Infiltration Test Report

Project:	University of Colorado Anschutz Medical Campus – R2 Indoor Air Quality Assessment	**Subject:**	Findings and Recommendations
CRA Project #:	2019-169	**Date:**	May 8, 2019
Client:	Mike Barden	**Time:**	10:00 a.m.
Observers:	Joshua Harwood/Sean Convery		

SUMMARY OF ACTIVITIES AND FINDINGS

Cator Ruma & Associates (CRA) joined CU Anschutz facility staff (Jeff and Jordan) and an observer from CAA Icon (Morgan) to survey the mechanical and controls systems as well as to observe the pressure gradients at the Research 2 building (P15) on the 8th of May 2019.

The ambient conditions were favorable for the testing. Ambient temperature was ~40 deg F. for the duration of the testing. Wind was variable out of the North at 10 to 20 mph and it was lightly raining during most of the day. These are considered favorable conditions because the wind and colder ambient temperature exacerbate stack effect in high rise buildings.

The survey of the controls systems indicates to CRA that the mechanical system is operating in a way that would naturally result in a negative building. A full survey of the automation system is available in Appendix A of this report. Airflow totals (as measured by flow stations in the building automation system) were:

- The total of supply air to the building was 416,000 CFM provided by 9 of the 10 supply air fans. 1 fan was in standby mode (not needed to meet the static pressure setpoint of the supply air manifold).
- The vivarium supply air represented 57,500CFM of the 416,000 total CFM
- The total of exhaust air from the building was 417,000 CFM from the 7 of the 9 primary exhaust fans in the building (2 of the 7 lab exhaust fans were in standby mode)
    - There are ~10 additional exhaust fans throughout the building that were in operation but do not have air flow monitoring stations. These fans likely represent 12,000 to 20,000 CFM of additional exhaust in R2. A review of the balance report could provide a more informed estimate of this additional exhaust airflow.
    - The BSL-3 Lab operates negative as expected. This represented an additional ~1,500 CFM exhaust deficit to the facility.
- The vivarium exhaust was 56,800 CFM of the 417,000.
- The elevator shafts were inspected looking for openings, such as a vent or open louver, that would contribute to stack effect. No openings were located.

After the review of the mechanical and controls system, a general pressure survey was performed on the first floor of the R2 building. A floor plan with test locations and full table of test results can be found in Appendix B of this summary. In general, the pressure survey confirmed the following:

- The Research 2 building is significantly negative to ambient. The differential pressure (D/P) increases as you move from the loading dock towards the core of the building (all measurements are inches water column "iwc"):
    - The loading dock area was 0.01 iwc negative to ambient
    - The service corridor was 0.06 iwc negative to the loading dock area
    - The R2 public lobby area averaged 0.03 to 0.05 iwc negative to ambient
    - The R1 building was 0.06 to 0.07 iwc negative to the R2 building

The final activity included a smoke infiltration test. A smoke emitting device was activated on the loading dock apron and smoke infiltration was observed and recorded. The smoke testing was performed twice:

- Test 1 – Dock doors were down, and the smoke device was very close to the opening
- Test 2 – Dock door was open, and the smoke device was placed on the ground rather than on the dock lift

Interestingly the results of the two smoke tests were very similar. Having the doors open did not significantly impact the amount of smoke that came into the loading dock area.

Video recordings were made and are available upon request.

RECOMMENDATIONS AND ACTION ITEMS:

The following recommendations will help to mitigate construction related fume infiltration into the facility during the loading dock construction.

1. A primary goal would be to increase the amount of supply air to the building specifically the first floor. Pressure balances in the Lab spaces and the vivarium are critical, so increasing the net supply air to the building must be approached cautiously. CRA recommends the following:
    a. Several of the supply air VAV boxes on the first floor were not able to achieve their supply air volume setpoint. An increase to the supply air static pressure setpoints should allow these boxes to satisfy air flow setpoints.

    b. Increasing supply airflow setpoints to VAV boxes on the first floor will increase the supply air to that portion of the building. Increase supply airflow setpoints to the maximum extent possible accounting for the capacity of the reheat coil and the desired temperature in the zone.

    c. Reducing return airflow setpoints on the first floor will help pressurize that portion of the building.

    d. The return air units that recirculate non-lab return air were operating in a partial relief mode (relief dampers open 20%). Ideally with a negative building these units should operate in

100% return mode with 0% relief. Further assessment and modification of the operating sequences of these units could reduce the negative pressure in the building.

2. Install door seals, door sweeps and coordinate moving material from the loading dock to the building with construction activities.

3. The loading dock has 1 roll up door on the West side that is no longer utilized due to the ongoing construction activities. Fully sealing that door with plastic and tape will minimize infiltration from the West.

4. Air curtains over the 3 North facing loading dock doors would create a barrier to infiltration from construction activities adjacent to the dock.
5. Install building pressure sensors on the ground floor and leverage these sensors in the non-lab return/ relief unit sequences to optimize relief for building pressure

The following action items could lead to additional recommendations and remediations to the pressure issues at R2:

1. Survey and modify the operation of the R1 building to bring that building closer to neutral.

2. Fully evaluate the non-lab supply and return air controls strategies and pressure relationships, modify and test sequences.

3. The building pressure sensors on 3rd and 10th floor showed ***failed*** during the survey. The last recorded values were 0.27 and 0.23 iwc which are very high and indicate a likely failure of those sensors.

NEXT STEPS

The next steps are as follows:

- Cator Ruma requests a copy of the Research 2 building's Test and Balance Report. A review of this report will further inform the strategy moving forward.

- Cu leadership and CAA Icon to determine if additional investigation is warranted and which remediation strategies to proceed with.

- Cator Ruma will proceed accordingly and retro-commission or design around the selected remediation strategy

Thank you again for the opportunity to survey your project and provide our recommendations. We look forward to continuing to support University of Colorado Anschutz Medical Campus.

Appendix A – Automation System Survey

Survey Initial Conditions

Documenting the initial operating conditions of the mechanical and controls system is an important step in the testing process. The intent is to understand and document the operating parameters and setpoints and to attempt to hold those conditions throughout the test, thereby limiting the variables.
Complete the following table, note any observations or overrides:

System	Equipment ID	Fan Speed and Airflow	Static Pressures	Misc Operating Parameters	Other Notes
Vivarium Supply Air System	SA-02-001	VFD Speed:62% Fan CFM: 28.82kCFM	1.94iwc in the common manifold	None	This unit was humidifying and heating the supply air as a result, it was cooling which caused de-humidification
	SA-02-002	VFD Speed: 61.9 Fan CFM: 0.19 k	1.94iwc in the common manifold	None	This flow station was reading low The manifold graphic has 9 duct static pressure sensors, all reading above 2iwc
Lab Supply Air System	SA-02-003	VFD Speed:41.9 HZ Fan CFM:57.6k	1.9iwc	None	North Riser Static Pressure:1.9 iwc Central Riser Static Pressure:1.9 iwc South Riser Static Pressure: 1.9 iwc
	SA-02-004	VFD Speed:40.6 HZ Fan CFM: 56.38k	2.05 iwc	None	The 8 SA units are connected via common manifolds and risers.
	SA-02-005	VFD Speed:40.9HZ Fan CFM: 25.78k	2.12 iwc	None	This unit SA CFM was ~50% of the other units at a similar fan speed. We confirmed the low supply air volume with a local reading, this unit runs lower on airflow.
	SA-02-006	VFD Speed:39.7hz Fan CFM: 50.37k	2.33iwc @ the unit	None	None
	SA-02-007	VFD Speed:39hz Fan CFM: 57.9k	2.28iwc @unit	None	None
	SA-02-008	VFD Speed: off Fan CFM:			This unit was in standby
	SA-02-009	VFD Speed: 39.7 Fan CFM: 53.8k (locally read)	2.28iwc@unit	None	The integration from the AFM to the BAS should be investigated. Showing 0kCFM on BAS the AFM is showing 53.8kCFM.

System	Equipment ID	Fan Speed and Airflow	Static Pressures	Misc Operating Parameters	Other Notes
	SA-02-010	VFD Speed:39.5hz Fan CFM: 56.5k	2.11 iwc	None	None
Non-Lab Return Air System	RA-02-01	VFD Speed:66% 40.1HZ Fan CFM:15.58kCFM	Fan inlet: 0.04 iwc Fan Outlet: 1.47 iwc in manifold	3rd floor BSP: shows failed (0.27 last value but not reliable) 10th Floor BSP: shows failed (o.23 but not reliable)	• 3rd floor and 10th floor BSP sensors come to this controller. • The return air VAV should track to 3,000 CFM less than the supply air VAVs. Record any associated observations Fan controls to a RA manifold on the 11th floor of 1.5iwc
	RA-02-02	VFD Speed: 71.67% 43HZ Fan CFM: 21.07kCFM	0.06iwc inlet 1.47 iwc in manifold		Unit ½ relief dampers were commanded 20% open return dampers commanded 80% open
Lab Manifold Exhaust System	FE-R-001	VFD Speed: 85% Air flow: 70.06KCFM	Fan inlet press: -1.89 iwc	Exhaust Stack Velocity: 3114.89 FPM	Fan VFDs are all controlled to an average manifold pressure or -1.9iwc actual pressure today was -1.89 with 4 fans at 85%
	FE-R-002	VFD Speed: 85% Air flow: 71.37kCFM	Fan inlet press: -1.89 iwc	Exhaust Stack Velocity:3196 FPM	
	FE-R-003	VFD Speed: off	Fan inlet press: -1.89 iwc	Exhaust Stack Velocity:	Off today
	FE-R-004	VFD Speed: 85% Airflow: 73.86 kCFM	Fan inlet press: -1.89 iwc	Exhaust Stack Velocity: 3307 FPM	
	FE-R-005	VFD Speed: 85% Airflow: 74.28	Fan inlet press: -1.89 iwc	Exhaust Stack Velocity: 3326 FPM	
	FE-R-006	VFD Speed:	Fan inlet press: -1.89 iwc	Exhaust Stack Velocity:	Off today
	FE-R-007	VFD Speed: 85% Airflow: 70.99 KCFM	Fan inlet press: -1.89 iwc	Exhaust Stack Velocity: 3175 FPM	
Vivarium General Exhaust	FE-R-008	VFD Speed: 69% Airflow: 27.21KCFM	1.02 iwc filter d/p	Duct Pressure 1:1.77” Duct Pressure 2: 2.08” Duct Pressure 3:2.05”	FE-R-008 and 009 share common duct. 3 Sensors are distributed on the second floor to ensure exhaust duct pressure profile

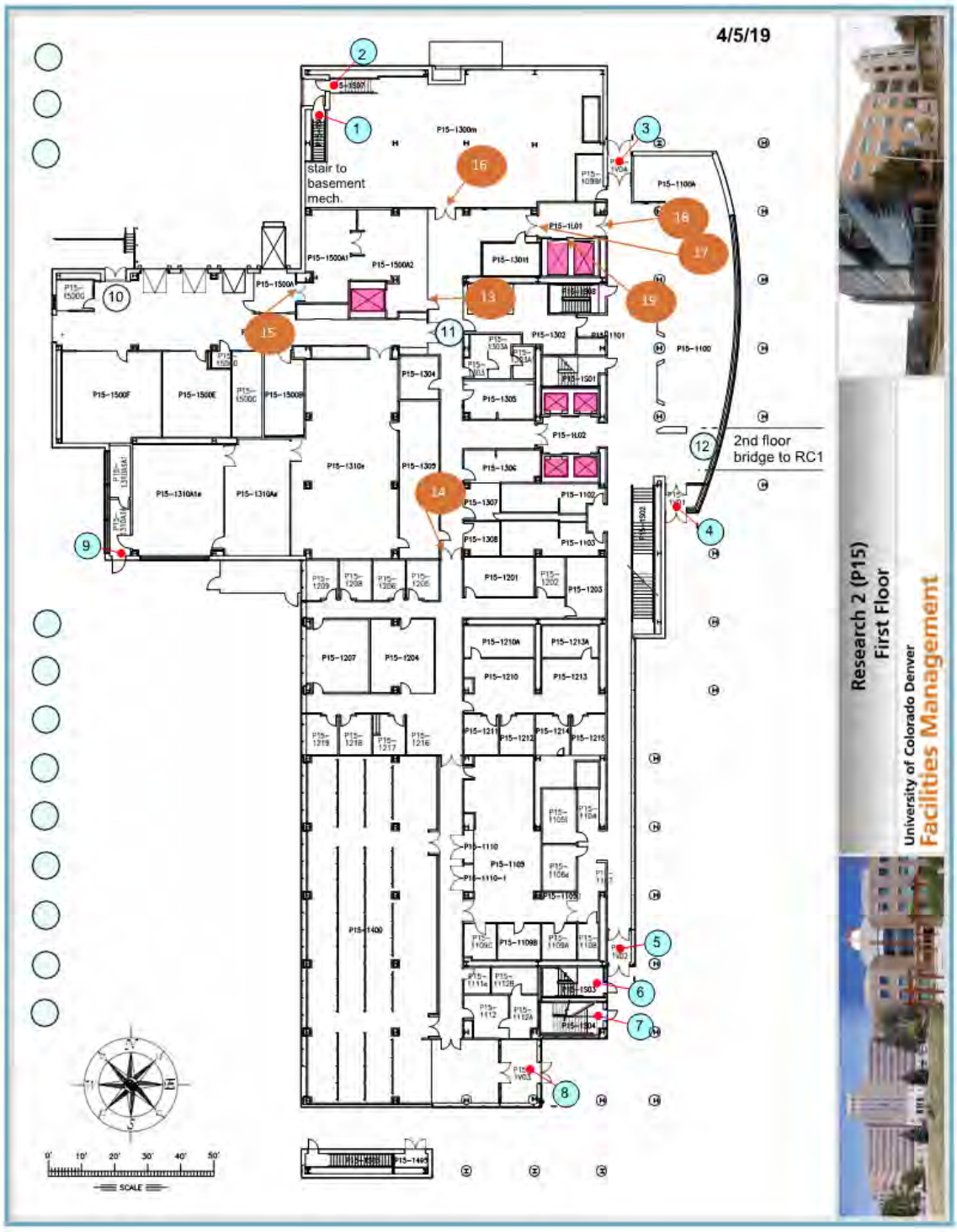
System	Equipment ID	Fan Speed and Airflow	Static Pressures	Misc Operating Parameters	Other Notes
	FE-R-009	VFD Speed: 69% Airflow: 29.6kCFM			These fans control to an average of -1.9 iwc in the ducts
ABSL3/ Quarantine Exhaust System	FE-R-10	VFD Speed:			Off today
	FE-R-11	VFD Speed:			Off today
Glass Wash Exhaust System	FE-R-13	VFD Speed:92% VFD	Fan suction pressure:		On, no flow station
Iodination Exhaust System	FE-R-14	VFD Speed:53% VFD	Filter Pressure drop:		On no flow station
BSL-3	FE-P15-015	59% VFD Speed 2.3kCFM			-1.13 iwc Common duct pressure
	FE-P15-016	59% VFD Speed 2.19KCFM			Big difference in the pressure drops across the filters
	BSL-3 Supply	3.5kCFM			Maintains a negative pressure in the BSL3 lab.

The following table illustrates observations made from the controls system relative to terminal units on the first floor:

Terminal Unit Designation	Observations
P15-1500G Loading dock office	VAV was short on airflow
P15-1500A1/A2	Vivarium elevator lobby had a matched pair of supply and return terminal unit airflows
P15-1502	VAV was 100% open
P15-L1	VAV was only 47% open, more air could be put into the elevator lobby
Corridor (back of house) terminal units	Cooling only units. North unit – 26% Open South RA unit was bouncing 100-300 CFM 100% open
P15-1100A	VAV 100% open short on airflow by 250 CFM
P15-1100	4 Boxes serve the open lobby area N most box 33% open Center box – 100% open S most box – 27% open Corridor box (West Box) – 50% Open
2nd Floor Terminal unit at R1 Bridge	N unit – 8% damper command 50% of airflow setpoint S unit – essentially same as n 716 CFM out of 1500
2nd floor VAV survey	Observed several units short on supply air (904 CFM with 1400 CFM setpoints) RA was 1016 CFM

Appendix B – Building Static Survey

The diagram below illustrates the locations of pressure testing:



The following table should be correlated with the diagram above. The table contains values that the UCD facilities team observed during their survey on April 5, 2019. CRA also surveyed these locations in addition to some additional locations (indicated by the orange colored bubbles). All pressure readings were taken in inches of water column (iwc).

Pressure Survey ID	High Pressure Reference Location	Low Pressure Reference Location	4/5/19 Pressure Reading iwc	5/8/19 Pressure Reading iwc	Notes
1	Ambient	Inside the stairwell	0.017 to 0.025	0.02	Negative to ambient
2	Ambient	Inside the mechanical room	0.008 to 0.013	0.02	Negative to ambient
3	Ambient	Inside the N main lobby vestibule	0.011 to 0.025	0.03 to 0.04	Negative to ambient Vestibule doors held open to the building during testing. Every effort was made to ensure other exterior doors were closed during test.
4	Ambient	Inside the S main lobby vestibule	0.011 to 0.031	0.03 to 0.05	Negative to ambient Vestibule doors held open to the building during testing. Every effort was made to ensure other exterior doors were closed during test.
5	Ambient	Inside the S corridor vestibule	0.022 to 0.051	0.048	Negative to ambient Vestibule doors held open to the building during testing. Every effort was made to ensure other exterior doors were closed during test.
6	Ambient	Inside the stairwell	0.022 to 0.051	Not surveyed	Negative to ambient
7	Ambient	Inside the stairwell	0.01 to 0.026	Not surveyed	Negative to ambient
8	Ambient	Inside the vestibule	0.01 to 0.015	Not surveyed	Negative to ambient
9	Ambient	Inside the loading dock vestibule	Neutral to 0.001	Not surveyed	Neutral to ambient
10	Ambient	Inside the loading dock area	Neutral	0.01	Negative to ambient
11	Loading dock	Corridor (back of house)	0.018 to 0.029	0.06	Corridor negative to dock area
12	2nd floor lobby	Pedestrian bridge to R1 building	0.032 to 0.038	006 to 0.07	R1 is negative to R2
13	Corridor	Vivarium elevator lobby	Not surveyed	0.009	Neutral to vivarium elevator
14	North side of the double doors	South side (freezer farm side)	Not surveyed	0.01	Negative towards the main building elevators
15	Vivarium elevator lobby	Loading dock	Not surveyed	0.03	Vivarium elevator lobby is negative to the loading dock
16	Mechanical Room	Corridor (back of house)	Not surveyed	0.006	Slight negative towards the building
17	Freight Elevator lobby	Corridor (back of house)	Not surveyed	0.005	Slight negative to elevator lobby with the double doors closed
18	Freight Elevator lobby	Main L1 lobby	Not surveyed	0.004	
19 1st floor	Freight Elevator Lobby	Elevator shaft	Not surveyed	0.006 to 0.01	Freight Elevator shaft is slightly negative to lobby. Observed more negative as elevator rose. The shaft is common to both cars.
19 7th floor	Freight Elevator Lobby	Elevator shaft	Not surveyed	0.001 to -0.003	The pressure gradient flipped when the car rose from below. The shaft is generally slightly negative to the lobby when the cars are idle

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