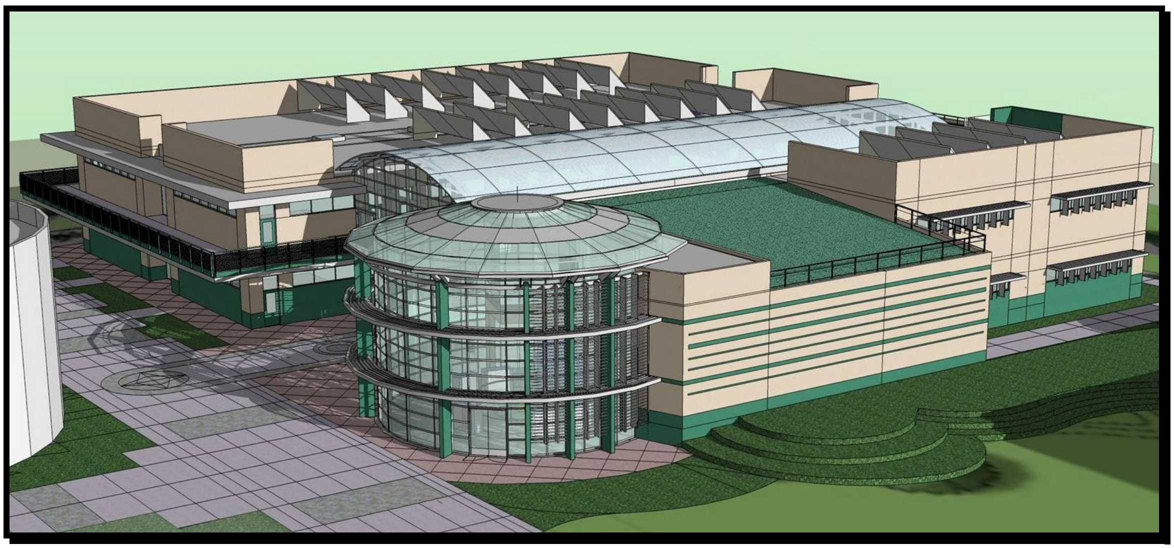
AE Senior Thesis – Single Zone vs. Multi Zone



The Harker School - Science and Technology Building
San Jose, CA

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Mechanical Option

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EXECUTIVE SUMMARY

The Harker School is one of the top K-12 schools in the state of California located in San Jose, CA. The new Science and Technology Building is a two story, 50,000 ft^2 located on the upper school campus(grades 9-12).

In the November ASHRAE meeting, Donald Wulfinghoff gave a presentation which advocated the use of single zone systems in all buildings. This project offered an ideal chance to research and implement many of the ideas he talked about in his presentation.

After modeling the new system in Carrier's Hourly Analysis program, it showed that the single zone system performed slightly less effectively than the VAV system it was compared to.

It is however unclear on whether or not the direct/indirect evaporative cooling system offers much more cost saving as it has been touted to do so. While the actual operating costs of the system are unclear at the moment, it's first cost alone was worth more than the 20 year operating cost of the proposed single zone system.

The added equipment to the roof of the building was originally thought to result in an increase in cost, but in fact it has done the opposite. Due to the smaller air handling units, some of the larger beams were no longer needed. Replacing them with smaller ones ended up saving several thousand dollars, even though some other smaller beams needed to be replaced with larger ones.

In the classroom chosen to be analyzed acoustically, it was found to have a sub par reverberation time. To remedy the issue, a ten by ten block of acoustical tiles were painted over to reduce their acoustical absorption quality and to increase their reflectivity. Not only did that solve the problem, but it also now helps the sound distribute throughout the room better.

ACKNOWLEDGEMENTS

Western Allied Mechanical, for teaching me so much last summer and for helping me acquire this project

Harker School Owner Representative Mike Bassoni for always being willing to help me out with all of my questions and requests for information

Penn State AE staff and faculty for a great four years in this great major

All my friends and classmates here at Penn State for always being there when I needed them

And most importantly to all my friends and family back home, thank you for sticking with me and supporting me all these years despite the fact that I've been 3000 miles away for the better part of 8 months out of the year

BUILDING OVERVIEW

Located in San Jose, California, The Harker School is one of the San Francisco Bay Area's most prestigious private schools. It is composed of three separate campuses ranging from kindergarten all the way through high school. Bucknall, the Lower School campus, serves students in kindergarten up to fifth grade. The Middle School campus, Blackford, runs from sixth grade to eighth grade. Lastly the Upper School campus, Saratoga, has grades ninth through twelfth. It is on this Upper School campus that the new Science and Technology Building is located.

It is a two story 50,000 square foot building which has a variety of offices, classrooms, and laboratories located in an East and a West wing. The two wings are separated by a double height open forum which is heated by a radiant floor system. Along with the previously mentioned spaces, the West wing also has a 192 seat lecture room, and a rotunda which has a large glass façade and roof.

Access to the East wing of the building is located all around the perimeter on the ground level as well as the second level via a cantilevered walkway that encompasses the whole wing including inside the rotunda. Sandwiched in between the classrooms and offices of both floors of the East wing are prep offices for the biology, technology, chemistry, and biology departments.

LEED Certification was a primary goal in the design process. Pending a formal review, there are enough points to achieve this. The Silver rating is possibly only a couple points away, however it is unknown at this time whether or not a higher rating will be pursued. There are also plans for a solar power system, but no timetable is currently set for its implementation.

Another goal was to minimize energy use and save on operation costs as much as possible. That is why a new cutting edge direct/indirect evaporative cooling system was selected for use in this project. There are only a few systems of its kind currently in use in the greater San Francisco Bay Area. It has the potential to cut operating costs down to a fraction of what more traditional systems costs are.

BUILDING STATISTICS

Building Name: The Harker School – Science and Technology Building

Location and Site: The Harker School – Upper School Campus, San Jose, Ca

Occupant Name: The Harker School

Occupancy: E-1 (Classroom, Prep Office), A-3 (Lecture Room, Rotunda)

Size: 50,000 ft^2

Stories: Two above grade

Primary Project Team:
Owner: The Harker School www.harker.org
Architect of Record: DES Architects and Engineers www.des-ae.com/
General Contractor: XL Construction www.xlconstruction.com
Mechanical Engineer: Western Allied Mechanical www.westernallied.com
Electrical Engineer: AMS Electrical
Civil Engineer: Sandis www.sandis.net
Landscape Architect: DES Architects and Engineers www.des-ae.com/
Acoustical Engineer: Charles M. Salter Associates Inc. www.cmsalter.com
Structural Engineer: DES Architects and Engineers www.des-ae.com/

Dates of Construction: June ’07 – August ‘08

Cost: $22.5 Million

Delivery Method: Design-Build

Codes and Zoning:
2001 California Building, Plumbing, Mechanical Code
2004 California Electrical Code
2001 California Code for Building Conservation (Chapter 5 and Appendices 1, 5, and 6)
2005 Building Energy Efficiency Standards

Electrical:

Power is spread throughout the building by an 800A, 480/277V distribution panel which feeds two panel boards that control lighting, mechanical equipment, and various first floor spaces. It also feeds two step down transformers that each feed a 600A, 208/120V distribution panel. One panel serves 7 panel boards which control first floor outlets and miscellaneous power. The other panel serves 5 panel boards which control the second floor.

Lighting:

Classrooms are illuminated by 20' fluorescent direct/indirect lighting fixtures. Offices and hallways have 2'x2' and 2'x4' ceiling mounted fluorescent lighting. The lecture room has various types of direct fluorescent downlighting. The rotunda has several types of recessed and surface mounted HID lighting. The forum has 8" 2-lamp fluorescent downlighting underneath the second floor's walkways, and 22" pendant mounted HID lighting.

Structural:

The floor of the building is 5" concrete slab on grade (3500psi). The second floor is concrete (3500psi) on metal deck supported by W-flange steel beams, and steel columns. The steel columns are only located in the west wing of the building and are supported by concrete spread footings.

EXISTING MECHANICAL SYSTEM

Overview

The building is conditioned by three 100% OA air handling units which feed VAV boxes throughout the building. As previously mentioned, the forum connecting the two wings is heated by a radiant flooring system. The radiant flooring system is served by a single boiler which also serves the heating coils and reheat coils in the AHUs and VAV boxes respectively. Two pumps circulate the hot water through the system. One moves it throughout the building, and a second one moves it though the radiant flooring system.

Equipment

AHUs

There are a total of three AHUs in the building. They use a direct/indirect evaporative cooling system to condition the air along with a traditional 2-pipe boiler. They serve the classrooms, laboratories, and offices in the two wings of the building. AHU-1 serves the West wing, and AHU-2 and 3 serve the East wing

VAV Boxes

There are 33 VAV boxes serving the main rooms in the building. Located in the ceiling plenum, there are several types of VAVs depending on the CFM required for the space being served.

Boiler

There is only one boiler in the building. It is used to supply hot water for building heating to the VAV boxes, AHUs, and the radiant flooring in the forum.

Pumps

There are two pumps used to distribute the hot water from the boiler. The first one is located on the roof with the boiler which distributes the water to the air handling units the various equipment throughout the building. The second pump is located on the first floor in the forum, and it supplies the radiant flooring system with hot water.

REDESIGN OBJECTIVES

The main purpose of the AE Senior Thesis is to analyze an existing building's system, and develop an in-depth redesign of the system based on the results of the analysis. The goal in this specific redesign is to try to obtain a lower operating costs than a multi zone VAV system serving the same area.

One issue that arose in the first technical report is the requirements outlined by ASHRAE Standard 62.1 is that none of the three AHUs were compliant. The redesign will take place with this in mind, to ensure that all of the spaces are properly ventilated per the ASHRAE Standards.

Another purpose is to see the difference between a more traditional system and a newer system. The system currently designed for The Harker School Science and Technology Building is a direct/indirect evaporative cooling system. This kind of system is going to be one of only a few in the San Francisco Bay Area. This thesis project will be a good opportunity to compare its effectiveness with that of another system.

PROPOSED SYSTEM REDESIGN

In the November ASHRAE meeting, Donald Wulfinghoff gave a presentation which advocated the use of single zone systems in all buildings. This project offers an ideal chance to research and implement many of the ideas he talked about in his presentation.

If done correctly, a single zone system will do a better job of meeting the demands of each zone than a multi-zone system would do since each zone will have its own dedicated air handling unit. The issue of under-ventilation in the spaces will be easily fixed as well.

Another positive aspect of utilizing a single zone system is that air will not be distributed throughout the building. Between labs, offices, and classrooms, there is a lot of potential for contaminants to enter the air. In a high school, illness is passed around pretty easily. While a single zone system won't solve that problem completely, it can help to lessen it by keeping any contaminants that may be around isolated to a single zone.

Overview

Do to the large number of spaces throughout the building, having a dedicated air handler for each of them would be unfeasible. The main problem with that would be that there would not be enough space on the roof to hold all of the necessary air handling units. Instead of this, spaces with similar loads and requirements will be grouped together into zones that will be served by a single air handling unit.

The unconditioned forum space with the radiant flooring will be excluded from the redesign as it is not related to the single zone/multi zone comparison.

Zone Definitions

Zone 1: 1100 Lecture Room

Zone 2: 1101 Physics
1102 Robotics
1106 Physics
1107 Physics
1111 Physics
1112 Physics

Zone 3: 1103 Technology
1104 Technology
1108 Technology
1109 Multimedia

1110 Future Technology

Zone 4: 1202 Biology

1203 Biology

1207 Biology

1211 Biology

1212 Biology

Zone 5: 1204 Chemistry

1205 Chemistry

1208 Chemistry

1209 Chemistry

1210 Chemistry

Zone 6: 1206 Special Projects

1235 Chemistry Prep

Zone 7: 1113 Rotunda

1200 Cyber Café

Zone 8: 1131 Copy/Work Room

1133 Office

1134 Office

1135 Office

1140 Sound Room

1201 Conference Room

1215 Audio/Visual

1217 Office

1218 Biology Prep

1229 Optical

Zone 9: 1105 Teacher Lounge

1144 Technology Prep

1145 Physics Prep

1218 Biology Prep

Major Equipment

AHU

The air handler chosen for the redesign is the 39M Aero from Carrier. It was chosen because it has a lot of the features talked about by Donald Wulfinghoff in his presentation as well as in his book "Energy Efficiency Manual." The most important of these features is the energy recovery ventilator section.

Variable frequency drives are also important. When serving single zone systems, it is important because it allows the fan to shift down during average conditions, and shift back up to capacity during peak conditions.

HEPA filters are also an integral part in the system. They are not only important because of the health benefits they provide, but in today's political environment, anything that can help stop or reduce the effectiveness of a terrorist attack should also be considered.

Because of the lack of free space in the building, I decided to go with air-cooled DX coils for cooling in order to avoid changing the room schedule to fit in a chiller plant somewhere in the building.

Boiler

The boiler chosen is the Mighty Therm 500 from Laars. The reason for the change from the previous system is that I am not including the forum in the redesign because it is an unconditioned space. That means that the radiant flooring in the forum is also not part of the redesign. The decreased load on the boiler was not large enough to stay with the same model, so a downgrade was necessary. It is not as efficient as the original boiler, but it is not too much less.

Energy Analysis

To ensure that the equipment chosen would be compatible with the analysis software, Carrier's Hourly Analysis Program (HAP) was used.

Since the existing system is extremely difficult to model, a more conventional VAV system with hot water and chilled water coils was used for comparison in lieu of the direct/indirect evaporative cooling system.

San Jose was not available in the library of simulation cities in HAP, but Sunnyvale was. Since it is only eleven miles away, I chose to use it as a suitable equivalent.

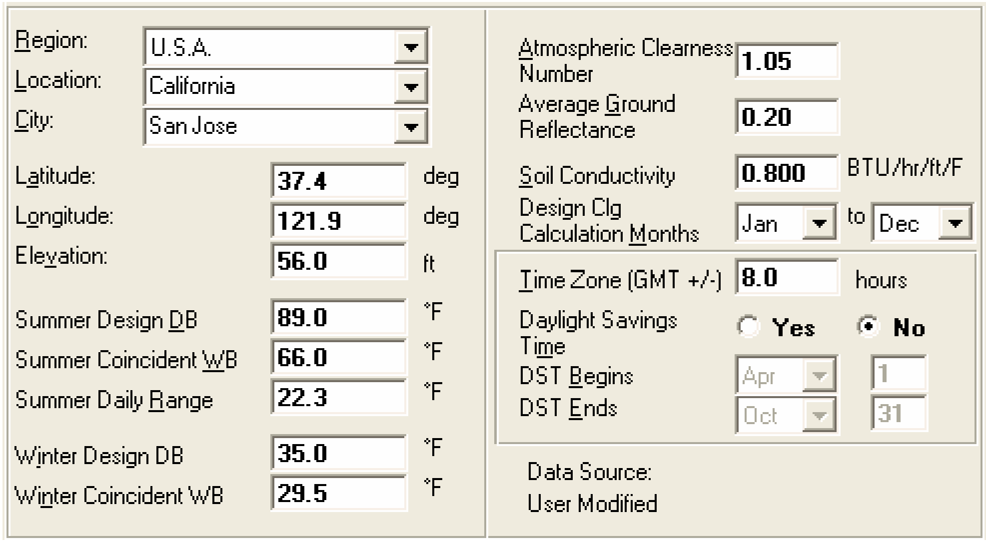


Figure 1 – San Jose Design Conditions

Operating Cost and Life Cycle Analysis

	Single Zone System	Multi Zone System
Total ($)	81,594	73,751
20 Year Cost	1,631,880	1,475,020

Table 1 – Annual Operating Cost and 20 Year Life Cycle Cost

Due to time constraints, I did not calculate initial cost. However, considering the initial cost for the existing system being quite expensive ($2,658,743) I feel confident in saying that the first cost of the single zone system would cost a fair amount less than the existing system.

Conclusions and Recommendations

As seen above, the operating cost for the single zone system is slightly larger than the multi zone system. Over a course of twenty years, it would result in an extra cost of $156,860. Under these circumstances I would say that the VAV system would be the better choice.

Had a viable option to model a direct/indirect evaporative cooling system be available, the single zone system may have been proven to be the better option just because of the fact that the direct/indirect system's first cost is greater than its 20 year operating cost. Unfortunately the most important factor, the operating cost of the direct/indirect system, just happens to be one that cannot be determined at this time.

STRUCTURAL BREADTH

Overview

With the alteration to the number and size of air handling units, the load on the roof will need to be analyzed in all areas affected, and if necessary the beams will be resized accordingly.

The following diagram shows the beams affected by the equipment addition and relocation. The red beams are ones that are having equipment added on top of them. The blue beams are ones that are having equipment removed from them.

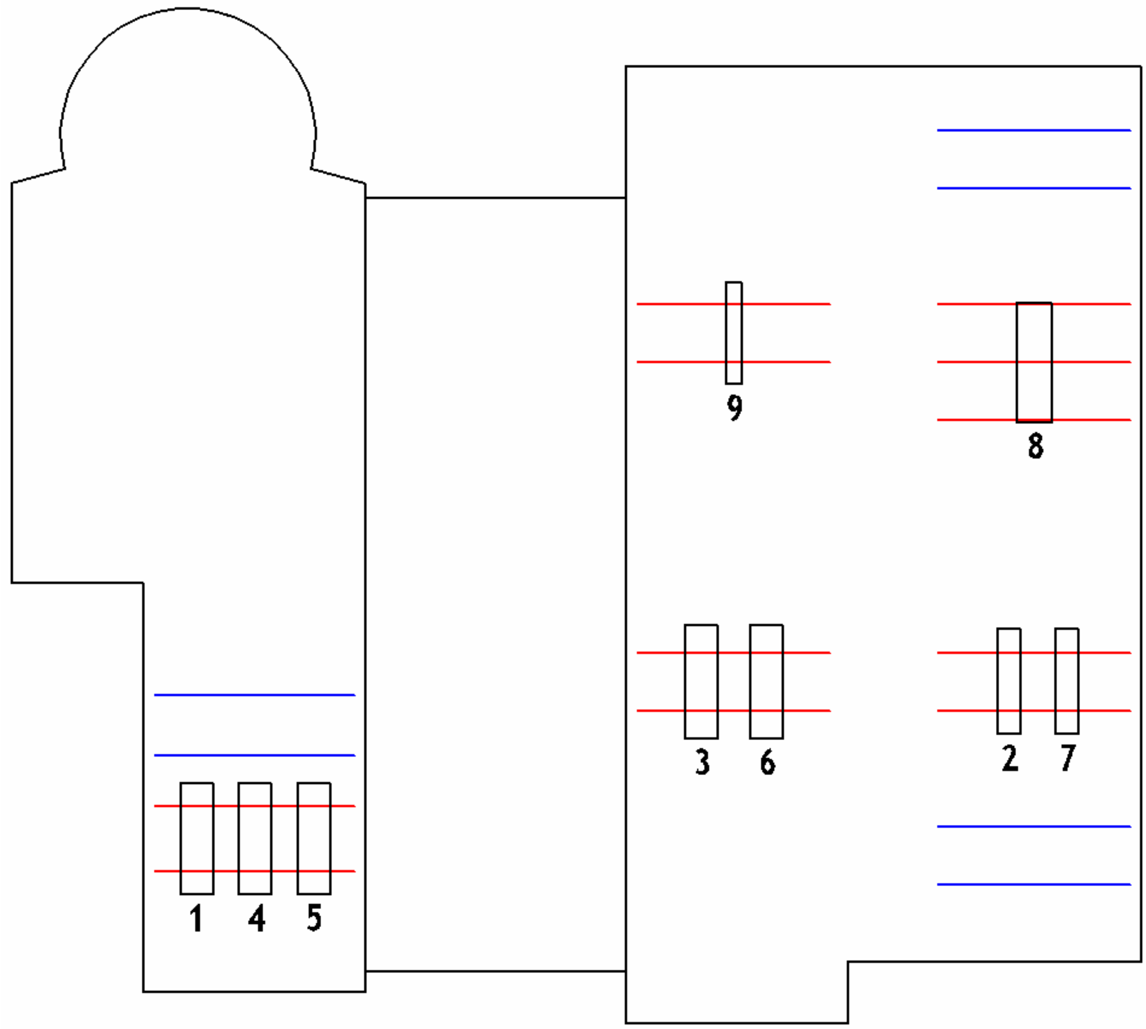


Figure 2 – Structural Adjustments

The following is the sizing of each air handling unit. More detailed physical data can be found in Appendix A.

Airflows / Dimensions

Size	Nominal Airflow (Cfm)
03	1,500
06	3,000
08	4,000
10	5,000
12	6,000
14	7,000
17	8,500
21	10,500
25	12,500
30	15,000
36	18,000
40	20,000
50	25,000
61	30,500

Table 2 – Sizing Chart

Zone 1

Zone Name	Maximum Cooling Sensible (MBH)	Design Air Flow (CFM)	Minimum Air Flow (CFM)	Time of Peak Load	Maximum Heating Load (MBH)	Zone Floor Area (ft²)	Zone CFM/ft²
Zone 1	57.6	4107	4107	Jul 1700	10.1	2642.0	1.55

Table 3 – Design Information

Size: 10

Weight: 5738 lbs

Zone 2

Zone Name	Maximum Cooling Sensible (MBH)	Design Air Flow (CFM)	Minimum Air Flow (CFM)	Time of Peak Load	Maximum Heating Load (MBH)	Zone Floor Area (ft²)	Zone CFM/ft²
Zone 1	20.5	1563	1563	Oct 1400	5.1	2126.0	0.74

Table 4 – Design Information

Size: 6

Weight: 4392 lbs

Zone 3

Zone Name	Maximum Cooling Sensible (MBH)	Design Air Flow (CFM)	Minimum Air Flow (CFM)	Time of Peak Load	Maximum Heating Load (MBH)	Zone Floor Area (ft²)	Zone CFM/ft²
Zone 1	73.5	5267	5267	Jul 1700	18.8	6619.0	0.80

Table 5 - Design Information

Size: 12

Weight: 6215 lbs

Zone 4

Zone Name	Maximum Cooling Sensible (MBH)	Design Air Flow (CFM)	Minimum Air Flow (CFM)	Time of Peak Load	Maximum Heating Load (MBH)	Zone Floor Area (ft²)	Zone CFM/ft²
Zone 1	63.1	4502	4502	Jul 1700	17.2	5393.0	0.83

Table 6 - Design Information

Size: 10

Weight: 5738 lbs

Zone 5

Zone Name	Maximum Cooling Sensible (MBH)	Design Air Flow (CFM)	Minimum Air Flow (CFM)	Time of Peak Load	Maximum Heating Load (MBH)	Zone Floor Area (ft²)	Zone CFM/ft²
Zone 1	67.3	4841	4841	Jul 1600	18.8	5391.0	0.90

Table 7 - Design Information

Size: 10

Weight: 5738 lbs

Zone 6

Zone Name	Maximum Cooling Sensible (MBH)	Design Air Flow (CFM)	Minimum Air Flow (CFM)	Time of Peak Load	Maximum Heating Load (MBH)	Zone Floor Area (ft²)	Zone CFM/ft²
Zone 1	70.0	5042	5042	Jul 1600	20.9	5393.0	0.93

Table 8 - Design Information

Size: 12

Weight: 6215 lbs

Zone 7

Zone Name	Maximum Cooling Sensible (MBH)	Design Air Flow (CFM)	Minimum Air Flow (CFM)	Time of Peak Load	Maximum Heating Load (MBH)	Zone Floor Area (ft²)	Zone CFM/ft²
Zone 1	32.0	2317	2317	Jul 1500	8.7	2705.0	0.86

Table 9 - Design Information

Size: 6

Weight: 4392 lbs

Zone 8

Zone Name	Maximum Cooling Sensible (MBH)	Design Air Flow (CFM)	Minimum Air Flow (CFM)	Time of Peak Load	Maximum Heating Load (MBH)	Zone Floor Area (ft²)	Zone CFM/ft²
Zone 1	92.0	6720	6720	Jun 1500	43.7	3405.0	1.97

Table 10 - Design Information

Size: 14

Weight: 6804 lbs

Zone 9

Zone Name	Maximum Cooling Sensible (MBH)	Design Air Flow (CFM)	Minimum Air Flow (CFM)	Time of Peak Load	Maximum Heating Load (MBH)	Zone Floor Area (ft²)	Zone CFM/ft²
Zone 1	17.5	1259	1259	Jul 1600	1.9	1518.0	0.83

Table 11 - Design Information

Size: 3

Weight: 3678

Analysis

The blue beams were the simplest to adjust. Since all of the beams without equipment on them were uniform on each wing, I simply matched them to their respective counterparts. The two on the East wing were changed from W18x65 to W16x26. The four on the West wing were changed from W18x65 to W16x31.

Sample Calculation

AHU-9

Existing beam = W16x31

Moment Capacity = 202 ft-K LRFD (Dead loads must be multiplied by 1.6)

Dead load due to concrete slab

Tributary Width x Depth of Slab x Weight of Concrete

10' x 4.5/12' x 150lbs/ft^3 = 562.5 lb/ft

Total Dead Load = Concrete Slab + Beam Self Weight

= 562.5 + 31

= 573.5 lb/ft x 1.6 = 949.6 lb/ft

Total Live Load = Live load x Tributary Width

= 20 psi x 10'

=200 lb/ft

Total Distributed Load = Total Dead + Total Live

= 949.6 + 200

= 1149.6 lb/ft

Max Moment Due to Distributed Load = $wL^2/8$

= $(1149.6)(37\ ft)^2/8$

= 196.7 ft-K

Weight of AHU-9 = 3678 lb

Distributed Across Two Beams = 1839 lb per beam x 1.6 = 2942.4 lb

Max Moment Due to Point Load at Midspan = PL/4

= (2942.4)(37)/4

= 27 ft-K

Total Max Moment = 196.7 + 27

= 223.7 ft-K

Greater than moment capacity, therefore a larger beam must be selected.

Using the steel manual, W16x36 is selected and has a moment capacity of 240 ft-K

Check with new self-weight:

New Dead Load = Concrete Slab + Beam Self Weight

= 562.5 + 36

= 598.5 lb/ft x 1.6 = 957.6 lb/ft

Total Distributed Load = 957.6 + 200

= 1157.6 lb/ft

Max Moment Due to Distributed Load = $wL^2/8$

= $(1157.6)(37\text{ ft})^2/8$

= 198.1 ft-K

New Total Max Moment = 198.1 + 27

= 225.1 ft-K

225.1 ft-K is less than the moment capacity of 240 ft-K so W16x36 is selected.

Note: AHU-1, 4, and 5 were treated as a distributed load, thus it was used along with the dead and live load to find the max moment in one step. AHU-

3/6 and AHU-2/7 were treated as a single point load for ease of calculation. This caused the calculation to not be as accurate, but it also erred on the conservative side.

Conclusions and Recommendations

Beams Added	Length	Number	Cost per Linear Foot	Total Cost
W16x36	37	5	37.5	6937.5
W16x40	37	2	48.5	3589
W16x45	37	4	60.5	8954
W16x26	37	2	31.5	2331
W16x31	37	4	37.5	5550
Beams Removed				Total Savings
W16x26	37	2	31.5	2331
W16x31	37	9	37.5	12487.5
W18x65	37	4	78.5	11618
W18x71	37	1	92	3404
W18x97	37	1	104	3848
			Overall Difference	6327

Table 12 – Cost Difference

Even though the number of units on the roof has increased, the overall cost has gone down since the new units are so much smaller than the previous ones. The amount of savings may not be much, but saving a few thousand dollars is always a better alternative to losing a few thousand dollars.

ACOUSTICAL BREADTH

Overview

For the acoustical study, I decided to analyze the reverberation time in one of the typical classrooms, Physics Room 1111. In order to do this I constructed a spreadsheet that would calculate the reverberation time once the surface area and absorption coefficient was entered for each material and frequency.

The Sabine equation for reverberation time is:

T_{60} = 0.049V/¤S¤

Where V is the room volume, S is the surface area of the respective material, and ¤ is the absorption coefficient of the respective material at a specific frequency.

Analysis

In order to determine the target reverberation time, the following table was used.

Room Volume (m^3)	Target Reverberation Time
10,000	1
1000	0.8
100	0.6

Table 13 – Recommended Reverberation Time

Converting cubic meters into cubic feet, and interpolating to get the value that corresponds to the room volume of 10800 cubic feet, the target reverberation time is found to be 0.85 seconds. For the purposes of this analysis I extended the acceptable range of time from a quarter second above and below, or from 0.6 to 1.1 seconds.

Frequency (Hz)	Reverberation Time	Compliance
125	0.48	Unacceptable
250	0.54	Unacceptable
500	0.7	Acceptable
1000	0.67	Acceptable
2000	0.53	Unacceptable
4000	0.56	Unacceptable

Table 14 – Current Results

As seen above, the reverberation time is not acceptable for the majority of the frequencies in the room. In order to remedy this problem, a 10 tile by 10 tile section of the ceiling acoustical panels at the front center of the room will be painted over to increase their reflectivity and decrease their absorption.

Conclusions and Recommendations

Frequency (Hz)	Reverberation Time	Compliance
125	0.63	Acceptable
250	0.77	Acceptable
500	1	Acceptable
1000	0.97	Acceptable
2000	0.78	Acceptable
4000	0.82	Acceptable

Table 15 – Modified Results

That small change has successfully increased the reverberation time for all incorrect frequencies into the acceptable range without pushing the previously acceptable frequencies out of it.

The cost of making this change is negligible, as several cans of paint will not even cost a fraction of the total construction costs.

Another benefit of making this change is that the altered tiles will not only correct the reverberation time problem, but they will also aid in the acoustical quality of the room by doing a better job of diffusing the sound from the speaker throughout the entire room.

REFERENCES

American Institute of Steel Construction, Steel Construction Manual, 13th edition, 2006

ASHRAE Standard 62.1-2007: Ventilation for Acceptable Indoor Air Quality. American Society of Heating Refrigeration and Air Conditioning Engineers, Inc. Atlanta, GA. 2007

ASHRAE 90.1–2004: Energy Standard for Buildings Except Low-Rise Residential Buildings. American Society of Heating Refrigeration and Air Conditioning Engineers, Inc., Atlanta, GA. 2004.

Long, M., Architectural Acoustics, Elsevier Inc., Burlington, MA., 2006

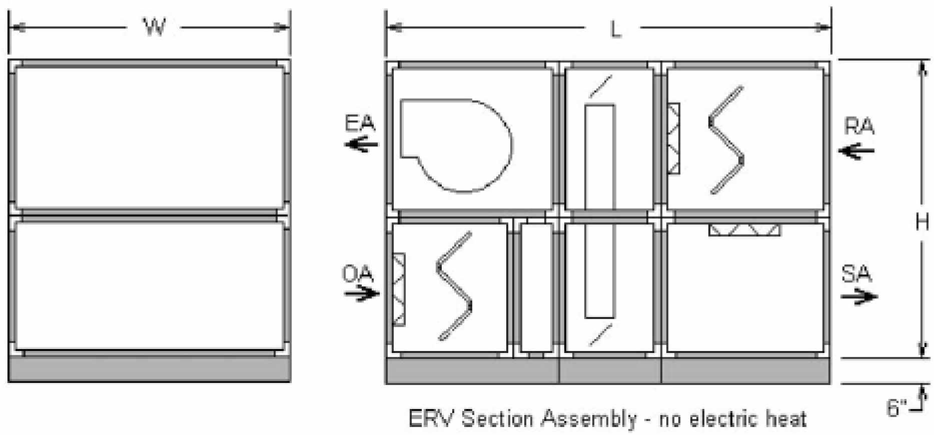
McQuiston, Parker, Spitler, Heating Ventilating, and Air Conditioning: Analysis and Design, John Wiley and Sons, Hoboken, NJ., 2005

R.S. Means, Costworks Program 2008, Means, Incorporated, Kingston, MA. 2008
Wulfinghoff, D., Energy Efficiency Manual, Energy Institute Press, Wheaton, MD. 1999

APPENDIX A – HVAC EQUIPMENT PHYSICAL DATA

STANDARD CONFIGURATIONS AND PHYSICAL DATA

The following illustrations (Fig. 23-26) show the various Aero Energy Recovery system configuration options available.

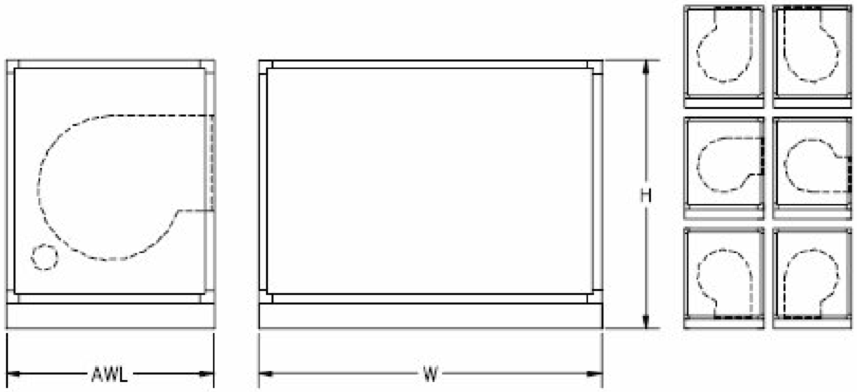


ERV Section Assembly - no electric heat

39M UNIT SIZE	L (in.)	W (in.)	H (in.)	WEIGHT (lb)
3	102	33	66	1688
6	102	46	66	2082
8	108	54	72	2427
10	108	67	72	2798
12	108	67	86	2975
14	114	72	86	3244
17	120	79	92	3658
21	120	79	112	3922
25	138	86	112	4375
30	138	104	112	4950

Fan motor sections

HORIZONTAL DRAW-THRU SUPPLY FAN



INDOOR 39MN UNIT SIZE	03	06	08	10	12	14	17	21	25	30	36	40	50	61
Dimensions (in.) H	39	39	42	42	49	49	52	62	62	62	73	79	89	104
W	33	46	54	67	67	72	79	79	86	104	109	109	117	117
AWL FC	24	30	36	36	42	48	48	48	60	60	60	60	66	66
AF	42	42	36	36	42	48	48	48	60	60	60	66	72	78
AF DB	42	42	42	42	48	54	54	54	66	66	60	66	72	78
Weight (lb) FC	480	550	640	700	810	910	990	1100	1360	1560	1840	1960	2480	2830
AF	550	620	640	700	810	900	990	1100	1360	1560	1840	2120	2670	3270
AF DB	550	620	670	740	850	940	1030	1150	1400	1600	1750	2010	2520	3080

OUTDOOR 39MW UNIT SIZE	03	06	08	10	12	14	17	21	25	30	36	40	50	61
Dimensions (in.) H	43	43	46	46	53	53	56	66	66	66	77	83	93	108
W	36	49	57	70	70	75	82	82	89	107	112	112	120	120
AWL FC	24	30	36	36	42	48	48	48	60	60	60	60	66	66
AF	42	42	36	36	42	48	48	48	60	60	60	66	72	78
AF DB	42	42	42	42	48	54	54	54	66	66	60	66	72	78
Weight (lb) FC	590	690	800	890	1010	1140	1230	1340	1650	1890	2180	2300	2860	3210
AF	690	780	800	890	1010	1130	1230	1340	1650	1890	2180	2480	3070	3700
AF DB	690	780	850	940	1070	1180	1290	1410	1700	1950	2090	2370	2920	3510

All dimensions in inches unless otherwise noted.

LEGEND

AF — Airfoil
AWL — Airway Length
DB — Downblast
FC — Forward Curved
H — Height
W — Width

Upblast fans not available for 39MW outdoor units.

SPECIFICATIONS

Fan supports, structural members, panels, or flooring shall not be welded, unless aluminum, stainless steel, or other corrosion-resistant material is used.

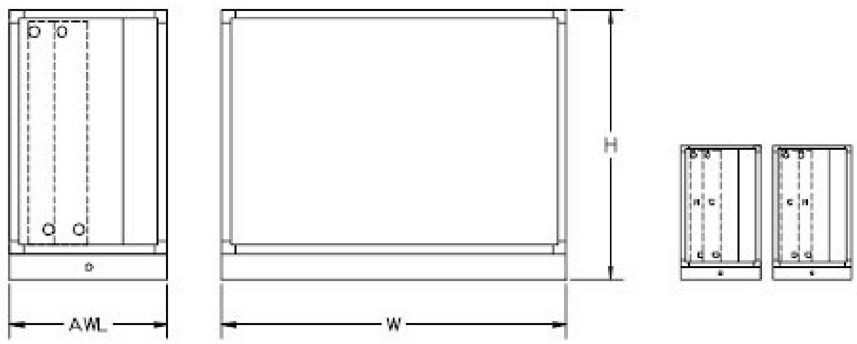
The fan section shall have a double-wall, insulated, galvanized steel floor. Accessibility options shall be hinged double-wall access door on either side, hinged double-wall access doors on both sides, or removable double-wall access panels.

A. Thermal pane reinforced glass viewports shall be available as a factory-installed option on the access panel(s) or door(s) of this section.
B. Marine lights shall be available as a factory-installed option with or without convenience outlets.

See the guide specifications on pages 88-113 for fan detail options.

Heat transfer sections (cont)

DUAL COIL SECTION WITH DRAIN PAN



INDOOR 39MN UNIT SIZE	03	06	08	10	12	14	17	21	25	30	36
Dimensions (in.) H	39	39	42	42	49	49	52	62	62	62	73
W	33	46	54	67	67	72	79	79	86	104	109
AWL	36	36	36	36	36	36	36	36	36	36	36
Weight (lb)	210	240	260	280	300	310	340	380	400	440	510

OUTDOOR 39MW UNIT SIZE	03	06	08	10	12	14	17	21	25	30	36
Dimensions (in.) H	43	43	46	46	53	53	56	66	66	66	77
W	36	49	57	70	70	75	82	82	89	107	112
AWL	36	36	36	36	36	36	36	36	36	36	36
Weight (lb)	340	390	420	470	490	510	550	590	620	690	770

LEGEND

AWL — Airway Length
H — Height
W — Width

NOTES:
1. All dimensions in inches unless otherwise noted.
2. Dual coil sections are not available on sizes 40-61.

SPECIFICATIONS
Coil face areas available:
- Large
- Medium

All coil sections shall be solid double-wall construction of galvanized steel with insulation sealed between the inner and outer panels. The panel assemblies shall not carry a resultant minimum R-value of less than 13. Coil sections shall have removable frame sections to facilitate vertical coil extraction.

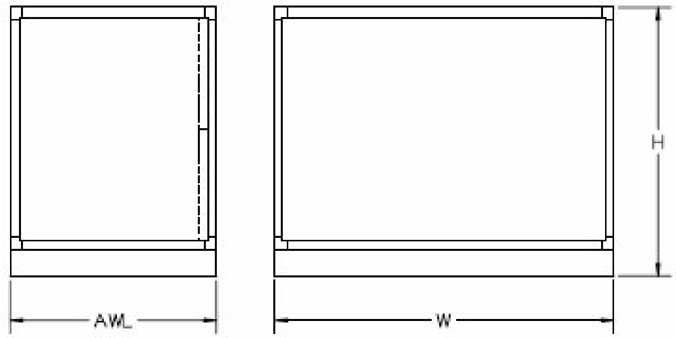
Drain pans shall be insulated double-wall galvanized or stainless steel construction. The pan shall be sloped in 4 directions toward the drain fitting. Drain pan shall have a recessed bottom drain design with integral FPT elbow for side discharge and trapping. One drain outlet shall be supplied for each cooling coil section. Drain pan shall allow no standing water and shall comply with ASHRAE Standard 62. Where 2 or more coils are stacked in a coil bank, intermediate drain pans shall be provided and the condensate shall be piped to the bottom drain pan. The bottom coil shall not serve as a drain path for the upper coil.

Accessibility options shall be hinged double-wall access door on either side, hinged double-wall access doors on both sides, or removable double-wall access panels.

See the guide specifications on pages 88-113 for coil detail options.

Filtration components (cont)

HORIZONTAL, BLOW-THRU FRONT LOADING HEPA FILTER SECTION



INDOOR 39MN UNIT SIZE	03	06	08	10	12	14	17	21	25	30	36	40	50	61
Dimensions (in.) H	39	39	42	42	49	49	52	62	62	62	73	79	89	104
W	33	46	54	67	67	72	79	79	86	104	109	109	117	117
AWL	48	48	48	48	48	48	48	48	48	48	48	48	48	48
Weight (lb)	320	370	420	470	510	540	590	670	710	810	960	1020	1190	1360

OUTDOOR 39MW UNIT SIZE	03	06	08	10	12	14	17	21	25	30	36	40	50	61
Dimensions (in.) H	43	43	46	46	53	53	56	66	66	66	77	83	93	108
W	36	49	57	70	70	75	82	82	89	107	112	112	120	120
AWL	48	48	48	48	48	48	48	48	48	48	48	48	48	48
Weight (lb)	470	540	610	690	730	770	830	910	960	1100	1260	1320	1510	1680

FILTER SIZES (Qty)	39M UNIT SIZE													
	03	06	08	10	12	14	17	21	25	30	36	40	50	61
12x24	—	1	—	1	2	3	3	—	—	—	4	4	3	7
24x24	1	1	2	2	2	2	3	6	6	8	8	8	12	12
Face Area (sq ft)	4	6	8	10	12	14	18	24	24	32	40	40	54	62

All dimensions in inches unless otherwise noted.

LEGEND

AWL — Airway Length
H — Height
HEPA — High-Efficiency Particulate Air
W — Width

SPECIFICATIONS
Blow-thru HEPA filter sections shall contain a face loading filter frame and be capable of accepting standard size 12-in. deep HEPA box filters.

Filter types as shown on the equipment schedule. Accessibility options shall be hinged double-wall access door on either side, hinged double-wall access doors on both sides, or removable double-wall access panels.
Thermal pane reinforced glass viewports shall be available as a factory-installed option on the access panel(s) or door(s) of bag/cartridge filter sections only.

MIGHTY THERM®

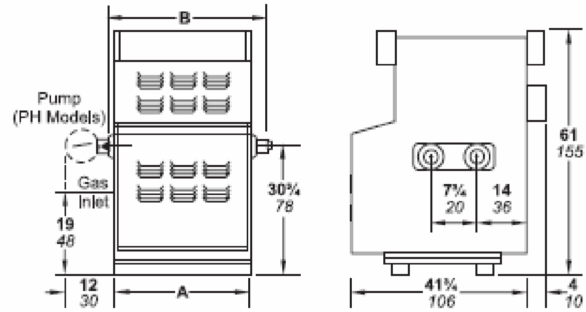
Hydronic Boilers

HH	Hydronic Heating Boiler
PH	Hydronic Heating Boiler with mounted pump

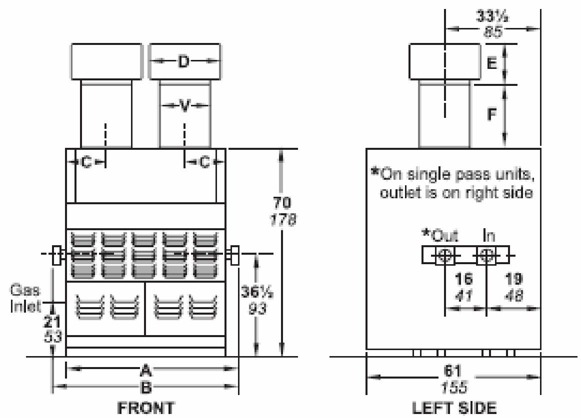
Outdoor Sizes 500,000 - 4,500,000 BTU/h

Submittal Data LAARS Heating Systems

Outdoor
Sizes 500-1825



Outdoor
Sizes 2200-4500



Dimensional Data

Outdoor Models HH/PH*	Input[1,4] BTU/h x1000	Output[1,4] BTU/h x1000	IBR Net[1,4] Rating BTU/h x1000	Gas Connection Size inches[2] Natural[5]	LP[5]	Water Conn. Size in[2]	Dimensions inches[2] A	B	C	D	E	F	V	Ship Weight lbs[3]
500	500	410	357	1	3/4	2	33 3/4	45 1/4	——	——	——	——	——	800
600	600	492	428	1	3/4	2	38 3/4	50 1/4	——	——	——	——	——	910
715	715	586	510	1	3/4	2	44 1/4	55 3/4	——	——	——	——	——	995
850	850	697	606	1	3/4	2	50 3/4	62 1/4	——	——	——	——	——	1030
1010	1010	828	720	1 1/4	1	2 1/2	58	69 1/2	——	——	——	——	——	1180
1200	1200	984	856	1 1/4	1	2 1/2	66 1/4	77 3/4	——	——	——	——	——	1330
1430	1430	1173	1020	1 1/4	1 1/4	2 1/2	76	87 1/2	——	——	——	——	——	1490
1670	1670	1370	1191	1 1/2	1 1/4	2 1/2	85 1/2	97	——	——	——	——	——	1600
1825	1825	1497	1302	1 1/2	1 1/4	2 1/2	92 1/4	103 3/4	——	——	——	——	——	1660
2200	2205	1786	1553	1 1/2 /2	1 1/2	4	65 1/2	83	16	28 1/4	15	24	18	2320
2800	2745	2223	1933	1 1/2 /2	1 1/2	4	78	95 1/2	20	28 1/4	15	24	18	2600
3200	3150	2552	2219	2	1 1/2	4	88	105 1/2	23	31 1/2	16 1/2	36	20	2750
3600	3645	2952	2567	2/2 1/2	2	4	100 1/2	118	29	31 1/2	16 1/2	36	20	3175
4000	4050	3281	2853	2 1/2	2	4	110 1/2	128	30 1/2	34 1/2	18	36	22	3380
4500	4500	3645	3170	2 1/2	2	4	123	140 1/2	34	37 3/4	19 1/2	36	24	3790

APPENDIX B – AHU SIZE AND WEIGHT TABLES

Unit Size	3	6	10	12	14
ERV	1688	2082	2798	2975	3244
HEPA	470	540	690	730	770
Coils	340	390	470	490	510
Supply Fan	590	690	890	1010	1140
Return Fan	590	690	890	1010	1140
Total Weight	3678	4392	5738	6215	6804

Unit Size	3	6	10	12	14
ERV	102	102	108	108	114
HEPA	48	48	48	48	48
Coils	36	36	36	36	36
Supply Fan	24	30	36	42	48
Total Length	210	216	228	234	246

APPENDIX C – REVERBERATION TIME CALCULATIONS

Reverberation Time							
Surface	Surface Area (SQFT)	Absorption Coefficient					
		125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Stained and Sealed Concrete	1080.000	0.010	0.010	0.015	0.020	0.020	0.020
5/8" Acoustical Tile	1080.000	0.680	0.760	0.600	0.650	0.820	0.760
Painted Concrete	114.875	0.100	0.050	0.060	0.070	0.090	0.080
1/2" Gypsum	567.250	0.290	0.100	0.050	0.040	0.070	0.090
1/4" Cork Board	228.000	0.290	0.100	0.050	0.040	0.070	0.090
Solid Core Wood Door	18.250	0.190	0.140	0.090	0.060	0.060	0.050
Painted Hollow Metal Door	26.250	0.020	0.030	0.030	0.030	0.030	0.020
White Board	88.000	0.020	0.030	0.030	0.030	0.030	0.020
Glass	141.000	0.550	0.250	0.180	0.120	0.070	0.040
Wood Cabinets	149.500	0.190	0.140	0.090	0.060	0.060	0.050
	□S□	1099.0175	979.03125	754.76	793.86375	996.56875	939.475

Volume	10800					
Frequency		125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Reverberation Time (Seconds)		0.48	0.54	0.70	0.67	0.53	0.56
Target Reverb Time = 0.6-1.1		Bad	Bad	Good	Good	Bad	Bad

Modified Reverberation Time							
Surface	Surface Area (SQFT)	Absorption Coefficient					
		125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Stained and Sealed Concrete	1080.000	0.010	0.010	0.015	0.020	0.020	0.020
5/8" Acoustical Tile	680.000	0.680	0.760	0.600	0.650	0.820	0.760
Painted Concrete	114.875	0.100	0.050	0.060	0.070	0.090	0.080
1/2" Gypsum	567.250	0.290	0.100	0.050	0.040	0.070	0.090
1/4" Cork Board	228.000	0.290	0.100	0.050	0.040	0.070	0.090
Solid Core Wood Door	18.250	0.190	0.140	0.090	0.060	0.060	0.050
Painted Hollow Metal Door	26.250	0.020	0.030	0.030	0.030	0.030	0.020
White Board	88.000	0.020	0.030	0.030	0.030	0.030	0.020
Glass	141.000	0.550	0.250	0.180	0.120	0.070	0.040
Wood Cabinets	149.500	0.190	0.140	0.090	0.060	0.060	0.050
Painted Ceiling Tile	400.000	0.020	0.030	0.030	0.030	0.030	0.020
	□S□	835.0175	687.03125	526.76	545.86375	680.56875	643.475

Volume	10800					
Frequency	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Reverberation Time (Seconds)	0.63	0.77	1.00	0.97	0.78	0.82
Target Reverb Time = 0.6-1.1	Good	Good	Good	Good	Good	Good