223	252	182	118	114	239	446	2320	403	4394	2969	2226
Pz	8	1	12	2	2	12	8	8	2	4	4	11	16	0	0	0	8	0
Rp	5	5	5	5	5	5	5	5	5	5	5	5	5	0	0	0	5	0
Ra	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Pz*Rp	40	5	60	10	10	60	40	40	10	20	20	55	80	0	0	0	40	0
Az*Ra	13.02	4.26	20.04	6.6	8.28	16.32	13.38	15.12	10.92	7.08	6.84	14.34	26.76	139.2	24.18	263.64	178.14	133.56
Voz	53.02	9.26	80.04	16.6	18.28	76.32	53.38	55.12	20.92	27.08	26.84	69.34	106.76	139.2	24.18	263.64	218.14	133.56
Vpz	310	50	125	50	50	120	100	100	50	75	75	120	175	225	50	500	350	250
Vdz	1020	125	375	125	200	260	200	250	125	250	250	390	490	600	200	2150	700	875
Vdzm	1020	125	375	125	200	260	200	250	125	250	250	390	490	600	200	2150	700	875
Zd	0.05	0.07	0.21	0.13	0.09	0.29	0.27	0.22	0.17	0.11	0.11	0.18	0.22	0.23	0.12	0.12	0.31	0.15
Ep	0.30	0.40	0.33	0.40	0.25	0.46	0.50	0.40	0.40	0.30	0.30	0.31	0.36	0.38	0.25	0.23	0.50	0.29
Er	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ez	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fa	0.30	0.40	0.33	0.40	0.25	0.46	0.50	0.40	0.40	0.30	0.30	0.31	0.36	0.38	0.25	0.23	0.50	0.29
Fb	0.30	0.40	0.33	0.40	0.25	0.46	0.50	0.40	0.40	0.30	0.30	0.31	0.36	0.38	0.25	0.23	0.50	0.29
Fc	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Evz	0.97	0.95	0.50	0.81	0.77	0.50	0.61	0.59	0.72	0.78	0.78	0.56	0.53	0.52	0.66	0.61	0.52	0.61

APPENDIX B:

RTU-4

RESULTS		
Vot	**Minimum outdoor air intake, Vou/Ev, cfm**	**10432**
	Percent outdoor air intake, Vot/Vps	**47%**
Ev	**System ventilation efficiency**	**0.55**

ZONE LEVEL

	Zones served by system	**INFO TECH**	**INST PLAN**	**TECH LAB OFF**	**CONT RM G120**	**VIS COMM PROD**	**FOREN LAB G118**	**PREP G118A**	**BUS CLASS**	**CADD LAB G116**	**KEY LAB G110**	**COMP LAB G103**
	Space type (select from pull-down list)	Computer l	Office spac	Office spac	Computer l	Computer L	Science lab	Computer	Classrooms	Computer l	Computer L	Computer L
Az	Floor area of zone, ft2	1262	263	1040	395	1150	1153	221	926	1240	1040	1345
Pz	Zone population, largest # of people expected to occupy zone	41	32	32	12	30	25	2	30	30	32	32
Rp	People outdoor air rate from Table 6.1, cfm/person	10	5	5	10	10	10	5	10	10	10	10
Ra	Area outdoor air rate from Table 6.1, cfm/ft2	0.12	0.06	0.06	0.12	0.12	0.18	0.06	0.12	0.12	0.12	0.12
Pz*Rp		410	160	160	120	300	250	10	300	300	320	320
Az*Ra		151.44	15.78	62.4	47.4	138	207.54	13.26	111.12	148.8	124.8	161.4
Voz	Outdoor airflow to the zone corrected for zone air distribution effectiveness, (Pz*Rp + Az*Ra)/Ez, cfm	561.44	175.78	222.4	167.4	438	457.54	23.26	411.12	448.8	444.8	481.4
Vpz	Primary airflow to zone from air handler (intake plus recirculated air, but not local recirculation such as at mixing boxes), cfm. **In VAV systems, use the design**	625	200	250	200	450	525	260	425	450	500	500
Vdz	Supply/discharge to zone including primary air Vpz and locally recirculated air, cfm. **In VAV systems, use the design value.**	1375	750	1725	560	1475	1050	260	1200	1830	1725	1775
Vdzm	Minimum supply/discharge to zone used to calculate Ev, cfm. **In CAV systems, Vdzm = Vdz. In VAV systems, Vdzm is the minimum expected value of Vdz.**	1375	750	1725	560	1475	1050	260	1200	1830	1725	1775
Zd	Outdoor air fraction required in air discharged to zone, = Voz/Vdzm	0.41	0.23	0.13	0.30	0.30	0.44	0.09	0.34	0.25	0.26	0.27
Ep	Primary air fraction to zone, = Vpz/Vdz (=1 for single duct and single zone systems)	0.45	0.27	0.14	0.36	0.31	0.50	1.00	0.35	0.25	0.29	0.28
Er	Fraction of secondary recirc to zone representative of system average, only applies if Ep<1. For plenum return <=1. For duct return with local secondary recirc =0.	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Ez	Zone air distribution effectiveness, Table 6.2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fa	Fraction of supply air to zone from sources outside zone, = Ep + (1-Ep)*Er	0.73	0.63	0.57	0.68	0.65	0.75	1.00	0.68	0.62	0.64	0.64
Fb	Fraction of supply air to zone from full mixed primary air, = Ep = Vpz/Vdz	0.45	0.27	0.14	0.36	0.31	0.50	1.00	0.35	0.25	0.29	0.28
Fc	Fraction of outdoor air to zone from sources outside zone, = 1 - (1-Ez) * (1-Er) * (1-Ep)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

SYSTEM LEVEL

Ps	System population, maximum simultaneous # of occupants of space served by system	390	
D	Occupant diversity, ratio of system peak occupancy to sum of space peak occupancies, = Ps/ΣPz	0.84	
Vou	Uncorrected outdoor air intake, = D*ΣRp*Pz +ΣRa*Az, cfm	5739	
Vps	Total system primary flow to all zones, Σ Vpz, cfm	22000	**Note: In VAV systems, Vps is equal to the fan airflow, and the formula in cell c40 needs to be replaced by this value.**
Xs	Mixing ratio at primary air handler of uncorrected outdoor air intake to system primary flow, = Vou/Vps	0.26	

SYSTEM EFFICIENCY

Evz	Zone ventilation efficiency, (Fa +Xs*Fb - Zd*Fc)/Fa	0.60	0.74	0.84	0.70	0.67	0.59	1.17	0.63	0.71	0.72	0.69
Ev	System ventilation efficiency, min(Evz)	0.55										

			Percent outdoor air intake	
Vot	**Minimum outdoor air intake, Vou/Ev, cfm**	**10432**	**47%**	= Vot/Vps

APPENDIX B:

RTU-4 (Continued)

	MAR CLASS	SCH STORE	OFFICE G104A	DIG COMM G117	DIG PROD LAB G108	OFFICE G116A	OFFICE G107B	TECH ED LAB G106	TECH ED PROD	VIDEO CONF	MEDIA RM G122	CORR G129	CORR G128	CORR G129	CORR G126	CORR G127
	Classrooms (	Office space	Office spac	Classrooms	Computer L	Office spac	Office spac	Classroom	Wood/metal	Conference	Classroom	Corridors	Corridors	Corridors	Corridors	Corridors
Az	753	357	106	997	1067	139	129	1358	899	734	204	341	1762	319	580	800
Pz	28	4	1	36	30	2	1	36	20	9	2	0	0	0	0	0
Rp	10	5	5	10	10	5	5	10	10	5	10	0	0	0	0	0
Ra	0.12	0.06	0.06	0.12	0.12	0.06	0.06	0.12	0.18	0.06	0.12	0.06	0.06	0.06	0.06	0.06
Pz*Rp	280	20	5	360	300	10	5	360	200	45	20	0	0	0	0	0
Az*Ra	90.36	21.42	6.36	119.64	128.04	8.34	7.74	162.96	161.82	44.04	24.48	20.46	105.72	19.14	34.8	48
Voz	370.36	41.42	11.36	479.64	428.04	18.34	12.74	522.96	361.82	89.04	44.48	20.46	105.72	19.14	34.8	48
Vpz	475	50	50	500	450	50	50	625	400	100	100	50	150	50	50	50
Vdz	1200	160	120	1450	1780	125	100	975	975	390	310	100	900	150	290	400
Vdzm	1200	160	120	1450	1780	125	100	975	975	390	310	100	900	150	290	400
Zd	0.31	0.26	0.09	0.33	0.24	0.15	0.13	0.54	0.37	0.23	0.14	0.20	0.12	0.13	0.12	0.12
Ep	0.40	0.31	0.42	0.34	0.25	0.40	0.50	0.64	0.41	0.26	0.32	0.50	0.17	0.33	0.17	0.13
Er	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Ez	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fa	0.70	0.66	0.71	0.67	0.63	0.70	0.75	0.82	0.71	0.63	0.66	0.75	0.58	0.67	0.59	0.56
Fb	0.40	0.31	0.42	0.34	0.25	0.40	0.50	0.64	0.41	0.26	0.32	0.50	0.17	0.33	0.17	0.13
Fc	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Evz	0.71	0.73	1.02	0.64	0.72	0.94	1.00	0.55	0.63	0.74	0.91	0.90	0.87	0.94	0.87	0.84

APPENDIX B:

RTU-6

RESULTS		
Vot	Minimum outdoor air intake, Vou/Ev, cfm	2380
	Percent outdoor air intake, Vot/Vps	40%
Ev	System ventilation efficiency	0.74

ZONE LEVEL

	Zones served by system	READ STACK	COMP RES H109	MEDIA RM DIST	WORK RM H102	LIBRARIA N H106	AV EQUIP H104	PER STOR H105	CORR/VES T H111/101
	Space type (select from pull-down list)	Libraries	Computer l	Media Cent	Office spac	Libraries	Storage roo	Storage roo	Corridors
Az	Floor area of zone, ft2	3038	877	497	232	273	301	331	471
Pz	Zone population, largest # of people expected to occupy zone	60	30	20	4	6	0	0	0
Rp	People outdoor air rate from Table 6.1, cfm/person	10	10	10	5	5	0	0	0
Ra	Area outdoor air rate from Table 6.1, cfm/ft2	0.12	0.12	0.12	0.06	0.12	0.12	0.12	0.06
Pz*Rp		600	300	200	20	30	0	0	0
Az*Ra		364.56	105.24	59.64	13.92	32.76	36.12	32.76	18.06
Voz	Outdoor airflow to the zone corrected for zone air distribution effectiveness, (Pz*Rp + Az*Ra)/Ez, cfm	964.56	405.24	259.64	33.92	62.76	36.12	32.76	18.06
Vpz	Primary airflow to zone from air handler (intake plus recirculated air, but not local recirculation such as at mixing boxes), cfm. **In VAV systems, use the design**	1050	500	350	50	125	75	75	50
Vdz	Supply/discharge to zone including primary air Vpz and locally recirculated air, cfm. **In VAV systems, use the design value.**	5250	1600	600	180	200	150	100	100
Vdzm	Minimum supply/discharge to zone used to calculate Ev, cfm. **In CAV systems, Vdzm = Vdz. In VAV systems, Vdzm is the minimum expected value of Vdz.**	5250	1600	600	180	200	150	100	100
Zd	Outdoor air fraction required in air discharged to zone, = Voz/Vdzm	0.18	0.25	0.43	0.19	0.31	0.24	0.33	0.18
Ep	Primary air fraction to zone, = Vpz/Vdz (=1 for single duct and single zone systems)	0.20	0.31	0.58	0.28	0.63	0.50	0.75	0.50
Er	Fraction of secondary recirc to zone representative of system average, only applies if Ep<1. For plenum return <=1. For duct return with local secondary recirc =0.	0.70	0.70	1.00	0.70	0.00	0.00	0.00	0.00
Ez	Zone air distribution effectiveness, Table 6.2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fa	Fraction of supply air to zone from sources outside zone, = Ep + (1-Ep)*Er	0.76	0.79	1.00	0.78	0.63	0.50	0.75	0.50
Fb	Fraction of supply air to zone from full mixed primary air, = Ep = Vpz/Vdz	0.20	0.31	0.58	0.28	0.63	0.50	0.75	0.50
Fc	Fraction of outdoor air to zone from sources outside zone, = 1 - (1-Ez) * (1-Er) * (1-Ep)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

SYSTEM LEVEL

Ps	System population, maximum simultaneous # of occupants of space served by system	115
D	Occupant diversity, ratio of system peak occupancy to sum of space peak occupancies, = Ps/ΣPz	0.96
Vou	Uncorrected outdoor air intake, = D*ΣRp*Pz +ΣRa*Az, cfm	1765
Vps	Total system primary flow to all zones, Σ Vpz, cfm	5900
Xs	Mixing ratio at primary air handler of uncorrected outdoor air intake to system primary flow, = Vou/Vps	0.30

Note: In VAV systems, Vps is equal to the fan airflow, and the formula in cell c40 needs to be replaced by this value.

SYSTEM EFFICIENCY

Evz	Zone ventilation efficiency, (Fa +Xs*Fb - Zd*Fc)/Fa	0.84	0.80	0.74	0.87	0.80	0.82	0.86	0.94
Ev	System ventilation efficiency, min(Evz)	0.74							

			Percent outdoor air intake	
Vot	**Minimum outdoor air intake, Vou/Ev, cfm**	**2380**	**40%**	= Vot/Vps

APPENDIX B:

RTU-7

RESULTS		
Vot	Minimum outdoor air intake, Vou/Ev, cfm	6342
	Percent outdoor air intake, Vot/Vps	53%
Ev	System ventilation efficiency	0.59

ZONE LEVEL

	Zones served by system	DANCE STUD F120	CHOR MUS F117	INST OFF F117A	IP F117B	MUSIC LIB F117C	BAND REH F112	ENS RM F110	INST OFF F115	INST OFF F114
	Space type (select from pull-down list)	Music/theater	Music/theate	Office spac	Office sp	Storage roo	Music/theal	Music/theate	Office space	Office spa
Az	Floor area of zone, ft2	980	1209	129	76	101	3099	556	120	127
Pz	Zone population, largest # of people expected to occupy zone	30	46	1	3	0	152	26	1	1
Rp	People outdoor air rate from Table 6.1, cfm/person	10	10	5	5	0	10	10	5	5
Ra	Area outdoor air rate from Table 6.1, cfm/ft2	0.06	0.06	0.06	0.06	0.12	0.06	0.06	0.06	0.06
Pz*Rp		300	460	5	15	0	1520	260	5	5
Az*Ra		58.8	72.54	7.74	4.56	12.12	185.94	33.36	7.2	7.62
Voz	Outdoor airflow to the zone corrected for zone air distribution effectiveness, (Pz*Rp + Az*Ra)/Ez, cfm	358.8	532.54	12.74	19.56	12.12	1705.94	293.36	12.2	12.62
Vpz	Primary airflow to zone from air handler (intake plus recirculated air, but not local recirculation such as at mixing boxes), cfm. **In VAV systems, use the design**	400	650	50	50	50	1950	350	50	50
Vdz	Supply/discharge to zone including primary air Vpz and locally recirculated air, cfm. **In VAV systems, use the design value.**	1260	950	100	100	100	3000	575	100	100
Vdzm	Minimum supply/discharge to zone used to calculate Ev, cfm. **In CAV systems, Vdzm = Vdz. In VAV systems, Vdzm is the minimum expected value of Vdz.**	1260	950	100	100	100	3000	575	100	100
Zd	Outdoor air fraction required in air discharged to zone, = Voz/Vdzm	0.28	0.56	0.13	0.20	0.12	0.57	0.51	0.12	0.13
Ep	Primary air fraction to zone, = Vpz/Vdz (=1 for single duct and single zone systems)	0.32	0.68	0.50	0.50	0.50	0.65	0.61	0.50	0.50
Er	Fraction of secondary recirc to zone representative of system average, only applies if Ep<1. For plenum return <=1. For duct return with local secondary recirc =0.	0.50	0.50	0.00	0.00	0.50	1.00	1.00	0.00	0.00
Ez	Zone air distribution effectiveness, Table 6.2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fa	Fraction of supply air to zone from sources outside zone, = Ep + (1-Ep)*Er	0.66	0.84	0.50	0.50	0.75	1.00	1.00	0.50	0.50
Fb	Fraction of supply air to zone from full mixed primary air, = Ep = Vpz/Vdz	0.32	0.68	0.50	0.50	0.50	0.65	0.61	0.50	0.50
Fc	Fraction of outdoor air to zone from sources outside zone, = 1 - (1-Ez) * (1-Er) * (1-Ep)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

SYSTEM LEVEL

Ps	System population, maximum simultaneous # of occupants of space served by system	280
D	Occupant diversity, ratio of system peak occupancy to sum of space peak occupancies, = Ps/ΣPz	0.79
Vou	Uncorrected outdoor air intake, = D*ΣRp*Pz +ΣRa*Az, cfm	3735
Vps	Total system primary flow to all zones, Σ Vpz, cfm	11920
Xs	Mixing ratio at primary air handler of uncorrected outdoor air intake to system primary flow, = Vou/Vps	0.31

Note: In VAV systems, Vps is equal to the fan airflow, and the formula in cell c40 needs to be replaced by this value.

SYSTEM EFFICIENCY

Evz	Zone ventilation efficiency, (Fa +Xs*Fb - Zd*Fc)/Fa	0.72	0.59	1.06	0.92	1.05	0.64	0.68	1.07	1.06
Ev	System ventilation efficiency, min(Evz)	0.59								

			Percent outdoor air intake	
Vot	**Minimum outdoor air intake, Vou/Ev, cfm**	**6342**	**53%**	= Vot/Vps

APPENDIX B:

RTU-7 (Continued)

	MUSIC LIB F112D	IP F112A	IP F112C	DRESS RM F130	DRESS RM F129	SHOP F128	CERAMIC S F109	ART RM F108	GRAB N GO F106	TICKET F102	CORR F133	CORR F135	CORR F134	BA/GUA ST F112B
	Storage roon	Office sp	Office sp	Office spac	Office spac	Art classr	Art classro	Art classro	Office space	Office spac	Corridors	Corridors	Corridors	Storage roo
Az	112	56	55	488	487	197	517	1569	260	112	1206	1201	885	405
Pz	0	2	2	20	20	2	15	30	2	2	0	0	0	0
Rp	0	5	5	5	5	10	10	10	5	5	0	0	0	0
Ra	0.12	0.06	0.06	0.06	0.06	0.18	0.18	0.18	0.06	0.06	0.06	0.06	0.06	0.12
Pz*Rp	0	10	10	100	100	20	150	300	10	10	0	0	0	0
Az*Ra	13.44	3.36	3.3	29.28	29.22	35.46	93.06	282.42	15.6	6.72	72.36	72.06	53.1	48.6
Voz	13.44	13.36	13.3	129.28	129.22	55.46	243.06	582.42	25.6	16.72	72.36	72.06	53.1	48.6
Vpz	50	50	50	200	200	75	300	600	50	50	100	100	75	75
Vdz	100	100	100	400	400	210	425	2000	250	200	225	225	850	150
Vdzm	100	100	100	400	400	210	425	2000	250	200	225	225	850	150
Zd	0.13	0.13	0.13	0.32	0.32	0.26	0.57	0.29	0.10	0.08	0.32	0.32	0.06	0.32
Ep	0.50	0.50	0.50	0.50	0.50	0.36	0.71	0.30	0.20	0.25	0.44	0.44	0.09	0.50
Er	0.00	0.00	0.00	0.00	0.00	0.50	1.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00
Ez	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fa	0.50	0.50	0.50	0.50	0.50	0.68	1.00	0.65	0.20	0.25	0.44	0.44	0.09	0.50
Fb	0.50	0.50	0.50	0.50	0.50	0.36	0.71	0.30	0.20	0.25	0.44	0.44	0.09	0.50
Fc	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Evz	1.04	1.05	1.05	0.67	0.67	0.78	0.65	0.70	0.80	0.98	0.59	0.59	0.61	0.67

APPENDIX B:

RTU-8

ZONE LEVEL

		Zones served by system Auditorium Stage	
	Space type (select from pull-down list)	Music/theater/dance	
Az	Floor area of zone, ft2	2691	
Pz	Zone population, largest # of people expected to occupy zone	70	
Rp	Area outdoor air rate from Table 6.1, cfm/ft2	10	
Ra	People outdoor air rate from Table 6.1, cfm/person	0.06	
Pz*Rp		700	
Az*Ra		161.46	
Ez	Zone air distribution effectiveness, Table 6.2	1	
Voz	Outdoor airflow to the zone corrected for zone air distribution effectiveness, (Pz*Rp + Az*Ra)/Ez, cfm	861	
Vpz	Primary airflow to zone from air handler. **In VAV systems, use the design value.** cfm	4500	
Vpzm	The minimum value of the primary airflow to zone from air handler. **In CAV systems, Vpzm = Vpz.** cfm	4500	
Zp	Primary outdoor air fraction, Voz/Vpzm	0.19	

SYSTEM LEVEL

Ps	System population, maximum simultaneious # of occupants of space served by system	70	
D	Occupant diversity, ratio of system peak occupancy to sum of space peak occupancies, = Ps/ΣPz	1.00	
Vou	Uncorrected outdoor air intake, = D*ΣRp*Pz +ΣRa*Az,	861	
Xs	Mixing ratio at primary air handler of uncorrected outdoor air intake to system primary flow, = Vou/Vps	0.19	Not used in calculation

SYSTEM EFFICIENCY

Max Zp	Max Zp	0.19	
Ev	System ventilation efficiency, Table 6.3 based on maxZp	0.90	
			Percent outdoor air intake
Vot	**Minimum outdoor air intake, Vou/Ev, cfm**	**957**	**21%** = Vot/Sum of Vpz

APPENDIX B:

RTU-9

ZONE LEVEL

		Zones served by system Auditorium	
	Space type (select from pull-down list)	Multi-use Assembly	
Az	Floor area of zone, ft2	4564	
Pz	Zone population, largest # of people expected to occupy zone	511	
Rp	Area outdoor air rate from Table 6.1, cfm/ft2	7.5	
Ra	People outdoor air rate from Table 6.1, cfm/person	0.06	
Pz*Rp		3832.5	
Az*Ra		273.84	
Ez	Zone air distribution effectiveness, Table 6.2	1	
Voz	Outdoor airflow to the zone corrected for zone air distribution effectiveness, (Pz*Rp + Az*Ra)/Ez, cfm	4106	
Vpz	Primary airflow to zone from air handler. **In VAV systems, use the design value.** cfm	9000	
Vpzm	The minimum value of the primary airflow to zone from air handler. **In CAV systems, Vpzm = Vpz.** cfm	9000	
Zp	Primary outdoor air fraction, Voz/Vpzm	0.46	

SYSTEM LEVEL

Ps	System population, maximum simultaneious # of occupants of space served by system	511	
D	Occupant diversity, ratio of system peak occupancy to sum of space peak occupancies, = Ps/ΣPz	1.00	
Vou	Uncorrected outdoor air intake, = D*ΣRp*Pz +ΣRa*Az,	4106	
Xs	Mixing ratio at primary air handler of uncorrected outdoor air intake to system primary flow, = Vou/Vps	0.46	Not used in calculation

SYSTEM EFFICIENCY

Max Zp	Max Zp	0.46	
Ev	System ventilation efficiency, Table 6.3 based on maxZp	0.60	
			Percent outdoor air intake
Vot	**Minimum outdoor air intake, Vou/Ev, cfm**	**6844**	**76%** = Vot/Sum of Vpz

APPENDIX B:

RTU-10

ZONE LEVEL

		Zones served by system	**Cafeteria**	
	Space type (select from pull-down list)	Cafeteria / fast food dining		
Az	Floor area of zone, ft2	6992		
Pz	Zone population, largest # of people expected to occupy zone	500		
Rp	Area outdoor air rate from Table 6.1, cfm/ft2	7.5		
Ra	People outdoor air rate from Table 6.1, cfm/person	0.18		
Pz*Rp		3750		
Az*Ra		1258.56		
Ez	Zone air distribution effectiveness, Table 6.2	1		
Voz	Outdoor airflow to the zone corrected for zone air distribution effectiveness, (Pz*Rp + Az*Ra)/Ez, cfm	5009		
Vpz	Primary airflow to zone from air handler. **In VAV systems, use the design value.** cfm	13000		
Vpzm	The minimum value of the primary airflow to zone from air handler. **In CAV systems, Vpzm = Vpz.** cfm	13000		
Zp	Primary outdoor air fraction, Voz/Vpzm	0.39		

SYSTEM LEVEL

Ps	System population, maximum simultaneious # of occupants of space served by system	500	
D	Occupant diversity, ratio of system peak occupancy to sum of space peak occupancies, = Ps/ΣPz	1.00	
Vou	Uncorrected outdoor air intake, = D*ΣRp*Pz +ΣRa*Az,	5009	
Xs	Mixing ratio at primary air handler of uncorrected outdoor air intake to system primary flow, = Vou/Vps	0.39	Not used in calculation

SYSTEM EFFICIENCY

Max Zp	Max Zp	0.39		
Ev	System ventilation efficiency, Table 6.3 based on maxZp	0.70		
			Percent outdoor air intake	
Vot	**Minimum outdoor air intake, Vou/Ev, cfm**	**7155**	**55%**	= Vot/Sum of Vpz

APPENDIX B:

RTU-11

RESULTS		
Vot	**Minimum outdoor air intake, Vou/Ev, cfm**	**10485**
	Percent outdoor air intake, Vot/Vps	**52%**
Ev	**System ventilation efficiency**	**0.81**

ZONE LEVEL

	Zones served by system	**WORKR M B120**	**LD CLASS**	**LANG ART**	**LANG ART**	**MOD MENT**	**FOR LANG**	**FOR LANG**	**LANG ART**	**LANG ART**	**BD CLASS B130**	**CORR B133**
	Space type (select from pull-down list)	Office spa	Classroom	Classroom	Classroom	Classrooms	Classroom	Classroom	Classroom	Classroom	Classrooms	Corridors
Az	Floor area of zone, ft2	239	746	750	750	750	868	750	747	750	799	1120
Pz	Zone population, largest # of people expected to occupy zone	9	28	28	28	28	30	28	28	28	22	0
Rp	People outdoor air rate from Table 6.1, cfm/person	10	10	10	10	10	10	10	10	10	10	0
Ra	Area outdoor air rate from Table 6.1, cfm/ft2	0.06	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.06
Pz*Rp		90	280	280	280	280	300	280	280	280	220	0
Az*Ra		14.34	89.52	90	90	90	104.16	90	89.64	90	95.88	67.2
Voz	Outdoor airflow to the zone corrected for zone air distribution effectiveness, (Pz*Rp + Az*Ra)/Ez, cfm	104.34	369.52	370	370	370	404.16	370	369.64	370	315.88	67.2
Vpz	Primary airflow to zone from air handler (intake plus recirculated air, but not local recirculation such as at mixing boxes), cfm. **In VAV systems, use the design**	170	500	450	400	400	550	450	400	450	400	125
Vdz	Supply/discharge to zone including primary air Vpz and locally recirculated air, cfm. **In VAV systems, use the design value.**	350	1200	1200	1200	1200	1400	1200	1200	1200	1200	250
Vdzm	Minimum supply/discharge to zone used to calculate Ev, cfm. **In CAV systems, Vdzm = Vdz. In VAV systems, Vdzm is the minimum expected value of Vdz.**	350	1200	1200	1200	1200	1400	1200	1200	1200	1200	250
Zd	Outdoor air fraction required in air discharged to zone, = Voz/Vdzm	0.30	0.31	0.31	0.31	0.31	0.29	0.31	0.31	0.31	0.26	0.27
Ep	Primary air fraction to zone, = Vpz/Vdz (=1 for single duct and single zone systems)	0.49	0.42	0.38	0.33	0.33	0.39	0.38	0.33	0.38	0.33	0.50
Er	Fraction of secondary recirc to zone representative of system average, only applies if Ep<1. For plenum return <=1. For duct return with local secondary recirc =0.	0.00	0.50	0.70	0.90	1.00	0.50	0.70	0.90	0.70	0.50	0.00
Ez	Zone air distribution effectiveness, Table 6.2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fa	Fraction of supply air to zone from sources outside zone, = Ep + (1-Ep)*Er	0.49	0.71	0.81	0.93	1.00	0.70	0.81	0.93	0.81	0.67	0.50
Fb	Fraction of supply air to zone from full mixed primary air, = Ep = Vpz/Vdz	0.49	0.42	0.38	0.33	0.33	0.39	0.38	0.33	0.38	0.33	0.50
Fc	Fraction of outdoor air to zone from sources outside zone, = 1 - (1-Ez) * (1-Er) * (1-Ep)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

SYSTEM LEVEL

Ps	System population, maximum simultaneous # of occupants of space served by system	600
D	Occupant diversity, ratio of system peak occupancy to sum of space peak occupancies, = Ps/ΣPz	0.90
Vou	Uncorrected outdoor air intake, = D*ΣRp*Pz +ΣRa*Az, cfm	8465
Vps	Total system primary flow to all zones, Σ Vpz, cfm	20100
Xs	Mixing ratio at primary air handler of uncorrected outdoor air intake to system primary flow, = Vou/Vps	0.42

Note: In VAV systems, Vps is equal to the fan airflow, and the formula in cell c40 needs to be replaced by this value.

SYSTEM EFFICIENCY

Evz	Zone ventilation efficiency, (Fa +Xs*Fb - Zd*Fc)/Fa	0.81	0.81	0.81	0.82	0.83	0.82	0.81	0.82	0.81	0.82	0.88
Ev	System ventilation efficiency, min(Evz)	0.81										

			Percent outdoor air intake	
Vot	**Minimum outdoor air intake, Vou/Ev, cfm**	**10485**	**52%**	= Vot/Vps

APPENDIX B:

RTU-13

ZONE LEVEL

		Zones served by system Gymnasium 1	
	Space type (select from pull-down list)	Gym, stadium (play area)	
Az	Floor area of zone, ft2	6492	
Pz	Zone population, largest # of people expected to occupy zone	650	
Rp	Area outdoor air rate from Table 6.1, cfm/ft2	0	
Ra	People outdoor air rate from Table 6.1, cfm/person	0.3	
Pz*Rp		0	
Az*Ra		1947.6	
Ez	Zone air distribution effectiveness, Table 6.2	1	
Voz	Outdoor airflow to the zone corrected for zone air distribution effectiveness, (Pz*Rp + Az*Ra)/Ez, cfm	1948	
Vpz	Primary airflow to zone from air handler. **In VAV systems, use the design value.** cfm	9500	
Vpzm	The minimum value of the primary airflow to zone from air handler. **In CAV systems, Vpzm = Vpz.** cfm	9500	
Zp	Primary outdoor air fraction, Voz/Vpzm	0.21	

SYSTEM LEVEL

Ps	System population, maximum simultaneious # of occupants of space served by system	650	
D	Occupant diversity, ratio of system peak occupancy to sum of space peak occupancies, = Ps/ΣPz	1.00	
Vou	Uncorrected outdoor air intake, = D*ΣRp*Pz +ΣRa*Az,	1948	
Xs	Mixing ratio at primary air handler of uncorrected outdoor air intake to system primary flow, = Vou/Vps	0.21	Not used in calculation

SYSTEM EFFICIENCY

Max Zp	Max Zp	0.21	
Ev	System ventilation efficiency, Table 6.3 based on maxZp	0.90	
			Percent outdoor air intake
Vot	**Minimum outdoor air intake, Vou/Ev, cfm**	**2164**	**23%** = Vot/Sum of Vpz

APPENDIX B:

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ZONE LEVEL

		Zones served by system Gymnasium 2	
	Space type (select from pull-down list)	Gym, stadium (play area)	
Az	Floor area of zone, ft2	6492	
Pz	Zone population, largest # of people expected to occupy zone	650	
Rp	Area outdoor air rate from Table 6.1, cfm/ft2	0	
Ra	People outdoor air rate from Table 6.1, cfm/person	0.3	
Pz*Rp		0	
Az*Ra		1947.6	
Ez	Zone air distribution effectiveness, Table 6.2	1	
Voz	Outdoor airflow to the zone corrected for zone air distribution effectiveness, (Pz*Rp + Az*Ra)/Ez, cfm	1948	
Vpz	Primary airflow to zone from air handler. **In VAV systems, use the design value.** cfm	9500	
Vpzm	The minimum value of the primary airflow to zone from air handler. **In CAV systems, Vpzm = Vpz.** cfm	9500	
Zp	Primary outdoor air fraction, Voz/Vpzm	0.21	

SYSTEM LEVEL

Ps	System population, maximum simultaneious # of occupants of space served by system	650	
D	Occupant diversity, ratio of system peak occupancy to sum of space peak occupancies, = Ps/ΣPz	1.00	
Vou	Uncorrected outdoor air intake, = D*ΣRp*Pz +ΣRa*Az,	1948	
Xs	Mixing ratio at primary air handler of uncorrected outdoor air intake to system primary flow, = Vou/Vps	0.21	Not used in calculation

SYSTEM EFFICIENCY

Max Zp	Max Zp	0.21	
Ev	System ventilation efficiency, Table 6.3 based on maxZp	0.90	
			Percent outdoor air intake
Vot	**Minimum outdoor air intake, Vou/Ev, cfm**	**2164**	**23%** = Vot/Sum of Vpz