Airflow Testing Report

Prepared for

Portland Public Schools

August 2021

9700 SW Capitol Hwy, Suite 110
Portland, OR 97219
ameresco.com

PROJECT OVERVIEW

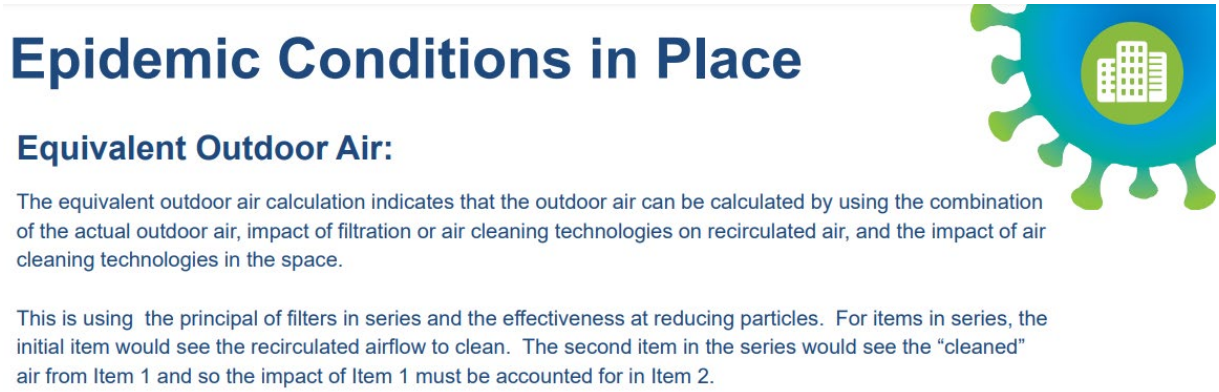
As part of the continuing process to ensure a safe return to in-person learning, Portland Public Schools has contracted with Ameresco to test the airflow and ventilation of all educational and office spaces in each school. The data is reviewed by both Ameresco and PPS personnel to identify any potential shortcomings in the airflow from the HVAC systems. To accomplish this task, Ameresco has partnered with a local NEBB certified Test-Adjust-Balance (TAB) firm, Neudorfer Engineers, who will measure the airflow to each zone with calibrated measurement equipment in accordance with current testing standards and procedures. As part of this effort, HVAC professionals will review the operation of the HVAC equipment serving every educational and office space in each school.

Ameresco is pleased to have partnered with PPS over the last decade as the district's Energy Services Company (ESCO) on six energy efficiency construction projects, four service projects, and numerous energy audits. Our partnership has resulted in reducing over 3,000 tons of CO_2 and other GHG emissions and over $1,000,000 in utility cost savings per year. Ameresco appreciates this opportunity to play a small role in the safe reopening of schools.

About Ameresco, Inc.
Founded in 2000, Ameresco, Inc. (NYSE:AMRC) is a leading cleantech integrator and renewable energy asset developer, owner and operator. Our comprehensive portfolio includes energy efficiency, infrastructure upgrades, asset sustainability and renewable energy solutions delivered to clients throughout North America and the United Kingdom. Ameresco's sustainability services in support of clients' pursuit of Net Zero include upgrades to a facility's energy infrastructure and the development, construction, and operation of distributed energy resources. Ameresco has successfully completed energy saving, environmentally responsible projects with Federal, state and local governments, healthcare and educational institutions, housing authorities, and commercial and industrial customers. With its corporate headquarters in Framingham, MA, Ameresco has more than 1,000 employees providing local expertise in the United States, Canada, and the United Kingdom. For more information, visit www.ameresco.com.

Explanation of ASHRAE Total Effective Air Changes per Hour (ACH_e) Calculation

ASHRAE has been updating their Building Readiness document to reflect the most current understanding in the engineering community for how to operate and maintain buildings during the pandemic. Their update on 4/27/2021 provided an explanation of the impact air filters and air cleaning devices have on the air in buildings. They provided the methodology, formulas, and an Excel-based tool for determining the equivalent outside air a space is receiving by having a mix of outside air, filtered recirculated air, and additional air filtration or cleaning devices in the room. Here is the explanation from ASHRAE:



As part of the airflow testing project that Portland Public Schools has partnered with Ameresco to complete, we are including the calculation of the Total Effective Air Changes per Hour (ACH_e) to show the impact of the air filtration that is active in nearly all spaces in the PPS schools. The formula for doing so is:

$$\mathrm{ACH_e} = \left(ACH_{oa} + ACH_f\right) * E_Z + ACH\_ir$$

where:

- $\mathrm{ACH_{oa}}$ = air changes per hour of outside air = outside airflow in cubic feet per minute * 60 minutes per hour / room volume in cubic feet
- $\mathrm{ACH_f}$ = air changes per hour of clean air from filtered recirculated air with filters of the specified MERV rating as determined by ASHRAE
- E_z = Zone Air Distribution Effectiveness = how effective the HVAC system is at circulating and mixing the air to distribute the clean air throughout the room
- ACH_ir = the air changes per hour of clean air from portable air filters in the room = number of filters * CADR * 60 minutes per hour / room volume in cubic feet
    - CADR = Clear Air Delivery Rate = the CFM of clean air as specified by the manufacturer of the air filter

In order to include these calculations in the airflow testing reports, Ameresco and PPS have made the following assumptions as not all the variables are known:

1. PPS is in process of upgrading the air filters in their HVAC systems to MERV 13 and plans to be complete with that project for the start of the ’21-’22 school year. In this report and for the sake of the ACH_e calculation, we are using the filters that are in place at the time of the measurements, so some of them are still MERV 8.
2. ASHRAE has guidelines for what should be used for the Zone Air Distribution Effectiveness (E_z) based on the HVAC system configuration, but they do not provide a value for every HVAC system and room configuration. For the majority of PPS rooms, an E_z of 0.8 – 1.0 would be most appropriate, so we have made the conservative assumption of using 0.8 for every space as that yields the lower ACH_e.
3. The CADR for a given air filter is from manufacturer ratings and is based on certain conditions (fan speed, particulate size, filter cleanliness, etc.) that change with operating conditions.

NEUDORFER ENGINEERS INC.

TEST REPORT TYPE:
SURVEY REPORT

Portland Public Schools Airflow Testing
Marysville K-8
7733 SE Raymond St, Portland, OR 97206

Job Number: 2021-0297

Project Completion Date: **08/31/21**
Revision Date: **-** **Revision Number:** **-**

SEATTLE

5516 1st Avenue South
Seattle, Washington 98108
Phone (206) 621-1810
Fax (206) 343-9820

PORTLAND

2501 SE Columbia Way, Suite 230
Vancouver, Washington 98661
Phone (503) 235-8924
Fax (503) 235-8925

Portland Public Schools Airflow Testing
Marysville K-8

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REPORT TITLE

CERTIFIED TEST: SURVEY REPORT

Project: Portland Public Schools Airflow Testing
Marysville K-8

NEI Job#: 2021-0297

Mechanical Engineer: NA

Architect: NA

HVAC Contractor: NA

TAB Firm: Neudorfer Engineers Inc
Test Engineer: Zach Mayer

5516 1st Ave South
Seattle, Washington 98108
Phone (206) 621-1810
Fax (206) 343-9820

2501 SE Columbia Way, Suite 230
Vancouver, Washington 98661
Phone (503) 235-8924
Fax (503) 235-8925

CERTIFICATION

Portland Public Schools Airflow Testing

The data presented in this report is a record of system measurements and final adjustments that have been obtained in accordance with the current edition of the NEBB Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems. Any variances from design quantities, which exceed NEBB tolerances, are noted in the Test-Adjust-Balance Report Project Summary.

Significant / Noteworthy Remarks are noted on the General Remarks and General Field Notes pages. Other remarks are noted on individual test sheets.

Noted deficiencies are not the TAB firms responsibility to repair. Prior to issuance of this report, Deficiency Reports are forwarded to our contracted agent.

Warranty is limited to one year from date of this report. Within that time, any discrepancies, ambiguities, or omissions found in this report will be retested, adjusted, or balanced as needed. A written notification will be required.

Submitted and Certified by:

NEBB TAB Firm:	**Neudorfer Engineers Inc**
Certification No:	**3414**
Expiration Date:	**March 31, 2023**
Certification Date:	**March 31, 2021**
(Date completed)	*Signed and Sealed by:*
NEBB Supervisor:	**Mike Vawter P.E.**
NEBB Supervisor:	**Eric Stotts**

TERMS AND ABBREVIATIONS

Project: Portland Public Schools Airflow Testing

AC or ACU Air Conditioner or Air Conditioning Unit
AH or AHU Air Handler or Air Handling Unit
AVG Average
BHP Brake Horsepower
CAV Constant Air Volume
CBV Calbirated Balancing Valve (Circuit Setter)
CC Cooling Coil
CD Ceiling Diffuser
CFM Cubic Feet per Minute
CH Chiller
CHWS Chilled Water Supply
CHWR Chilled Water Return
CP Circulating Pump
CR Ceiling Register
CRAC Computer Room Air Conditioner
CRU Computer Room Unit
CT Cooling Tower
CU Condenser Unit
CUH Cabinet Unit Heater
CWS Condenser Water Supply
CWR Condenser Water Return
DAT Discharge Air Temperature
DB Dyr Bulb
DD Direct Drive
DDC Direct Digital Controls: EMS Control System for the HVAC
Des. Design
Dia. Diameter
Disch. Discharge
EA Exhaust Air
EAT Entering Air Temperature
Economizer Controls and components that allow an air handler to logically utilize outdoor air for cooling as opposed to the use of mechanical cooling.
EF Exhaust Fan
EG Exhaust Grille
EMCS Energy Management Control System
ERU Energy Recovery Unit
E.S.P. External Static Pressure
HRC Heat Recovery Coil
EWT Entering Water Temperature
FCU Fan Coil Unit
FD Fire Damper
FLA Full Load Amperage: Maximum amperage a motor can draw.
Flow Hood Instrument that captures air and converts the reading to CFM.
FHT Fume Hood Test
FPB Fan Powered Box
FPM Feet per Minute
FR Field Report
FT Foot, Feet
FTU Fan Terminal Unit
GPM Gallons per Minute
HC Heating Coil
TDH Pressure Difference across the entering and leaving side of a pump.
HEPA High Efficiency Particulate Arrestance
HP Horsepower
HVAC Heating Ventilation and Air Conditioning
HWS Heating Water Supply
HWR Heating Water Return
HX Heat Exchanger
HZ Hertz, cycle per second
in. inches
in.w.g. inches of water gauge
Kfactor Correction factor to the free area need to calculate CFM.
KW Kilowatts
LAT Leaving Air Temperature
LWG Low Wall Grille
LWR Low Wall Register
LWT Leaving Water Temperature
MAU Make-up Air Hangling Unit
MBH 1,000 BTUH
N/A Not Applicable
OSA Outside Air
OBD Opposed Blade Damper
ΔP Pressure Drop.
PH Phase
PSI Pounds per Square Inch
RA Return Air
RAD Radiator
RAT Return Air Temperature
RF Return Fan
RH Relative Humidity
RHC Reheat Coil
RPM Revolutions per Minute
RTU Roof Top Unit
SA Supply Air
SAT Supply Air Temerature
S.F. Service Factor
SF Supply Fan
SFD Smoke/Fire Damper
SP Static Pressure
sq.ft. square feet
Suct. Suction
SWG Sidewall Grille
SWR Sidewall Register
TAB Test; Adjust; and Balance
TSP Total Static Pressure: Difference between the entering and leaving static pressure of a fan.
UH Unit Heater
VAV Variable Air Volume; box that contains a motorized damper that modulates airflow.
VD Volume Damper
VFD Variable Frequency Drive
Velgrid Instrument that reads used to read velocity in feet per minute.
VVT Variable Volume Terminal
WC Water Column
W.G. Water Gauge
WB Wet Bulb

INSTRUMENT CALIBRATIONS

Portland Public Schools Airflow Testing

Instrument Type	Air Data Meter with Flowhood	Instrument Serial #	**M00475**
Instrument Manufacturer	**Shortridge**	Calibration Date	**11/4/2020**
Instrument Model Number	**ADM 870**	Calibration Due	**11/4/2021**

Instrument Type	Differential Pressure Water Meter	Instrument Serial #	**W14090**
Instrument Manufacturer	**Shortridge**	Calibration Date	**10/16/2020**
Instrument Model Number	**HDM-250**	Calibration Due	**10/16/2021**

Instrument Type	Psychrometer	Instrument Serial #	**8084305**
Instrument Manufacturer	**Extech**	Calibration Date	**10/13/2020**
Instrument Model Number	**RH390**	Calibration Due	**10/13/2021**

Instrument Type	Tachometer	Instrument Serial #	**B185B5022P**
Instrument Manufacturer	**Nidec**	Calibration Date	**10/11/2020**
Instrument Model Number	**MT-200**	Calibration Due	**10/11/2021**

Instrument Type	Amp Probe	Instrument Serial #	**33380179WS**
Instrument Manufacturer	**Fluke**	Calibration Date	**10/9/2020**
Instrument Model Number	**323 Clamp Meter**	Calibration Due	**10/9/2021**

Instrument Type	Digital Thermometer	Instrument Serial #	**45400509WS**
Instrument Manufacturer	**Fluke**	Calibration Date	**10/9/2020**
Instrument Model Number	**52 II**	Calibration Due	**10/9/2021**

Instrument Type	Manometer	Instrument Serial #	**M00475**
Instrument Manufacturer	**Shortridge**	Calibration Date	**11/4/2020**
Instrument Model Number	**ADM 870**	Calibration Due	**11/4/2021**

Instrument Type	Thermal Anemometer	Instrument Serial #	**AVM440742003**
Instrument Manufacturer	**Alnor Instruments**	Calibration Date	**11/9/2020**
Instrument Model Number	**AVM 440**	Calibration Due	**11/9/2021**

Instrument Type	Ultrasonic Flow Meter	Instrument Serial #	**N5K1435T**
Instrument Manufacturer	**Fuji**	Calibration Date	**10/14/2020**
Instrument Model Number	**Portaflow-C**	Calibration Due	**10/14/2021**

PROJECT Portland Public Schools Airflow Testing
LOCATION Marysville K-8; 7733 SE Raymond St, Portland, OR 97206

REPORT SUMMARY

This project has been surveyed per plans and specifications using the National Environmental Balancing Bureau (NEBB) standards and procedures.

The scope of work for this project was to assess the current airflows for each classroom, office, and special purpose space. Air changes per hour were calculated along with the % of OSA for the spaces and any deficiencies found for each piece of equipment has been noted in the following report.

All ventilation equipment was commanded to run by the BMS system. Ventilation units were measured with a flowhood on the supply outlets. Outside air was recorded with a flowhood on the OSA louvre where accessible. AK factors were calculated from flowhood readings. The remaining OSA values were recorded with a velgrid. AHU supply air was recorded by a summation of the outlets as recorded by flowhood or velgrid when appropriate. Outside air was recorded with a velgrid or airfoil and calculated by the free area method.

The measured airflows in this report represent the performance of the equipment at the time of measurement, which vary over time based on operating conditions. There are factors outside the control of Neudorfer that impact airflow, and variance in those factors is expected and normal. One significant factor is the MERV rating and condition of the air filters on the equipment. During the summer of 2021, PPS began upgrading the filters on all their fan systems to MERV 13. Those upgraded filters are more effective at capturing particles but also impact the amount of airflow from the equipment. These filter changes were occurring while the airflow measurement project was happening, so some schools had the new filters, and some had the old filters at the time of measurement. On the data page included this report, there is a line stating whether or not the upgraded filters were in place at the time of measurement.

AIRFLOW SURVEY REPORT

Project: Portland Public Schools Airflow Testing
Location: Marysville K-8; 7733 SE Raymond St, Portland, OR 97206
Filter Status: Not Upgraded

Room	Equipment Info		Room Dimensions					Airflow Measurements			Calculated ACH					Notes
	Served By	Equipment Type	Room Length	Room Width	Room Area	Room Height	Room Volume	Total CFM Supply	OA CFM Supply	OA %	Air Changes per Hour (supply)	Air Changes per Hour (OA)	# of Portable Filters	Total Effective Air Changes per Hour (ACH_e) with Portable Filter	Total Effective Air Changes per Hour (ACH_e) without Portable Filter	
First Floor																
Cafeteria 100	Auditorium Fan	AHU	54.0	75.0	4,050	24.5	99,225	8,665	8,665	100%	4.5	4.5	1	3.7	3.6	
100D	-	-	54.8	15.9	871	19.5	16,991	-	-	-						Open and shared with Cafeteria.
100B	AHU-2	AHU	28.8	22.6	651	9.8	6,379	1,075	770	72%	10.1	7.2	1	9.5	7.1	
100B2	-	-	-	-	-	-	-	-	-	-	0	0	0	N/A	0.0	This is a walk-in cooler.
100B3	-	-	4.2	5.5	23	8.1	187	-	-	-	0	0	0	N/A	0.0	This is storage.
Conf. Rm 101	EF	EF	41.2	21.5	886	11.9	10,541	-340	0	0%	1.9	0.0	1	2.3	0.9	Ventilation provided by adjacent spaces.
101A	EF	EF	12.1	11.5	139	11.9	1,656	-70	0	0%	2.5	0.0	1	10.5	1.1	Ventilation provided by adjacent spaces.
Conf. Rm 101B	EF	EF	11.5	10.3	118	11.8	1,398	-70	0	0%	3.0	0.0	1	12.5	1.3	Ventilation provided by adjacent spaces.
101C	-	-	8.7	8.4	73	10.9	797	-	-	-	0	0	1	19.6	0.0	Ventilation provided by adjacent spaces.
Conf. Rm 102	-	-	15.2	28.5	128	10.7	1,370	-	-	-	0	0	1	11.4	0.0	Ventilation provided by adjacent spaces.
103	EF	EF	10.1	17.2	174	11.9	2,067	-80	0	0%	2.3	0.0	1	8.6	1.0	Ventilation provided by adjacent spaces.
Conf. Rm 104	-	-	16.4	23.6	387	11.0	4,257	-	-	-	0	0	1	3.7	0.0	Ventilation provided by adjacent spaces.
Rm 105	UV	UV	22.8	35.3	805	11.8	9,497	735	350	48%	4.6	2.2	1	4.5	2.9	
Rm 107	UV	UV	22.8	35.3	805	11.8	9,497	645	85	13%	4.1	0.5	1	3.6	2.0	
Library 108	Library Fan	FCU	58.4	39.0	2,278	23.5	47,591	1,815	1,815	100%	2.3	2.3	1	2.2	1.8	Non-rectangular room.
Rm 109	UV	UV	22.8	35.3	805	11.8	9,497	715	425	59%	4.5	2.7	1	4.6	3.0	
Rm 110	Library Fan	FCU	26.3	24.0	631	9.4	5,933	755	755	100%	7.6	7.6	1	8.7	6.1	Unit in economizer mode.
Rm 111	UV	UV	22.7	34.0	772	11.8	9,107	710	0	0%	4.7	0.0	1	3.8	2.1	OSA damper closed.
113	UV	UV	22.8	30.0	684	11.8	8,071	700	410	59%	5.2	3.0	1	5.3	3.4	
Rm 115	UV	UV	22.7	29.9	679	11.8	8,009	605	290	48%	4.5	2.2	1	4.7	2.8	
112	-	-	14.3	11.9	170	11.3	1,923	-	-	-	0	0	1	8.1	0.0	Ventilation provided by adjacent spaces.
116	-	-	14.4	7.7	111	11.3	1,253	-	-	-	0	0	0	N/A	0.0	Ventilation provided by adjacent spaces.
Rm 117	UV	UV	22.8	30.0	684	11.8	8,071	690	275	40%	5.1	2.0	1	4.9	3.0	
Rm 119	UV	UV	23.0	37.2	856	11.8	10,096	690	420	61%	4.1	2.5	1	4.3	2.7	

Date: 6/23/2021 Readings By: Zach Mayer

Neudorfer Engineers. Inc.
Consulting Engineers Seattle Portland
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AIRFLOW SURVEY REPORT

Project: Portland Public Schools Airflow Testing
Location: Marysville K-8; 7733 SE Raymond St, Portland, OR 97206
Filter Status: Not Upgraded

Room	Equipment Info		Room Dimensions					Airflow Measurements			Calculated ACH					Notes
	Served By	Equipment Type	Room Length	Room Width	Room Area	Room Height	Room Volume	Total CFM Supply	OA CFM Supply	OA %	Air Changes per Hour (supply)	Air Changes per Hour (OA)	# of Portable Filters	Total Effective Air Changes per Hour (ACH_e) with Portable Filter	Total Effective Air Changes per Hour (ACH_e) without Portable Filter	
First Floor																
120	-	-	19.2	17.0	290	8.90	2,581	-	-	-	0	0	1	6.0	0.0	Ventilation provided by adjacent spaces.
Rm 121	UV	UV	22.2	29.9	664	11.8	7,833	820	530	65%	6.3	4.1	1	6.2	4.2	
Rm 123	UV	UV	22.1	30.0	663	11.9	7,890	610	420	69%	4.6	3.2	1	5.2	3.2	
Rm 125	UV	UV	22.1	29.9	661	11.9	7,863	850	475	56%	6.5	3.6	1	6.2	4.2	
Rm 127	UV	UV	27.8	37.2	1,070	11.7	12,519	675	470	70%	3.2	2.3	1	3.5	2.2	Non-rectangular room.
Conf. Rm 132	-	-	14.3	19.3	206	8.9	1,833	-	-	-	0	0	1	8.5	0.0	Ventilation provided by adjacent spaces.
Rm 133	UV	UV	28.0	38.5	1,078	11.8	12,720	690	465	67%	3.3	2.2	1	3.5	2.2	
Rm 135	UV	UV	30.0	22.0	660	11.9	7,854	545	135	25%	4.2	1.0	1	4.2	2.2	
Rm 137	UV	UV	30.0	22.0	660	11.9	7,854	670	315	47%	5.1	2.4	1	5.1	3.1	
138	-	-	14.2	8.8	125	14.3	1,787	-	-	-	0	0	1	8.7	0.0	Ventilation provided by adjacent spaces.
Rm 139	UV	UV	30.0	24.5	735	14.1	10,364	885	505	57%	5.1	2.9	1	4.8	3.3	
Rm 141	UV	UV	37.0	22.9	847	14.1	11,947	825	800	97%	4.1	4.0	1	4.6	3.3	
Rm 143	UV	UV	29.5	22.9	676	14.1	9,525	880	470	53%	5.5	3.0	1	5.2	3.5	
Rm 145	UV	UV	29.9	22.9	685	14.2	9,723	890	610	69%	5.5	3.8	1	5.4	3.8	
Gym 146	Gym Fan	AHU	39.1	58.3	2,280	27.0	61,547	1,230	1230	100%	1.2	1.2	1	1.2	1.0	
Conf. Rm 146A	146A FCU	FCU	15.2	7.0	106	9.6	1,021	145	55	38%	8.5	3.2	1	20.2	4.9	
Rm 147	UV	UV	29.9	22.8	682	14.2	9,680	905	595	66%	5.6	3.7	1	5.4	3.8	
Rm 149	UV	UV	35.1	22.9	804	14.2	11,414	885	520	59%	4.7	2.7	1	4.4	3.0	
150	150 FCU	FCU	17.7	17.2	304	11.9	3,623	350	147	42%	5.8	2.4	1	7.7	3.4	
Rm 151	UV	UV	31.7	26.4	837	14.2	11,884	1,400	520	37%	7.1	2.6	1	5.4	4.1	
152	150 FCU	FCU	16.9	10.4	176	14.2	2,496	180	75.6	42%	4.3	1.8	1	8.8	2.6	This is an office.
Rm 153	UV	UV	34.9	22.9	799	14.2	11,349	815	525	64%	4.3	2.8	1	4.3	2.9	
Conf. Rm 154	150 FCU	FCU	16.9	10.4	176	14.2	2,496	120	50.4	42%	2.9	1.2	1	8.0	1.7	
Rm 155	UV	UV	35.0	22.9	802	14.2	11,381	742	557	42%	3.9	2.9	1	4.2	2.8	

Date: 6/23/2021 Readings By: Zach Mayer

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First Floor																
156	150 FCU	FCU	16.9	10.4	176	14.2	2,496	230	96.6	42%	5.5	2.3	1	9.5	3.3	
Rm 157	UV	UV	22.8	35.3	805	14.10	11,348	805	805	100%	4.3	4.3	1	4.8	3.4	
159	UV	UV	17.1	17.6	355	11.8	4,189	230	0	0%	3.3	0.0	1	5.2	1.5	Non-rectangular room. OSA damper closed.

Date: 6/23/2021 Readings By: Zach Mayer

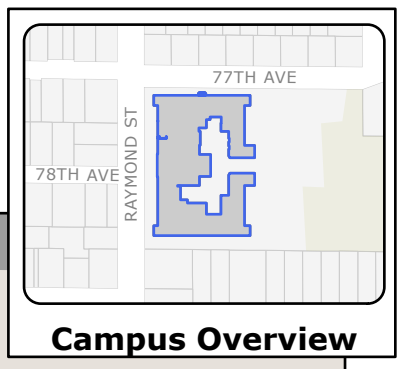
Project: Portland Public Schools Airflow Testing
Location: Marysville K-8; 7733 SE Raymond St, Portland, OR 97206

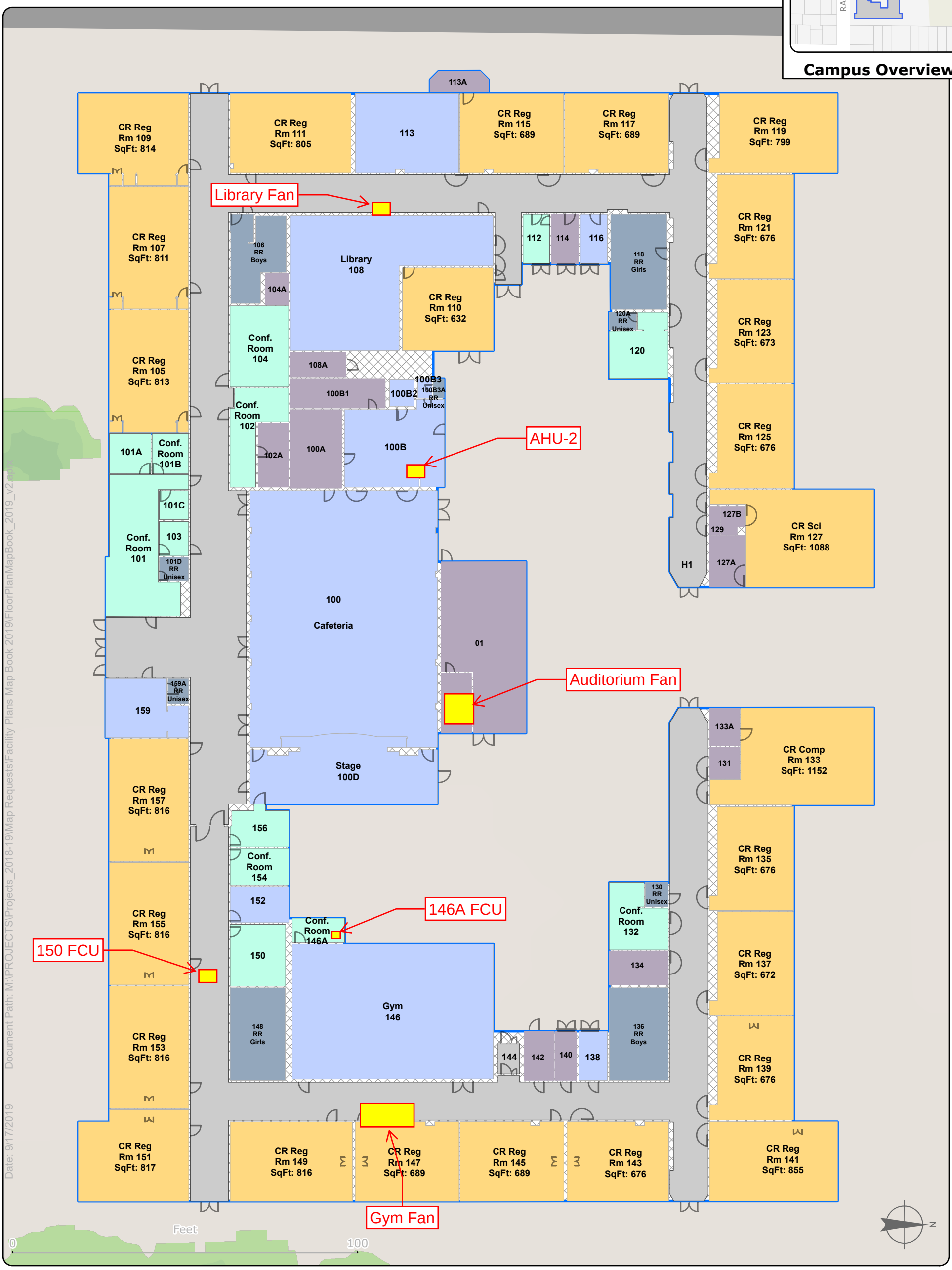
NOTE #	NOTE DESCRIPTION

FOR INTERNAL USE ONLY

DO NOT DISTRIBUTE

MARYSVILLE: First Floor





Space Use

- Classroom
- Office
- Rest Room
- Special Purpose
- Corridor
- Other
- Stairs/Elevator

School Grounds

- Campus Footprints
- Athletic Field
- Playground: Paved
- Playground: Unpaved
- Streets
- Doors

Total Number Of Rooms By Classification

Classrooms: 25	Special Purpose: 12
Office Spaces: 14	Storage: 11