Technical Assignment 1

A Report On
ASHRAE Standard 62.1 Addendum n

A Report Investigating the
Ventilation Compliance of
LA Fitness, West Oaks
Houston,Texas

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Executive Summary:

The purpose of this report is to evaluate a two story 45,000 sf athletic workout facility in Houston, TX for its compliance with the ASHRAE Standard 62.1-2004 minimum ventilation rates. Standard 62.1's scope also specifies guidelines for acceptable indoor air quality. This standard was written to avoid the adverse health effects that arise from poorly designed mechanical systems. The addition of addendum 'n' to this standard makes the data more site specific because it is based off of not only number of occupants, as previous drafts were, but also includes factors such as floor area, efficiency of ventilation, mixing of air, and function of the space.

The ventilation rate procedure was utilized to find the results contained in this report. It was assumed that air mixes perfectly in these calculations. Most of the air handlers in the building serve only one zone, thus eliminating an important zone primary air fraction (Z_p) from most calculations, and there was an occupant diversity of 1.0 as gathered from the MEP design documents.

The building's mechanical system is served by 13 packaged rooftop units. These are constant volume air handling units that operate with supply airflows ranging from 3,500-10,500 cfm. There is currently a total supply of 84,400 cfm consisting of 19.4% outdoor air for ventilation purposes. According to Standard 62.1-2004, the building requires 20.9% outdoor air if the same total supply cfm is used; however, only 3 of the 13 rooftop units in this building meet their individual requirement for the spaces they serve. This suggests that although approximately enough outdoor air is being brought into the building, the distribution of the outdoor air may need to be reevaluated to avoid future ventilation problems.

Assumptions:

Every space was assumed to have perfect mixing for the purposes of these calculations. When considering ventilation issues, contaminant concentrations were treated as uniform as well because there was no data to suggest otherwise. Similarly, outdoor air was assumed to be clean and acceptable for ventilation.

An occupant diversity factor of 1.0 had to be assumed from the design data obtained from the MEP firm. There was no data suggesting a difference between the system population (P_s) and the zone population (P_z) during operation, so a conservative approach was used.

Spaces such as the elevator shaft, a small storage closets, and stairwells were not evaluated in this analysis. They were not considered critical areas for ventilation, and it is assumed that transfer air from adjacent spaces will provide enough ventilation to meet their needs.

Ventilation effectiveness (E_z) = 1 for this distribution due to ceiling distribution of cool air. This is assuming that it will be necessary to cool the space for most of the year. Due to the prevailing weather in Houston and the function of the building it can be assumed that this is the situation.

Space Characteristics:

The West Oaks location of LA Fitness has a very diverse program of spaces. Areas designed for conditioning and ventilation range from 148-10520 sf. The building spaces have functions that vary from pool use to juice bar which means that each zone must be carefully reviewed. The MEP designers chose to use eleven separate air handlers that were designated to meet single zone requirements. In addition, two more air handlers were installed; they each served multiple zones.

The design values for area were obtained from the CAD drawings supplied by Heights Venture Architects. The design occupancy values came directly off the program included in the design documents.

Table A: Space Characteristics

Space	Area (ft^2)	Design Occupancy
Aerobics	3083	61.7
Raquetball	835	4
Raquetball	835	4
Raquetball	835	4
Raquetball	835	4
Raquetball	835	4
Child Restrooms	148	1.2
Storage	228	0
Kid's Club	1840	36.6
Free Weights	2974	59.5
Basketball	3810	20
Storage	460	8.8
Sp. Exercise	1366	27.3
Equipment Room	147	0.5
Cardiovascular	10520	210.4
Mezzanine	3000	60
Trainer's Office	217	2.7
Spinning	1141	22.8
Pool Equipment	290	1
Pool & Spa	4112	82.3
Locker Rooms	4125	8.8
Reception	1420	14
Membership Sales	687	8
Juice Bar	280	2.6

Procedure:

There were two different procedures used to obtain all of the ventilation data discussed in this report. Both of these procedures used came from Sections 6.2.1-6.2.9 of ASHRAE Standard 62.1-2004 Addendum ‘n’. The first procedure deals with the situation of where one air handler supplies a mixed air to a single zone, while the second case deals with one air handler supplying mixed air to multiple zones.

Single Zone Systems:

Step 1: Designation of single zone system.

Step 2: Zone floor areas (Az) were collected from design drawings via CAD files and zone population (P_z) was determined from architectural program documents supplied by Heights Venture Architects.

Step 3: Outdoor airflow rates per person (R_p) and per area (R_a) were obtained from Table 6-1 of the standard based.

Step4: Breathing zone outdoor airflow (V_{bz}) was calculated from this equation:

$$V_{bz} = R_p*P_z + R_a*A_z$$

Step 5: Check Table 6-2 of the standard to find the zone air distribution effectiveness. For this case: $E_z = 1.0$ (see assumptions for clarification)

Step 6: Calculate zone outdoor airflow (V_{oz}) using distribution effectiveness found above.

$$V_{oz} = V_{bz} / E_z$$

which for our case reduces to:

$$V_{oz} = V_{bz}$$

Step 7: Establish outdoor air intake flow (V_{ot})

For air handler serving one zone:

$$V_{ot} = V_{oz}$$

As stated in Section 6.2.3 of the standard.

Step 8: Compare this V_{ot} to the design data provided.

Multiple Zone Systems:

For a single air handler that serves multiple zones, start by repeating *Steps 1-6* from above.

Step 7: Calculate the zone primary outdoor air fraction using this equation:

$$Z_p = V_{oz} / V_{pz}$$

where Vp_z is the designed zone primary airflow from design documents including both outdoor and recirculated air. Design decisions are made based on on the maximum Z_p value for an air handler. Record this value.

Step 8: Look up the system ventilation efficiency E_v from Table 6-3 for the highest Z_p value found for a given air handler.

Step 9: Find the uncorrected outdoor air intake (V_{ou}) from this equation:

$$V_{ou} = (D * \Sigma_{\text{all zones}} R_p * P_z) + (\Sigma_{\text{all zones}} R_a * A_z)$$

where D =1 for this building (see assumptions)

Step 10: Calculate the design outdoor air intake (V_{ot}) with this equation:

$$V_{ot} = V_{ou} / E_v$$

Step 11: Compare this V_{ot} value to the design data provided.

Outside Air Requirements by Space:

Table B: Space Comparisons of Outdoor Air Requirements

Space	Area (ft^2)	Design Occupancy	V_{ot}
Aerobics	3083	61.7	1419
Raquetball	835	4	130
Raquetball	835	4	130
Raquetball	835	4	130
Raquetball	835	4	130
Raquetball	835	4	130
Child Restrooms	148	1.2	0
Storage	228	0	35
Kid's Club	1840	36.6	773
Free Weights	2974	59.5	1368
Basketball	3810	20	629
Storage	460	8.8	0
Sp. Exercise	1366	27.3	698
Equipment Room	147	0.5	0
Cardiovascular	10520	210.4	5119
Mezzanine	3000	60	1380
Trainer's Office	217	2.7	27
Spinning	1141	22.8	525
Pool Equipment	290	1	19
Pool & Spa	4112	82.3	3620
Locker Rooms	4125	8.8	807
Reception	1420	14	154
Membership Sales	687	8	142
Juice Bar	280	2.6	74

Comparison of ΣV_{oz} with V_{ot}:

After applying the ventilation rate procedure to this building, the outdoor air intake flow (V_{ot}) was found. These results are shown in the table below. The zone outdoor airflow was identical to the outdoor air intake flow with only two exceptions,. This is because eleven of the rooftop units serve single zones. As a result, the nominal outside air is 98% of the required outside air for the building. This result is typically uncommon in buildings because most air handlers serve multiple zones.

Table C: Nominal and Required Outdoor Air

	V_{oz}	V_{ot}
RTU-1	154	154
RTU-2	950	1188
RTU-3	3620	3620
RTU-4	807	807
RTU-5	629	629
RTU-6	1368	1368
RTU-7	1419	1419
RTU-8	651	651
RTU-9	2420	2420
RTU-10	2420	2420
RTU-11	944	1049
RTU-12	524.5	524.5
RTU-13	1380	1380
Entire Building	17286	17628

Discussion of Z_p Values:

Two air handlers in this building deal with the issue of Z_p: RTU-2 and RTU-11

Each of these units serves multiple zones. These zones all have differing outdoor air requirements. The way that Standard 62.1 deals with this issue is through a primary outdoor air fraction (Z_p). The maximum Z_p from all of the zones in a single system has to be the one that the system is designed to meet. For example, RTU-11 serves three different spaces, two of which have a ventilation efficiency of 1.0. However, the Z_p value for the special exercise room yields a ventilation efficiency of 0.9. The air handler must be designed to meet the 0.9 value because it is the limiting factor. It is impossible to deliver a higher fraction of outdoor air to one zone than to another from the same constant volume unit. Perfect mixing is assumed here and the most conservative factors must be used to ensure proper ventilation.

RTU-2	A_2	P_z	R_p	R_a	E_z	V_{bz}	V_{oz}
Child Restrooms	148	1.2	5	0.06	1	14.9	14.9
Membership Sales	687	8	7.5	0.12	1	142.4	142.4
Storage	211	1.2	5	0.12	1	31.3	31.3
Juice Bar	260	2.6	7.5	0.18	1	66.3	66.3
Kid's Club	1829	36.6	10	0.18	1	695.2	695.2
Zone Total:	3135	49.6	-	-	-	950.2	950.2
	V_{pz}	Z_p	E_v	V_{ou}	V_{ot}	Design OA	Meets 62.1n
Child Restrooms	50	0.30	0.8	14.9			
Membership Sales	750	0.19	0.9	142.4			
Storage	200	0.16	0.9	31.3			
Juice Bar	400	0.17	0.9	66.3			
Kid's Club	3600	0.19	0.9	695.2			
Zone Total:	5000	-	-	950.2	1187.7	700	No

RTU-11	A_2	P_z	R_p	R_a	E_z	V_{bz}	V_{oz}
Trainer's Office	217	2.7	5	0.06	1	26.5	26.5
Lower Stairs	1500	10	20	0.06	1	290.0	290.0
Sp. Exercise	1366	27.3	20	0.06	1	628.0	628.0
Zone Total:	3083	40	-	-	-	944.5	944.5
	V_{pz}	Z_p	E_v	V_{ou}	V_{ot}	Design OA	Meets 62.1n
Trainer's Office	250	0.11	1	26.5			
Lower Stairs	2250	0.13	1	290.0			
Sp. Exercise	3000	0.21	0.9	628.0			
Zone Total:	5500	-	-	944.5	1049.4	750	No

Appendix A: Calculations

RTU-1	A_2	P_z	R_p	R_a	E_z	V_{bz}	V_{oz}
Reception	1395	14	5	0.06	1	153.7	153.7
	V_{pz}	Z_p	E_v	V_{ou}	V_{ot}	Design OA	Meets 62.1n
Reception	5000	-	-	-	153.7	500	Yes

RTU-2	A_2	P_z	R_p	R_a	E_z	V_{bz}	V_{oz}
Child Restrooms	148	1.2	5	0.06	1	14.9	14.9
Membership Sales	687	8	7.5	0.12	1	142.4	142.4
Storage	211	1.2	5	0.12	1	31.3	31.3
Juice Bar	260	2.6	7.5	0.18	1	66.3	66.3
Kid's Club	1829	36.6	10	0.18	1	695.2	695.2
Zone Total:	3135	49.6	-	-	-	950.2	950.2
	V_{pz}	Z_p	E_v	V_{ou}	V_{ot}	Design OA	Meets 62.1n
Child Restrooms	50	0.30	0.8	14.9	18.6		
Membership Sales	750	0.19	0.9	142.4	158.3		
Storage	200	0.16	0.9	31.3	34.8		
Juice Bar	400	0.17	0.9	66.3	73.7		
Kid's Club	3600	0.19	0.9	695.2	772.5		
Zone Total:	5000	-	-	950.2	1187.7	700	No

RTU-3	A_2	P_z	R_p	R_a	E_z	V_{bz}	V_{oz}
Pool	4112	82.3	20	0.48	1	3619.8	3619.8
	V_{pz}	Z_p	E_v	V_{ou}	V_{ot}	Design OA	Meets 62.1n
Pool	10,500	-	-	-	3619.8	3500	No

RTU-4	A_2	P_z	R_p	R_a	E_z	V_{bz}	V_{oz}
Lockers	3843	76.9	7.5	0.06	1	807.3	807.3
	V_{pz}	Z_p	E_v	V_{ou}	V_{ot}	Design OA	Meets 62.1n
Lockers	8300	-	-	-	807.3	3350	Yes

RTU-5	A2	Pz	Rp	Ra	Ez	Vbz	Voz
Basketball	3810	20	20	0.06	1	628.6	628.6
	Vpz	Zp	Ev	Vou	Vot	Design OA	Meets 62.1n
Basketball	7500	-	-	-	628.6	750	Yes

RTU-6	A_2	P_z	R_p	R_a	E_z	V_{bz}	V_{oz}
Free Weights	2974	59.5	20	0.06	1	1368.4	1368.4
	V_{pz}	Z_p	E_v	V_{ou}	V_{ot}	Design OA	Meets 62.1n
Free Weights	6000	-	-	-	1368.4	750	No

RTU-7	A_2	P_z	R_p	R_a	E_z	V_{bz}	V_{oz}
Aerobics	3083	61.7	20	0.06	1	1419.0	1419.0
	V_{pz}	Z_p	E_v	V_{ou}	V_{ot}	Design OA	Meets 62.1n
Aerobics	10000	-	-	-	1419.0	1000	No

RTU-8	A_2	P_z	R_p	R_a	E_z	V_{bz}	V_{oz}
Racquetball (5)	4175	20	20	0.06	1	650.5	650.5
	V_{pz}	Z_p	E_v	V_{ou}	V_{ot}	Design OA	Meets 62.1n
Racquetball (5)	4000	-	-	-	650.5	500	No

RTU-9	A_2	P_z	R_p	R_a	E_z	V_{bz}	V_{oz}
Cardio	5260	105.2	20	0.06	1	2419.6	2419.6
	V_{pz}	Z_p	E_v	V_{ou}	V_{ot}	Design OA	Meets 62.1n
Cardio	6600	-	-	-	2419.6	1675	No

RTU-10	A_2	P_z	R_p	R_a	E_z	V_{bz}	V_{oz}
Cardio	5260	105.2	20	0.06	1	2419.6	2419.6
	V_{pz}	Z_p	E_v	V_{ou}	V_{ot}	Design OA	Meets 62.1n
Cardio	6600	-	-	-	2419.6	1675	No

RTU-11	A_2	P_z	R_p	R_a	E_z	V_{bz}	V_{oz}
Trainer's Office	217	2.7	5	0.06	1	26.5	26.5
Lower Stairs	1500	10	20	0.06	1	290.0	290.0
Sp. Exercise	1366	27.3	20	0.06	1	628.0	628.0
Zone Total:	3083	40	-	-	-	944.5	944.5
	V_{pz}	Z_p	E_v	V_{ou}	V_{ot}	Design OA	Meets 62.1n
Trainer's Office	250	0.11	1	26.5	26.5		
Lower Stairs	2250	0.13	1	290.0	290.0		
Sp. Exercise	3000	0.21	0.9	628.0	697.7		
Zone Total:	5500	-	-	944.5	1049.4	750	No

RTU-12	A_2	P_z	R_p	R_a	E_z	V_{bz}	V_{oz}
Spinning	1141	22.8	20	0.06	1	524.5	524.5
	V_{pz}	Z_p	E_v	V_{ou}	V_{ot}	Design OA	Meets 62.1n
Spinning	3500	-	-	-	524.5	500	No

RTU-13	A_2	P_z	R_p	R_a	E_z	V_{bz}	V_{oz}
Mezzanine	3000	60	20	0.06	1	1380.0	1380.0
	V_{pz}	Z_p	E_v	V_{ou}	V_{ot}	Design OA	Meets 62.1n
Mezzanine	5900	-	-	-	1380.0	750	No

Table D: Actual vs. Required Outdoor Air Results

	V_{oz}	V_{ot}	Actual Design OA	Total Airflow	Design %OA	62.1n %OA
RTU-1	154	154	500	5000	10.0	3.1
RTU-2	950	1188	700	5000	14.0	23.8
RTU-3	3620	3620	3500	10500	33.3	34.5
RTU-4	807	807	3350	8300	40.4	9.7
RTU-5	629	629	750	7500	10.0	8.4
RTU-6	1368	1368	750	6000	12.5	22.8
RTU-7	1419	1419	1000	10000	10.0	14.2
RTU-8	651	651	500	4000	12.5	16.3
RTU-9	2420	2420	1675	6600	25.4	36.7
RTU-10	2420	2420	1675	6600	25.4	36.7
RTU-11	944	1049	750	5500	13.6	19.1
RTU-12	524.5	524.5	500	3500	14.3	15.0
RTU-13	1380	1380	750	5900	12.7	23.4
Entire Building	17286	17628	16400	84400	19.4	20.9

Appendix B:
Ventilation Rate Procedure vs. Indoor Air Quality Approach

The Ventilation Rate Procedure was used in this report to evaluate acceptable ventilation of all spaces. The other option provided by Standard 62.1-2004 addendum n is the Indoor Air Quality Procedure. Both methods strive to keep ventilation rates at healthy levels for building occupants, but the two methods approach the problem differently.

The Ventilation Rate Procedure is based on a number of prescriptive steps that a designer should take to ensure minimum outside air requirements. This method relies on dilution as the means to a healthier indoor environment. The underlying assumption of using the Ventilation Rate Procedure is that outside air is “fresh” and will mix perfectly with recirculated air to dilute contaminants to the spaces served. The factors found in older versions of Standard 62.1 rely on occupant densities alone to calculate contaminants. The addition of Addendum n to the standard now includes design considerations such as floor area, ventilation efficiency, mixing, function of the space, as well as occupants in the calculations. It is a concise and effective method for most building applications.

The Indoor Air Quality Procedure, though not explored in this report, also manages the problem of keeping buildings healthy for occupants. However, where the Ventilation Rate Procedure used dilution of contaminants, the IAQ Procedure uses suppression of contaminants. This method is more space specific in regards to how much outdoor air is required and which zones need additional monitoring equipment for suppression or exhaust systems for purging. Credit is also given in this method for reduction of source contaminants. This is an effective design tool that can be used in buildings such as labs where contaminant levels must be critically monitored.

The Ventilation Rate Procedure is more common in system design. It does not require as many tests or as much initial information to be known. Designing spaces with extra monitoring equipment for the IAQ Procedure generally raises the first cost. This design may also limit the versatility of a space over time as owners or building functions change. While both methods are adequate for achieving a healthy indoor environment in buildings, the Ventilation Rate Procedure seems more attractive for most applications.

References Used:

1. "ASHRAE/IESNA Standard 62-2001". ASHRAE Incorporated, Atlanta GA. 2001.

2. "ASHRAE/IESNA Addendum n to ASHRAE/IESNA Standard 62-2001". ASHRAE Incorporated, Atlanta GA. 2003.