



From Fumes to Function: A Commissioning Success Story

Hardik Miyani, PE, CEM, CRE, CPHC, LEED Green Associate

Energy and Decarbonization Project Manager, Baumann Consulting

AIA Quality Assurance



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Course Description

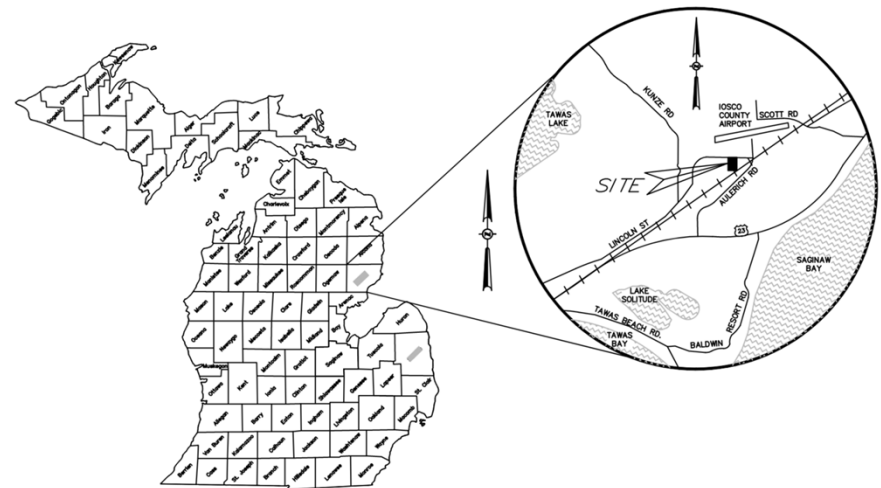
Proper building pressurization is essential to protect occupants, maintain air quality, and ensure energy efficiency. This case study details how commissioning resolved an industrial facility's issue of CO and NO₂ from a vehicle garage infiltrating office areas. Using Integrated System Testing (IST), all mechanical, electrical and control systems were evaluated under seasonal conditions. Commissioning activities included smoke and pressurization testing, sensor calibration, and sequence validation. Staff were trained, and an SOP was developed for long-term compliance. The presentation demonstrates commissioning as a proactive, data-driven process that enhances safety, efficiency, and reliability in industrial facilities.

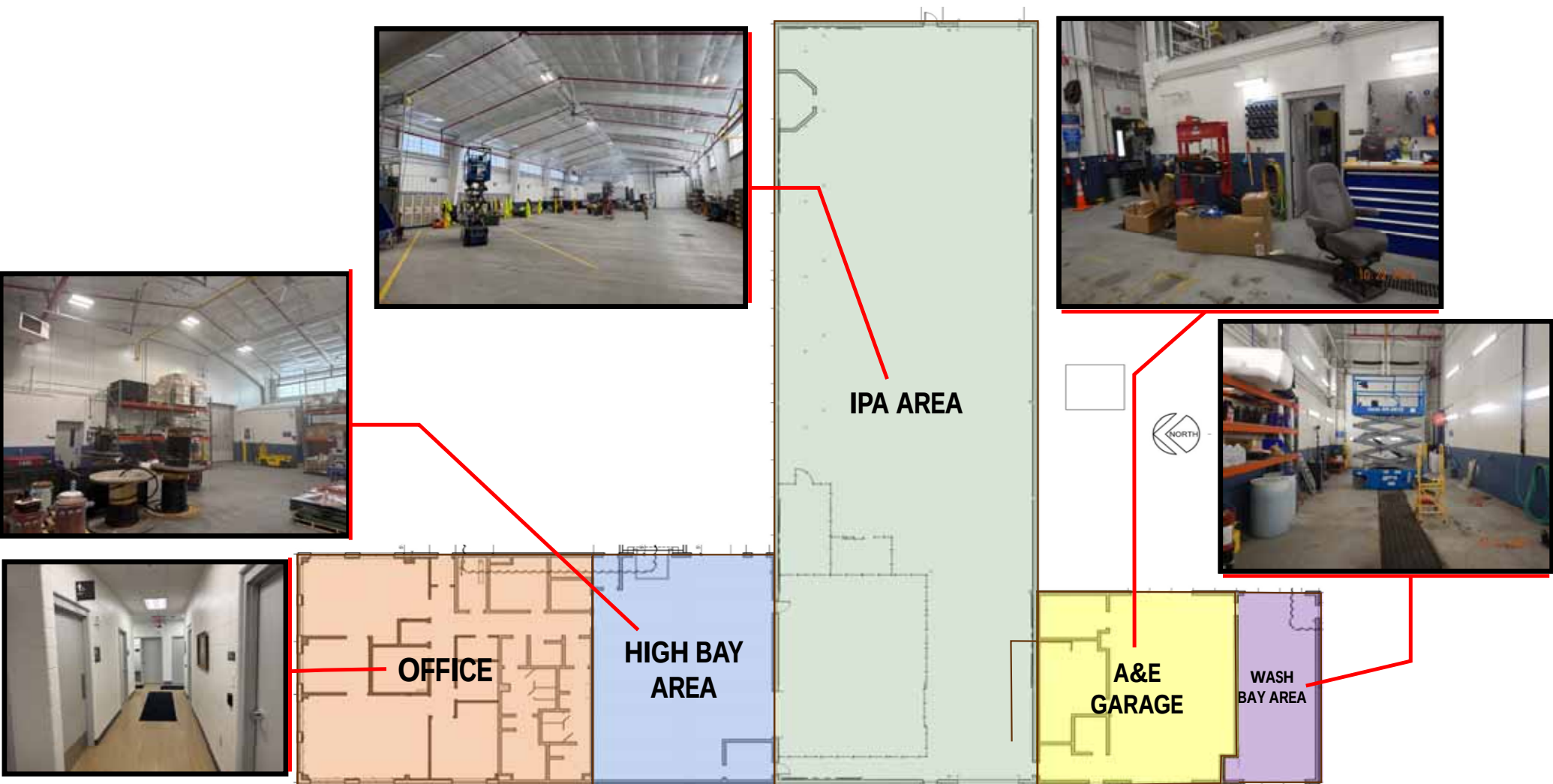
Learning Objectives

- Describe the impact of improper building pressurization on indoor air quality and occupant safety.
- Apply commissioning techniques, such as integrated system testing and smoke tests, to diagnose and resolve pressurization issues.
- Analyze the effectiveness of CO/NO₂ sensor testing and the sequence of operation in maintaining safe facility environments.
- Develop Standard Operating Procedures (SOPs) and staff training programs to sustain proper pressurization control.

Introduction

- Location: Tawas, MI
- Facility Type: Fleet Vehicle Industrial Facility
- Size: 22,000 ft² | 2,044 m²



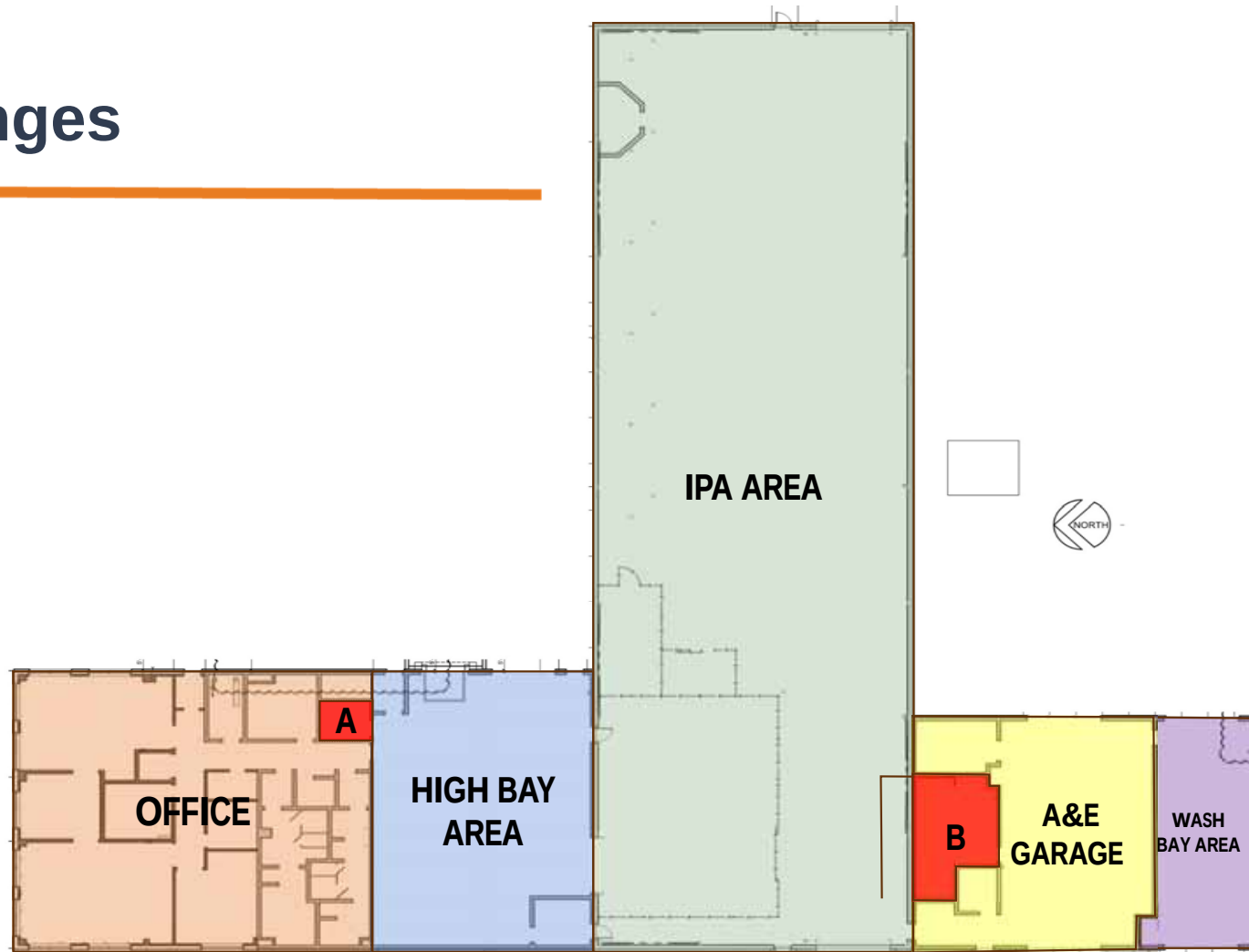


Challenges

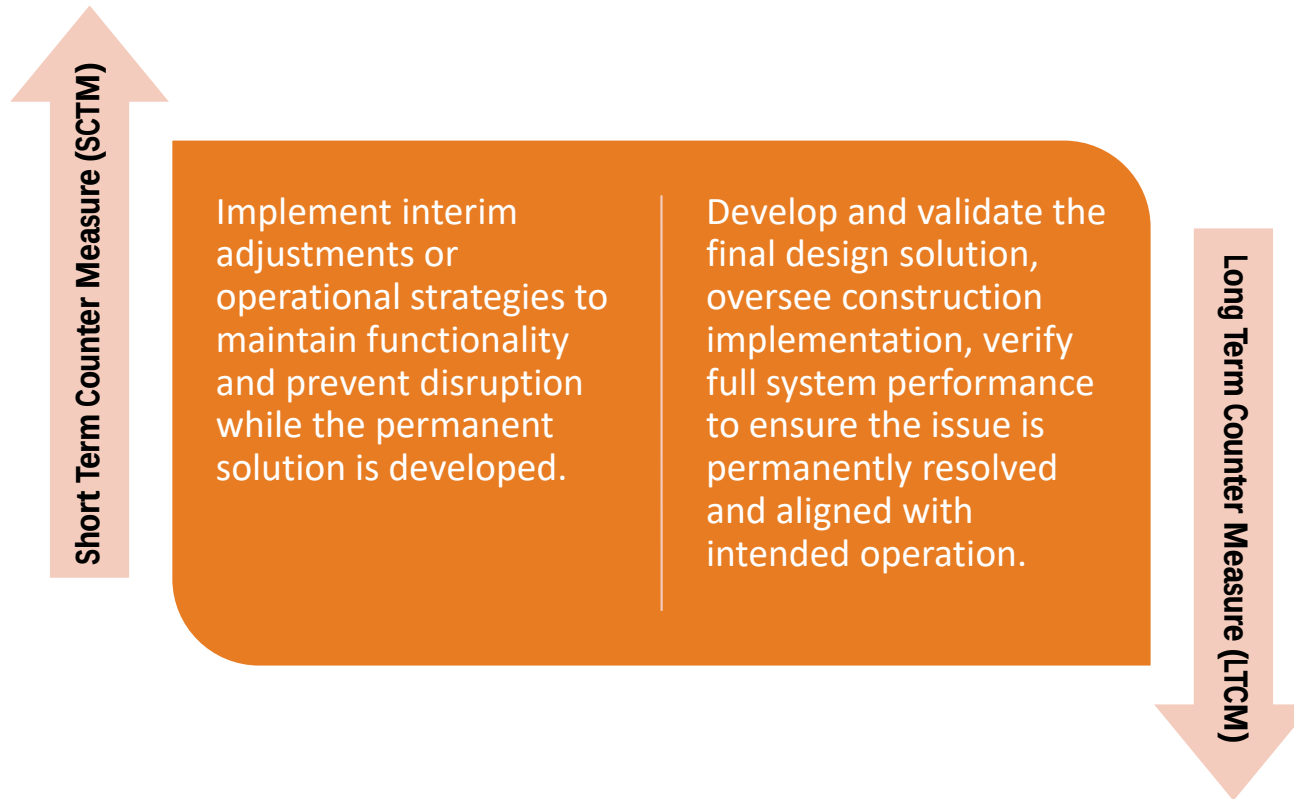
- Signs of vehicle smoke exhaust found in the office.
- Multiple staff members fainting on site, leading to serious health and safety concerns on site.



Challenges



Solution



Design Phase

- Design review
 - Design codes missing
 - Incomplete SOO of existing equipment's
 - Missing equipment's
 - Incorrect location of equipment's
- Developed SOO for building pressurization test

TEST TEMPLATE

3.4 FPT-Office Positive Pressure Verification

3.4 FPT-Office Positive Pressure Verification

Lines 23

GENERAL INFORMATION

- 1 Record outdoor temperature (°F)
- 2 Record outdoor relative humidity (%)
- 3 Record the office interior temperature (°F)
- 4 Record office interior relative humidity (%)

OPERATE MAKEUP AIR UNIT AND PURGE EXHAUST FAN ONLY

- 5 Confirm positive pressure in the office
- 6 Record the pressure difference

OPERATE MAKEUP AIR UNIT AND PURGE EXHAUST FAN WITH CEILING FAN RUNNING FORWARD

- 7 Confirm positive pressure in the office
- 8 Record the pressure difference

OPERATE MAKEUP AIR UNIT AND PURGE EXHAUST FAN WITH CEILING FAN RUNNING BACKWARD

- 9 Confirm positive pressure in the office
- 10 Record the pressure difference

OPERATE CEILING FAN RUNNING FORWARD ONLY

- 11 Confirm positive pressure in the office
- 12 Record the pressure difference

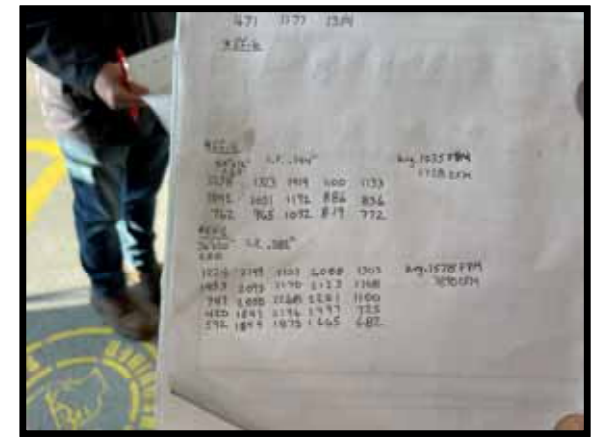
OPERATE CEILING FAN RUNNING BACKWARD ONLY

- 13 Confirm positive pressure in the office
- 14 Record the pressure difference

WRAP-UP

- 15 Make or verify that the unit is operating under normal conditions.
- 16 Release all overrides and return the system to normal operations.

Space Pressurization Test



Space Pressurization Test Results

OFFICE A

#4 Office TWS-2000 - Office Positive Pressure Verification

Test: (Passed on 11/03/2020) | Page 1 of 2

System: [Icon]

Test Description: The test was conducted under the following conditions:
1. The Overhead between the elevator and the office conditions.
2. The door between the elevator and the office was closed.
3. All pressure sensor calibration checks were passed.
4. The fan was in the office side (PS) as normal operation.

Attempts: [Icon]

Attempt No. 1 [Icon]

Test Results:

Test Item	Result	Value
1. Record outdoor temperature (°F)	Pass	35.0°F
2. Record outdoor relative humidity (%)	Pass	38%
3. Record the office indoor temperature (°F)	Pass	71.1°F
4. Record office indoor relative humidity (%)	Pass	38.2%

Operate elevator and shut down fan (PS)

Test Item	Result	Value
5. Confirm positive pressure in the office	Pass	The pressure was correct before the test.
6. Confirm positive pressure in the office	Pass	The pressure was correct before the test.

Operate elevator and shut down fan (PS)

Test Item	Result	Value
7. Confirm positive pressure in the office	Pass	The pressure was correct before the test.
8. Confirm positive pressure in the office	Pass	The pressure was correct before the test.

Test: (Passed on 11/03/2020) | Page 2 of 2

System: [Icon]

OFFICE B

#5 Office TWS-4000 - Office Positive Pressure Verification

Test: (Passed on 11/03/2020) | Page 1 of 2

System: [Icon]

Test Description: The test was conducted under the following conditions:
1. The Overhead between the elevator and the office conditions.
2. The door between the elevator and the office was closed.
3. All pressure sensor calibration checks were passed.
4. The fan was in the office side (PS) as normal operation.

Attempts: [Icon]

Attempt No. 1 [Icon]

Test Results:

Test Item	Result	Value
1. Record outdoor temperature (°F)	Pass	35.0°F
2. Record outdoor relative humidity (%)	Pass	38%
3. Record the office indoor temperature (°F)	Pass	71.1°F
4. Record office indoor relative humidity (%)	Pass	38.2%

Operate elevator and shut down fan (PS)

Test Item	Result	Value
5. Confirm positive pressure in the office	Pass	The pressure was correct before the test.
6. Confirm positive pressure in the office	Pass	The pressure was correct before the test.

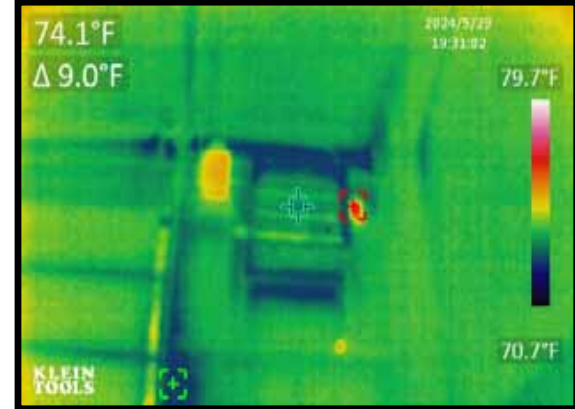
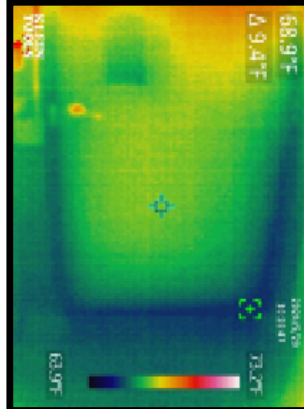
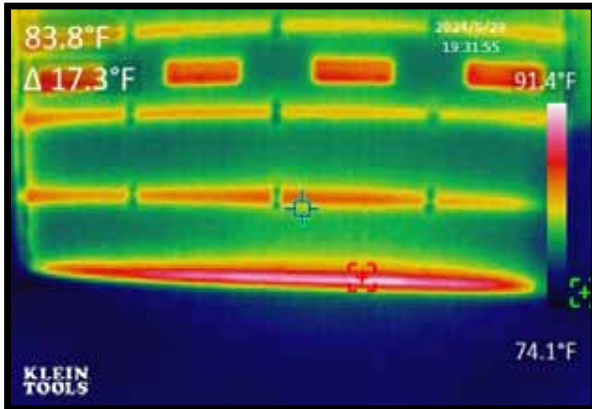
Operate elevator and shut down fan (PS)

Test Item	Result	Value
7. Confirm positive pressure in the office	Pass	The pressure was correct before the test.
8. Confirm positive pressure in the office	Pass	The pressure was correct before the test.

Test: (Passed on 11/03/2020) | Page 2 of 2

System: [Icon]

Issues Identified with Existing Systems



Issues Identified with Existing Systems



Phase 2: Integrated System Testing (IST)

- Integrated System Testing is a commissioning phase during which all major building systems are exercised together under realistic operating conditions.
- It goes beyond individual component or subsystem verification, to ensure that systems such as HVAC, electrical, controls, fire/life safety, building automation, etc., actually work in sync.
- The key objective: Verify that the performance of the fully integrated facility meets the Owner's Project Requirements (OPR) and design intent under combined operation and abnormal conditions.

Integrated System Testing Process



Ensure all individual systems have been designed, installed and operating correctly.



Developing integration test scripts/sequence scenarios that capture both normal and abnormal operating modes.



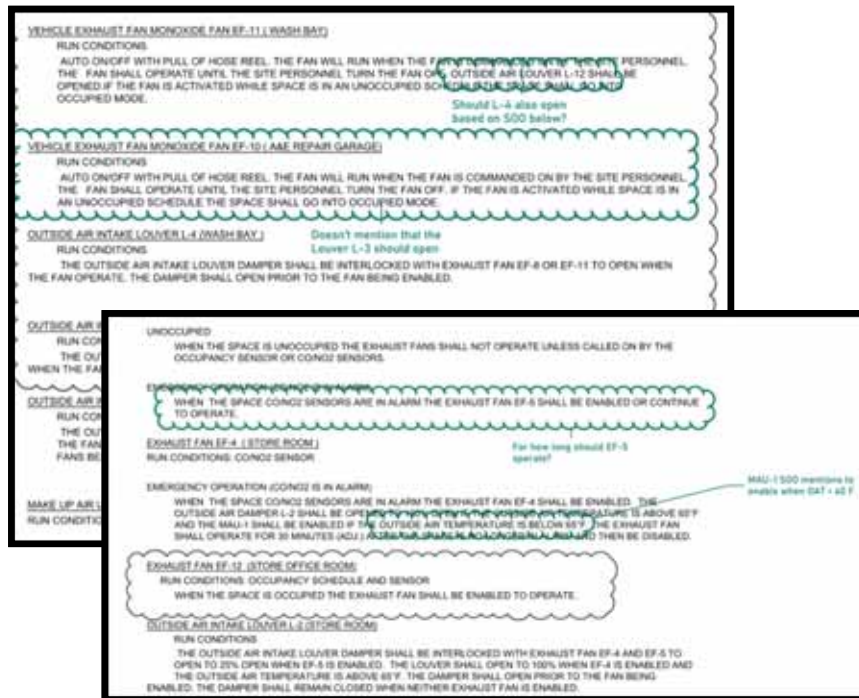
Coordinating across all trades (mechanical, electrical, controls, fire/life safety) to schedule and prepare required instrumentation and monitoring.



Execute the scenarios, monitor system responses, identify deviations and document results for review.

Design and Construction Process

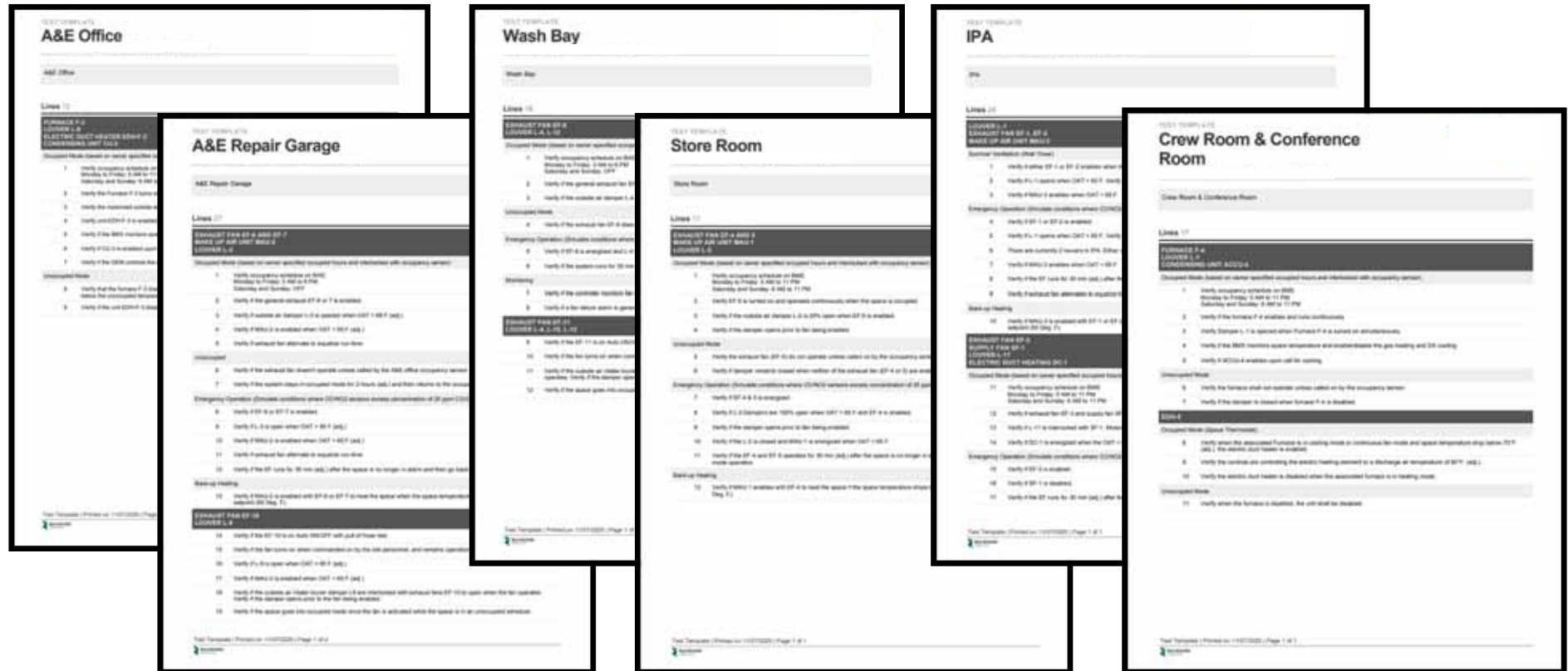
Design Phase



Construction Phase



IST Functional Performance Test Scripts



Calibration and TAB Report Review



Hi-Tech Test & Balance, Inc. **Air Apparatus Test Report**
NEBB Cert #3067

System: MAU-3
Date: 12/08/2013

Unit Data		Motor Data	
Make / Model No.	Stator / RPM: 600	Make/Frame	Indust / 215T
Type / Size	Make Up Air Unit	HP / RPM	20 / 1755
Serial Number	48703053025678	Full Load Amps	20.8-23.8 / 11.9 / 1.15
Discharge	Horizontal	Make Sheave	Horizontal / 50
Make Sheave	Horizontal / 50	Diam / Bore	6.5" / 1.375"
Diam / Bore	11" / 1.187" Bush	C.L. Distance	20.25"
No. Belts / Size	1 @ 4:860	Sheave Oper Diam	6.25"
No. Filters / Size	1"		

(T) Testroom (D) Total as read at RIG's (NG) Not given (NR) Not read (NA) Not Applicable

Test Data	Design	Actual	Test Data	Design	Actual
Total CFM	7910	7910	Discharge S.P.	NG	~ 410"
Fan RPM	1102	1102	Section S.P.	NG	~ 380"
EUA CFM	7910	8126	External S.P.	79"	790"
RUA CFM	0	0	Total S.P.	~ 1.16"	1.35"
EUA Damper Val	100%	100% Approx	Motor Volts	440	440-492-481
RUA Damper Val	0%	0% Approx	Motor Amps	11.8	6.9-7.2-7.3

Remarks: "8 @ 32"x12"x2" 2 @ 16"x16"x2" 1 @ 16"x25"x2"
Velgrid Reading: 29.25"x29.25"-0.94 SQ. FT.
AVG. FPM=1,364
CFM=8,126

Cx: As per the mechanical schedule on MO-3, MAU-3 has required air flow in 9000 CFM. Pg. 6 of TAB report shows MAU-3 is balanced based on 9000 CFM but Pg. 12 shows its balanced based on 7910 CFM. TAB contractor to update the clarity and update the report accordingly.

Cx: As per the mechanical schedule on MO-3, MAU-3 has a FIA of 4.5 ampere at 480V. TAB contractor to verify if this value is correct.

Hi-Tech Test & Balance, Inc. **Rectangular Duct Traverse Report**
NEBB Cert #3067

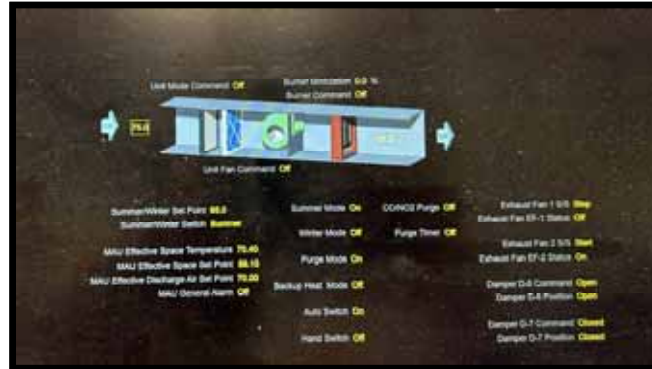
System: EF-5
Traverse: Store Room Drop

Duct	Required	Actual
S.P.:	100"	
Size:	23"x12"	FPM: 183
Area:	1.67 SQ. FT.	CFM: 306

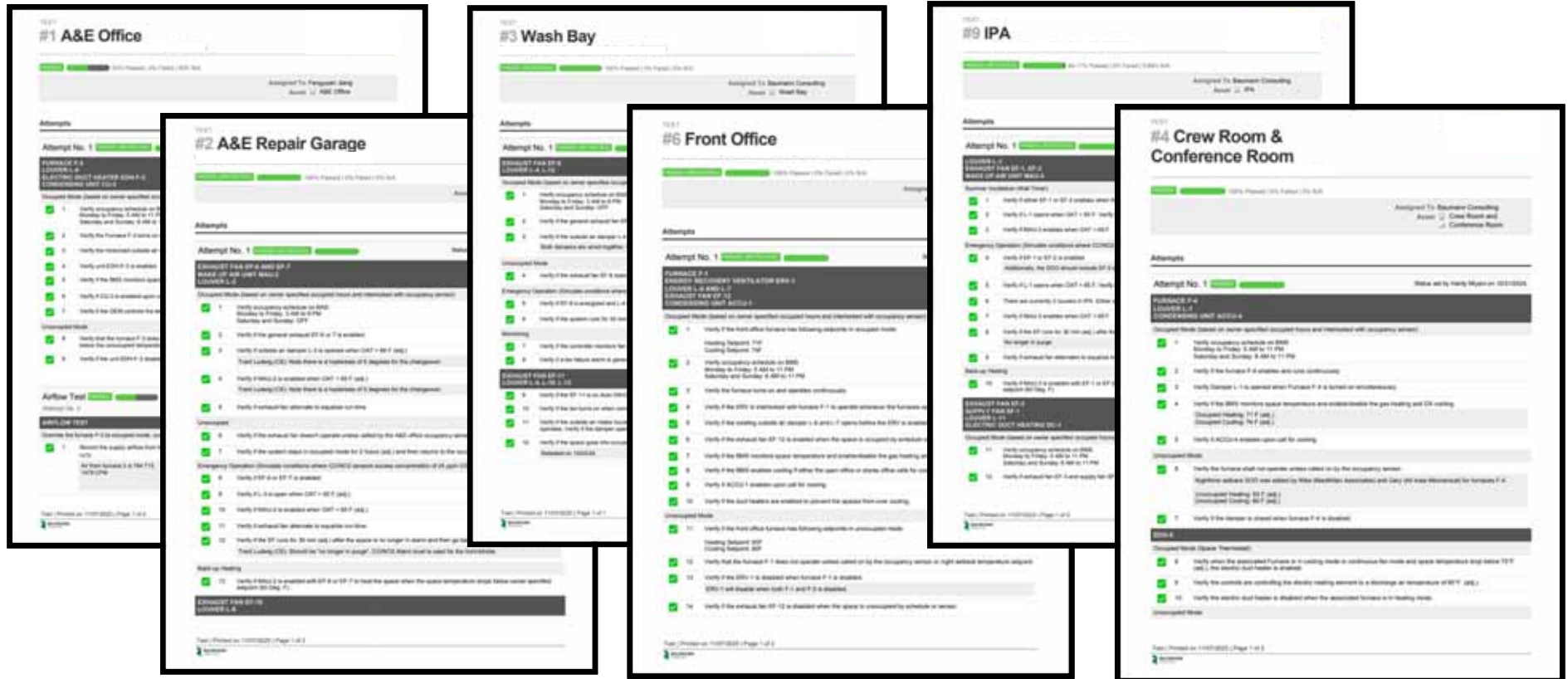
Cx: As per the mechanical schedule, the required airflow for EF-5 is 400 CFM.

Position	1	2	3	4	5	6	7	8
1	214	187	243	199	156			
2	190	201	195	152	157			
3	187	180	148	166	146			
4								
5								
6								
7								
8								
9								
10								
Velocity	391	368	607	517	459			
Total								

Remarks: Speed Controller at 4



Integrated System Testing Results



Space Pressurization Test Reports

OFFICE A

TEST #14 Storeroom & Office - Office Positive Pressure Verification - Cooling

Assigned To: Pangqian Jiang
Assigned To: High Bay 9 Office

Attempt No. 1

GENERAL SATISFACTION

1. Record outdoor and indoor temperature (°F)
82.0°F in high bay
75.0°F in high bay
The area between the high bay and the storeroom is not tested.

2. Record outdoor and indoor relative humidity (%)
40.0% high bay
40.0% office
It was noted the high bay humidity was higher than the office.

VERIFY POSITIVE PRESSURE

3. Verify positive pressure in the office
Based on flow, record outdoor and indoor air flow.

OPERATE MAKEUP AIR UNIT AND PURGE EXHAUST FAN ONLY

4. Confirm positive pressure in the office
30.0 cfm outdoor, purge fan 6 and 7 running.
(Average 5.2 cfm).

5. Record the pressure difference
After the high bay office door is closed, the pressure difference is 0.01 inches of w.c.

OPERATE MAKEUP AIR UNIT AND PURGE EXHAUST FAN ONLY

6. Confirm positive pressure in the office

7. Record the pressure difference
Negative pressure in the high bay.

OPERATE MAKEUP AIR UNIT AND PURGE EXHAUST FAN ONLY

8. Confirm positive pressure in the office

9. Record the pressure difference

Test | Printed on 11/07/2024 | Page 1 of 2

OFFICE B

TEST #12 A&E Office - Office Positive Pressure Verification - Cooling

Assigned To: Pangqian Jiang
Assigned To: High Bay 9 Office

Attempt No. 1

GENERAL SATISFACTION

1. Record outdoor and indoor temperature (°F)
80°F

2. Record outdoor relative humidity (%)
40%

3. Record the office indoor temperature (°F)
87.0°F

4. Record office indoor relative humidity (%)
35.0%

OPERATE MAKEUP AIR UNIT AND PURGE EXHAUST FAN ONLY

5. Confirm positive pressure in the office

6. Record the pressure difference
Average pressure difference is 0.00 inches of w.c.

OPERATE MAKEUP AIR UNIT AND PURGE EXHAUST FAN ONLY

7. Confirm positive pressure in the office

8. Record the pressure difference
Average pressure difference is 0.01 inches of w.c.

OPERATE MAKEUP AIR UNIT AND PURGE EXHAUST FAN ONLY

9. Confirm positive pressure in the office

10. Record the pressure difference
Average pressure difference is 0.00 inches of w.c.

OPERATE MAKEUP AIR UNIT AND PURGE EXHAUST FAN ONLY

11. Confirm positive pressure in the office

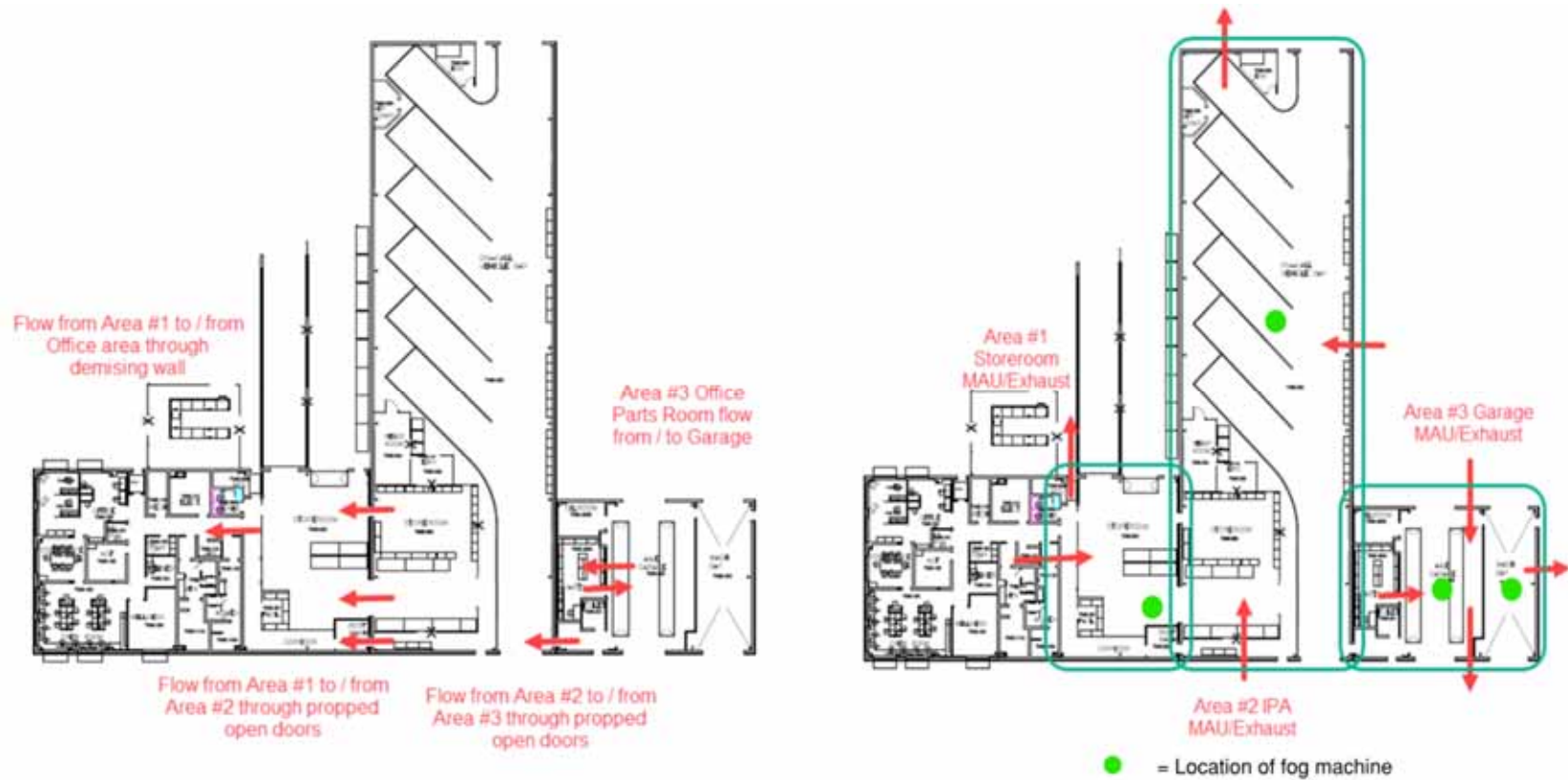
12. Record the pressure difference
Average pressure difference is 0.00 inches of w.c.

Test | Printed on 11/07/2024 | Page 1 of 2

Phase 3: Artificial Smoke Testing

- ASTM E1186-17 – Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems.
- Introduce artificial smoke in the testing area to validate the airflow movement of the MEP equipment and to identify potential air leakage in the building envelope.
- The test being performed is for a qualitative nature in determining the air leakage sites rather than determining quantitative leakage rates.

Artificial Smoke Test Planning



Artificial Smoke Test FPT Scripts

Phase 1: Smoke Mode- 10 Min

Phase 2:
Purge Mode – 15 min

Phase 3:

Alarm Mode – 15 min

TEST TEMPLATE

A&E Garage

A&E Garage

Lines 00

THE PURPOSE OF THIS TEST IS TO IDENTIFY ROOM GARAGE. BEFORE ALLOW FOR A DEPENDANT MOUNTING OF THE FOG MACHINE. WHEN THE (1) THE FOG IS PROPERLY POSITIONED (2) THE FOG IS COMPARED TO THE (3) THE FOG IS NOT IN PROPERLY (4) THE FOG MACHINE WILL BE SET UP

OPERATION MODE VERIFICATION

- Verify the system is on-line
- Verify the system is on-line
- Verify there is no operation
- Attach the BMS system

GASOLIN TEST SET-UP

- Verify there is no operation
- The garage office will be present
- Set-up table in center of room
- Locate personnel at the site
 - Baumgartner & fog consultant
 - Consumers - Located in
 - Consumers - Located in
 - Consumers - Located in

The purpose of testing is to test if smoke is noticed, the

GASOLIN TEST PROCEDURE

- Turn on fog machine. Verify
- (PHASE 1: FOG MACHINE present)
- TOTAL RUNTIME = 10 MIN
- (PHASE 2: FOG MACHINE, the BAS operator. The fog is
- TOTAL RUNTIME = 10 MIN
- During this period, the team will call phone video will be
- After 5 minutes of MAUEF movement of fog. Run fog

A&E Garage |

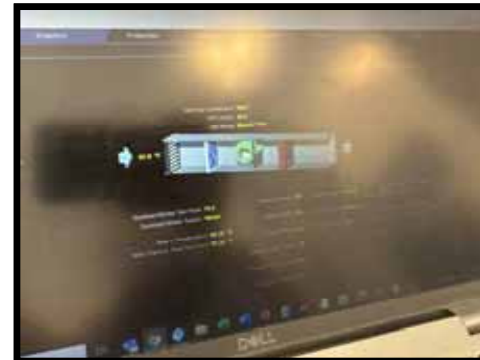
- Visually verify room to determine whether any areas have denser/fighter fog taking pictures as necessary. (Pictures can be added to this file item by pressing 'Add Image')
- (PHASE 3: FOG MACHINE = OFF, PURGE SYSTEM = On (After 15 minutes, shut-down fog machine. TOTAL RUNTIME = 15 MINUTES
- During this mode, the person in Joan's office must inspect the walls to determine whether fog is able to penetrate. Special attention should be given to the ceilings and corners of the office.
- During this mode, the person in Joan's office must inspect the HVAC systems. Verify no fog is entering through the diffusers.
- After 5 minutes, The MAUEF exhaust system will be activated by the BAS operator. The fog machine team will inform the parties in adjacent areas it has been activated.
- After 15 minutes, shut-down fog machine. (Final Condition: Fog machine off, MAUEF System activated)
- Turn Off system and describe conditions in the space. Were there clear areas that were not exhausted? Describe the directional movement of the fog? Was it clear the exhaust fans were pulling the fog in a certain direction?

Test Template (Printed on 11/06/2025) | Page 3 of 2

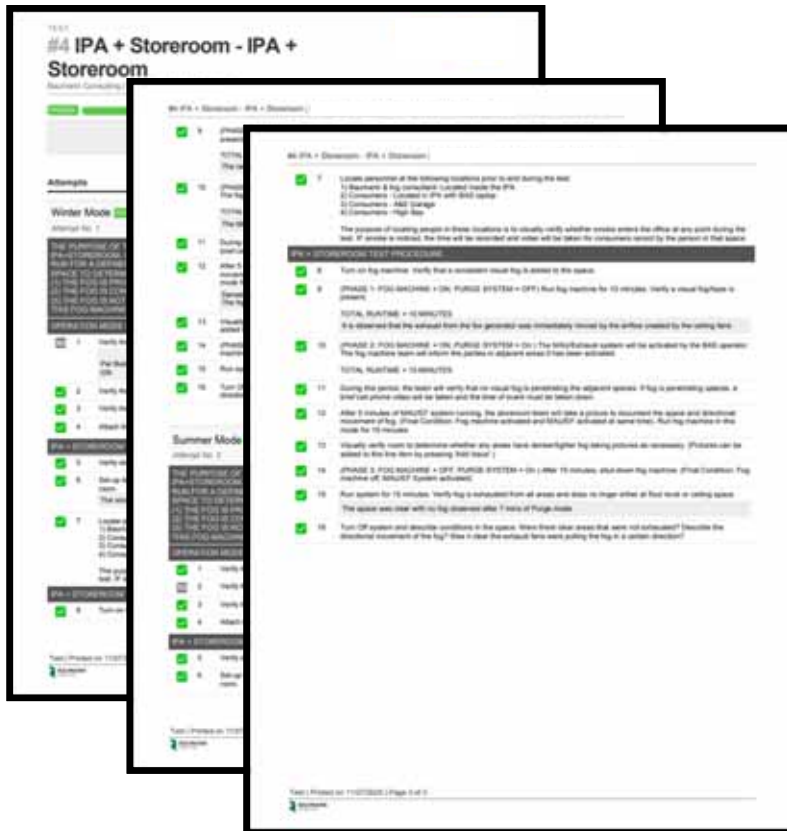
Test Template (Printed on 11/06/2025) | Page 1 of 2



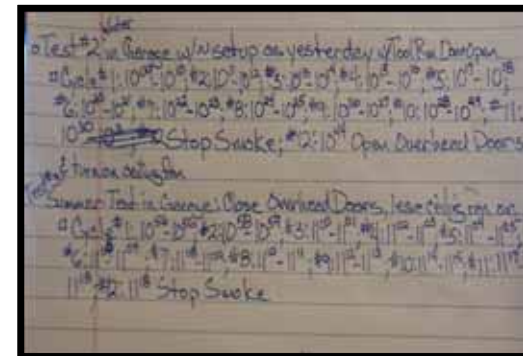
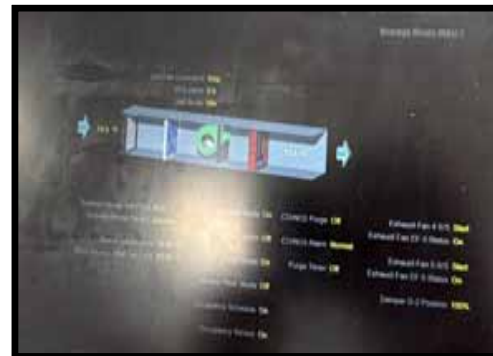
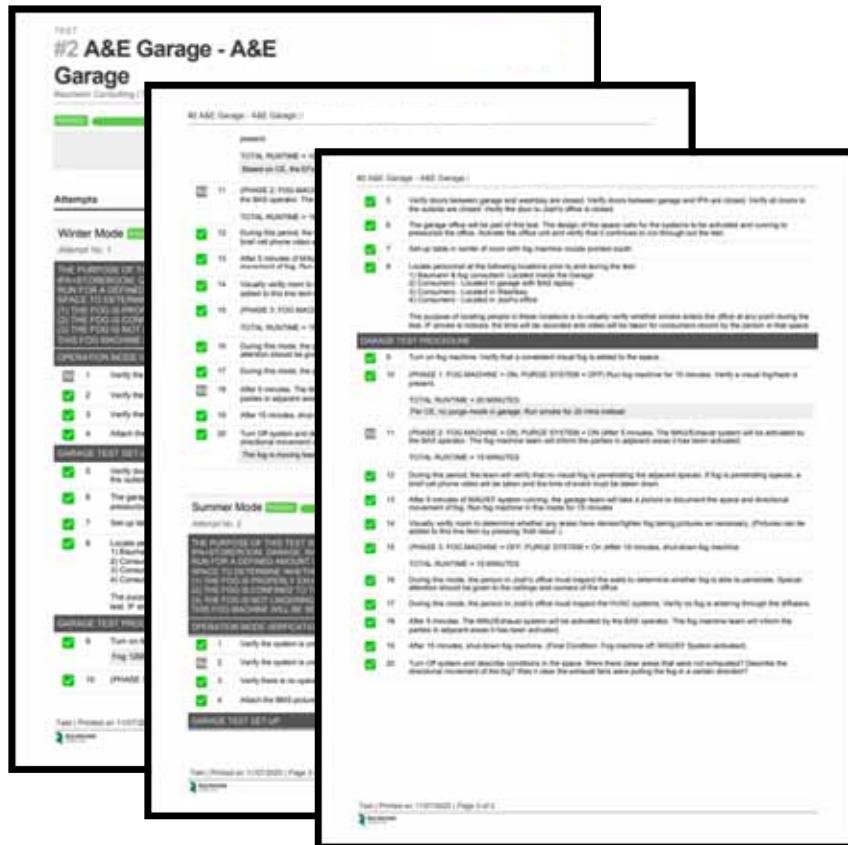
Artificial Smoke Test



Artificial Smoke Test



Artificial Smoke Test





Standard Operating Procedure

- No llding signage across the facility.
- Open overhead doors when space is in alarm.
- Keeping doors closed between adjacent spaces.
- Calibrate/replace the CO/NO₂ sensors
- Replacing filters every 3 months.
- Changing ceiling fans forward and reverse direction based on season.



Training Program



Table of Contents

- Document Overview
 - Information Provided
- Training Manual
 - Owners Training Requirements
 - Protocols for Informational Submittals
 - Protocols for Closeout Submittals



2 Training Manual

2.1 Owners Training Requirements

The Contractor shall coordinate and conduct all Owner qualified subcontractors or manufacturer representing Commissioning Agent. All sessions shall be video recorded. Owner Training should include:

- Preparation of Training Educational Materials
- Training Instruction
- Training Evaluation Matrix Sheet

2.2 Protocols for Informational Submittals

Contractors are required to submit an outline of demonstration and training, including a list of training proposed dates, times, length of instruction time, and training module. The outline shall include the training module.

2.3 Protocols for Closeout Submittals

At completion of training, Contractors are required to submit (within 10 days of the completion of each training module) the completed training manual(s) for Owner's use prepared in same PDF file format required for operation and maintenance manuals specified in Section 01 7823 "Operation and Maintenance Data."



2.6.1 Basis of Design and Operation

- System, subsystem
- Performance and
- Operating standards
- Regulatory requirements
- Equipment function
- Operating characteristics

2.6.2 Documentation Review Requirements

- Emergency manual
- Systems and equipment
- Systems and equipment
- Product maintenance
- Project Record Data
- Identification systems
- Warranties
- Maintenance services

2.6.3 Alarm Categorization and Control

- Instructions on response
- Instructions on stop
- Shutdown instructions
- Operating instructions
- Sequences for emergency
- Special opening

2.6.4 Operational Modes and Sequences

- Startup procedures
- Equipment or system
- Routine and emergency
- Regulation and control
- Control sequences



2.7 Preparation of Training Educational Materials

Contractors are required to assemble educational instruction, including documentation and training materials.

Contractor is required to assemble training modules in coordination with requirements in Section 01 7823 "Data."

Contractors are required to set up instructional equipment to the commencement of Training Module.

2.8 Instructional Training

Contractor is required to provide qualified instructors to adjust, operate, and maintain systems, subsystems, and equipment.

Contractor is required to provide instruction at multi-equipment that requires seasonal operation, contracts at start of each season.

Contractor is required to schedule training with Owner Manager, with at least 10 days' advance notice.

Contractors are required to conduct training on-site operational facility using the actual equipment in place.

Contractors are required to conduct training using final data submittals.

Contractor is required to collect used and leftover educational materials and return them to Owner including remove instructional equipment and materials.

Contractors are required to restore systems and equipment to condition existing before initial training use.



TRAINING EVALUATION

Training Module _____ Date: _____
 Instructor Name _____ Company: _____

Purpose: This form is used to evaluate each training session. Based upon this evaluation, later sessions can be improved. Each attendee please fill out one copy of this form. Mark questions that are not applicable with N/A.

	1 = very well	2	3 = not at all
1. How were the objectives of this training session met?	1		N/A
2. Do you know where the components/systems are located?	1		N/A
3. Do you know what area the components/systems are serving?	1		N/A
4. Do you understand the distinct types and purpose of these components?	1		N/A
5. Do you understand how to systematically troubleshoot common problems with these components/systems?	1		N/A
6. Do you know how the components/systems operate under all normal conditions?	1		N/A
7. How well do you understand the importance of reading the design intent for the systems covered?	1		N/A
8. Are you able to efficiently find the relevant information in the Systems Manual to operate and maintain the systems/components you were trained on?	1		N/A
9. Do you know how to perform the needed maintenance on the equipment and/or do you know how to get the information you need?	1		N/A
10. Do you know how to get updated technical service information for the components/systems?	1		N/A

- Explain why any questions got very low or very high ratings from you:
- What topics would you desire to be covered that were absent from this training session?
- You may provide other comments concerning anything about this training session (e.g., information prior to training, content):

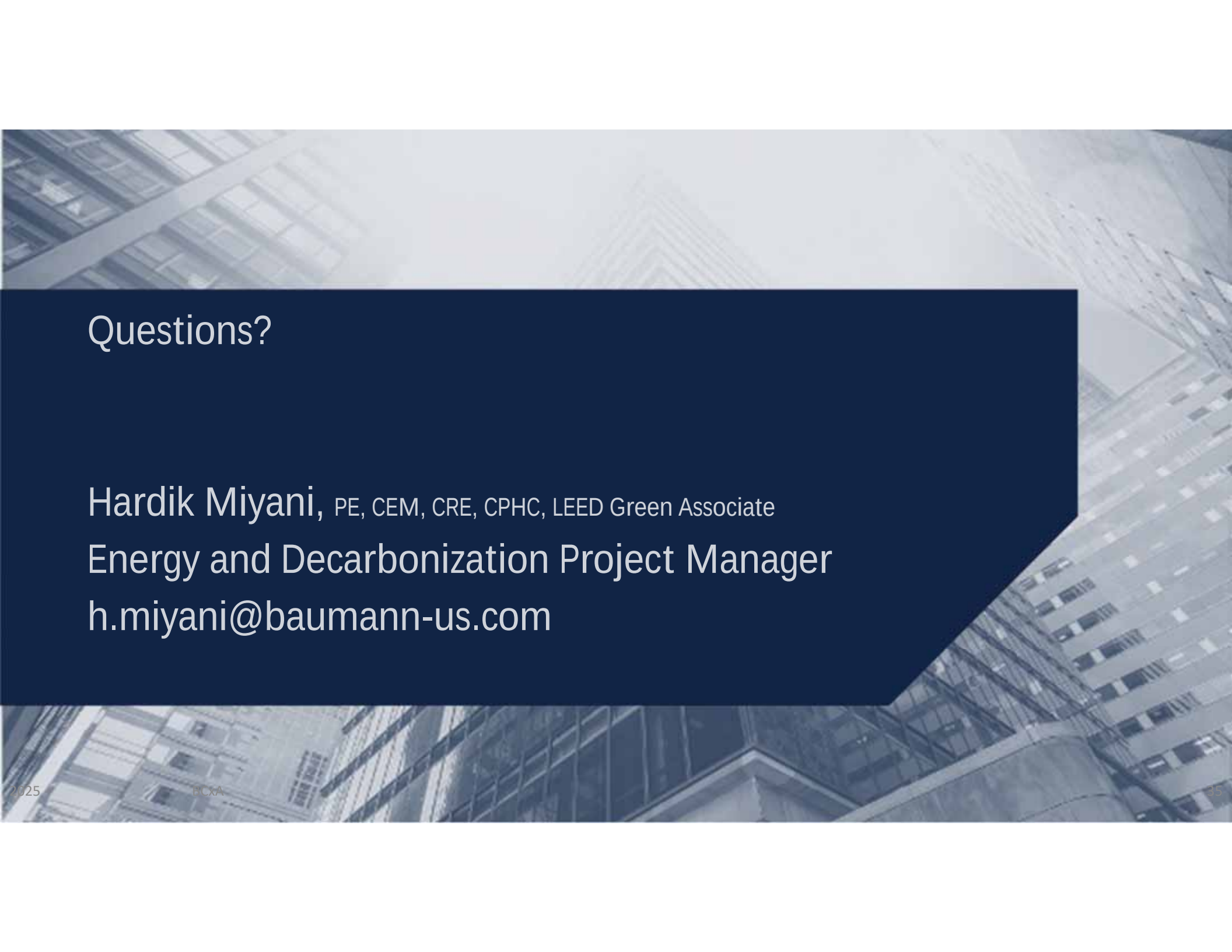
10-month Post Occupancy Walk Through

- Thermostats, CO/NO₂ sensors, and exhaust fans were operational and properly tagged.
- Filters have been regularly replaced per routine maintenance.
- Door between different spaces were left open with a door stopper installed.
- MAU supply grille blocked by stored items.
- Recent staff onboarding did not include key system details (sensor passwords, alarm setpoints, drawings, O&M manuals, calibration procedures, etc.).



Lessons Learned

- Proper pressurization is crucial to prevent contaminant migration and protect indoor air quality and occupant safety.
- Integrated system testing and smoke tests are essential for identifying interactions between systems and resolving pressurization issues.
- Regular CO/NO₂ sensor testing and sequence verification ensure ventilation systems respond correctly to maintain safe environments.
- Clear SOPs and ongoing staff training are necessary to sustain proper pressurization control and long-term operational performance.



Questions?

Hardik Miyani, PE, CEM, CRE, CPHC, LEED Green Associate
Energy and Decarbonization Project Manager
h.miyani@baumann-us.com