H2Engineering, Inc.

Fundamentals of Testing, Adjusting, and Balancing

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FBPE Provider #
0007513

Course #
TAB-101

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Course Description

This course will focus on:

- Various aspects and requirements of the testing, adjusting, and balancing (TAB) process
- How the TAB process benefits the project long-term
- What owners, design professionals, and contractors need to know in order to ensure the process is specified, performed, and documented properly
- Key challenges of the TAB process

Learning Objectives

1. The TAB process: what the purpose is and how it benefits the project long-term.

2. The necessary qualifications, training, and experience of the TAB personnel performing the work; why and how the qualifications and experience are vital to ensuring the systems are working properly and safely; and how to ensure qualified personnel are involved throughout the entire process.

3. The TAB procedural standards (scope of work and reporting) that is required, how to identify when the procedural standards are not being met, and what options are available to Owners and Design Professionals for quality assurance.

4. Roles and responsibilities of the Owner, Design Professionals, Commissioning Authorities, and Contractors throughout the TAB process, including detailing specifications to meet performance requirements, scheduling, reviewing, implementation, and verification that the systems are operating properly. Ultimately, each of these tasks and roles are necessary for ensuring the performance requirements of the design and applicable codes (safety, performance, and energy) are being achieved through design, implementation, and verification.

TAB PROCESS

SECTION 1

TAB Process

Question
What is TAB?

Answer
Testing, Adjusting, and Balancing

TAB Process

Terminology

- **Testing:** The use of specialized and calibrated instruments to measure temperatures, pressures, rotation speeds, electrical characteristics, velocities, and air/water quantities for evaluation of system performance.

- **Adjusting:** The setting of balancing devices such as dampers and valves, adjusting fan/pump speeds and pump impeller sizes, in addition to automatic control devices (thermostats, pressure controllers, etc) to achieve maximum specified system performance and efficiency during normal operation.

- **Balancing:** The methodical regulation of system fluid flows (air or water) through the use of acceptable procedures to achieve the desired or specified airflow or water flow.

TAB Process

What is the Purpose?

- Evaluate system performance
- Make adjustments to achieve:
  - Design intent
  - Maximum system performance
  - Maximum system efficiency
- Document performance and procedures for repeatability

TAB Process

What is the Benefit?

- Safety
- User/Occupant Comfort
- System Performance & Efficiency
- Reliability

- Risk/Liability
- Energy Costs
- User/Occupant Complaints
- Maintenance

What is Required by the Adopted Codes

Summary from Florida Building Code – Energy Conservation, 2017 Edition

C408.2: Mechanical Systems Commissioning & Completion Requirements:

- Completed prior to passing final mechanical inspection

C408.2.2: System Testing, Adjusting, and Balancing:

- Required for HVAC systems serving conditioned zones > 5000 SF
- TAB by licensed engineer or certified TAB organization/individual
- In accordance with generally accepted engineering standards.

- Exceptions:
  - Licensed mechanical contractor for 15 tons or less per system
  - Not required for < 65,000 Btu/hr per system

QUALIFICATIONS OF TAB PERSONNEL

SECTION 2

TAB Certifications

AABC

Associated Air Balance Council

NCI™ National Comfort Institute, Inc.

NEBB

National Environmental Balancing Bureau

TABB

TESTING, ADJUSTING AND BALANCING BUREAU

THE PROFESSIONAL'S CHOICE℠

NATIONAL BALANCING COUNCIL™

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TAB Personnel

Specialist Qualifications

- Certified member agency
- Certified Professional (TAB CP)
- Certified Technician (TAB CT)

- Certified member agency
- Test & Balance Engineer (TBE)
- Certified Technician

- Certified member agency
- NBC TAB Supervisor
- NBC TAB Technician

- Certified member agency
- ICB TABB Supervisor
- ICB TABB Technician

TAB Personnel

Specialist Qualifications

Certified Professional (TAB CP)

- Experience
  - 2 years TAB experience with BS Engineering OR
  - 4 years TAB experience with Associate's Degree OR
  - 6 - 8 years TAB experience with training courses
- Certified examination (air, water, engineering fundamentals)

Certified Technician

- Experience
  - 4 years of documented TAB fieldwork
  - 2 years of TAB fieldwork with NEBB Technician Course
- Certified examination (air & water)

TAB Personnel

Specialist Qualifications

Test & Balance Engineer (TBE)

- Experience
  - 8 years TAB experience OR
  - 4 years TAB experience with BS Engineering
- Certified examination (air, water, sound, vibration, engineering fundamentals)

Certified Technician

- 3 years of TAB experience
- Certified examination (air, water, sound, vibration)

TAB Personnel

Specialist Qualifications

TESTING, ADJUSTING AND BALANCING BUREAU
THE PROFESSIONAL'S CHOICE℠

ICC TABB Supervisor

- 5 years of TAB experience
- Certified examination (air, water)

Certified Technician

- 5 years of TAB experience
- Certified examination (air, water)

TAB must be hired directly by sheet metal contractor

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TAB Personnel

Specialist Qualifications

NBC TAB Supervisor

- 5 years of TAB experience
- Certified examination (air, water, engineering fundamentals

NBC TAB Technician

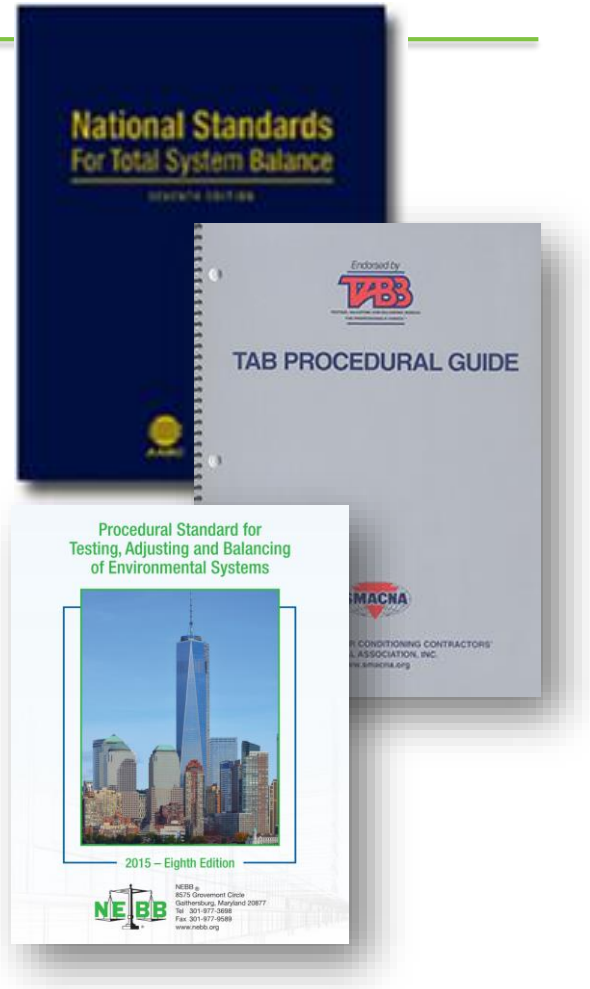
- 3 years of TAB experience
- Certified examination (air, water, engineering fundamentals)

TAB PROCEDURAL STANDARDS

SECTION 3

Procedural Standards

- Different procedural standard guide from each TAB organization
- Purposes are to establish:
  - Uniform and systematic process
  - Acceptable tolerances for results
  - Instrumentation range and accuracy
  - Consistent documentation
  - Repeatability



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TAB Methods

Capture Hood

- Measures and averages air velocity across sensing grid
- Know the limitations:
  - May require correction factors
  - Hood must cover opening area
  - Not for use on small outlets
  - Not for use on high velocity type outlets

TAB Methods

Velocity Grid / Anemometer

- Measures air velocity across sensing grid over equally spaced pattern
- Determine average air velocity

  CFM = Average air velocity (FPM) x Area (SF)

- Know the limitations:
  - For comparison purposes
  - Require correction factors to measure volume
  - Keeping grid in same plane for comparing velocities
  - Outlet must be bigger than device

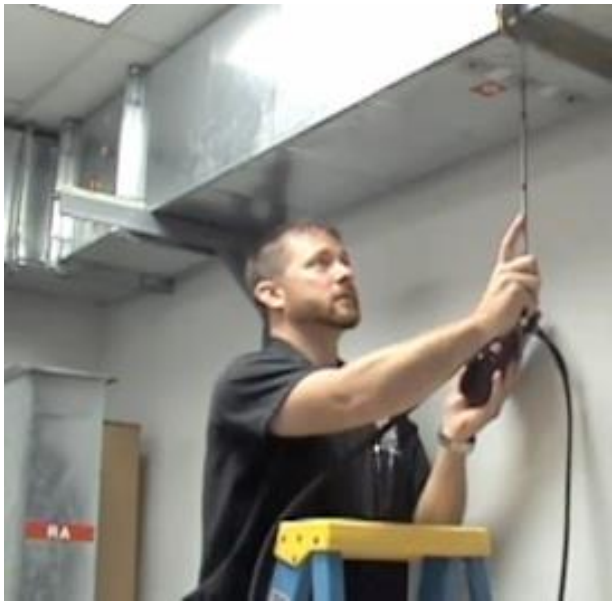
TAB Methods

Pitot Tube & Manometer

- Measures and averages velocity pressure across duct over equally spaced pattern (converted to velocity in FPM)
- Determine average air velocity

  CFM = Average air velocity (FPM) x Area (SF)

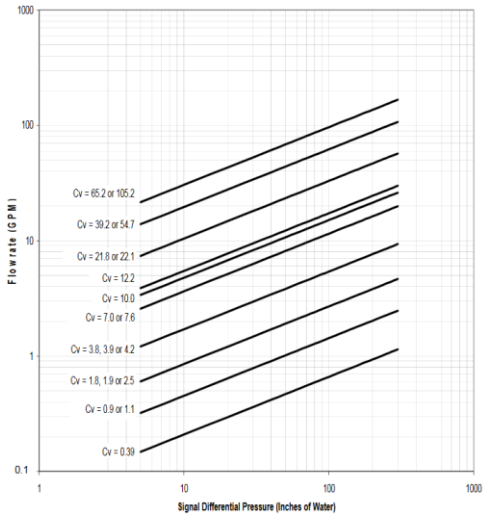
- Know the limitations:
  - Requires specific duct conditions
  - Requires several measurements in a specific pattern
  - Require correction factors to measure volume
  - Keeping grid in same plane for comparing velocities



TAB Methods

Differential Pressure Gauge / Manometer

- Measures differential pressure and compared to calibrated chart
- Know the limitations:
  - Calibrated devices may require certain pipe conditions
  - May require correction factors
  - Air must be removed from the system



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TAB Methods

Non-Intrusive Meters

- Measures acoustical signals to determine flow
- Know the limitations:
  - Recommended only when ports are not installed for measurements
  - Must be attached to clean pipe with no insulation
  - Must know specific piping information
  - Calibrated devices may require certain pipe conditions
  - Transit Time Flow: No air in system
  - Doppler Flow: Must have particulate or gas bubbles

TAB Methods

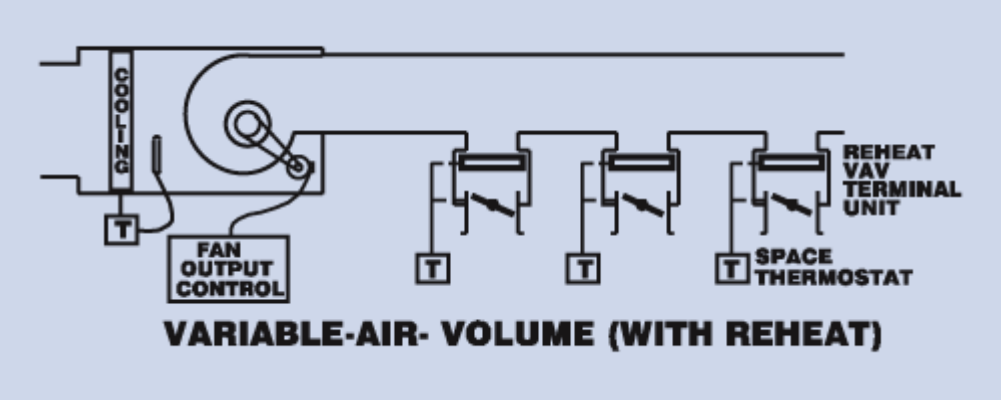
Understanding the System

- Constant volume VS variable volume
- Diversity
- Pressure Dependent VS Pressure Independent

TAB Methods

Constant Volume VS Variable Volume

- Constant Volume: System equipment maintains a consistent flow rate at all times. (Flow may still vary with pressure).
- Variable Volume: System equipment varies flow rate based upon system demand.

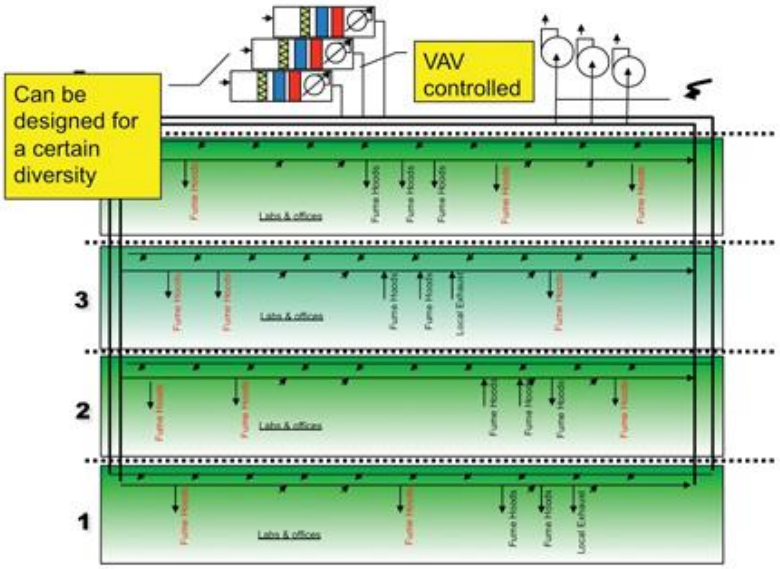


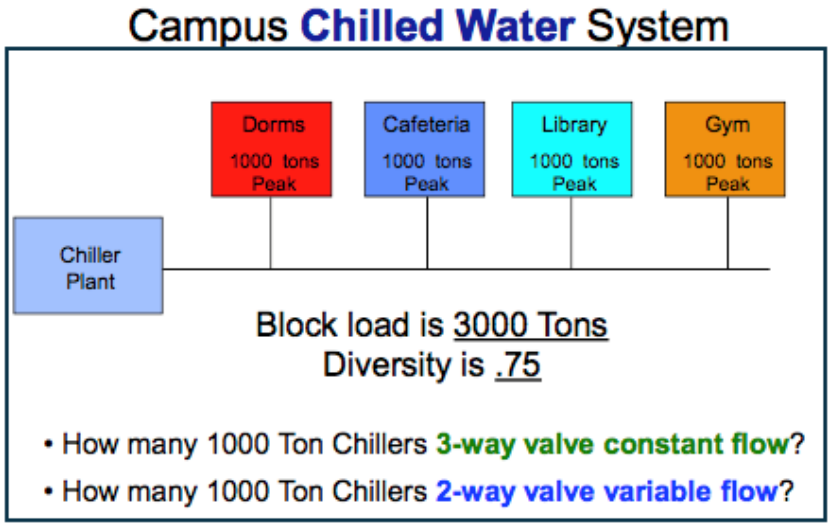
VARIABLE-AIR- VOLUME (WITH REHEAT)

TAB Methods

Diversity

- Diversity: The total flow for all zones exceeds the maximum flow capacity of the equipment.

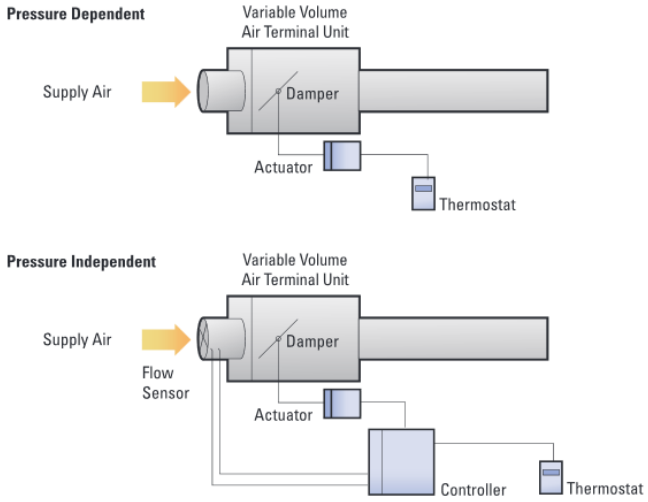


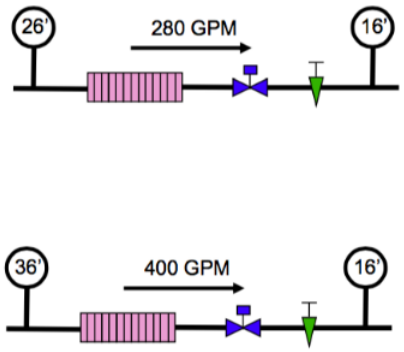


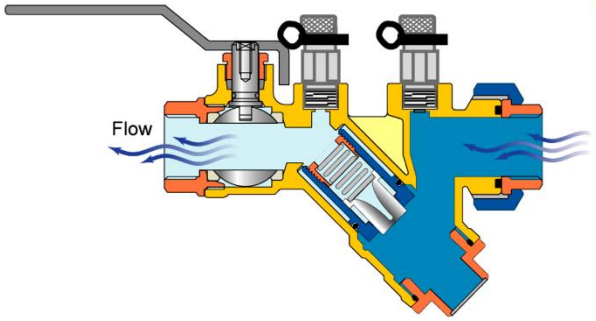
TAB Methods

Pressure Dependent VS Pressure Independent

- Pressure Dependent: Flow rate varies as the system inlet pressure varies. (Dependent only on the inlet pressure and size of opening).
- Pressure Independent: Flow rate is maintained constant regardless of system inlet pressure. (Equipped with flow measuring device so flow rate is independent of inlet pressure and size of opening).







Instrument & Calibration

- Required instruments for each function and range
- Calibrated by testing laboratory (National Institute of Standards and Technology… NIST)
- Instrumentation must be owned by certified TAB firm

Table 4.1 Instrumentation List – IP Units

FUNCTIONS/INSTRUMENT TYPE	MINIMUM RANGE	ACCURACY	RESOLUTION	CALIBRATION INTERVAL
Rotation Measurement	0-5000 RPM	± 2% of reading ± 2 RPM	1 RPM	12 Months Date:
Temperature Measurement Air	-40 to 240°F	± 0.5% of reading + 1.4°F	0.2°F	12 Months Date:
Temperature Measurement Immersion	-40 to 240°F	± 0.5% of reading + 1.4°F	0.2°F	12 Months Date:
Temperature Measurement Contact	-40 to 240°F	± 0.5% of reading + 1.4°F	0.2°F	12 Months Date:
Electrical Measurement - CAT III				12 Months
True RMS				Date:
Volts AC	0 to 600 VAC	± 2% of reading ± 5 digits	1.0 Volt	
Amperes	0 to 100 Amps	± 2% of reading ± 5 digits	0.1 Ampere	
Air Pressure Measurement	0 to 10.00 in w.g.	± 2% of reading	0.001 in w.g ≤ 1 in w.g.	12 Months
		± 0.001 in w.g.	0.01 in w.g. > 1 in w.g.	Date:
Air Velocity Measurement Hot Wire Anemometer OR Airfoil with Digital Meter	50 to 3900 fpm	±5% of reading, not less than ±7 fpm	1.0 fpm	12 Months Date:
Air Velocity Measurement Rotating Vane	50 to 2500 fpm	± 2% of reading ± 4 fpm	1.0 fpm	12 Months Date:
Humidity Measurement	10 to 90% RH	± 3% RH	1.0%	12 Months Date:
Direct Reading Hood	100 to 2000 cfm	± 5% of reading ± 7 cfm	Digital: 1 cfm Analog: N/A	12 Months Date:
Hydronic Pressure Measurement	-30 in h.g. to 60 PSI	± 2% of reading ± 1 PSI	0.5 PSI	12 Months
	0 to 100 PSI	± 2% of reading ± 1 PSI	1.0 PSI	Date:
	0 to 200 PSI	± 2% of reading ± 1 PSI	2.5 PSI	
Hydronic Differential Pressure Measurement	0 to 100 in w.g. 0 to 200 ft. w.g.	± 2% of reading ± 2 in. w.g. ± 2% of reading ± 0.2 ft. w.g.	1.0 in. w.g. 1.0 ft. w.g.	12 Months Date:

Report Requirements

General

- Complete record of TAB process
  - Documents TAB firm
  - Signed & sealed by certified TAB professional
  - Instrumentation list
- Documents HVAC system performance
  - Actual operating conditions
  - Items outstanding
  - Deviations
- Minimum report data for each system

Section 5. Standards for Reports and Forms 13

Section 5.
STANDARDS FOR REPORTS AND FORMS

5.1 REPORTS

The NEBB *Procedural Standard for Testing, Adjusting, and Balancing of Environmental Systems* establishes minimum requirements of a NEBB Certified TAB Report.

NEBB does not require the use of NEBB produced forms. Customized forms are acceptable based on the data acquisition requirements of this section. Contract document data reporting requirements shall take precedence when they exceed minimum requirements of NEBB.

5.2 REPORT FORMS

Listed below are the requirements for each NEBB Certified TAB Report.

"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 Standard for Testing, Adjusting and Balancing of Environmental Systems*. The measurements shown, and the information given, in this report are certified to be accurate and complete, at the time and date information was gathered. Any variances from design quantities, which exceed NEBB tolerances, are noted in the TAB report project summary."

1 This data may be included on the report title page or on a separate certification page.

5.2.3 TABLE OF CONTENTS

The table of contents, with page numbers, serves as a guide to the organization of the TAB report.

5.2.4 REPORT SUMMARY/REMARKS

A NEBB Certified TAB Report includes a required narrative description of system set-up conditions established prior to testing adjusting and balancing. The narrative must explain the rationale for how the system was configured for testing, such as to establish a full load condition, and the steps taken to achieve the desired set-up.

This section shall also include a listing of deficiencies in the summary and identifies the appropriate pages in the report. Part of the CP's responsibilities is to determine "noteworthy" deficiencies. This section might also be used to discuss possible recommendations such as solutions to system balance issues.

A summary of all *Procedural Standard* items that exceed NEBB and/or Contract Document tolerances or any other items that require discussion or explanation shall be included.

A list of all items which could not be obtained for reasons beyond the control of the CF shall be included.

5.2.5 ALL REPORT PAGES

All tested items included in the NEBB TAB Report shall be clearly identified with a unique designa-

5.3 REQUIRED REPORT DATA

Modern HVAC equipment is varied and complex. The following test report requirements are listed by component to insure that any type or arrangement of equipment can be accurately and completely tested and reported. The CF shall determine what components a unit includes and insure that final reports include each component's required data.

5.3.1 UNIT & NAMEPLATE DATA
(required for all stand-alone equipment - not required for individual components)

a) Unit Designation	Design
b) Manufacturer	Installed
c) Model Number	Installed
d) Serial Number	Installed
e) Type	Installed
f) Service	Design
g) Area Served	Design
h) Location.	Design
i) Unit Cross Sectional Sketch or Static Pressure Profile	Actual

5.3.2 FAN, MOTOR & DRIVE – ACCESSIBLE
(where fan and motor are accessible)

FAN:

a) Airflow	Design & Actual
b) TSP	Design & Actual
c) ESP	Design & Actual
d) Static Pressure Profile	Actual
e) RPM	Design & Actual
f) Rotation	Design & Actual

MOTOR:

a) Manufacturer	Installed
b) Horsepower	Installed
c) Frame	Installed
d) Full Load Amps	Installed
e) Service Factor	Installed
f) Volts	Nameplate & Actual
g) Corrected Nameplate Amps	Actual
h) Operating Amps	Actual
i) Brake Horsepower	Actual

BELT DRIVE:

a) Motor Sheave Manufacturer/PD/bore	Installed
b) Fan Sheave Manufacturer/PD/bore	Installed
c) C to C Distance	Installed
d) Belt Manufacturer/quantity/size	Installed

5.3.3 FAN, MOTOR & DRIVE – EMBEDDED
(where fan and motor are not accessible i.e. FPVAV, VRF, PTAC, etc.)

a) Airflow[1]	Design & Actual
b) Nameplate Volts	Actual[2]
c) Nameplate Amps	Actual[2]
d) Operating Volts	Actual[2]
e) Operating Amps	Actual[2]

1 Required for each FPVAV mode of operation; not required for embedded fans unless specified
2 Required if nameplate is accessible

5.3.4 FILTERS

a) Quantity	Installed
b) Size	Installed
c) Type	Design & Installed

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Report Requirements

Unit Data

- Unit and nameplate data required for all stand-alone equipment (make, model, serial #, etc)
- Fan, motor, and drive data
- Filter data (qty, size, type)

Unit Data	
Equipment Location	Basement
Area Served	Plant
Equipment Manufacturer	GREENHECK
Model	5WB-120-10-CW-UB-X
Serial Number	14/3750 15K

Sheave Data	
Motor Sheave Diameter	VP34 in.
Motor Sheave Bore	5/8 in.
Fan Sheave Diameter	AK74 in.
Fan Sheave Bore	1 in.
#Belts	1
Belt Size	AP60
Sheave Center Line	16 in.

Motor Data	
Motor Manufacturer	Marathon
Specified Motor HP	1 HP
Motor HP	1
Motor BHP	0.93 BHP
Phase	1
Voltage	208 Volts
Full Load Amps	6.70 Amps
Motor RPM	1725 RPM
Motor Service Factor	1.15
Starter Heater Elements	Thermally Protected
Corrected FL Amps	6.90 Amps
Motor Hertz	60 Hz
Motor Frame	56
Average Voltage	203 Volts
Average Amps	5.5 Amps

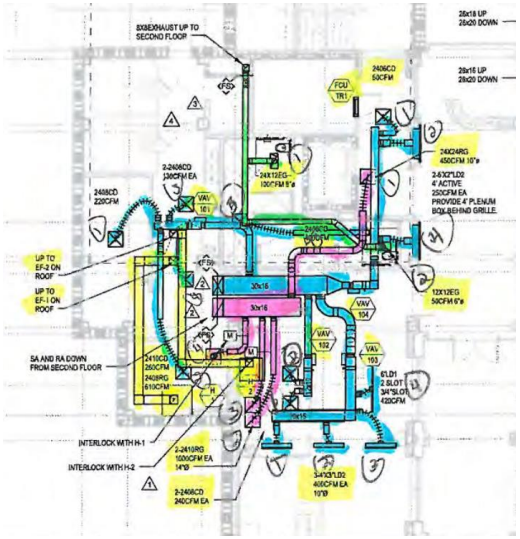
Report Requirements

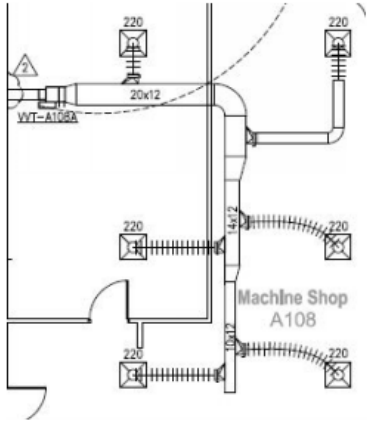
Schematic Layout Drawings

- Provide system sketch / diagram
- Identifies each specific outlet

AHU-A1N/WT-A108A Supply Outlet Summary

System/Unit	Location	Terminal Type	Terminal Size	Test 1	Design CFM	Final CFM	% Final Diff.
Outlet-01	MACHINE SHOP A108	Lay-In Ceiling	24x24x10	128	220	212	96
Outlet-02	MACHINE SHOP A108	Lay-In Ceiling	24x24x10	167	220	220	100
Outlet-03	MACHINE SHOP A108	Lay-In Ceiling	24x24x10	138	220	208	95
Outlet-04	MACHINE SHOP A108	Lay-In Ceiling	24x24x10	128	220	202	92
Outlet-05	MACHINE SHOP A108	Lay-In Ceiling	24x24x10	143	220	230	105
Outlet-06	MACHINE SHOP A108	Lay-In Ceiling	24x24x10	136	220	212	96
Totals:	-	-	-	-	**1320**	**1284**	**97**





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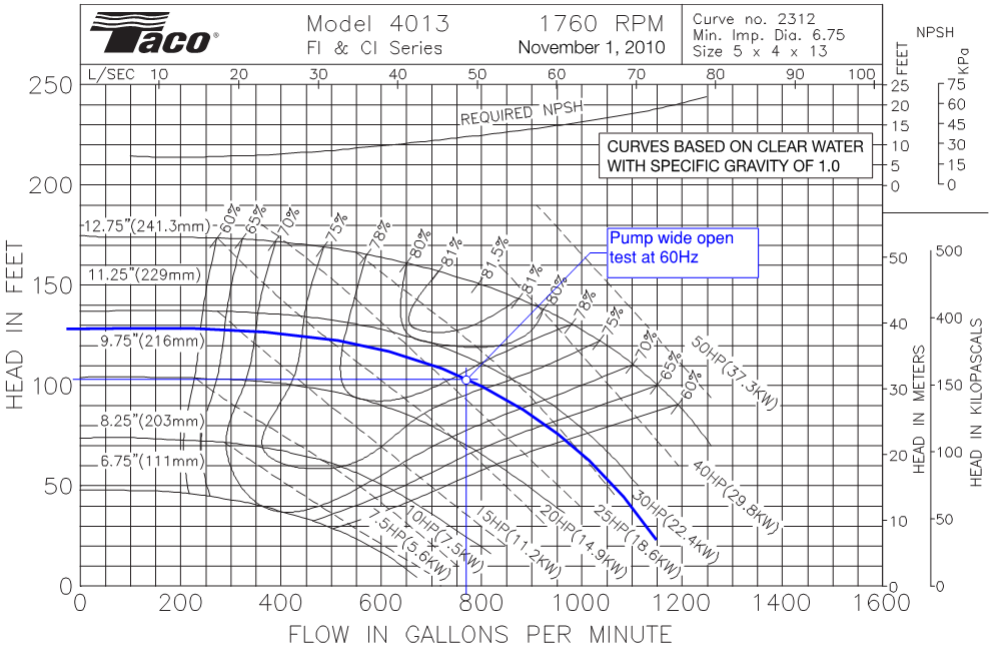
Report Requirements

Performance Curves

- Include for:
  - Fans
  - Pumps
  - Calibrated balancing devices
  - Etc
- Mark specific operating conditions



Report Requirements

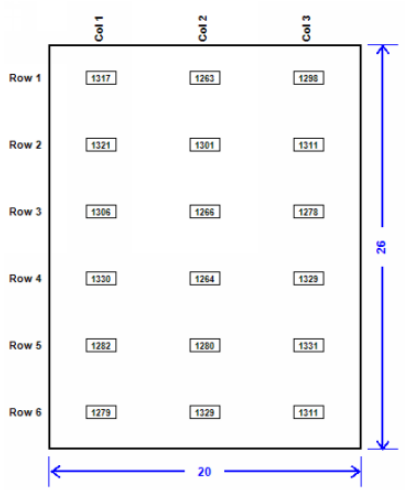
Traverse Charts

- Provide duct traverse diagrams and calculations
- Documents how traverses were taken and how airflow was determined

Unit Data	
Type of Traverse	Rectangular
Outer Height	26.00 in.
Outer Width	20.00 in.
Air Flow Area	3.61 sq. ft.
Number Of Rows	6
Readings Per Row	3
Total Readings	18

Final Data	
Sum of Readings	1800
Average Reading	1300 FPM
Design Total Flow	4700 CFM
Actual Total Flow	4693 CFM
Duct Static Press.	-0.14 in. wc

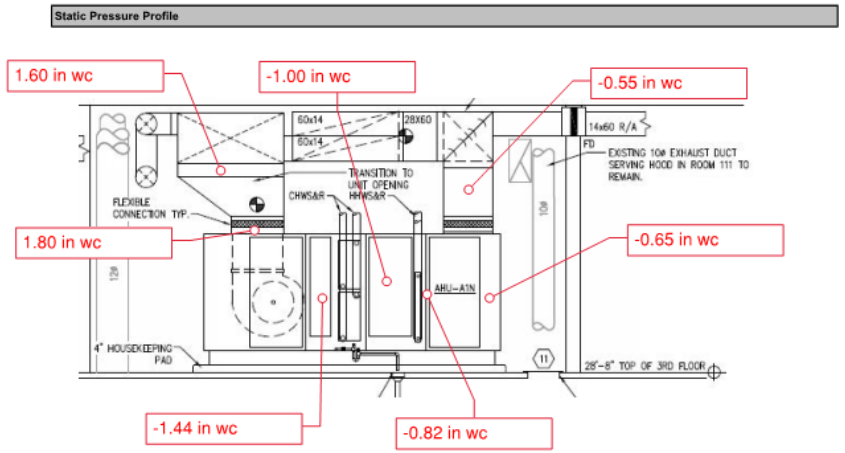
Traverse Data Points



Report Requirements

Static Pressure Profiles

- Documents performance of AHU
- Confirms actual performance with design
  - Pressure drop across components
  - External static pressure
  - Total static pressure



Test Pressures	
Specified Total SP	4.60 in. wc
Spec.Ext. SP	2.25 in. wc
Act. Ext. SP	2.15
Actual Inlet Pres.	-0.55 in. wc
Pre-Filter SP In	-0.65 in. wc
Cooling Coil SP In	-1.00 in. wc
Cooling Coil SP Out	-1.44 in. wc
Fan Section Pressure	1.80 in. wc
Actual Discharge Pressure	1.60 in. wc

Report Requirements

Capacity Tests

- Documents performance of equipment
- Confirms actual performance with design
- Seasonal tests

AHU-A4.1/Cooling Coil		AHU-A4.1/Cooling Coil	
Design Total MBH	1,631 MBH	Actual Total MBH	1728.0 MBH
Design Sensible MBH	1,231 MBH	Actual Sensible MBH	1168.0 MBH
Ent Air DB Temp Design	77.1 Deg F	Ent. Air DB Temp Actual	72.6 Deg F
Ent Air WB Temp Design	65.4 Deg F	Ent Air WB Temp Actual	62.1 Deg F
Leav Air DB Temp Design	55.0 Deg F	Leav Air DB Temp Actual	50.4 Deg F
Leav Air WB Temp Design	54.8 Deg F	Leav Air WB Temp Actual	49.3 Deg F
Design GPM	220 Gpm	Actual GPM	210 Gpm
Design CFM	51,000 CFM	Actual Coil PD	1.12 FTHD
Ent Water Temp Design	45 Deg F	Actual CFM	48500 CFM
Leav Water Temp Design	60 Deg F	Ent. Water Temp Actual	44 Deg F
		Leav. Water Temp Actual	60 Deg F

Documentation / Notation Requirements

- Repeatability is key
- Provide notes for:
  - Issues
  - Exceptions
  - Methods
  - Etc.

Diversity Tests

AHU-1

SAT 1.1	MAX	1415 CFM	SAT 1.10	MAX	1650 CFM
SAT 1.2	MIN	745 CFM	SAT 1.11	MAX	1740 CFM
SAT 1.3	MAX	1420 CFM	SAT 1.12	MIN	870 CFM
SAT 1.4	MIN	890 CFM	SAT 1.13	MIN	850 CFM
SAT 1.5	MIN	920 CFM	SAT 1.14	MAX	1625 CFM
SAT 1.6	MIN	880 CFM	SAT 1.15	MAX	2220 CFM
SAT 1.7	MIN	900 CFM	SAT 1.16	MAX	3020 CFM
SAT 1.8	MAX	1650 CFM	SAT 1.17	MAX	200 CFM
SAT 1.9	MAX	1715 CFM			

UNIT TOTAL: 22710 CFM

THIS REPORT IS TRUE AND CORRECT IN THAT IT REFLECTS THE ACTUAL CONDITIONS AS OF THIS DATE. THE SYSTEMS HAVE BEEN BALANCED AND ADJUSTED AS CLOSE TO THE DESIGN REQUIREMENTS AS THE FIELD CONDITIONS WILL PERMIT. SPECIFIC ITEMS NOTED DURING TESTING ARE CONTAINED ON THE FOLLOWING PAGES OF THE REPORT.
ADDITIONAL NOTES ARE AS FOLLOWS:

1) AHU-9: We attempted to raise the chilled water setpoint to increase the chilled water flow and test the capacity on 7/14/2015. The chilled water valve is approximately 50% open and will not move. We reported this on 7/14/2015.
2) AHU-P2: On 6/2/2015 we reported that the airflow setpoint and damper position were not being shown for this unit. On 7/21/2015, this had not been corrected.

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Documentation / Notation

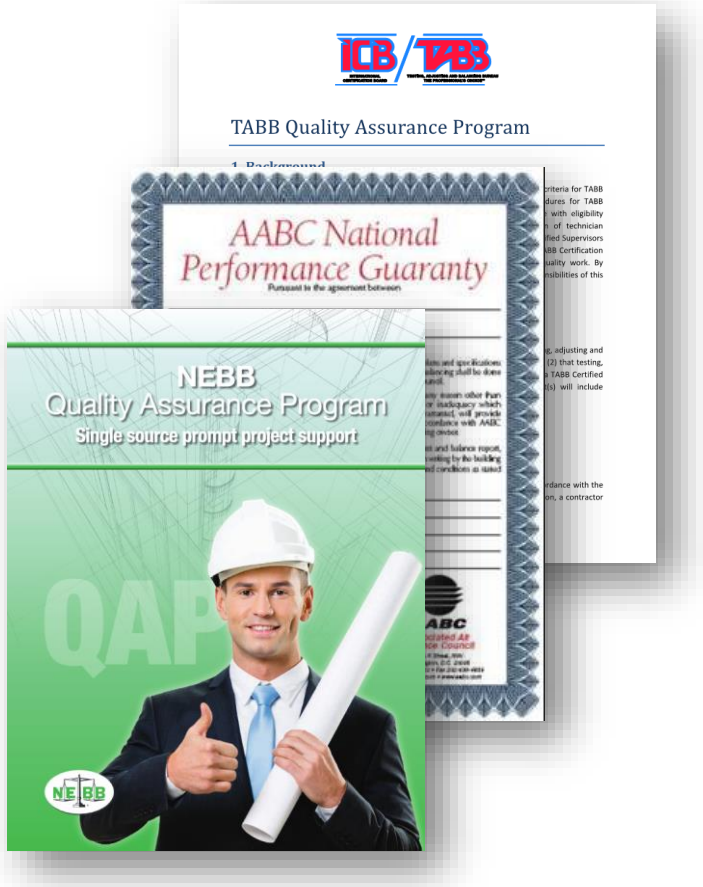
Example of Repeatability

		MAXIMUM							MINIMUM		
			1.1" STATIC ①		.9" STATIC ②		.75" STATIC ③			.25" STATIC ④	
VAV #	CONTROL NAME	DESIGN CFM	ACTUAL CFM	DAMPER POSITION	ACTUAL CFM	DAMPER POSITION	ACTUAL CFM	DAMPER POSITION	DESIGN CFM	ACTUAL CFM	DAMPER POSITION
VAV-201	AME_RM200H	300	302	58%	302	62%	302	65%	150	156	62%
VAV-202	AME_RM203	1200	1224	65%	1224	70%	1224	76%	600	608	69%
VAV-203	AME_RM230	300	302	59%	302	62%	302	65%	150	148	61%
VAV-204	AME_RM228	700	700	74%	700	81%	700	93%	350	343	81%
VAV-205	AME_RM225	600	599	67%	599	72%	599	79%	300	288	71%
VAV-206	AME_RM221	600	591	64%	591	72%	591	82%	300	307	74%
VAV-207	AME_RM218	800	810	61%	810	68%	810	80%	400	405	68%
VAV-208	AME_RM211	800	789	63%	789	67%	789	72%	400	410	66%
VAV-209	AME_RM223	400	406	75%	406	83%	**380**	**100%**	200	202	87%
VAV-210	AME_RM216	600	604	64%	604	72%	604	86%	300	310	74%
VAV-211	AME_RM212	800	797	66%	797	74%	797	88%	400	415	73%
VAV-212	AME_RM200E	300	291	62%	291	64%	291	68%	150	155	65%
VAV-213	AME_RM210	300	302	62%	302	66%	302	69%	150	151	66%
VAV-214	AME_RM208	750	743	58%	743	65%	743	72%	380	370	64%
VAV-215	AME_RM205	600	597	73%	597	82%	**576**	**100%**	300	299	85%
VAV-220	AME_RM105SE	720	723	67%	723	78%	**872**	**100%**	360	371	74%
VAV-221	AME_RM105E	720	726	57%	726	62%	726	68%	360	386	60%
VAV-222	AME_RM105W	720	716	37%	716	39%	716	41%	360	358	39%
VAV-223	AME_RM106A	200	199	55%	199	56%	199	60%	150	152	55%
VAV-224	AME_RM105NW	720	727	57%	727	61%	727	67%	360	360	59%
VAV-225	AME_RM105NE	720	715	60%	715	65%	715	72%	360	365	63%
VAV-226	AME_RM104D	300	303	59%	303	64%	303	68%	150	154	62%
VAV-227	AME_RM104G	500	497	63%	497	66%	497	71%	250	255	64%
VAV-228	AME_RM104C	400	390	71%	390	74%	390	80%	200	195	73%
VAV-229	AME_RM104B	400	394	68%	394	70%	394	74%	200	195	58%
VAV-230	AME_RM104	730	735	86%	735	76%	735	92%	370	365	74%
VAV-231	AME_RM104A	400	400	100%	**352**	**100%**	**320**	**100%**	200	**180**	**100%**
VAV-232	AME_RM103	1500	1492	67%	1492	75%	1492	88%	750	755	75%
VAV-233	AME_RM100BN	800	806	60%	806	64%	806	70%	400	404	64%
VAV-234	AME_RM100BS	400	400	68%	400	72%	400	61%	200	213	70%
VAV-235	AME_RM106E	1500	1496	61%	1496	66%	1496	71%	750	770	64%
VAV-236	AME_RM106W	1500	1508	60%	1508	67%	1508	74%	750	766	64%
VAV-237	AME_RM102	225	225	52%	225	54%	225	58%	110	114	52%
VAV-238	AME_RM106B	200	202	50%	202	52%	202	54%	100	103	51%
VAV-239	AME_RM100D	700	708	60%	708	66%	708	74%	350	363	64%
VAV-240	AME_RM107	1800	1786	71%	1786	79%	1786	91%	900	874	78%
VAV-241	AME_RM108	1100	1130	62%	1130	68%	1130	78%	550	569	67%
VAV-242	AME_RM111	300	303	62%	303	65%	303	69%	150	159	63%
VAV-243	AME_RM110	225	225	53%	225	58%	225	62%	110	117	54%
VAV-244	AME_RM109ANE	2000	1971	57%	1971	62%	1971	70%	1000	947	60%
VAV-245	AME_RM109ASE	2000	2042	64%	2042	70%	2042	81%	1000	1122	73%
VAV-246	AME_RM109B	1300	1336	76%	1336	87%	1336	100%	650	642	85%
VAV-247	AME_RM105N	720	730	55%	730	59%	730	66%	360	376	56%

① 1.24" static at 2nd floor sensor and 1.11" at 1st floor sensor.
② 1.08" static at 2nd floor sensor and .91" at 1st floor sensor.
③ .9" static at 2nd floor sensor and .76" at 1st floor sensor.
④ .28" static at 2nd floor sensor and .25" at 1st floor sensor.

Quality Assurance

- Applies to any TAB work by member
- Invoked by Owner, Architect, or Engineer
- Complaint filed with national headquarters
- Review board investigates and resolves, if necessary
- Board may provide additional supervision and personnel at no cost to building owner to complete the project
- Warranty period depends on organization (90 days – 1 year)



ROLES & RESPONSIBILITIES

SECTION 4

Roles & Responsibilities

Design Engineer

- Include all requirements for TAB in bid documents … BE SPECIFIC
- Review and approve TAB contractor qualifications
- Review and approve TAB scope of work
- Coordinate any modifications with TAB contractor
- Review TAB report
  - Reject if incomplete or incorrect
  - Approve if complete and correct

Roles & Responsibilities

Construction Manager / General Contractor

- Coordinate TAB process with all sub-contractors
- Ensure TAB qualifications and scope is submitted for review by Design Engineer
- Coordinate schedule for TAB work with TAB contractor
- Ensure issues with completing TAB work are communicated regularly
- Coordinate schedule for TAB verification with Commissioning Authority
- Ensure seasonal tests are scheduled and performed

Roles & Responsibilities

Sub-Contractors (Mechanical, Electrical, BAS)

- Coordinate schedule for TAB work with Construction Manager
- Coordinate with TAB contractor for schedule and work
- Correct deficiencies identified by TAB contractor

Roles & Responsibilities

TAB Contractor

- Ensure qualified and trained personnel are performing TAB work
- Submit qualifications, report format, and procedures for review and approval
- Review plans for potential issues… notify Design Engineer ASAP
- Communicate and document field issues with Contractors
- Perform work in accordance with Procedural Standards and Specifications
- Coordinate scheduling needs with Construction Manager
- Provide signed/sealed final report
- Verify selected TAB results with Commissioning Authority

Roles & Responsibilities

Commissioning Authority

- Review bid documents to ensure all requirements for TAB are included and specific
- Review TAB contractor qualifications
- Review TAB scope of work
- Coordinate any modifications with TAB contractor
- Review TAB report and provide recommendation for approval/rejection
- Verify TAB results (using sampling rate)
    - Be sure to include each major system

Roles & Responsibilities

Authority Having Jurisdiction

- Ensure TAB is completed and approved prior to:
  - Passing final mechanical inspection
  - Issuing Certificate of Occupancy

Roles & Responsibilities

Owner

- Determine and communicate contracting method for TAB with Design Engineer
- Communicate expectations for TAB with Design Engineer
- Communicate expectations for TAB verification with Commissioning Authority
- Ensure TAB is completed and approved prior to granting Substantial Completion

KEY CHALLENGES

SECTION 5

Key Challenges

Schedule

- Most CMs do not understand TAB
- Schedule is often set without input from lower tier subs
- Required pre-tasks are not always on time
- TAB is one of the last tasks

Act ID	Description	Orig Dur	Early Start	Early Finish
7467	Start-up	1	15JUL15	15JUL15
7470	Test & Balance w/ report	2	16JUL15	17JUL15
7471	PFP testing w/ Cert of	2	18JUL15	20JUL15
7472	Cx systems	2	21JUL15	22JUL15
7475	Duct cleaning	5	23JUL15 *	28JUL15
9000	Cx & Close-out	40	27JUN15	13AUG15
9003	Substantial Completion	1	01AUG15	01AUG15

Act ID	Description	Orig Dur	Early Start	Early Finish
1710	Test and Balance	13d	14JUL14	30JUL14
1190	Project Substantial Completion	0		30JUL14

Key Challenges

Existing Systems

- Existing systems rarely operate per original design
- Old TAB reports are not always correct or complete
- Connecting to existing systems may yield to issues at end of project
- Preliminary testing/verification can prevent issues at the end of the project

SYSTEM AHU-14

AREA SERVED	OPENING NO.	OPENING SIZE	K FACTOR	REQUIRED VEL	REQUIRED CFM	PRELIMINARY VEL	PRELIMINARY CFM
Supply							
Mail Room 112	1						170
Mail Room 112	2						154
Office 107	3						83
Office 113	4						197
Conference Room 114	5						93
Conference Room 114	6						154
Conference Room 114	7						194
Conference Room 114	8						173
Total Supply CFM							1218
Return							
Office 107	1						236
Office 113	2						495
Conference Room 114	3						384
Total Return CFM							1115

SYSTEM/UNIT: EF-22
AREA:

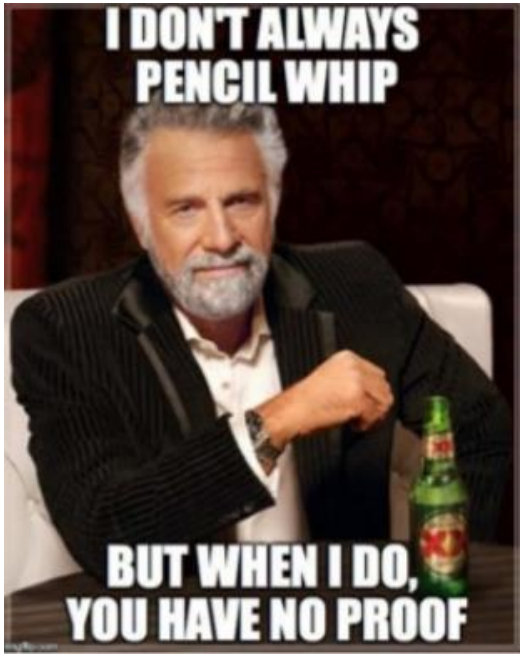
Unit Data	
Model	SWB-222-30

Test Data	
Specified Fan CFM	4000 CFM
Actual Fan CFM	3050 CFM
Inlet Press. (Inches)	0.88 in. wc
Discharge Press. (Inches)	0.95 in. wc
Actual Fan RPM	642 RPM

Key Challenges

Questionable Reports

- Perfect TAB results or no issues
- Schedule issues but achieved on time
- TAB of value engineered systems
- “Drive-by” TAB / Pencil-whipped reports



Pencil Whip: To complete a form, record, or document without having performed the implied work or without supporting data or evidence

Key Challenges

Communication

- TAB Contractor is responsible for identifying issues
- **Scenario 1: Communication for Benefit of Direct Client**
  - TAB contractor's "client" does not want to look bad
  - TAB communicates issues to mechanical contractor who does not report them
  - CM does not understand why TAB takes so long
  - Negatively affects project schedule and results
- **Scenario 2: Communication for Benefit of the Project**
  - TAB contractor's "client" does not want to look bad
  - TAB communicates issues to mechanical contractor and CM
  - CM helps reporting and resolving issues
  - Positively affects project schedule and results

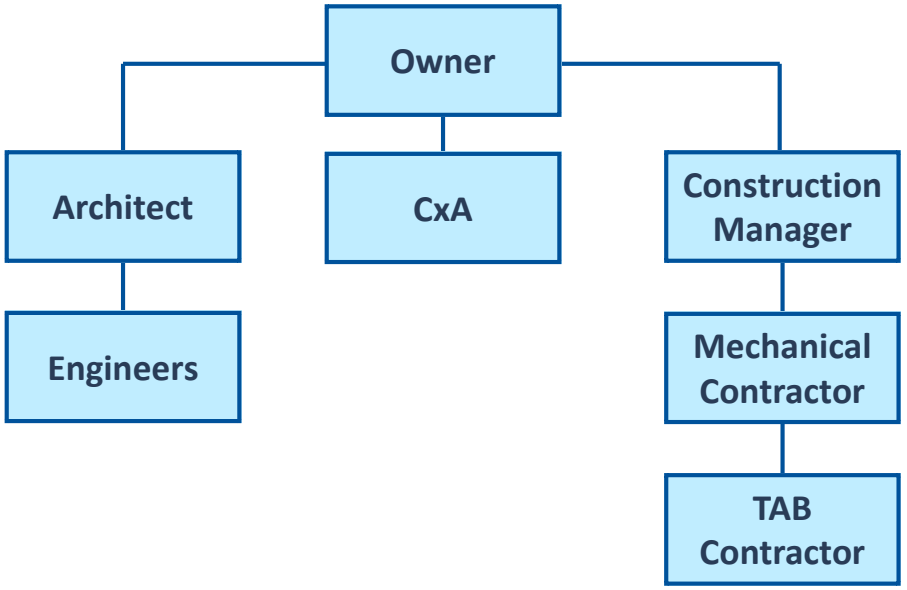
- 1-09: A repair had been attempted without mechanical contractors knowledge and piping became kinked and stopped with sodder.
- 2-08: No circuit setter or T/P ports to read pressure. Tried to determine water flow by temperature, however fan was not operating. Controls could not find this box within the controls system.
- 6-02: Could not get water flow through circuit setter no matter which way the control valve was turned. We believe the control valve may be installed backwards.
- 6-06: When hot water control valve was commanded open, valve did not respond.
- 6-07: When hot water control valve was commanded open, valve did not respond.
- 6-11: When hot water control valve was commanded open, valve did not respond.

Key Challenges

Contracting Methods

- Potential Conflicts of Interest
- Communication Issues
- No Direct Route to TAB

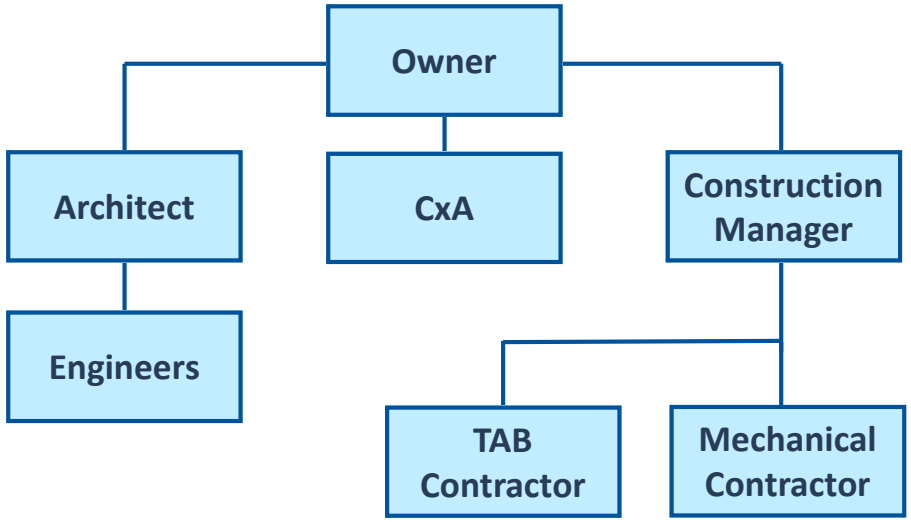
Typical: 2nd Tier Sub / Direct Sub to Mechanical



Key Challenges

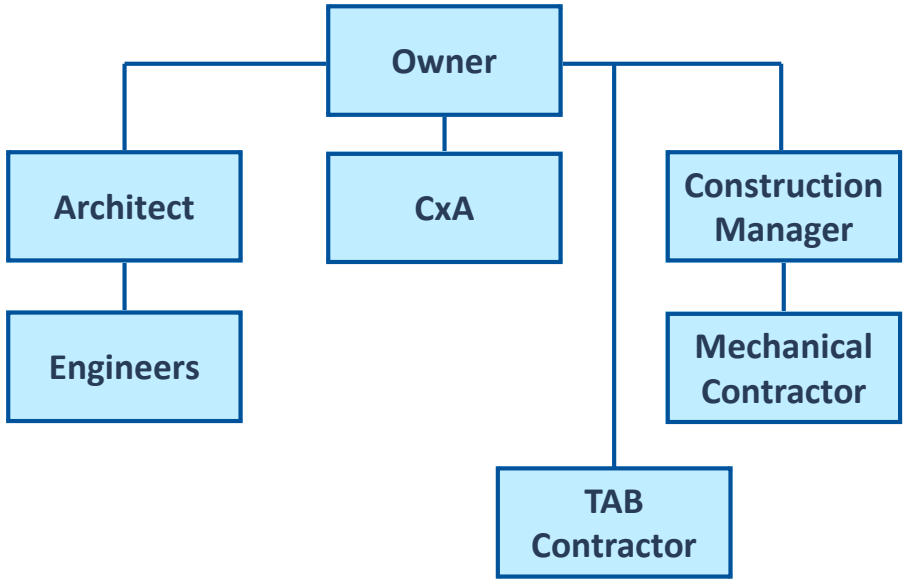
Contracting Methods

Option 1: Direct Sub to Construction Manager



- Keeps everything under one contract
- Communication improves

Option 2: Direct Sub to Owner



- Multiple contracts
- Communication improves
- Possible coordination issues

Key Challenges

Personnel Qualifications / Understanding

- Many TAB personnel:
  - Do NOT understand procedural standards
  - Do NOT understand how different systems work
  - Do NOT use the proper tools
  - Do NOT understand engineering fundamentals
  - Are NOT certified but are managing projects

General Notes

- AHU-5: Unit has no hot water or chilled water piping installed – DX unit

PROJECT SUMMARY

The scope of work for this project consists of balancing all supply air and return air devices for one existing package roof top unit (RTU). This RTU provides conditioned air via a DX cooling coil and electric heat. The unit is set to maintain a supply duct static pressure. There are five modulating zone dampers that are part of this system as well as constant volume supply diffusers.

Certified personnel must be on site at ALL times

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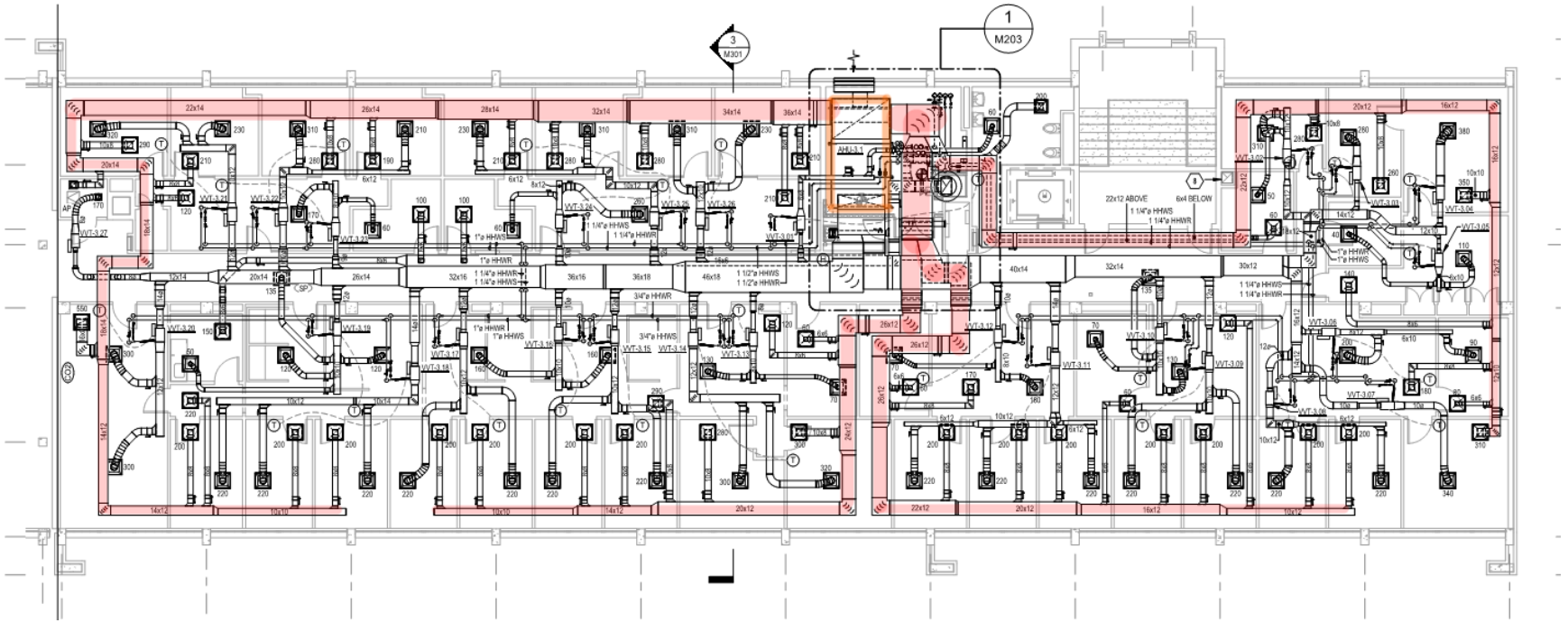
Key Challenges

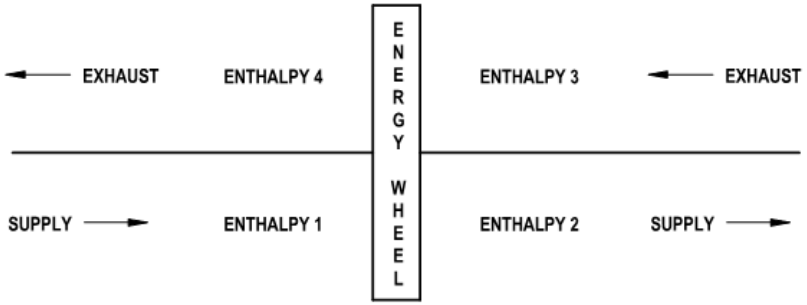
Phased TAB

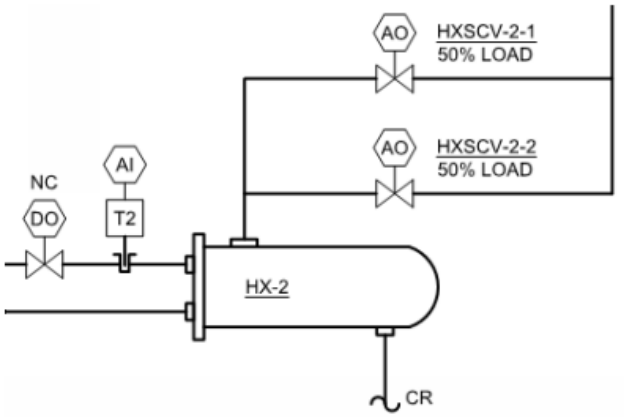


Key Challenges

Missing Systems

- Energy Recovery Wheel
  - Wheel RPM
  - Entering/Leaving Enthalpy
- Steam Heat Exchangers
  - Steam Pressure
  - Entering/Leaving Water Temp
- Domestic Hot Water
  - Pumps
  - Heat Exchangers
  - Entering/Leaving Water Temp





Key Challenges

CxA Verification

- Loosely defined scopes
  - Up to CxA discretion
  - Usually results in reading airflows at outlets
  - What about major equipment?

FPT Sampling Rates.

Component	Sampling Rate
HVAC Systems	
Air handling units	100 %
Exhaust fans	100 %
Supply air fans	100 %
Energy recovery units	100 %
VAV boxes	25 %
Fan coil units	50 %
Ductwork	25 %
Heat exchangers	100 %
Pumps	100 %
Meters	100 %
BAS graphics, reporting	100 %
Test & Balance verification	25 %
Chilled Beams	50 %

Key Challenges

CxA Verification

- Specific scopes
  - Coordinated with Owner / Engineer
  - Verify major equipment/systems
  - Verify samples of similar equipment
  - Include air-side and water-side

Review and inspect Testing, Adjusting, and Balancing work (conducted by others) on a sample basis as follows:

.1	Air Handling Units:	100%
.2	Fans:	100%
.3	Pumps:	100%
.4	VAV Terminals:	10%
.5	Diffusers / Registers / Grilles:	10%
.6	Chilled Beams:	25%
.7	Chillers:	100%
.8	Boilers:	100%
.9	Fume Hoods:	10%

Hydronic Systems

1) Chiller Evaporator, CHW Pumps, TES Tanks: Sample 100%
2) Boilers, HHW Pumps: Sample 100%
3) Process Cooling Water Pumps: Sample 100%
4) AHU-1 & 4 Coils: Sample 50% (1 AHU)
5) AHU-2, 3 & 5 Coils: Sample 33% (1 AHU)
6) VAV Terminal Unit Coils: Sample 5%

Air Side Systems

1) AHU-1 & 4: Sample 50% (1 AHU)
2) AHU-2, 3 & 5: Sample 33% (1 AHU)
3) Laboratory Exhaust Fans: Sample 33% (2 Fans)
4) VAV Terminal Units: Sample 5%
5) Fume Hoods: Sample 5%
6) Air Terminal Outlets: Sample 5%

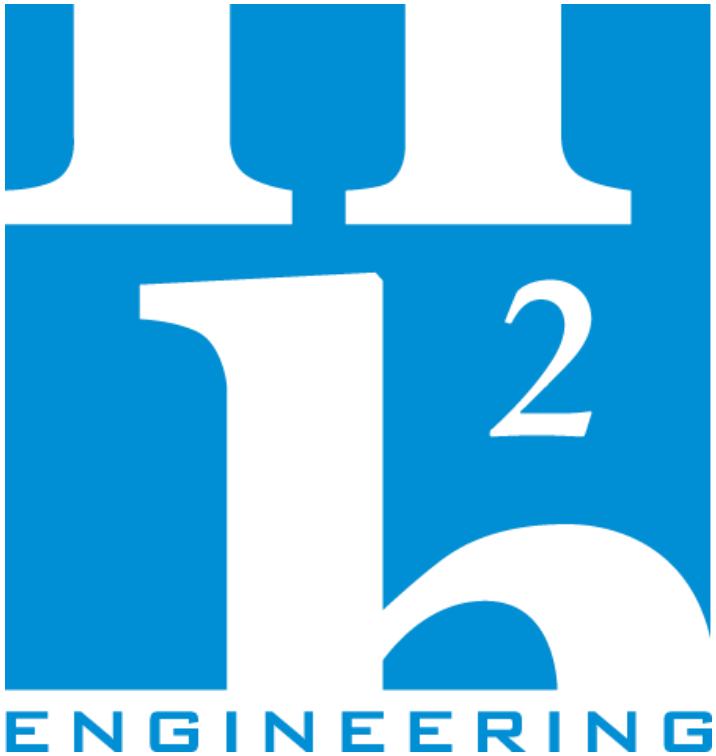
SUMMARY

SECTION 6

Summary

How to Achieve Successful TAB

- Make sure TAB scope is properly identified and documented
- Identify contracting method for TAB to best fit Owner's needs
- Acquire preliminary TAB data on existing equipment to be re-used.
- Make sure schedule is adequate for TAB work to be done correctly
- Make sure certified TAB personnel are performing work
- TAB reports
  - Complete with graphs, charts, notes, etc
  - Repeatable
  - Accurate data
- Make sure CxA verification scope is identified



Our Mission is to be

YOUR FIRST CHOICE

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