RMF Engineering
Reliability. Efficiency. Integrity.

LAB RETRO-CX: THE REBIRTH OF A RESEARCH FACILITY

Course No. CXENERGY1807

Rob Clegg, PE
Travis Campbell, CxA

acg

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AABC Commissioning Group

AIA Provider Number 50111116

Lab Retro-Cx: The Rebirth of a Research Facility

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RMF Engineering

April 25, 2018

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Course Description

Science and research changes constantly. Laboratory needs change and each change can dramatically affect the operation of adjacent labs. However, adjacent labs are rarely tested to confirm correct operation. Changes including additions such as new fume hoods can overburden the exhaust system, resulting in code or health issues. As laboratories age, they become problematic. Sensors fall out of calibration, control devices fail and become outdated. Laboratories must be regularly tested to weed out and repair these issues. A small percentage of devices out of calibration can tip the entire system into a state where it doesn’t meet basic requirements, much less code requirements.

Learning Objectives

At the end of the this course, participants will be able to:

1. Understand the different types of laboratories and special considerations for each and general tips and tricks to Retro-cx a lab.

2. Consider the impact of partial renovations and common devices and sensors that fail or go out of calibration and why.

3. Get to know the elements of Laboratory HVAC and common design configurations.

4. Get familiar with common sequence requirements and how to get to the root cause of symptoms.

AGENDA

01 | Introduction

02 | Why Retro-Cx Labs

03 | Designs & Considerations

04 | Lab Retro-Cx Process

05 | Results

06 | Wrap-up

280
employees

35
year history

13
offices

ABOUT RMF

Areas of Service

- Mechanical
- Electrical
- Utility Master Planning
- Utility Infrastructure
- Assessments/Inspections
- Commissioning

2017 ENR TOP 500

RMF ranked in the Nation's top A/E Design Firms in ENR 2016 & 2017.

2017 BD+C TOP 20

Ranked **16th** in BD+C 2017 Top E/A Firms & 12th in University Engineering.

2017 CSE TOP 40

Ranked **35th** in CSE 2017 Top MEP Firms

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WHY RETRO-Cx LABORATORIES

» RMF Recently Performed Retro-Cx at Two College Chemistry & Biology Research Laboratories
  - Both Over 100k Square Feet
  - Both had Numerous Partial Renovations
  - Both Include Pneumatic and Direct Digital Controls
  - Both Include Research Laboratories, Teaching Laboratories, Classrooms, and Lecture Halls
  - Both Serve Professors, Graduate Students, and Undergraduate Students

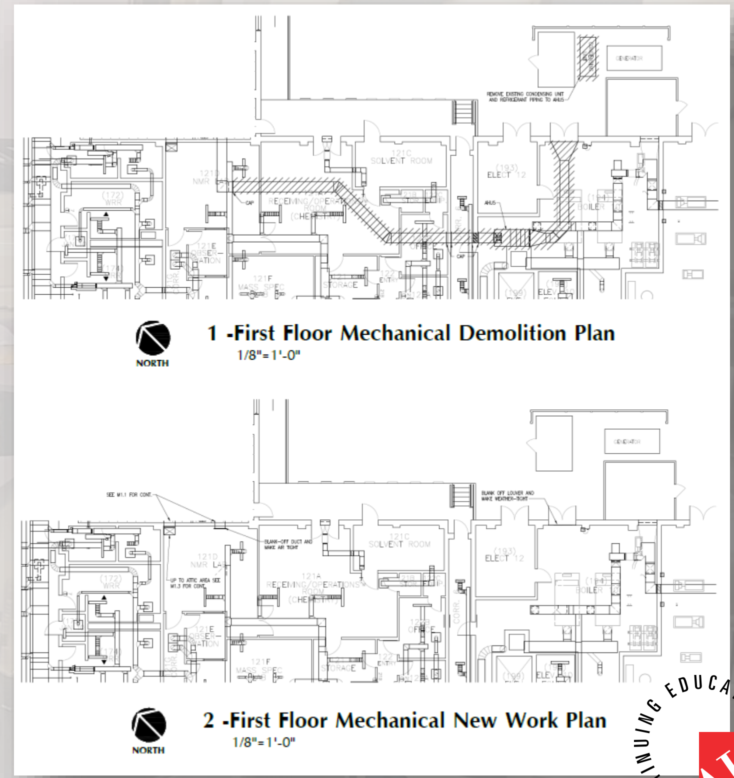
WHY RETRO-Cx LABORATORIES

» Research Laboratories Typically Change Often

- ➢ Changes and Updates to Technology
- ➢ New Grant Money
- ➢ Different Researchers

» Individual Lab Renovations Effect Whole Building Operation

- ➢ Increase/Decrease Exhaust Requirements
- ➢ System Diversity Changes
- ➢ Zone and Building Pressurization Effects



WHY RETRO-Cx LABORATORIES

- » Control Devices Lose Calibration
  - ➢ Dust Clogs Flow Sensors
  - ➢ Sensing Devices Drift Over Time
  - ➢ Sash Height Loses Alignment with Flow

- » Yearly Fume Hood Certification
- » Re-TAB = New Calibration Factors
- » Ever Changing Lab Equipment
- » Single-point Facility Corrections

DESIGN & CONSIDERATIONS

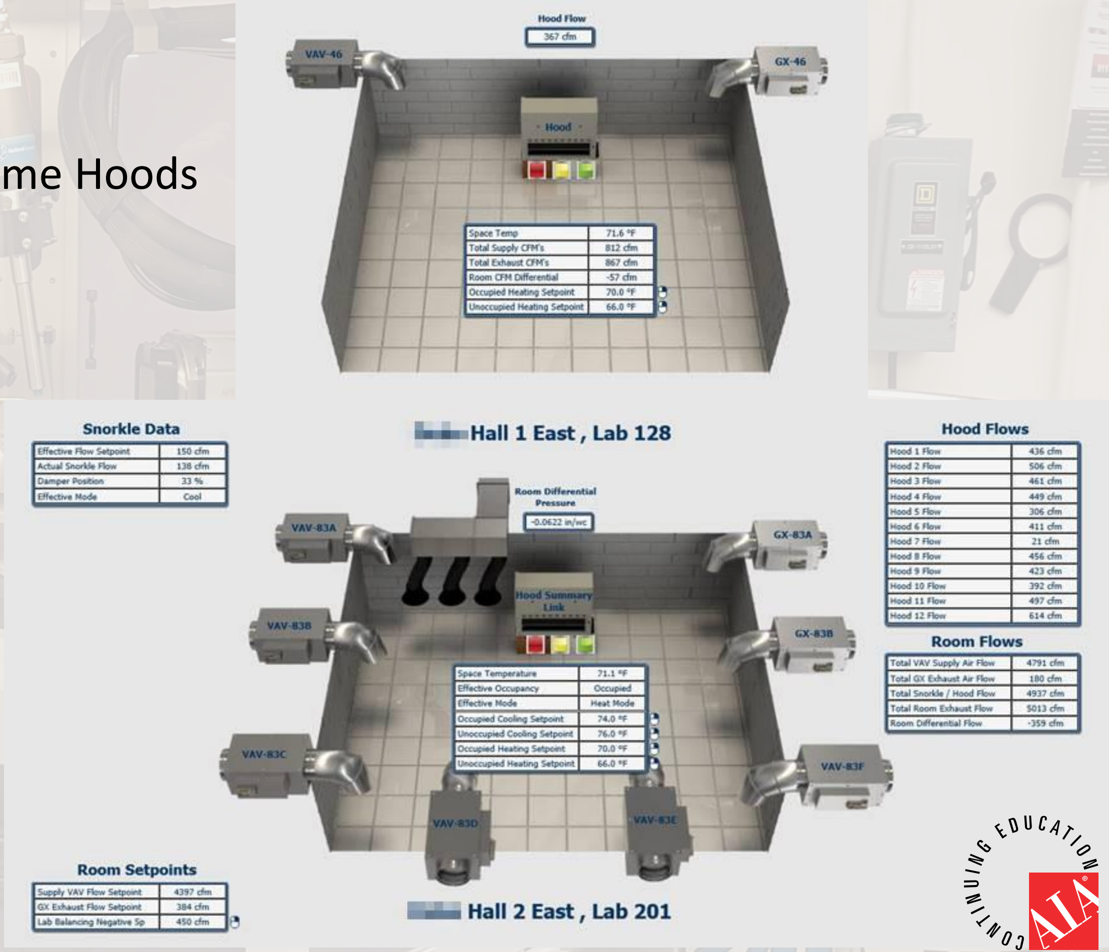
» Specialized Facilities
- ➢ Bio-Safety Levels (BSL-1 to BSL-3)
- ➢ Animal Bio-Safety Level (A-BSL)
- ➢ Agriculture Bio-Safety Level (BSL-Ag)

» Specialized Equipment
- ➢ Nuclear Magnetic Resonance (NMR)
- ➢ Electron Microscope
- ➢ Sub -80^{o}C equipment
- ➢ Bio-Safety Cabinets

DESIGN & CONSIDERATIONS

» Lab Design Configuration

- ➢ From **1** Fume Hood to **12** Fume Hoods
- ➢ Snorkel Exhaust
- ➢ Cabinet Exhaust
- ➢ Bench Top Exhaust
- ➢ Sink Exhaust
- ➢ Bio-Safety Levels
- ➢ No Return Air
- ➢ Strict Temperature Control
- ➢ Strict Humidity Control



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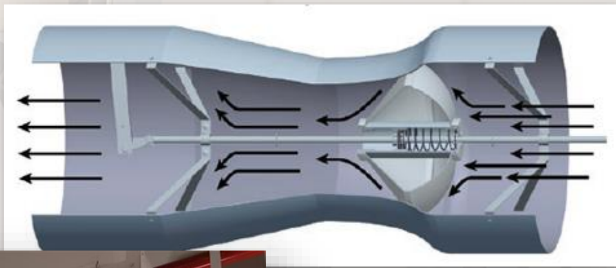
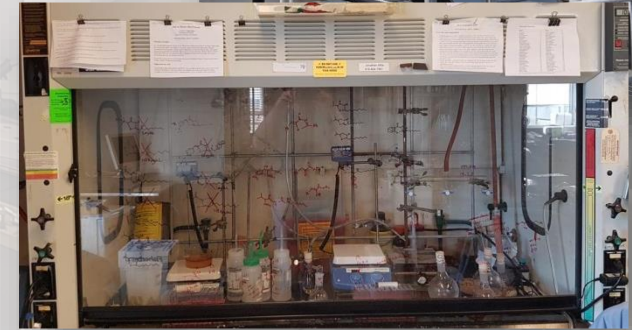
DESIGN & CONSIDERATIONS

» Lab HVAC Equipment vs Standard HVAC Equipment

- ➢ 100% OA AHU's
- ➢ Strobic fans
- ➢ Fume Hoods
- ➢ Air Valves (Rather than Damper VAVs)
- ➢ Low-Velocity/Low-Noise Diffusers
- ➢ Reheat Coils Based on Max VAV Flow





DESIGN & CONSIDERATIONS

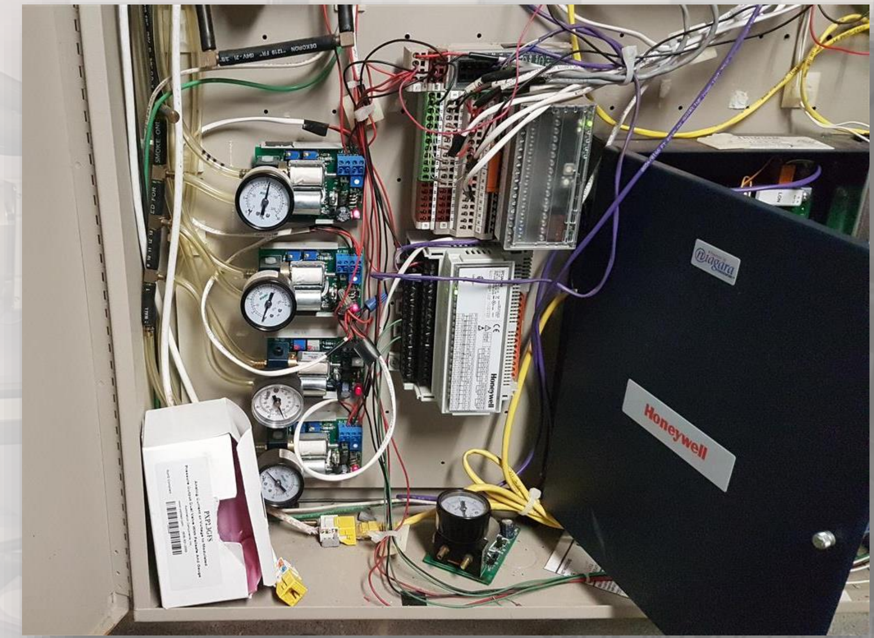
» Lab HVAC Controls vs Standard HVAC Controls

- ➢ Humidity Control
    - • Dehumidification Modes
    - • Humidifiers
- ➢ Variable Exhaust Control via Duct Static Pressure (vs Fixed EA and RA tracking SA)
- ➢ Exhaust Valve Control via Fume Hoods Sash Height (vs constant volume EA)
- ➢ Supply Air Flow Control Based on Exhaust Flow
    - ➢ (vs Room Temperature Control)

VS

DESIGN & CONSIDERATIONS

» Laboratory Controls
  - Air Change Driven
  - Lab Pressure Driven
  - Exhaust and Supply Air Flows
  - Temperature Control Secondary



» Lab AHU Controls
  - Five Coil AHU's
  - 100% Outside Air Units
  - 100% Exhaust
  - Energy Recovery Strategies

LAB RETRO-Cx PROCESS

» Working in an Active Laboratory
- ➢ Undergrad Students on Strict Schedules
- ➢ Grad Students Running Research 24/7
- ➢ Professors Running Research 24/7

» Communication Is Key
- ➢ Occupant Surveys
- ➢ Monday Morning Meetings
- ➢ Weekly Updates
- ➢ Permission From Occupants = Buy-In

Day	DOBO 103	DOBO 104	DOBO 107	DOBO 123	DOBO 125	DOBO 126	DOBO 128	DOBO 129	DOBO 130	DOBO 131
Mon, Oct. 9	Class 8-8:50A Class 9-9:50A Class 10-10:50A Class 11-11:50A Class 12-12:50P Class 1-2:15P Class 3-4:15P **Open 4:15-6P** Class 6-7:60P	**Open 8A-12P** Class 12-2:50P Class 3-5:50P	**Open 8A-12P** Class 12-2:50P Class 3-5:50P	Class 8-10:50A Class 11A-1:50P Class 2-4:50P **Open 5-6:30P** Class 6:30-9:20P	Class 8-10:50A Class 11A-1:50P Class 2-4:50P **Open 5-6:30P** Class 6:30-9:20P	Class 8-10:50A Class 11A-1:50P Class 2-4:50P **Open 5-6:30P** Class 6:30-9:20P	**Open 8-9A** Class 9-11:50A Class 12-2:50P Class 3-5:50P Class 6-8:50P	Class 8-10:50A Class 11A-1:50P Class 2-4:50P Class 5-7:50P	Class 8-10:50A Class 11A-1:50P Class 2-4:50P Class5-7:50P	**Open 8-11A** Class 11A-12:15P **Open 12:15-2P** Class 2-4:50P
Tues, Oct. 10	Class 8-9:15A Class 9:30-10:45A Class 11A-12:15P Class 12:30-1:45P Class 2-3:15P Class 3:30-4:45P Class 5-6:15P	**Open 8A-2P** Class 2-4:50P **Open 5-7P**	**OPEN**	Class 8-10:50A Class 11A-1:50P Class 2-4:50P **Open 5-6:30P** Class 6:30-9:20P	Class 8-10:50A Class 11A-1:50P Class 2-4:50P **Open 5-6:30P** Class 6:30-9:20P	Class 8-10:50A Class 11A-1:50P Class 2-4:50P **Open 5-6:30P** Class 6:30-9:20P	Class 8-10:50A **Open 11A-3P** Class 3-5:50P Class 6-8:50P	Class 8-10:50A Class 11A-12:15P **Open 12:15-2P** Class 2-4:50P Class 5-7:50P	Class 8-10:50A **Open 11A-2P** Class 2-4:50P Class 5-7:50P	**Open 8A-2P** Class 2-4:50P
Wed, Oct. 11	Class 8-8:50A Class 9-9:50A Class 10-10:50A Class 11-11:50A Class 12-12:50P Class 1-2:15P Class 3-4:15P **Open 4:30-7P**	**Open 8A-2P** Class 2-4:50P **Open 5-7P**	**Open 8A-12P** Class 12-2:50P Class 3-5:50P	Class 8-10:50A Class 11A-1:50P Class 2-4:50P **Open 5-6:30P** Class 6:30-9:20P	Class 8-10:50A Class 11A-1:50P Class 2-4:50P **Open 5-6:30P** Class 6:30-9:20P	Class 8-10:50A Class 11A-1:50P Class 2-4:50P **Open 5-6:30P** Class 6:30-9:20P	**Open 8-9A** Class 9-11:50A Class 12-2:50P Class 3-5:50P Class 6-8:50P	Class 8-10:50A Class 11A-1:50P **Open 2-5P** Class 5-7:50P	Class 8-10:50A Class 11A-1:50P Class 2-4:50P Class 5-7:50P	**Open 8-11A** Class 11A-12:15P **Open 12:30-7P**

Hall Recommissioning

November 2017 Testing Schedule

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
			1	2	3	4
5	6 2nd Floor East	7	8	9	10	11
12	13 2nd Floor East	14	15	16 2nd Floor Center	17	18
19	20 2nd Floor Center	21	22	23	24 2nd Floor West	25
26	27 2nd Floor West	28	29	30		

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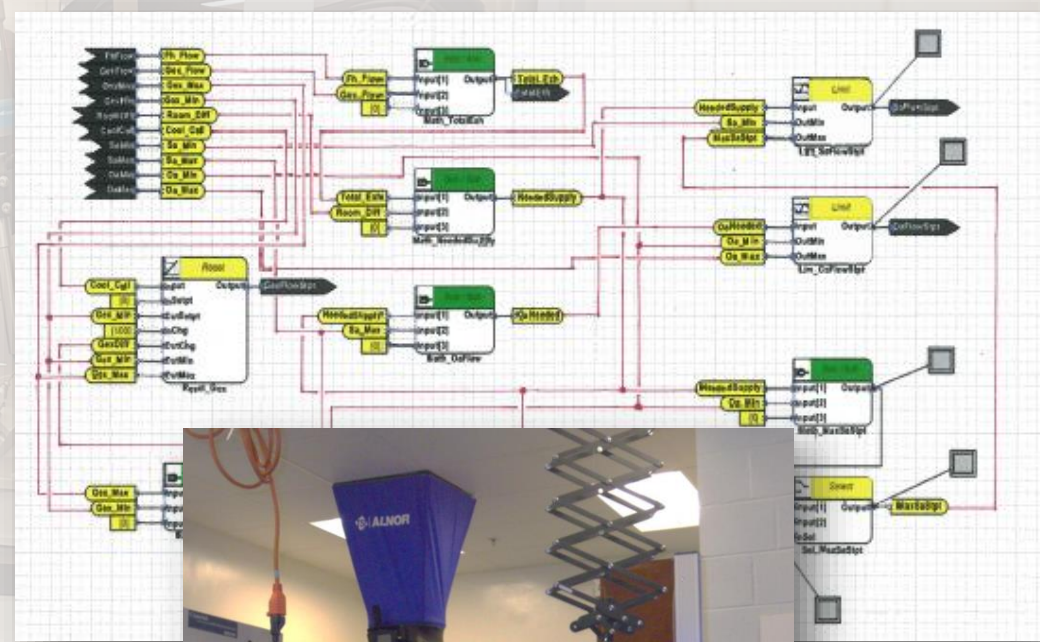
LAB RETRO-Cx PROCESS

- » Equipment Examination
  - ➢ Inspect Equipment
  - ➢ Check Cleanliness
  - ➢ Look for Obstructions
  - ➢ Impulse “Improvements”
  - ➢ Verify As-Built Layout and Devices
- » Design Review
  - ➢ Does the Design Still Meet Intent?
  - ➢ Diversity/Back-Up/Air Changes
  - ➢ Control Sequence

LAB RETRO-Cx PROCESS

- » Testing Parameters
  - ➢ Air Flows
  - ➢ Pressures
  - ➢ Temperatures
  - ➢ Sequencing
- » What to Look For
  - ➢ At Every Sequence Verify:
    - Primary Criteria
    - Air Changes
    - Room Pressure



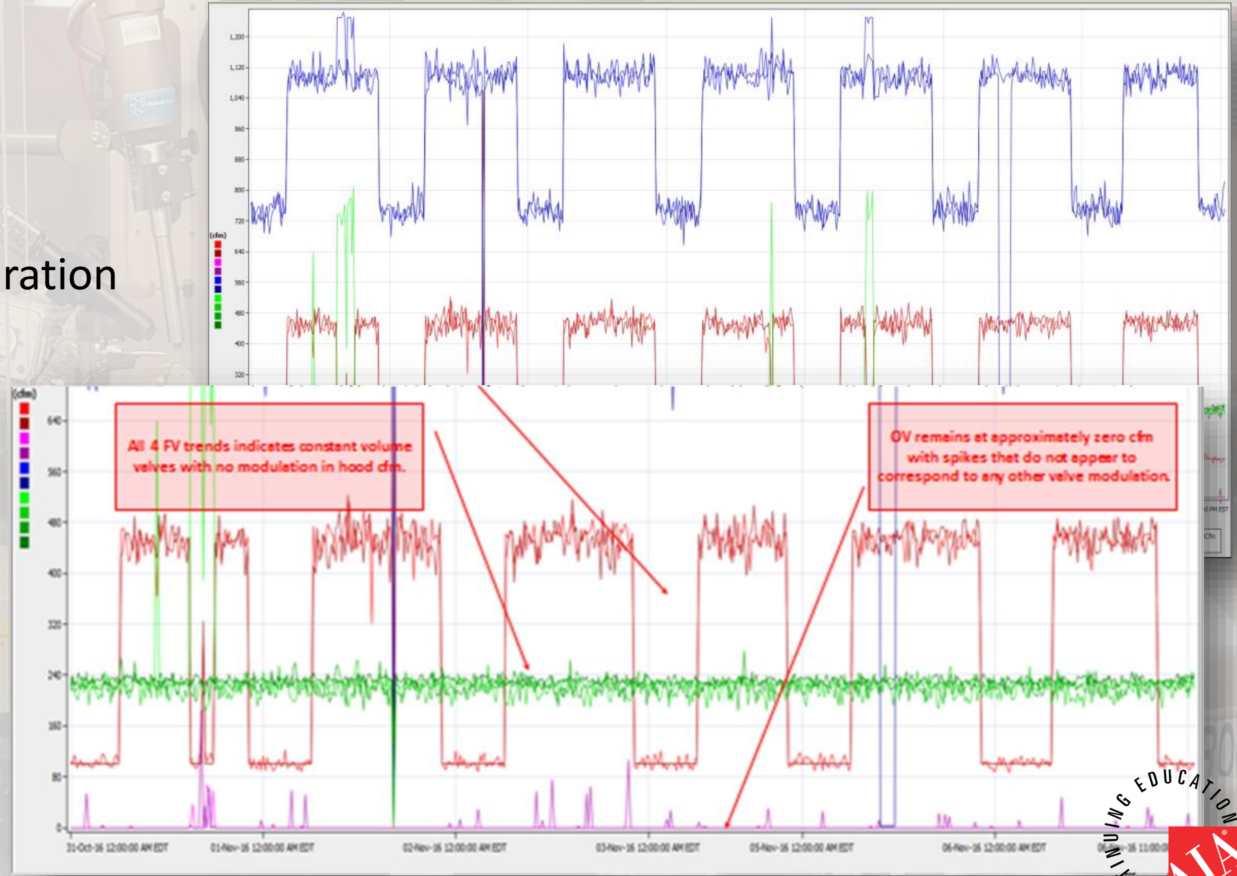
RETRO-Cx PROCESS

RETRO-Cx PROCESS

LAB RETRO-Cx PROCESS

» Trending

- ➢ Check Each Mode
- ➢ Find Hidden Issues
- ➢ Verify Authentic Operation
  - w/o Overrides
  - w/o Simulation



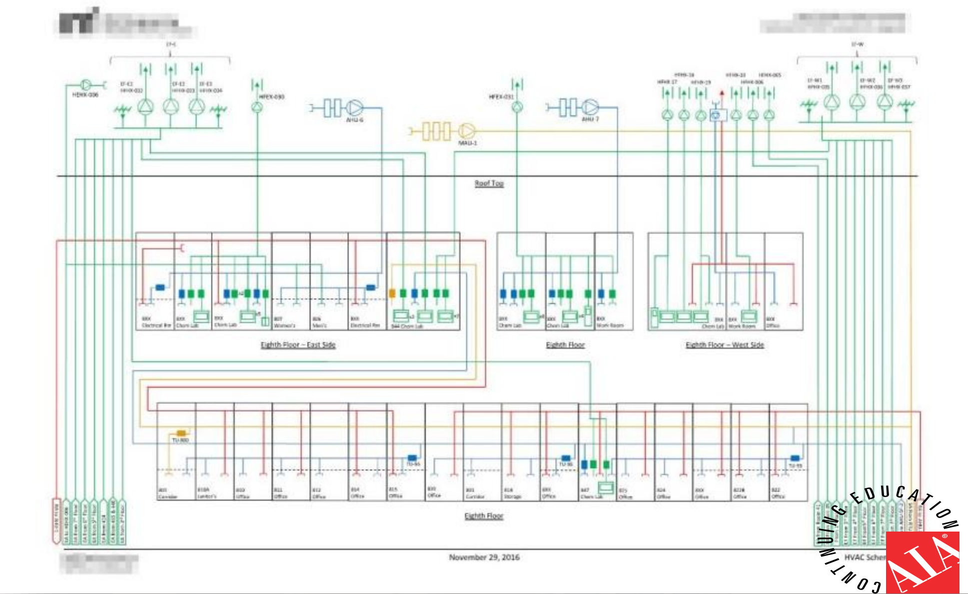
RETRO-Cx RESULTS

» Deliverables

- ➢ Design Review
- ➢ Retro-Cx Plan
- ➢ Critical Facility Requirements (CFR)
- ➢ Completed Test Forms
- ➢ Issues Log
- ➢ Energy Conservation Measures (ECM's)
- ➢ Final Report

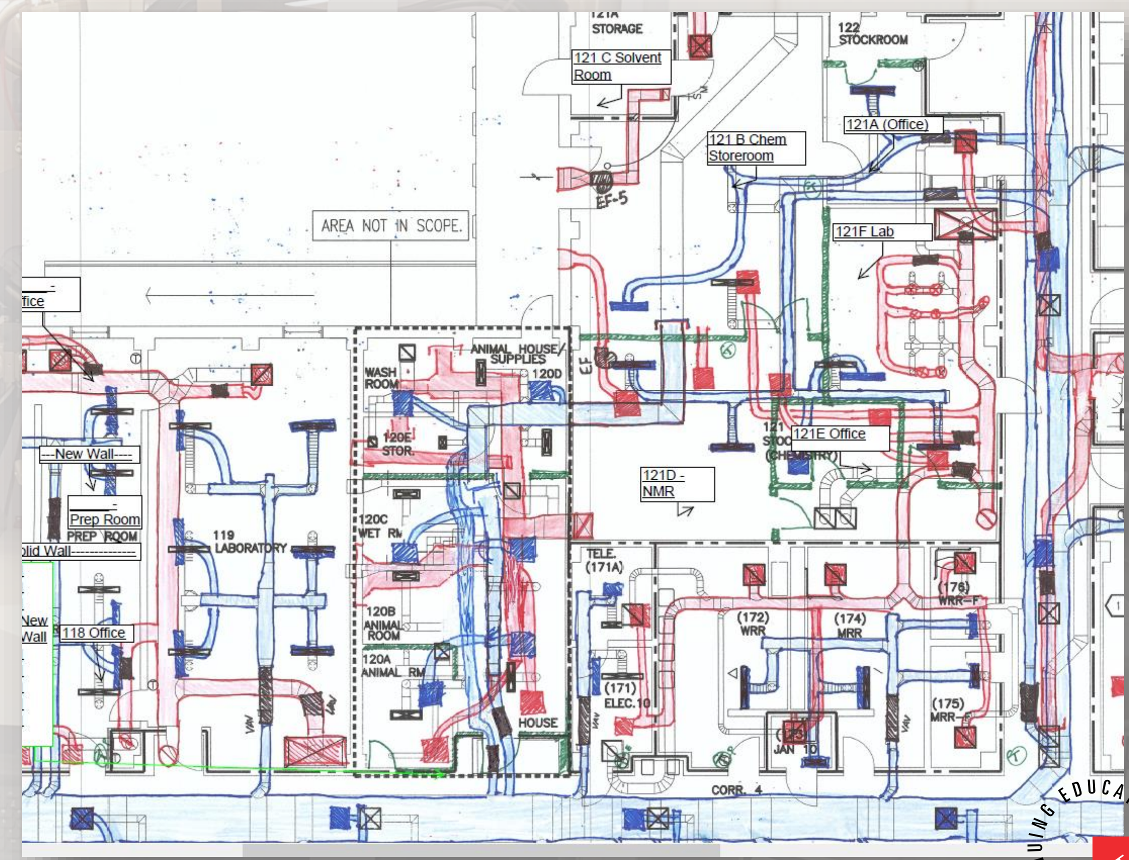
Hall Laboratories

Lab No.	Req Airflow Unnoc	Req Airflow Occ	Air Changes UnOcc Req.	Air Changes Occ Req.	Air Changes Design	Size H	Size Sqft	Volume ft^3	Design Exhaust Air Flow HV	Design Exhaust Air Flow GV	Design Exhaust Air Flow Total
12	876	1314	4.00	6.0	6.0	12.50		13136	91	1225	1316
15	387	580	4.00	6.0	6.0	12.50		5800	85	494	579
17	363	544	4.00	6.0	6.0	12.50		5440	88	456	544
22	178	267	4.00	6.0	10.7	12.50		2670	147	330	477
28	1020	1530	4.00	6.0	0.0	12.50	1224.00	15300			0
28B	122	183	4.00	6.0	0.0	12.50	146.00	1825			0
29	240	360	4.00	6.0	0.0	12.50	288.00	3600			0
29A	236	354	4.00	6.0	0.0	12.50	283.00	3538			0
30	220	330	4.00	6.0	0.0	12.50	264.00	3300			0
114	273	410	4.00	6.0	8.2	12.50		4100	210	350	560
308	1382	2072	4.00	6.0	0.0	12.50	1669.00	20723			0
316	1017	1526	4.00	6.0	6.7	12.50	1229.00	15260	1700		1700
414	1036	1554	4.00	6.0	6.8	12.50	1251.00	15535	1088	663	1751
417	1081	1622	4.00	6.0	5.0	12.50		16216	885	472	1357
420	700	1051	4.00	6.0	6.5	12.50		10505	1145		1145
425	755	1133	4.00	6.0	7.5	12.50		11325	888	527	1415
435	719	1078	4.00	6.0	6.8	12.50		10780	895	323	1218
440	690	1035	4.00	6.0	6.0	12.50		10345	895	148	1043
508	899	1349	4.00	6.0	6.0	12.50		13485	1350		1350
512	867	1300	4.00	6.0	4.8	12.50		13000	923	125	1048
512C	190	286	4.00	6.0	10.9	12.50		2855	517		517
520	366	549	4.00	6.0	7.7	12.50		5490	414	289	703
521	368	552	4.00	6.0	6.1	12.50		5515	422	140	562
522	589	884	4.00	6.0	11.3	12.50		8840	885	775	1660
535	608	913	4.00	6.0	6.6	12.50		9125	228	775	1003
536	362	543	4.00	6.0	5.8	12.50		5425	121	400	521
538	362	543	4.00	6.0	8.1	12.50		5425	634	100	734



RETRO-Cx RESULTS

» Inspection Results
- Installation Issues
- Deviations from Design
- Updated As-Builts
- System Cleanliness



RETRO-Cx RESULTS

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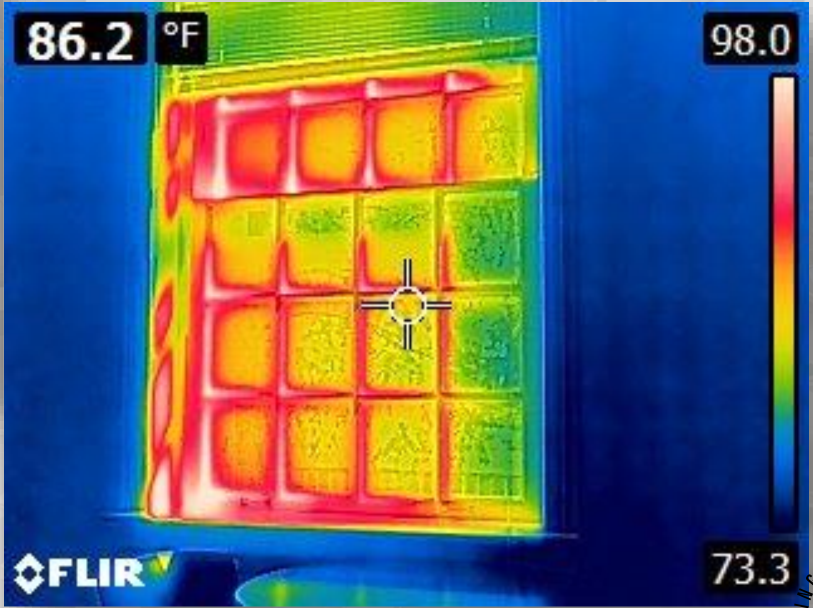
RETRO-Cx RESULTS

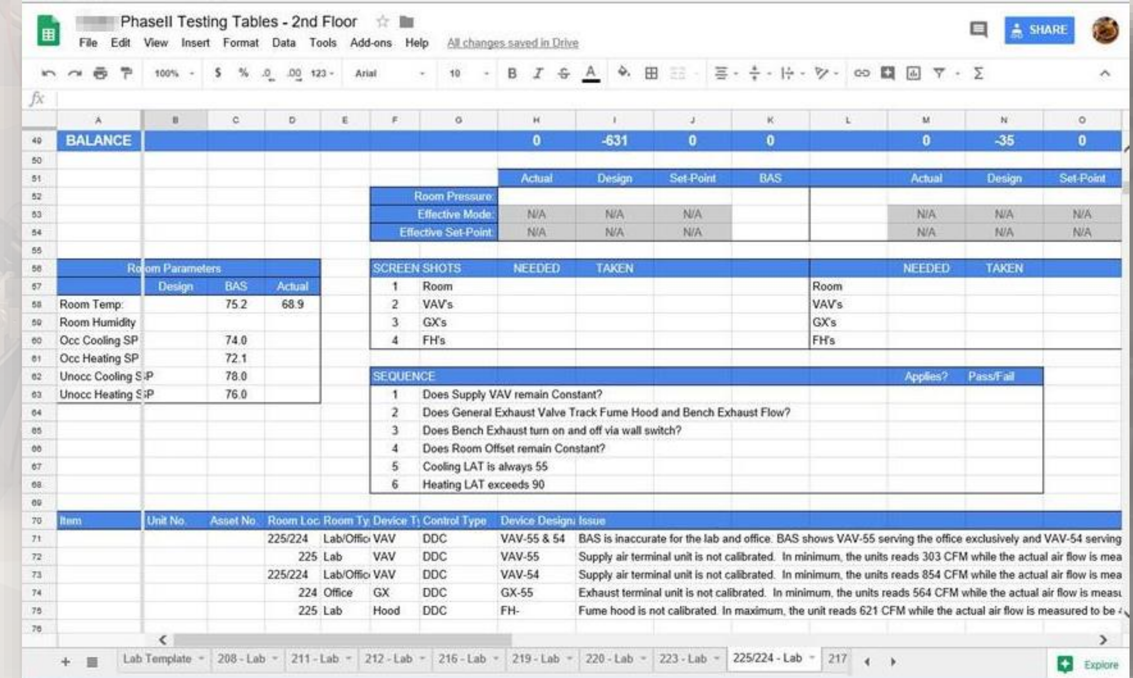


RETRO-Cx RESULTS

RETRO-Cx RESULTS

» Testing Results

- ➢ Device Calibration
- ➢ System Hunting
- ➢ Clogged Reheat Coils
- ➢ Positively Pressurized



Phasell Testing Tables - 2nd Floor

File Edit View Insert Format Data Tools Add-ons Help All changes saved in Drive

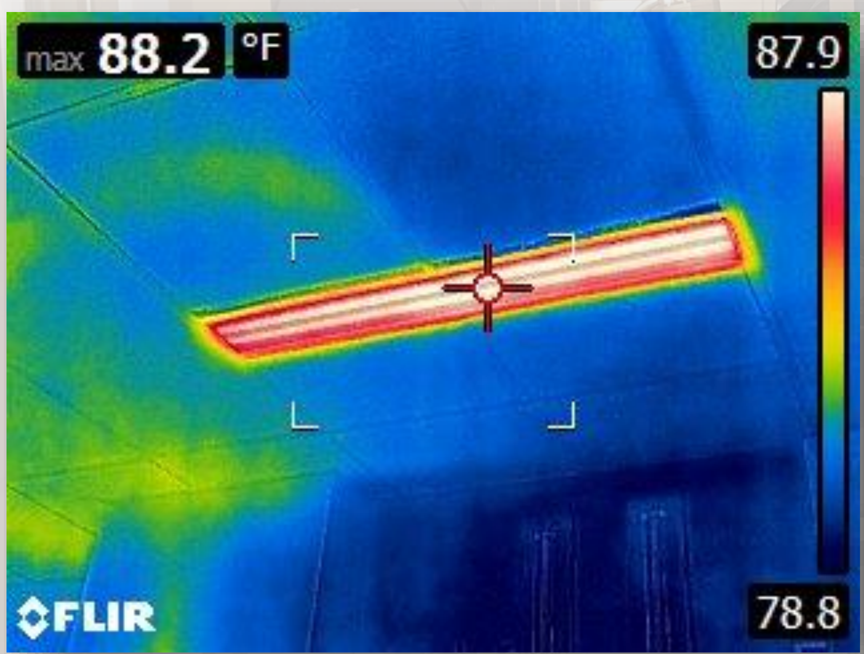
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
49	BALANCE							0	-631	0	0		0	-35	0
50															
51								Actual	Design	Set-Point	BAS		Actual	Design	Set-Point
52						Room Pressure:									
53						Effective Mode:		N/A	N/A	N/A			N/A	N/A	N/A
54						Effective Set-Point:		N/A	N/A	N/A			N/A	N/A	N/A
55															
56	Room Parameters					SCREEN SHOTS		NEEDED	TAKEN				NEEDED	TAKEN	
57		Design	BAS	Actual		1	Room					Room			
58	Room Temp:		75.2	68.9		2	VAV's					VAV's			
59	Room Humidity					3	GX's					GX's			
60	Occ Cooling SP		74.0			4	FH's					FH's			
61	Occ Heating SP		72.1												
62	Unocc Cooling SP		78.0			SEQUENCE							Applies?	Pass/Fail	
63	Unocc Heating SP		76.0			1	Does Supply VAV remain Constant?								
64						2	Does General Exhaust Valve Track Fume Hood and Bench Exhaust Flow?								
65						3	Does Bench Exhaust turn on and off via wall switch?								
66						4	Does Room Offset remain Constant?								
67						5	Cooling LAT is always 55								
68						6	Heating LAT exceeds 90								
69															

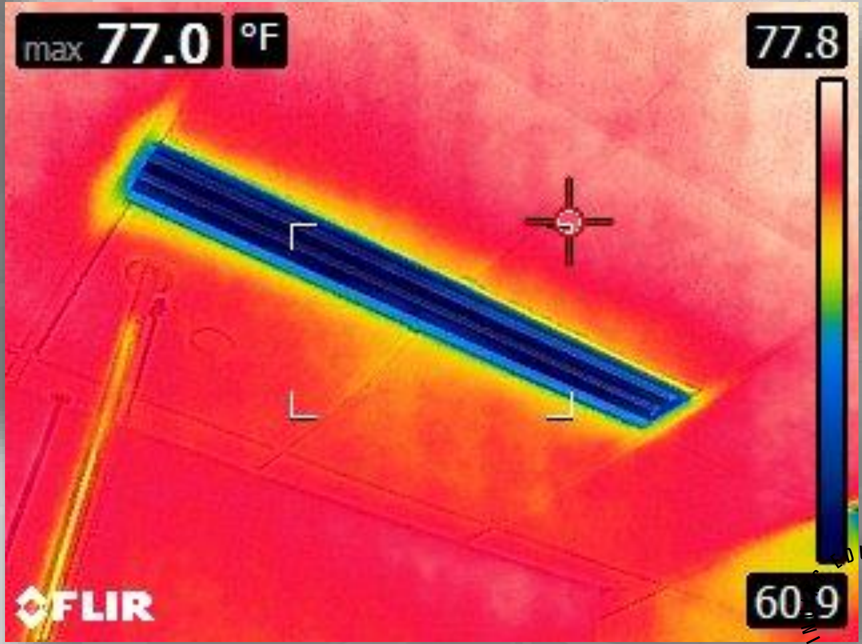
	Item	Unit No.	Asset No.	Room Loc	Room Ty	Device Ty	Control Type	Device Design	Issue
71				225/224	Lab/Offic	VAV	DDC	VAV-55 & 54	BAS is inaccurate for the lab and office. BAS shows VAV-55 serving the office exclusively and VAV-54 serving
72				225	Lab	VAV	DDC	VAV-55	Supply air terminal unit is not calibrated. In minimum, the units reads 303 CFM while the actual air flow is mea
73				225/224	Lab/Offic	VAV	DDC	VAV-54	Supply air terminal unit is not calibrated. In minimum, the units reads 854 CFM while the actual air flow is mea
74				224	Office	GX	DDC	GX-55	Exhaust terminal unit is not calibrated. In minimum, the units reads 564 CFM while the actual air flow is measu
75				225	Lab	Hood	DDC	FH-	Fume hood is not calibrated. In maximum, the unit reads 621 CFM while the actual air flow is measured to be

Lab Template | 208 - Lab | 211 - Lab | 212 - Lab | 216 - Lab | 219 - Lab | 220 - Lab | 223 - Lab | 225/224 - Lab | 217

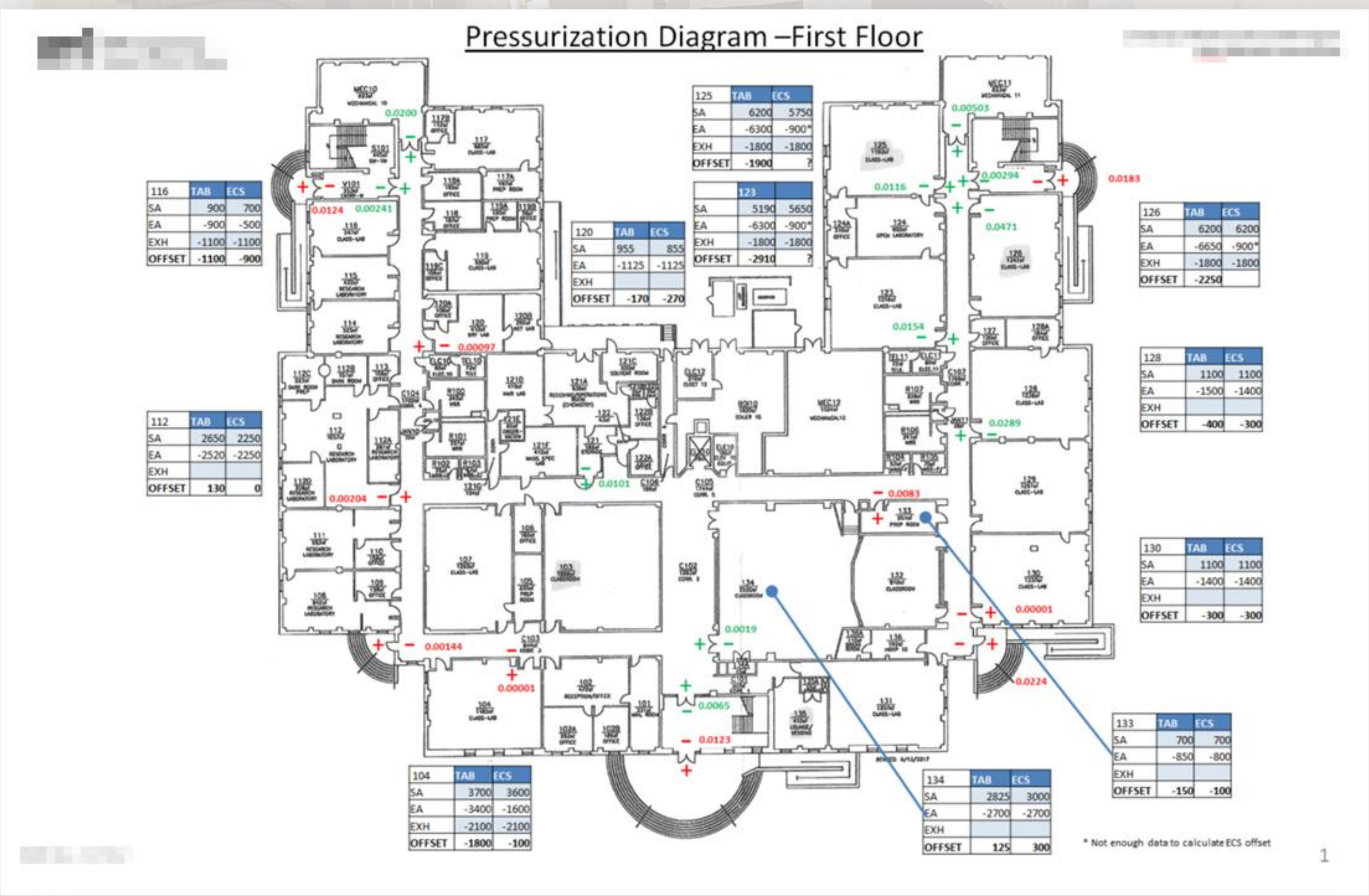
Explore

RETRO-Cx RESULTS





RETRO-Cx RESULTS



116	TAB	ECS
SA	900	700
EA	-900	-500
EXH	-1100	-1100
OFFSET	-1100	-900

112	TAB	ECS
SA	2650	2250
EA	-2520	-2250
EXH		
OFFSET	130	0

120	TAB	ECS
SA	955	855
EA	-1125	-1125
EXH		
OFFSET	-170	-270

125	TAB	ECS
SA	6200	5750
EA	-6300	-900*
EXH	-1800	-1800
OFFSET	-1900	?

	123	
SA	5190	5650
EA	-6300	-900*
EXH	-1800	-1800
OFFSET	-2910	?

126	TAB	ECS
SA	6200	6200
EA	-6650	-900*
EXH	-1800	-1800
OFFSET	-2250	

128	TAB	ECS
SA	1100	1100
EA	-1500	-1400
EXH		
OFFSET	-400	-300

130	TAB	ECS
SA	1100	1100
EA	-1400	-1400
EXH		
OFFSET	-300	-300

133	TAB	ECS
SA	700	700
EA	-850	-800
EXH		
OFFSET	-150	-100

134	TAB	ECS
SA	2825	3000
EA	-2700	-2700
EXH		
OFFSET	125	300

104	TAB	ECS
SA	3700	3600
EA	-3400	-1600
EXH	-2100	-2100
OFFSET	-1800	-100

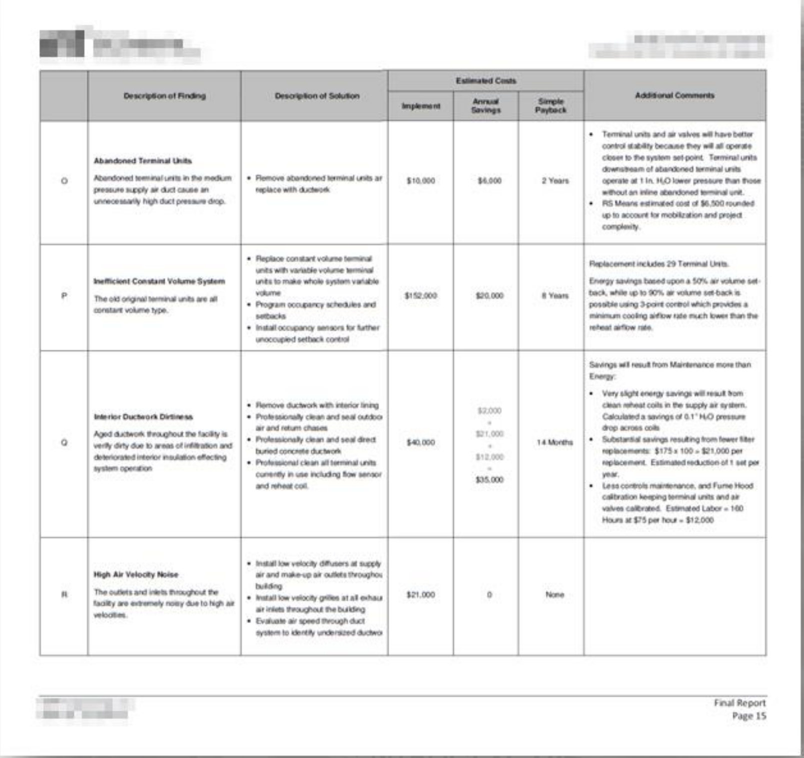
RETRO-Cx RESULTS

» Energy Conservation Measures (ECM's)

➢ Recommended major corrections or changes (typically in the form of projects or technology improvements) that result in significantly lower energy consumption

» Facility Improvement Measures (FIM's)

» Recommended major corrections or changes (typically in the form of projects or technology improvements) that result in significantly improved system performance



	Description of Finding	Description of Solution	Estimated Costs			Additional Comments
			Implement	Annual Savings	Simple Payback	
O	**Abandoned Terminal Units** Abandoned terminal units in the medium pressure supply air duct cause an unnecessarily high duct pressure drop.	• Remove abandoned terminal units ar replace with ductwork	$10,000	$6,000	2 Years	• Terminal units and air valves will have better control stability because they will all operate closer to the system set-point. Terminal units downstream of abandoned terminal units operate at 1 In. H_2O lower pressure than those without an inline abandoned terminal unit. • RS Means estimated cost of $6,500 rounded up to account for mobilization and project complexity.
P	**Inefficient Constant Volume System** The old original terminal units are all constant volume type.	• Replace constant volume terminal units with variable volume terminal units to make whole system variable volume • Program occupancy schedules and setbacks • Install occupancy sensors for further unoccupied setback control	$152,000	$20,000	8 Years	Replacement includes 29 Terminal Units. Energy savings based upon a 50% air volume set-back, while up to 90% air volume set-back is possible using 3-point control which provides a minimum cooling airflow rate much lower than the reheat airflow rate.
Q	**Interior Ductwork Dirtiness** Aged ductwork throughout the facility is verify dirty due to areas of infiltration and deteriorated interior insulation effecting system operation	• Remove ductwork with interior lining • Professionally clean and seal outdoo air and return chases • Professionally clean and seal direct buried concrete ductwork • Professional clean all terminal units currently in use including flow sensor and reheat coil.	$40,000	$2,000 + $21,000 + $12,000 = $35,000	14 Months	Savings will result from Maintenance more than Energy: • Very slight energy savings will result from clean reheat coils in the supply air system. Calculated a savings of 0.1" H_2O pressure drop across coils • Substantial savings resulting from fewer filter replacements: $175 x 100 = $21,000 per replacement. Estimated reduction of 1 set per year. • Less controls maintenance, and Fume Hood calibration keeping terminal units and air valves calibrated. Estimated Labor = 160 Hours at $75 per hour = $12,000
R	**High Air Velocity Noise** The outlets and inlets throughout the facility are extremely noisy due to high air velocities.	• Install low velocity diffusers at supply air and make-up air outlets throughou building • Install low velocity grilles at all exhau air inlets throughout the building • Evaluate air speed through duct system to identify undersized ductwo	$21,000	0	None	

Final Report
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THANK YOU!

RMF Engineering
Reliability. Efficiency. Integrity.

This concludes The American Institute of Architects Continuing Education Systems Course

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