Technical Report 1

ASHRAE Std. 62.1 & 90.1 Analysis

Steelstacks Preforming Arts Center

Bethlehem, Pa

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Executive Summary

The American Society of Heating, Refrigeration, and Air-Conditioning Engineers Standards 62.1 and 90.1 provide the basis for building ventilation and provide proper energy efficiency standards to buildings. This report is to analyze the Steelstacks Performing Arts Center and find out if it has met and exceed all of the provided standards. The Steelstacks building is a 67,000 square foot building located in Bethlehem, Pennsylvania on the old Bethlehem Steel campus. The building has a variety of spaces including, two Cinemas, a multipurpose Blast Furnace Room for social and corporate events, as well a large common area to relax and eat. Steelstacks will host a variety of events from rock and jazz concerts to movies to Arts & Antique Markets and Musikfest.

The ASHRAE Standard 62.1-2007 compliance analysis showed that the Steelstacks building is in total compliance with the standard entirely. Section 5 showed that Steelstacks has an acceptable indoor air quality environment. Sections 6 calculations proved that the ventilation rates were of an acceptable quality for ASHRAE standards.

The ASHRAE Standard 90.1-2007 compliance analysis showed that the Steelstacks building is in full compliance with this standard. It showed it had ample sizing for all of its equipment as well as allowable power densities within the building.

The Steelstacks Performing Arts Center was designed with LEED in mind, and upon completion they are expecting to achieve LEED Gold. Due to this, many areas of the building systems were taking into account when designing and many were overdesigned in such areas of insulation and building systems. Much of this will be covered In Technical Report 2, but some relevant information will be described in this Report. This is the main reason that all of the standards were in compliance with both of the ASHRAE standards.

Mechanical Overview

The Steelstacks Performing Arts Center has six Carrier packaged rooftop units which provide most of the conditioning for the spaces, ranging from 3-55 tons. Three of the packaged systems have energy recovery wheels. Along with these systems, it also has a split AHU system to exclusively serve the Blast Furnace Room (The blast furnace room is a hall that is used for large gathering, and looks out onto the previously used Blast Furnaces of Bethlehem Steel). The Steelstacks also utilizes a mini-split system for additional temperature controls to the smaller areas of the buildings; these units are fed by 3 small condensing units on the fourth floor. The Steelstacks building also includes one make-up air unit for the Kitchen areas due to the large amount of exhaust coming from this area.

The domestic hot water system is provided by two parallel gas fired water heaters located on the fourth floor. Each water heater has capacity for 130 gallons of water and can heat up to 349 gallons per hour of 100°F water. The heater operates at a maximum supply temperature of 140°F and return temperature of 40°F. Water is circulated through the building by a .167 HP and 7.5GPM pump.

ASHRAE 62.1-2007 Overview

ASHRAE 62.1 prescribes the minimum requirements for outside ventilation air and indoor air qualities for a building. Section 5 and Section 6 are applied below to the Steelstacks Performing Arts Center in Bethlehem Pennsylvania.

ASHRAE 62.1-Section 5- Systems and Equipment

Section 5.1- Natural Ventilation

Steelstacks does not have any rooms that have a natural ventilation option. The only windows in the building are large viewing windows that overlook the sites of Bethlehem.

Section 5.2- Ventilation Air Distribution

Specification 23.0093-1.6F states that the when the supply fan is enable and the NTFC enthalpy calculation determines that outdoor are conditions are unsuitable for using atmospheric cooling, the outside dampers will be held at their minimum of 15% to satisfy all minimum ventilation airflow requirements.

Section 5.3- Exhaust duct Location

Exhaust ducts have a negative pressure relative to the zones they are controlling; therefore they prevent any potential leaking into the occupant spaces along with the proper sealing.

Section 5.4- Ventilation System Controls

The mechanical ventilation for the building is primarily supplied by the six rooftop units. These units are controlled by Building Management System (BMS) that is automatically put into operation during normal hours. It also has manual overrides that can be controlled by the onsite computer, but not limited to, because it has web capabilities which would allow for the building to be manually controlled from anywhere with internet access.

Section 5.5- Airstream Surfaces

Specification Section 23.3113-2.2A states that the ducts shall "comply with SMACNA HVAC Duct Construction Standards—Metal and Flexible" which specifies an acceptable resistance to both mold growth and erosion.

Section 5.6- Outdoor Air Intakes

All of the outdoor intakes are in compliance with the distances listed on Table 5-1 of ASHRAE Standards 62.1

TABLE 5-1 Air Intake Minimum Separation Distance

Object	Minimum Distance, ft (m)
Significantly contaminated exhaust (Note 1)	15 (5)
Noxious or dangerous exhaust (Notes 2 and 3)	30 (10)
Vents, chimneys, and flues from combustion appliances and equipment (Note 4)	15 (5)
Garage entry, automobile loading area, or drive-in queue (Note 5)	15 (5)
Truck loading area or dock, bus parking/idling area (Note 5)	25 (7.5)
Driveway, street, or parking place (Note 5)	5 (1.5)
Thoroughfare with high traffic volume	25 (7.5)
Roof, landscaped grade, or other surface directly below intake (Notes 6 and 7)	1 (0.30)
Garbage storage/pick-up area, dumpsters	15 (5)
Cooling tower intake or basin	15 (5)
Cooling tower exhaust	25 (7.5)

Note 1: Significantly contaminated exhaust is exhaust air with significant contaminant concentration, significant sensory-irritation intensity, or offensive odor.
Note 2: Laboratory fume hood exhaust air outlets shall be in compliance with NFPA 45-1991[3] and ANSI/AIHA Z9.5-1992.[4]
Note 3: Noxious or dangerous exhaust is exhaust air with highly objectionable fumes or gases and/or exhaust air with potentially dangerous particles, bioaerosols, or gases at concentrations high enough to be considered harmful. Information on separation criteria for industrial environments can be found in the ACGIH Industrial Ventilation Manual [5] and in the *ASHRAE Handbook—HVAC Applications*.[6]
Note 4: Shorter separation distances are permitted when determined in accordance with (a) Chapter 7 of ANSI Z223.1/NFPA 54-2002[7] for fuel gas burning appliances and equipment, (b) Chapter 6 of NFPA 31-2001[8] for oil burning appliances and equipment, or (c) Chapter 7 of NFPA 211-2003[9] for other combustion appliances and equipment.
Note 5: Distance measured to closest place that vehicle exhaust is likely to be located.
Note 6: No minimum separation distance applies to surfaces that are sloped more than 45 degrees from horizontal or that are less than 1 in. (3 cm) wide.
Note 7: Where snow accumulation is expected, distance listed shall be increased by the expected average snow depth.

Also the system outdoor air intake is in accordance with Part D of ASHRAE 62.1 Section 5.6.2 Rain Entrapment. The only outdoor air intake is for AHU-1, which serves the Blast Service room; it must be sized for less than 500 fpm. I used the highest CFM possible for this AHU to ensure that it would be safe at any condition.

$A_{opening}$= 60" * 48"= 2880 in^2= 20 ft^2

CFM for Outdoor Air Intake = 5300 CFM

$FPM_{opening}$ =[CFM]/$A_{opening}$

$FPM_{opening} = 5300\ CFM / 20\ ft^2$

$FPM_{opening} = 265\ FPM < 500\ FPM$

Rain Intrusion, Snow Entrainment and Bird Screens are also satisfied for the outdoor units at the Steelstacks.

Section 5.7- Local Capture of Contaminants

There is no non-combustion equipment that produces contaminants in the Steelstacks building; therefore this section is not applicable.

Section 5.8- Combustion Air

Combustion producing processes are designed to consume the proper amount of combustion air as well as the products of combustion vented directly outdoors.

Section 5.9- Particulate Matter Removal

In Specification Section 23.4100-1.5D it states that all filters must comply with ASHRAE Standard 52.2 for methods of testing and rating.

Section 5.10- Dehumidification Systems

The BMS system is designed to monitor and control room humidity. RTU-1 through RTU-4 and RTU-6 are set to start dehumidifying a room that has a relative humidity of 55%, while RTU-5 is set at 40 %RH. At these set points the system will enable the DX system to dehumidify to the set point and modulate the hot gas reheat valve to maintain space temperature set point.

Section 5.11- Drain Pans

All drain pans are constructed of 16-gauge aluminized steel, and are packaged with the rooftop and condensing units, with all the slopes, outlets, seal, and pan size conforming to ASHRAE 62.1.

Section 5.12- Finned-Tubed Coil Selection for Cleaning

Drain pans that comply with section 5.11 are provided below all condensate producing heat exchanges in the systems. All finned-coils have proper allowances for cleaning and instructions for cleaning.

Section 5.13 Humidifiers and Water-Spray System

This sections in not applicable due to the climate and usage of the Steelstacks building it does not need to utilize any humidifiers or water-spray systems.

Section 5.14 Access for Inspection, Cleaning, and Maintenance

Equipment access doors have been sized and located appropriately, and all of the proper equipment clearances have been met. These access doors and clearances provide unobstructed access for inspections, cleanings, and maintenance for all applicable equipment.

Section 5.15- Building Envelope and Interior Surfaces

The Steelstacks building complies with all three subsections of 5.15. The building has a weather barrier to prevent liquid water penetrations into the envelope. Vapor retarder is applied to spaces below grade to prevent vapor water diffusion. Exterior joints and seams are caulked to prevent leakage. All of these steps also require proper verification and testing on of these materials.

Section 5.16- Building with Attached Parking Garages

Steelstacks does not have any attached parking, so this section is not applicable.

Section 5.17- Air Classification and Recirculation

All of the spaces in Steelstacks are specified as being a class 1 space, except for the kitchen. Class 1 air may be recirculated or transferred to any space as specified in ASHRAE Standard 62.1 Section 5.17. The kitchen air is exhausted directly out of the building so the classification is not significant.

Section 5.18- Requirements for Building containing ETS Areas and ETS-Free Areas

Steelstacks does not have any designated smoking areas so this section does apply to this building.

ASHRAE 90.1-Section 6- Procedures

Section 6 of ASHRAE Standards 62.1 outlines the Ventilation Rate Procedure, which is designed to be a prescriptive procedure to determine outdoor air intake rates based on space type, occupancy and floor area (ft^2). These criteria are taken into account along with a number of other restrictions and considerations to give values for Ventilation.

The Steelstacks building consists of six packaged rooftop units along with one split system air-handling unit. The building has one make-up air unit and four energy recovery ventilators.

The following calculation method is taken directly from ASHRAE 62.1- Section 6, and will be used to calculated compliance with Section6:

Breathing Zone Outdoor Airflow (V_{bz})

$$V_{bz} = R_p * P_z + R_z * A_z \qquad \text{(Equation 6-1)}$$

A_z = *zone floor area*; the net occupiable floor area of the zone (ft^2)

P_z = *zone population*: the largest number of people expected to occupy the zone during typical usage.

R_p = outdoor airflow rate required per person as determined form Table 6-1

R_a = outdoor airflow rate required per unit area as determined form Table 6-1

Zone Air Distribution Effectiveness

The *zone air distribution effectiveness* (E_z) shall be determined by using table 6-2.

E_z= 1.0 Ceiling supply of cool air

Zone Outdoor Airflow (V_{oz})

$$V_{oz} = V_{bz}/E_z \qquad \text{(Equation 6-2)}$$

Single Zone Systems

One air handler supplies a mixture of outdoor air and recirculated air to only one zone then the V_{ot} should be found as follows

$$V_{ot} = V_{oz} \qquad \text{(Equation 6-3)}$$

Primary Outdoor Air Fraction (Z_p)

$$Z_p = V_{oz}/V_{pz} \quad \text{(Equation 6-5)}$$

V_{pz}= the primary zone airflow

Uncorrected Outdoor Intake (V_{ou})

Assume diversity Factor of 1 (D=1)

$$V_{ou} = D\sum(R_p + P_z) + \sum(R_a + A_z)$$

Outdoor Air intake (V_{ot})

$$V_{ot} = V_{ou}/E_v \quad \text{(Equation 6-8)}$$

The Chart in Appendix C shows each room and its associated values. All zones have meet ASHRAE efficiency standards and therefor have satisfied Section 6. The high value of Z_p for all the units seemed to come from the high population areas such as the theaters and the bar. This can be attributed to the idea the occupancy estimated is based on the maximum possibly value of persons in that space, on most occasions these zones will be at some level under this, and the Z_p value will be much lower.

ASHRAE 62.1- Results and Conclusions

Steelstacks Performing Arts Center is completely compliant with ASHRAE Standard 62.1 2007 Sections 5 and 6. These standards have been designed with the quality of life in mind and by complying with them; the Steelstacks building has set forth an example of good air quality conditions for Performing Arts Centers.

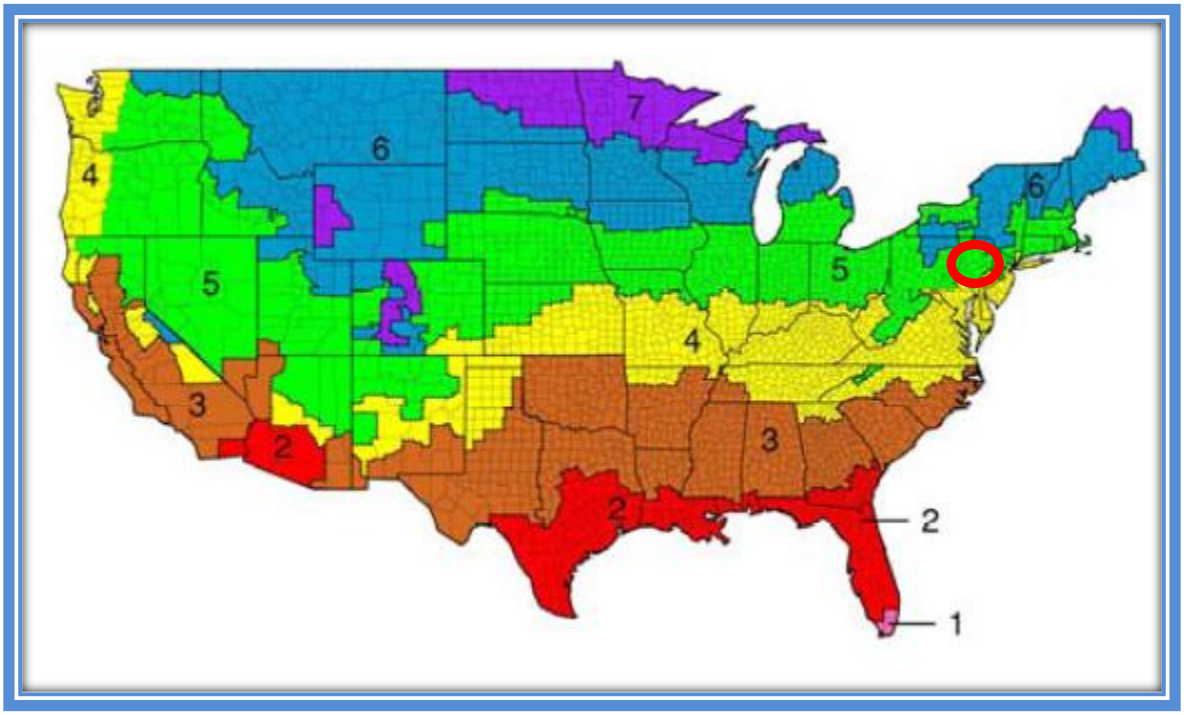
ASHRAE 90.1 2007 Overview

ASHRAE 90.1-2007 prescribes minimum requirements for the building envelope, HVAC systems, service water heating, power, lighting and electric motor efficiency. The sections below are applied below to Steelstacks Performing Arts Center in Bethlehem Pennsylvania.

ASHRAE 90.1- Section 5- Building Envelope

5.1 General

The Steelstacks building is located in Bethlehem, Pa which falls into climate category 5A.



5.2 Compliance

Steelstacks falls into option A and is able to use the Prescribed Building Envelope Options. This is because the vertical fenestration area does not exceed 40% of the gross wall area for each space condition category and the skylight fenestration area does not exceed 5% of the gross roof area for each space conditioning category. The Steelstacks fenestration compliance is shown below with the total being less than 40%.

Side	Total	Glass	% Glass
South	12160	0	0%
North	12160	9676	80%
East	7040	2048	29%
West	7040	2048	29%
Total	**38400**	**13772**	**36%**

The prescribed standard specifies that the envelope systems of nonresidential conditioned spaces located in climate zone 5A is in compliance with the entire individual requirements set forth in Sections 5.4, 5.5, 5.7, and 5.8 of ASHRAE Standard 90.1. The table of these requirements is in Appendix D. Below is a summary of the requirements and if they were met.

Value	Minimum Roof Insulation R-Value	Minimum Wall Insulation R-Value for Mass Wall	Fenestration Assembly Maximum U-Value	Fenestration Maximum SHGC
Required	R-20	R-11.4	0.45	40
Designed	R-30	R-15	.40	35
Compliance	YES	YES	YES	YES

ASHRAE 90.1- Section 6- Heating, Ventilation, and Air Conditioning

Steelstacks will have to be in compliance with Sections 6.4 Mandatory Provision, and 6.5 Prescriptive path. The simplified approach in sections 6.3 is not applicable because Steelstacks is over two stories high and has a gross floor area over 25,000 ft^2. Using the Table in Appendix C, it can be seen how Steelstacks has performed compared to the ASHRAE standards.

6.4 Mandatory Provisions

	MBH	Minimum ASHRAE EER	Actual EER	Pass/Fail
RTU-1	214.7	10.8	11.6	Pass
RTU-2	58.9	11	14.8	Pass
RTU-3	116.6	11	12.0	Pass
RTU-4	665.4	10.8	12.9	Pass
RTU-5	617.7	110.8	12.4	Pass
RTU-6	33.3	11	11.4	Pass
AHU-1	291.2	10.8	12.2	Pass

All of all RTU and AHU units meet the minimum requirements set in ASHRAE.

All of the Mechanical equipment is covered by the US National Appliance Energy Conservation Act of 1987; therefore they all carry a permanent label installed by the manufacturers stating that the equipment complies with the requirements of Standard 90.1.

The BMS system controls all of the air temperatures within the building. Each zone has sensors for temperature and humidity that report back to the BMS which in turn supplies information to the respective air-conditioning units to condition the space to the proper set points. The BMS also has the capabilities of maintaining off hour controls of the HVAC system as well having automatic shut-offs.

6.5 Prescriptive Path

The first item of interest in this section is Economizers, Steelstacks has e conomizers on all of its RTU, while ASHRAE only required them on four of the units based on cooling capacity. Once again

the BMS has totally control of the economizers position, the BMS has sensors in all the rooms as well as outside so that it can determine the opening position of the economizers.

Table 6.5.3 found in Appendix F, shows the limitations for fan HP of the system, below, all of the fans are compared against the ASHRAE standards.

	hp	CFM	CFM*0.0011	Compliance
RTU-1	5	6800	7.48	YES
RTU-2	1	1650	1.82	YES
RTU-3	2	3050	3.36	YES
RTU-4	25	23485	25.83	YES
RTU-5	20	17500	19.25	YES
RTU-6	1.5	3000	3.30	YES
AHU-1	7.5	5300	5.83	YES

hp≤ CFM * .0011 for compliance

6.7 Submittals

The building will be commissioned using detailed commissioning manuals. This also is required for LEED®-NC certification.

ASHRAE 90.1- Section 7- Service Water Heating

Domestic hot water at Steelstacks is supplies by two parallel water heater located on the fourth floor of the building. They are identical water heaters and have efficiencies well above the required 62% for their size and fuel type. There are also 3 localized water heaters located throughout the building, but since they are electric water heaters with an assumed efficiency of 100% they are left out of this analysis.

Type	Fuel	Input (MBH)	Storage Capacity	Efficiency	Compliance
Vertical Storage	Natural Gas	300	130	96%	YES

ASHRAE 90.1- Section 8- Power

Section 8 prescribes the allowable voltage drop for a building's power system. The building designer designed based on this standard and sized all feeders and branch circuits to comply with the required 2% and 3% respective voltage drops at the design load.

ASHRAE 90.1- Section 9- Lighting

9.2 Compliance Paths

Compliance Path A: Building Area Method 9.5 will be used to analyze the lighting system. This was chosen because it is a more general approach to lighting systems power density.

9.4 Mandatory Provisions

The building lighting system is also integrated into the BMS of the building. To allow for automatic shut-offs of indoor and outdoor lights. The system is required to be programmed on a week to week basis, due to the ever changing schedule of the Steelstacks building.

9.5 Building Area Method Compliance Path

Steelstacks is classified as a Performing Arts center which gives it a Lighting Power Density maximum of 1.6 W/ft^2. On the table below I have calculated the lighting system power density on a floor by floor analysis. The building overall meets the requirement set out by ASHRAE, the fourth floor does not comply due to the fact that it many of the lights on this floor shine down onto the third floor but count as wattage for the fourth floor. For a more in-depth chart of how the Wattages were found look in Appendix G.

Floor	SF	Wattage	Watts/ft^2	Acceptable W/ft^2	Compliance
1	20015	11013	0.55	1.6	YES
2	18285	19742	1.08	1.6	YES
3	21057	14940	0.71	1.6	YES
4	7810	18120	2.32	1.6	NO
Total	67167	63815	0.95	1.6	YES

Steelstacks also takes advantage of the large curtain wall on the north side of the building for natural light. The lights in the effected rooms are dimmable or have section controlled switches that can be manipulated to lower the wattage in the room and allow for the natural ambient light to create a more natural entertainment environment.

ASHRAE 90.1- Results and Conclusions

After a thorough investigation into ASHRAE 90.1 standards, it is apparent that the Steelstacks building was designed with ASHRAE as a leading force. The building complied with all of the standards with ease. A lot of this can be attributed to the fact that Steelstacks was designed to achieve LEED Gold, to achieve this, many areas of the building design had to be overdesigned.

References

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Appendix A

TABLE 6-1 MINIMUM VENTILATION RATES IN BREATHING ZONE
(This table is not valid in isolation; it must be used in conjunction with the accompanying notes.)

Occupancy Category	People Outdoor Air Rate R_p		Area Outdoor Air Rate R_a		Notes	Default Values			Air Class
						Occupant Density (see Note 4)	Combined Outdoor Air Rate (see Note 5)		
	cfm/person	L/s·person	cfm/ft²	L/s·m²		#/1000 ft² or #/100 m²	cfm/person	L/s·person	
Correctional Facilities									
Cell	5	2.5	0.12	0.6		25	10	4.9	2
Dayroom	5	2.5	0.06	0.3		30	7	3.5	1
Guard stations	5	2.5	0.06	0.3		15	9	4.5	1
Booking/waiting	7.5	3.8	0.06	0.3		50	9	4.4	2
Educational Facilities									
Daycare (through age 4)	10	5	0.18	0.9		25	17	8.6	2
Daycare sickroom	10	5	0.18	0.9		25	17	8.6	3
Classrooms (ages 5–8)	10	5	0.12	0.6		25	15	7.4	1
Classrooms (age 9 plus)	10	5	0.12	0.6		35	13	6.7	1
Lecture classroom	7.5	3.8	0.06	0.3		65	8	4.3	1
Lecture hall (fixed seats)	7.5	3.8	0.06	0.3		150	8	4.0	1
Art classroom	10	5	0.18	0.9		20	19	9.5	2
Science laboratories	10	5	0.18	0.9		25	17	8.6	2
University/college laboratories	10	5	0.18	0.9		25	17	8.6	2
Wood/metal shop	10	5	0.18	0.9		20	19	9.5	2
Computer lab	10	5	0.12	0.6		25	15	7.4	1
Media center	10	5	0.12	0.6	A	25	15	7.4	1
Music/theater/dance	10	5	0.06	0.3		35	12	5.9	1
Multi-use assembly	7.5	3.8	0.06	0.3		100	8	4.1	1
Food and Beverage Service									
Restaurant dining rooms	7.5	3.8	0.18	0.9		70	10	5.1	2
Cafeteria/fast-food dining	7.5	3.8	0.18	0.9		100	9	4.7	2
Bars, cocktail lounges	7.5	3.8	0.18	0.9		100	9	4.7	2
General									
Break rooms	5	2.5	0.06	0.3		25	10	5.1	1
Coffee stations	5	2.5	0.06	0.3		20	11	5.5	1
Conference/meeting	5	2.5	0.06	0.3		50	6	3.1	1
Corridors	–	–	0.06	0.3		–			1
Storage rooms	–	–	0.12	0.6	B	–			1
Hotels, Motels, Resorts, Dormitories									
Bedroom/living room	5	2.5	0.06	0.3		10	11	5.5	1
Barracks sleeping areas	5	2.5	0.06	0.3		20	8	4.0	1
Laundry rooms, central	5	2.5	0.12	0.6		10	17	8.5	2
Laundry rooms within dwelling units	5	2.5	0.12	0.6		10	17	8.5	1
Lobbies/prefunction	7.5	3.8	0.06	0.3		30	10	4.8	1
Multipurpose assembly	5	2.5	0.06	0.3		120	6	2.8	1

TABLE 6-1 MINIMUM VENTILATION RATES IN BREATHING ZONE *(continued)*
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Occupancy Category	People Outdoor Air Rate R_p		Area Outdoor Air Rate R_a		Notes	Default Values			Air Class
						Occupant Density (see Note 4)	Combined Outdoor Air Rate (see Note 5)		
	cfm/person	L/s·person	cfm/ft²	L/s·m²		#/1000 ft² or #/100 m²	cfm/person	L/s·person	
Office Buildings									
Office space	5	2.5	0.06	0.3		5	17	8.5	1
Reception areas	5	2.5	0.06	0.3		30	7	3.5	1
Telephone/data entry	5	2.5	0.06	0.3		60	6	3.0	1
Main entry lobbies	5	2.5	0.06	0.3		10	11	5.5	1
Miscellaneous Spaces									
Bank vaults/safe deposit	5	2.5	0.06	0.3		5	17	8.5	2
Computer (not printing)	5	2.5	0.06	0.3		4	20	10.0	1
Electrical equipment rooms	–	–	0.06	0.3	B	–			1
Elevator machine rooms	–	–	0.12	0.6	B	–			1
Pharmacy (prep. area)	5	2.5	0.18	0.9		10	23	11.5	2
Photo studios	5	2.5	0.12	0.6		10	17	8.5	1
Shipping/receiving	–	–	0.12	0.6	B	–			1
Telephone closets	–	–	0.00	0.0		–			1
Transportation waiting	7.5	3.8	0.06	0.3		100	8	4.1	1
Warehouses	–	–	0.06	0.3	B	–			2
Public Assembly Spaces									
Auditorium seating area	5	2.5	0.06	0.3		150	5	2.7	1
Places of religious worship	5	2.5	0.06	0.3		120	6	2.8	1
Courtrooms	5	2.5	0.06	0.3		70	6	2.9	1
Legislative chambers	5	2.5	0.06	0.3		50	6	3.1	1
Libraries	5	2.5	0.12	0.6		10	17	8.5	1
Lobbies	5	2.5	0.06	0.3		150	5	2.7	1
Museums (children's)	7.5	3.8	0.12	0.6		40	11	5.3	1
Museums/galleries	7.5	3.8	0.06	0.3		40	9	4.6	1
Residential									
Dwelling unit	5	2.5	0.06	0.3	F,G	F			1
Common corridors	–	–	0.06	0.3					1
Retail									
Sales (except as below)	7.5	3.8	0.12	0.6		15	16	7.8	2
Mall common areas	7.5	3.8	0.06	0.3		40	9	4.6	1
Barbershop	7.5	3.8	0.06	0.3		25	10	5.0	2
Beauty and nail salons	20	10	0.12	0.6		25	25	12.4	2
Pet shops (animal areas)	7.5	3.8	0.18	0.9		10	26	12.8	2
Supermarket	7.5	3.8	0.06	0.3		8	15	7.6	1
Coin-operated laundries	7.5	3.8	0.06	0.3		20	11	5.3	2

TABLE 6-1 MINIMUM VENTILATION RATES IN BREATHING ZONE *(continued)*
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Occupancy Category	People Outdoor Air Rate R_p		Area Outdoor Air Rate R_a		Notes	Default Values			Air Class
						Occupant Density (see Note 4)	Combined Outdoor Air Rate (see Note 5)		
	cfm/person	L/s·person	cfm/ft²	L/s·m²		#/1000 ft² or #/100 m²	cfm/person	L/s·person	
Sports and Entertainment									
Sports arena (play area)	–	–	0.30	1.5	E	–			1
Gym, stadium (play area)	–	–	0.30	1.5		30			2
Spectator areas	7.5	3.8	0.06	0.3		150	8	4.0	1
Swimming (pool & deck)	–	–	0.48	2.4	C	–			2
Disco/dance floors	20	10	0.06	0.3		100	21	10.3	1
Health club/aerobics room	20	10	0.06	0.3		40	22	10.8	2
Health club/weight rooms	20	10	0.06	0.3		10	26	13.0	2
Bowling alley (seating)	10	5	0.12	0.6		40	13	6.5	1
Gambling casinos	7.5	3.8	0.18	0.9		120	9	4.6	1
Game arcades	7.5	3.8	0.18	0.9		20	17	8.3	1
Stages, studios	10	5	0.06	0.3	D	70	11	5.4	1

GENERAL NOTES FOR TABLE 6-1

1 **Related requirements:** The rates in this table are based on all other applicable requirements of this standard being met.
2 **Smoking:** This table applies to no-smoking areas. Rates for smoking-permitted spaces must be determined using other methods. See Section 6.2.9 for ventilation requirements in smoking areas.
3 **Air density:** Volumetric airflow rates are based on an air density of 0.075 lb_{da}/ft^3 (1.2 kg_{da}/m^3), which corresponds to dry air at a barometric pressure of 1 atm (101.3 kPa) and an air temperature of 70°F (21°C). Rates may be adjusted for actual density but such adjustment is not required for compliance with this standard.
4 **Default occupant density:** The default occupant density shall be used when actual occupant density is not known.
5 **Default combined outdoor air rate (per person):** This rate is based on the default occupant density.
6 **Unlisted occupancies:** If the occupancy category for a proposed space or zone is not listed, the requirements for the listed occupancy category that is most similar in terms of occupant density, activities and building construction shall be used.
7 **Health-care facilities:** Rates shall be determined in accordance with Appendix E.

ITEM-SPECIFIC NOTES FOR TABLE 6-1

A For high school and college libraries, use values shown for Public Assembly Spaces—Libraries.
B Rate may not be sufficient when stored materials include those having potentially harmful emissions.
C Rate does not allow for humidity control. Additional ventilation or dehumidification may be required to remove moisture.
D Rate does not include special exhaust for stage effects, e.g., dry ice vapors, smoke.
E When combustion equipment is intended to be used on the playing surface, additional dilution ventilation and/or source control shall be provided.
F Default occupancy for dwelling units shall be two persons for studio and one-bedroom units, with one additional person for each additional bedroom.
G Air from one residential dwelling shall not be recirculated or transferred to any other space outside of that dwelling.

Appendix B

TABLE 6-2 Zone Air Distribution Effectiveness

Air Distribution Configuration	E_z
Ceiling supply of cool air.	1.0
Ceiling supply of warm air and floor return.	1.0
Ceiling supply of warm air 15°F (8°C) or more above space temperature and ceiling return.	0.8
Ceiling supply of warm air less than 15°F (8°C) above space temperature and ceiling return provided that the 150 fpm (0.8 m/s) supply air jet reaches to within 4.5 ft (1.4 m) of floor level. ***Note:*** For lower velocity supply air, $E_z = 0.8$.	1.0
Floor supply of cool air and ceiling return provided that the 150 fpm (0.8 m/s) supply jet reaches 4.5 ft (1.4 m) or more above the floor. ***Note:*** Most underfloor air distribution systems comply with this proviso.	1.0
Floor supply of cool air and ceiling return, provided low-velocity displacement ventilation achieves unidirectional flow and thermal stratification.	1.2
Floor supply of warm air and floor return.	1.0
Floor supply of warm air and ceiling return.	0.7
Makeup supply drawn in on the opposite side of the room from the exhaust and/or return.	0.8
Makeup supply drawn in near to the exhaust and/or return location.	0.5

1. "Cool air" is air cooler than space temperature.
2. "Warm air" is air warmer than space temperature.
3. "Ceiling" includes any point above the *breathing zone.*
4. "Floor" includes any point below the *breathing zone.*
5. As an alternative to using the above values, E_z may be regarded as equal to air change effectiveness determined in accordance with ANSI/ASHRAE Standard 129[16] for all air distribution configurations except unidirectional flow.

Appendix C

RTU-1											
Room Name	**Occupancy Category**	**Az**	**Pz**	**Rp**	**Ra**	**Vbz**	**Ez**	**Voz**	**Ev**	**Vpz**	**Zp**
Kitchen Area	Cafeteria/fast food	4715	50	8	0.18	1249	1.0	1249	0.8	6600	0.19
Liquor Storage	Cafeteria/fast food	135	1	8	0.18	32	1.0	32	0.8	100	0.32
Storage	Storage	190	0	0	0.12	23	1.0	23	0.8	100	0.23
Vou = 1303.8											
Vot=1630											

RTU-2											
Room Name	**Occupancy Category**	**Az**	**Pz**	**Rp**	**Ra**	**Vbz**	**Ez**	**Voz**	**Ev**	**Vpz**	**Zp**

Small Theater	Music/theater/dance	1790	100	7.5	0.06	857	1.0	857	0.6	1650	0.52
Vou=857											
Vot=1428											

RTU-3											
Room Name	**Occupancy Category**	**Az**	**Pz**	**Rp**	**Ra**	**Vbz**	**Ez**	**Voz**	**Ev**	**Vpz**	**Zp**
Large Theater	Music/theater/dance	2890	197	7.5	0.06	1651	1.0	1651	0.6	3050	0.54
Vou=1651											
Vot=2752											

RTU-4											
Room Name	**Occupancy Category**	**Az**	**Pz**	**Rp**	**Ra**	**Vbz**	**Ez**	**Voz**	**Ev**	**Vpz**	**Zp**
Creative Commons	Multipurpose Assembly	3595	104	5	0.06	736	1.0	736	0.6	3620	0.20
Office	Office	250	1	5	0.06	20	1.0	20	0.6	210	0.10
Office	Office	185	1	5	0.06	16	1.0	16	0.6	150	0.11
Lobby	Lobby	845	50	5	0.06	301	1.0	301	0.6	1160	0.26
Concession Stand	Cafeteria/fast food	255	26	8	0.18	254	1.0	254	0.6	3720	0.07
Concession BOH	Cafeteria/fast food	480	48	8	0.18	470	1.0	470	0.6	1600	0.29
Gift shop	Sales	720	11	8	0.12	167	1.0	167	0.6	320	0.52
PodZone	Lobby	920	40	5	0.06	255	1.0	255	0.6	2250	0.11
Vou=2219											
Vot=3699											

RTU-5											
Room Name	**Occupancy Category**	**Az**	**Pz**	**Rp**	**Ra**	**Vbz**	**Ez**	**Voz**	**Ev**	**Vpz**	**Zp**
Musikfest Café	Cafeteria/fast food	7310	250	7.5	0.18	3191	1.0	3191	0.9	14300	0.22
Lobby	Lobby	340	51	5	0.06	275	1.0	275	0.9	1620	0.17
VIP Bar	Restaurant Dinning	765	20	7.5	0.18	288	1.0	288	0.9	1200	0.24
Vou=3754											
Vot=4171											

RTU-6											
Room Name	**Occupancy Category**	**Az**	**Pz**	**Rp**	**Ra**	**Vbz**	**Ez**	**Voz**	**Ev**	**Vpz**	**Zp**

Retail Storage	Storage	280	0	0	0.12	34	1.0	34	0.8	140	0.24
Corridor	Corridor	275	0	0	0.06	17	1.0	17	0.8	150	0.11
Storage Prep	Storage	495	0	0	0.12	59	1.0	59	0.8	280	0.21
Corridor	Corridor	350	0	0	0.06	21	1.0	21	0.8	100	0.21
Hall	Storage	170	0	0	0.06	10	1.0	10	0.8	100	0.10
Storage	Storage	160	0	0	0.12	19	1.0	19	0.8	110	0.17
Janitors Closet	Storage	80	0	0	0.12	10	1.0	10	0.8	50	0.19
Restroom Lobby	Lobby	135	1	5	0.06	13	1.0	13	0.8	50	0.26
Green Room	Break Room	265	8	5	0.06	56	1.0	56	0.8	280	0.20
Green Room	Break Room	175	4	5	0.06	31	1.0	31	0.8	550	0.06
Green Room	Break Room	160	1	5	0.06	15	1.0	15	0.8	310	0.05
Storage	Storage	360	0	0	0.12	43	1.0	43	0.8	180	0.24
Office	Office	85	1	5	0.06	10	1.0	10	0.8	120	0.08
Vou=337											
Vot=421											

AHU-1											
Room Name	**Occupancy Category**	**Az**	**Pz**	**Rp**	**Ra**	**Vbz**	**Ez**	**Voz**	**Ev**	**Vpz**	**Zp**
Blast Furnace Room	Multipurpose Assembly	3460	255	5	0.06	1483	1.0	1483	0.8	4830	0.31
Vou=1483											
Vot=1854											

Appendix D

TABLE 5.5-5 Building Envelope Requirements For Climate Zone 5 (A, B, C)*

Opaque Elements	Nonresidential Assembly Maximum	Nonresidential Insulation Min. R-Value	Residential Assembly Maximum	Residential Insulation Min. R-Value	Semiheated Assembly Maximum	Semiheated Insulation Min. R-Value
Roofs						
Insulation Entirely above Deck	U-0.048	R-20.0 c.i.	U-0.048	R-20.0 c.i.	U-0.119	R-7.6 c.i.
Metal Building	U-0.065	R-19.0	U-0.065	R-19.0	U-0.097	R-10.0
Attic and Other	U-0.027	R-38.0	U-0.027	R-38.0	U-0.053	R-19.0
Walls, Above-Grade						
Mass	U-0.090	R-11.4 c.i.	U-0.080	R-13.3 c.i.	U-0.151[a]	R-5.7 c.i.[a]
Metal Building	U-0.113	R-13.0	U-0.057	R-13.0 + R-13.0	U-0.123	R-11.0
Steel-Framed	U-0.064	R-13.0 + R-7.5 c.i.	U-0.064	R-13.0 + R-7.5 c.i.	U-0.124	R-13.0
Wood-Framed and Other	U-0.064	R-13.0 + R-3.8 c.i.	U-0.051	R-13.0 + R-7.5 c.i.	U-0.089	R-13.0
Walls, Below-Grade						
Below-Grade Wall	C-0.119	R-7.5 c.i.	C-0.119	R-7.5 c.i.	C-1.140	NR
Floors						
Mass	U-0.074	R-10.4 c.i.	U-0.064	R-12.5 c.i.	U-0.137	R-4.2 c.i.
Steel-Joist	U-0.038	R-30.0	U-0.038	R-30.0	U-0.052	R-19.0
Wood-Framed and Other	U-0.033	R-30.0	U-0.033	R-30.0	U-0.051	R-19.0
Slab-On-Grade Floors						
Unheated	F-0.730	NR	F-0.540	R-10 for 24 in.	F-0.730	NR
Heated	F-0.860	R-15 for 24 in.	F-0.860	R-15 for 24 in.	F-1.020	R-7.5 for 12 in.
Opaque Doors						
Swinging	U-0.700		U-0.500		U-0.700	
Nonswinging	U-0.500		U-0.500		U-1.450	
Fenestration	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**
Vertical Glazing, % of Wall						
Nonmetal framing (all)[b]	U-0.35	SHGC-0.40 all	U-0.35	SHGC-0.40 all	U-1.20	SHGC-NR all
Metal framing (curtainwall/storefront)[c]	U-0.45		U-0.45		U-1.20	
Metal framing (entrance door)[c]	U-0.80		U-0.80		U-1.20	
Metal framing (all other)[c]	U-0.55		U-0.55		U-1.20	
Skylight with Curb, Glass, % of Roof						
0%–2.0%	U_{all}-1.17	$SHGC_{all}$-0.49	U_{all}-1.17	$SHGC_{all}$-0.49	U_{all}-1.98	$SHGC_{all}$-NR
2.1%–5.0%	U_{all}-1.17	$SHGC_{all}$-0.39	U_{all}-1.17	$SHGC_{all}$-0.39	U_{all}-1.98	$SHGC_{all}$-NR
Skylight with Curb, Plastic, % of Roof						
0%–2.0%	U_{all}-1.10	$SHGC_{all}$-0.77	U_{all}-1.10	$SHGC_{all}$-0.77	U_{all}-1.90	$SHGC_{all}$-NR
2.1%–5.0%	U_{all}-1.10	$SHGC_{all}$-0.62	U_{all}-1.10	$SHGC_{all}$-0.62	U_{all}-1.90	$SHGC_{all}$-NR
Skylight without Curb, All, % of Roof						
0%–2.0%	U_{all}-0.69	$SHGC_{all}$-0.49	U_{all}-0.69	$SHGC_{all}$-0.49	U_{all}-1.36	$SHGC_{all}$-NR
2.1%–5.0%	U_{all}-0.69	$SHGC_{all}$-0.39	U_{all}-0.69	$SHGC_{all}$-0.39	U_{all}-1.36	$SHGC_{all}$-NR

*The following definitions apply: c.i. = continuous insulation (see Section 3.2), NR = no (insulation) requirement.
[a]Exception to Section A3.1.3.1 applies.
[b]Nonmetal framing includes framing materials other than metal with or without metal reinforcing or cladding.
[c]Metal framing includes metal framing with or without thermal break. The "all other" subcategory includes operable windows, fixed windows, and non-entrance doors.

Appendix E

TABLE 6.8.1B Electrically Operated Unitary and Applied Heat Pumps—Minimum Efficiency Requirements

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency[a]	Test Procedure[b]
Air cooled (cooling mode)	<65,000 Btu/h[c]	All	Split system	10.0 SEER (before 1/23/2006) 13.0 SEER (as of 1/23/2006)	ARI 210/240
			Single package	9.7 SEER (before 1/23/2006) 13.0 SEER (as of 1/23/2006)	
Through-the-wall (air cooled, cooling mode)	≤30,000 Btu/h[c]	All	Split system	10.0 SEER (before 1/23/2006) 10.9 SEER (as of 1/23/2006) 12 SEER (as of 1/23/2010)	
			Single package	9.7 SEER (before 1/23/2006) 10.6 SEER (as of 1/23/2006) 12.0 SEER (as of 1/23/2010)	
Small-duct high-velocity (air cooled, cooling mode)	< 65,000 Btu/h[c]	All	Split system	10 SEER	
Air cooled (cooling mode)	≥65,000 Btu/h and <135,000 Btu/h	Electric resistance (or none)	Split system and single package	10.1 EER (before 1/1/2010) 11.0 EER (as of 1/1/2010)	ARI 340/360
		All other	Split system and single package	9.9 EER (before 1/1/2010) 10.8 EER (as of 1/1/2010)	
	≥135,000 Btu/h and <240,000 Btu/h	Electric resistance (or none)	Split system and single package	9.3 EER (before 1/1/2010) 10.6 EER (as of 1/1/2010)	
		All other	Split system and single package	9.1 EER (before 1/1/2010) 10.4 EER (as of 1/1/2010)	
	≥240,000 Btu/h	Electric resistance (or none)	Split system and single package	9.0 EER (before 1/1/2010) 9.5 EER (as of 1/1/2010) 9.2 IPLV	
		All other	Split system and single package	8.8 EER (before 1/1/2010) 9.3 EER (as of 1/1/2010) 9.0 IPLV	
Water source (cooling mode)	<17,000 Btu/h	All	86°F entering water	11.2 EER	ISO-13256-1
	≥17,000 Btu/h and <65,000 Btu/h	All	86°F entering water	12.0 EER	ISO-13256-1
	≥65,000 Btu/h and <135,000 Btu/h	All	86°F entering water	12.0 EER	ISO-13256-1
Groundwater source (cooling mode)	<135,000 Btu/h	All	59°F entering water	16.2 EER	ISO-13256-1
Ground source (cooling mode)	<135,000 Btu/h	All	77°F entering water	13.4 EER	ISO-13256-1
Air cooled (heating mode)	<65,000 Btu/h[c] (cooling capacity)	—	Split system	6.8 HSPF (before 1/23/2006) 7.7 HSPF (as of 1/23/2006)	ARI 210/240
			Single package	6.6 HSPF (before 1/23/2006) 7.7 HSPF (as of 1/23/2006)	
Through-the-wall, (air cooled, heating mode)	≤30,000 Btu/h[c] (cooling capacity)	—	Split system	6.8 HSPF (before 1/23/2006) 7.1 HSPF (as of 1/23/2006) 7.4 HSPF (as of 1/23/2010)	
			Single package	6.6 HSPF (before 1/23/2006) 7.0 HSPF (as of 1/23/2006) 7.4 HSPF (as of 1/23/2010)	
Small-duct high-velocity (air cooled, heating mode)	< 65,000 Btu/h[c] (cooling capacity)	—	Split system	6.8 HSPF	

Appendix F

TABLE 6.5.3.1.1A Fan Power Limitation[a]

	Limit	Constant Volume	Variable Volume
Option 1: Fan System Motor Nameplate hp	Allowable Nameplate Motor hp	$hp \le CFM_S \cdot 0.0011$	$hp \le CFM_S \cdot 0.0015$
Option 2: Fan System bhp	Allowable Fan System bhp	$bhp \le CFM_S \cdot 0.00094 + A$	$bhp \le CFM_S \cdot 0.0013 + A$

[a] where
CFM_S = the maximum design supply airflow rate to conditioned spaces served by the system in cubic feet per minute
hp = the maximum combined motor nameplate horsepower
bhp = the maximum combined fan brake horsepower
A = sum of $(PD \times CFM_D/4131)$
where
PD = each applicable pressure drop adjustment from Table 6.5.3.1.1B in in. w.c.
CFM_D = the design airflow through each applicable device from Table 6.5.3.1.1B in cubic feet per minute

TABLE 6.5.3.1.1B Fan Power Limitation Pressure Drop Adjustment

Device	Adjustment
Credits	
Fully ducted return and/or exhaust air systems	0.5 in. w.c.
Return and/or exhaust airflow control devices	0.5 in. w.c.
Exhaust filters, scrubbers, or other exhaust treatment	The pressure drop of device calculated at fan system design condition
Particulate Filtration Credit: MERV 9 through 12	0.5 in. w.c.
Particulate Filtration Credit: MERV 13 through 15	0.9 in. w.c.
Particulate Filtration Credit: MERV 16 and greater and electronically enhanced filters	Pressure drop calculated at 2× clean filter pressure drop at fan system design condition
Carbon and other gas-phase air cleaners	Clean filter pressure drop at fan system design condition
Heat recovery device	Pressure drop of device at fan system design condition
Evaporative humidifier/cooler in series with another cooling coil	Pressure drop of device at fan system design condition
Sound Attenuation Section	0.15 in. w.c.
Deductions	
Fume Hood Exhaust Exception (required if 6.5.3.1.1 Exception [c] is taken)	–1.0 in. w.c.

Appendix G

Light fixture	Wattage	1st Floor Quantity	1st Floor Wattage	2nd Floor Quantity	2nd Floor Wattage	3rd Floor Quantity	3rd Floor Wattage	4th Floor Quantity	4th Floor Wattage
PA-64	64	14	896	20	1280	20	1280	22	1408
PB-20	20	7	140	0	0	0	0	0	0
PE-165	165	0	0	24	3960	0	0	0	0
PF-50	50	0	0	0	0	12	600	5	250
PG-54	54	0	0	37	1998	0	0	0	0
PJ-100	100	0	0	0	0	34	3400	40	4000
PK-250	250	0	0	0	0	0	0	27	6750
RA-30	30	0	0	32	960	0	0	2	60
RB-20	20	48	960	72	1440	15	300	8	160
RC-32	32	146	4672	120	3840	120	3840	80	2560
RE-150	150	0	0	0	0	0	0	14	2100
RF-64	64	0	0	8	512	11	704	0	0
RG-64	64	12	768	0	0	63	4032	1	64
RH-54	54	4	216	0	0	0	0	0	0
SA-32	32	0	0	92	2944	0	0	0	0
SB-25	25	4	100	0	0	0	0	0	0
SC-64	64	13	832	2	128	0	0	0	0
SD-2	2	254	508	0	0	0	0	3	6
SE-2	1.5	11	16.5	0	0	0	0	0	0
SF-20	20	8	160	0	0	0	0	0	0
SG-64	64	0	0	0	0	0	0	5	320
SJ-32	32	17	544	0	0	0	0	0	0
TA-20	20	36	720	0	0	0	0	0	0
TB-90	90	0	0	8	720	0	0	0	0
TC-50	50	0	0	20	1000	8	400	4	200
WA-64	64	6	384	6	384	6	384	0	0
WC-6	6	0	0	0	0	0	0	19	114
WC-32	32	3	96	0	0	0	0	4	128
WE-18	18	0	0	32	576	0	0	0	0
Total			**11013**		**19742**		**14940**		**18120**