Performance & Capacity Testing of Components

David Harrell, TBE
Engineered Air Balance Co., Inc.
10:30 a.m. – 12:00 p.m.

Topics covered will include:

Recommended components to be performance tested. Why and how capacity testing is set up and performed. Data recording and reporting. Inspections of field installations and how variations impact final performance data.

AABC

CONTINUING EDUCATION AIA

AIA Credits

Credit(s) earned on completion of this course will be reported to AIA CES for AIA members. Certificates of Completion for both AIA members and non-AIA members are available upon request.

This course is registered with AIA CES for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of handling, using, distributing, or dealing in any material or product.

Questions related to specific materials, methods and services will be addressed at the conclusion of this presentation

Copyright Materials

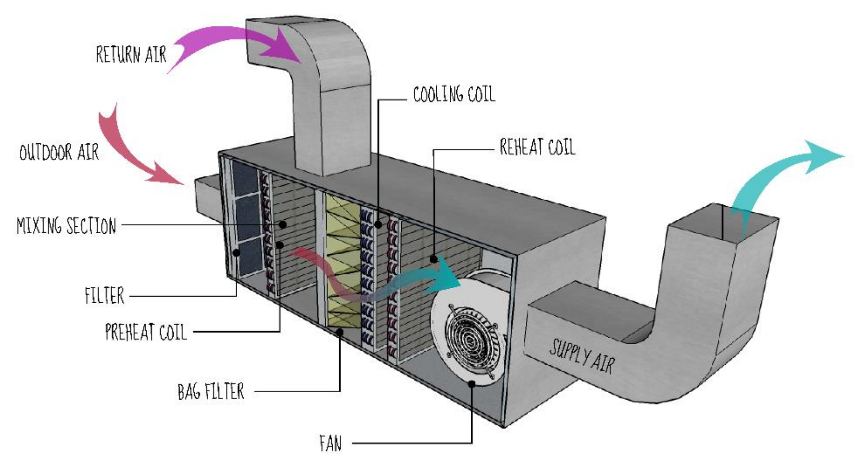
Course Description

- Equipment Performance Verification

- What testing is performed
- When is the performance and capacity testing performed
- Why is such testing performed
- How is it accurately accomplished

Learning Objectives

- To understand the recommended HVAC components that should be performance/capacity tested
- Be able to explain why and how capacity testing is set up and performed
- Understand what data should be recorded and reported for performance/capacity testing
- Identify the important aspects of inspecting field installations and how variations impact final performance data.

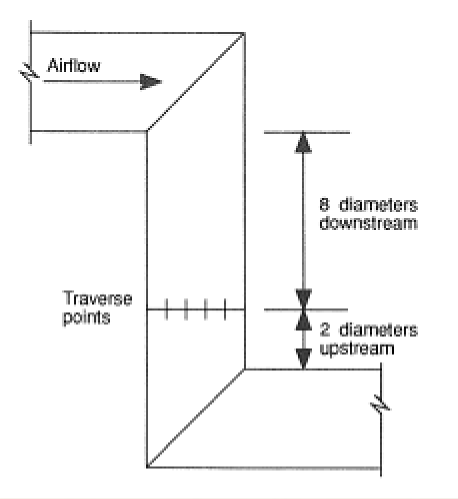


Capacity Testing – What is included? What equipment is tested?

- Airside capacity testing performed by Pitot tube traverse (preferred method)
  - Air Handling Units (Supply Air, Return Air, Outside Air)
    - AHU (of all sizes)
    - RTU
    - FCU
    - SAF
  - Exhaust air
    - General
    - Lab

Where are the tests performed?

- Where are the capacity tests performed?



Equation 2.4

$$d = \sqrt{\frac{4hw}{\pi}}$$

d = equivalent duct diameter
h = height of duct
w = width of duct
π = 3.1416

- The test locations should be determined by using the noted formula

Determine the Traverse Location

- Duct width – 36”
- Duct height – 18”
- $d = \sqrt{\frac{4\ x\ 36\ x\ 18}{\pi}}$ = 28.7”
- To accurately locate this traverse, it should be
  - 229” (19’) downstream of any obstruction (8 x 28.7)
  - 57” (4 ¾’) upstream of any obstruction (2 x 28.7)

Approved traverse methods?

- The primary preference for capacity testing is the Pitot tube traverse
  - Round ductwork – **Log Linear method**

Pitot tube marking for round ducts using ten measurements for each hole

TUBE MARKINGS FROM THE DUCT WALL	
1	“ diameter x 0.019 = “ from duct wall
2	“ diameter x 0.077 = “ from duct wall
3	“ diameter x 0.153 = “ from duct wall
4	“ diameter x 0.217 = “ from duct wall
5	“ diameter x 0.361 = “ from duct wall
6	“ diameter x 0.639 = “ from duct wall
7	“ diameter x 0.783 = “ from duct wall
8	“ diameter x 0.847 = “ from duct wall
9	“ diameter x 0.923 = “ from duct wall
10	“ diameter x 0.981 = “ from duct wall

Approved traverse methods, cont’

- Square/rectangle ductwork – **Log T method**

Log-Tchebycheff traverse locations

No. of Points or Traverse Lines	Position relative to Inner Wall	Use with side dimensions
3	0.064, 0.500, 0.936	≤ 12”
5	0.074, 0.288, 0.500, 0.712, 0.926	< 30”
6	0.061, 0.235, 0.437, 0.563, 0.765, 0.939	30” to 63”
7	0.053, 0.203, 0.366, 0.500, 0.634, 0.797, 0.947	> 63”

What is a AABC approved location cannot be determined

- If there is no suitable location for a traverse as outlined in the National Standards and/or Training Manual
  - Perform a traverse in the best possible location
  - Evaluate the data for accuracy
  - A below average traverse is better than no traverse at all
  - You made the attempt when the question(s) are asked

What if there is no possible way of obtaining a traverse of the entire unit?

Determine accurate Area and Correction Factors

AK’s & CF’s

Area Corrections (AK) vs. Instrument Correction Factors (CF)

- Area Factors for grilles, registers and diffusers should always be developed and documented in every TAB Report.
- Area Factors are created by comparing air device velocities to air volumes

Equation

$$Avg.velocity \times area\ factor\ (Ak) = CFM$$

or

$$area\ factor\ (Ak) = \frac{CFM}{Avg.velocity}$$

- Each air device of a specific size should have a field generated AK
- Review individual AK's for grilles of various sizes to determine if the Free Area factors are consistent.

Area Factors (AK) – Test 1

- Nominal grille size – 18” x 12”; double-deflection with face damper
  - Average velocity – 875 fpm
  - Pitot tube traverse CFM – 900
  - AK – 0.97
  - Utilized Free Area of the grille – 0.97 / 1.5 = 0.65 or 65%
  - Grilles of similar style and characteristics should have similar Free Area Factors when tested for AK’s
  - If all the similar styles cannot be tested, confirm that other sizes that have similar velocity and style characteristics do have the same free area factor.

Area Factors (AK) – Test 2

- Nominal grille size – 20” x 14”; double deflection with face damper
  - Average velocity – 935 fpm
  - Pitot tube traverse CFM – 755
  - AK – 1.24
  - Utilized Free Area of the grille – 1.24 / 1.94 = 0.64 or 64%

Instrument Correction Factors (CF)

- These are dimensionless
- This is the process of determining what corrections are required for an instrument that is measuring air volume directly.

Equation

$$\text{Pitot Tube Traverse CFM} \,/\, \text{Actual Hood Measurement} = \text{Correction Factor (CF)}$$

$$\text{Hood Measurement} \times \text{Correction } factor\ (CF) = \text{Actual Traverse } CFM$$

or

$$\text{Correction } factor\ \text{(CF)} = \frac{\text{Traverse } CFM}{Capture\ Hood\ CFM}$$

Instrument Correction Factors, cont'

- VAV Terminal box with 4 - 8"Ø ceiling supply diffusers
- The supply diffusers are proportioned as follows:
  - 250 cfm, 260 cfm, 270 cfm, 250 cfm
- The 10"Ø VAV Terminal Box is traversed with the following results:
  - Ave. inlet velocity 1985 fpm x Inlet area (0.55 sq. ft.) = 1090 CFM. Actual traverse of 1090 CFM / Actual hood total of 1030 = Instrument Correction Factor (CF) of 1.06.
  - ❖ This should be performed and documented in EVERY TAB REPORT

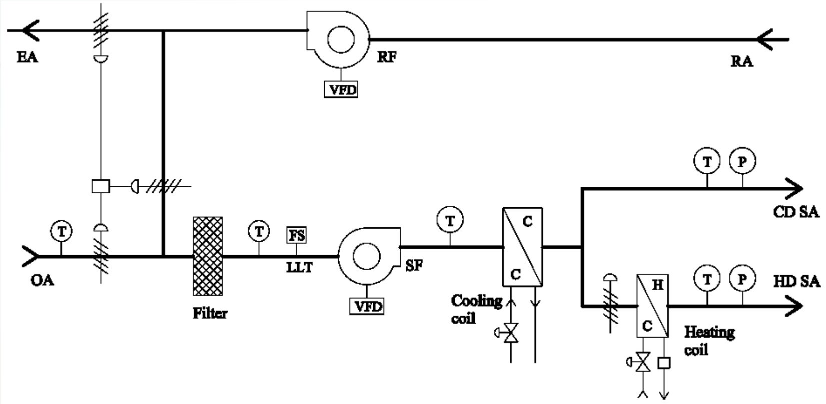
$$\text{Correction } factor\ (\text{CF}) = \frac{\text{Traverse } CFM}{Capture\ Hood\ CFM}$$

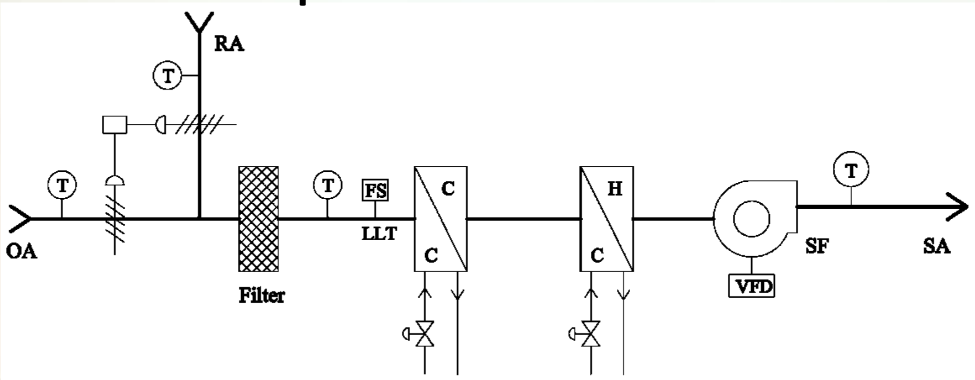
When should these tests be performed?

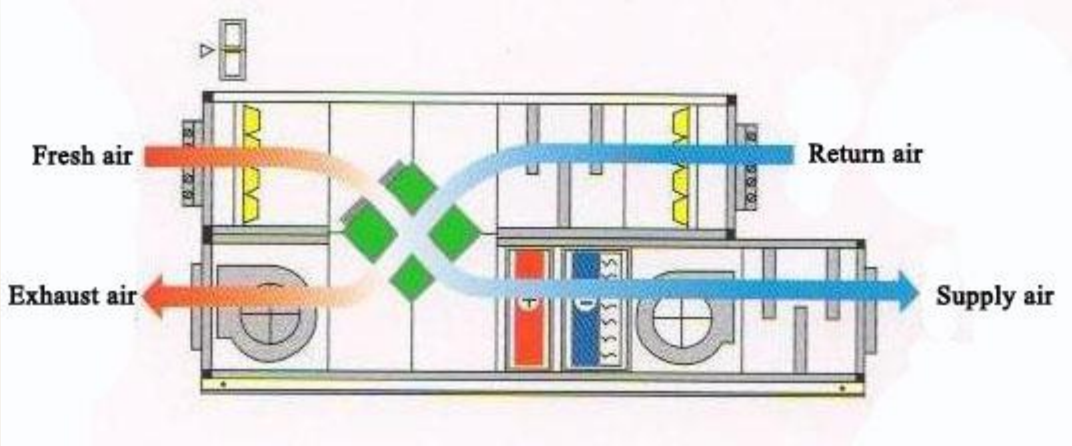
- Every project that has a TAB scope for work to be performed by a AABC Company
  - If total unit capacity traverses, Area Factor or Instrument Correction Factor tests are not performed on every project, how confident are you of the actual airflow values?
  - How can the heat transfer performance be accurate if the basic airflow cannot be confirmed as accurate?

Let's look at various AHU configurations

- Supply Fan
- Supply and Return Fan
- Energy Recovery with Exhaust Fans
- Roof Top Units





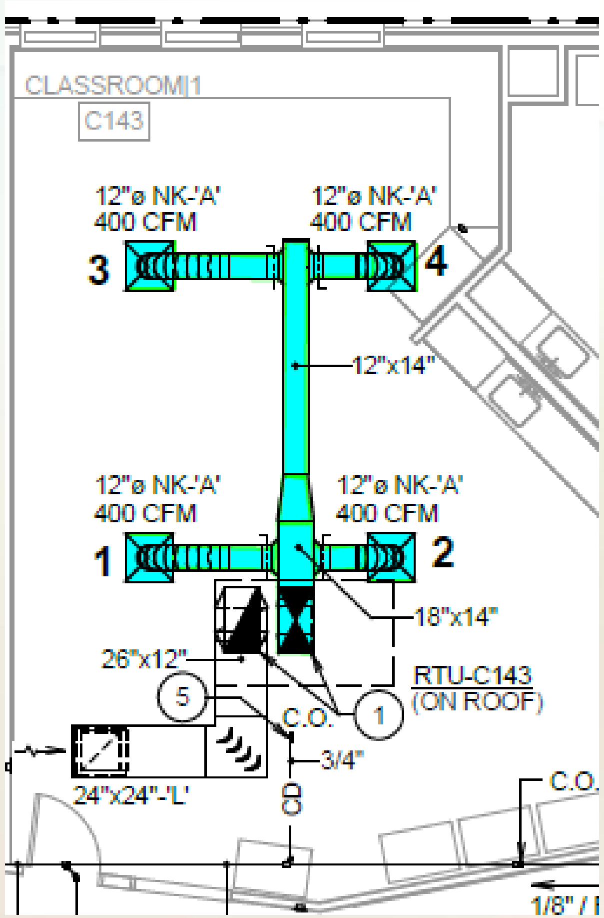


Unit configurations

- Basic roof top units that have an intake for outside air (no ductwork).
- How should you test outside air capacity?

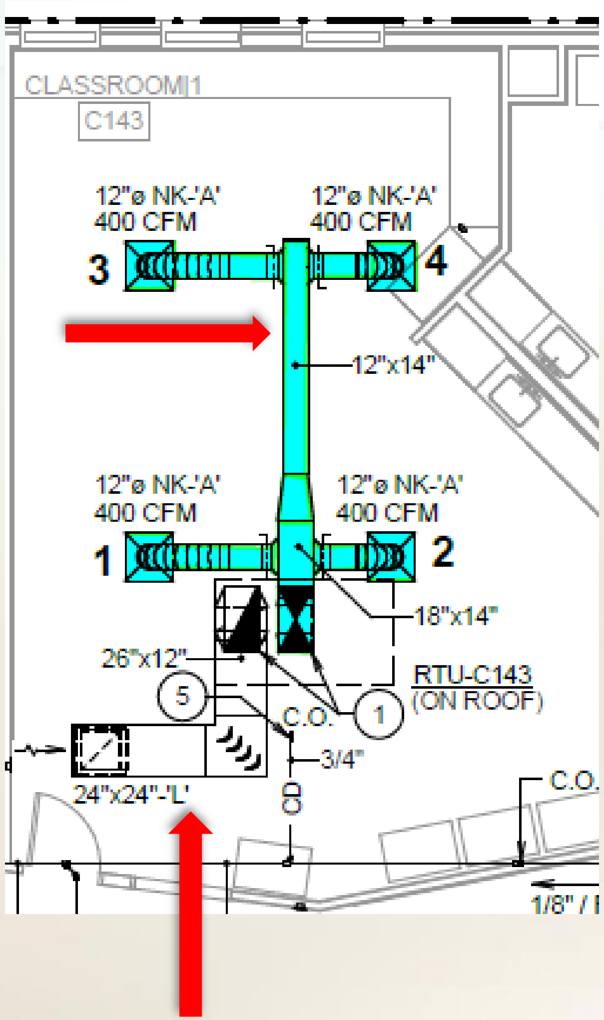
Typical RTU Configuration

- How can the outside/return air be determined?
- What tests could be performed?



Typical RTU Configuration

- Traverse a portion of the supply to determine instrument correction factors
- Traverse the return for total and to determine the air device instrument correction factor.
- Review the duct velocity
- Should the OA damper be
  - Open?
  - Closed?



Typical RTU Configuration, cont’

- The outside air damper should be closed
- Confirm the outside air damper seals.
  - If required, apply a blank-off to the OA intake to confirm the damper is sealed when closed
- Using the instrument correction factors that were generated for the supply and return, the outside air damper can be opened and the return volume can be tracked as the damper is opened and closed.

CF Comparison Example:

Supply Air Devices

- Capture Hood air volume = 740 CFM
- Airflow Traverse = 820 CFM
- 12” Ø Supply Air device CF = 1.11%
  - 820 / 740 = 1.11
  - Capture hood total of supply air devices not traversed = 700 x CF = 775
  - Uncorrected supply total 1440 CFM
  - Total corrected supply airflow = 1595 CFM

Return Air Device

- Capture Hood air volume = 1490 CFM
- Airflow Traverse = 1590 CFM
- 24” x 24” Air device CF = 1.07%
  - 1590 / 1490 = 1.07

CF Comparison Example, cont.

If supply air or return air devices are not traversed to determine instrument correction factors:

- 1 – The return airflow is indicated to be greater than the supply airflow

If only the supply air devices are traversed to determine instrument correction factors:

- 2 – It could be inferred that the outside air is already at 105 CFM and therefore, there is excessive damper leakage

Conclusions regarding Instrument CF's

- It is extremely important to have the information of instrument correction factors for the commissioning authorities.
- When airflows are being confirmed by a 3rd party, if this data cannot be provided, actual airflow verification may not match the actual recorded information in the TAB report.
- If only uncorrected airflows were used to determine unit totals, coil capacity testing may not calculate correctly due to inaccurate supply, return and outside airflow values.
- The example of small airflow errors that were in the pervious slide get very significant on large systems.

Large System Example

- Unit configuration SAF/RAF; OA determined by fan operating offset
- 50 - 12” Ø supply air devices field measured between 425 and 475 CFM with the average being 450 CFM – no correction determined
  - Total Supply Airflow ~ 22,500 CFM
- Plenum return traversed at 21,375 CFM
- OA Calculated to be 1125 CFM with a design of 1,200 CFM
- Using CF from prior example – SA is actually 24,975 CFM
- OA actually 3,600 CFM (300% high)

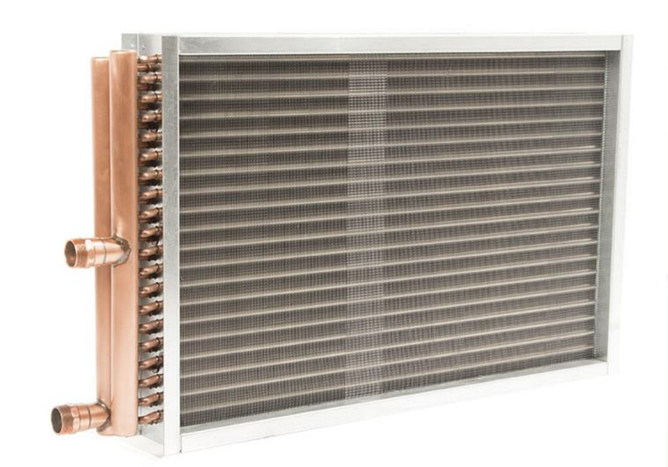
Equipment Performance Testing

- What is included?

  What equipment is tested?
- Airside performance testing performed after all Pitot tube traverse, AK & CF collection is complete

- Air Handling Units
  - Cooling Coils
    - Chilled Water
    - DX (Direct Expansion)
  - Heating Coils
    - Steam
    - Hot Water
    - Electric

Where is this data collected?

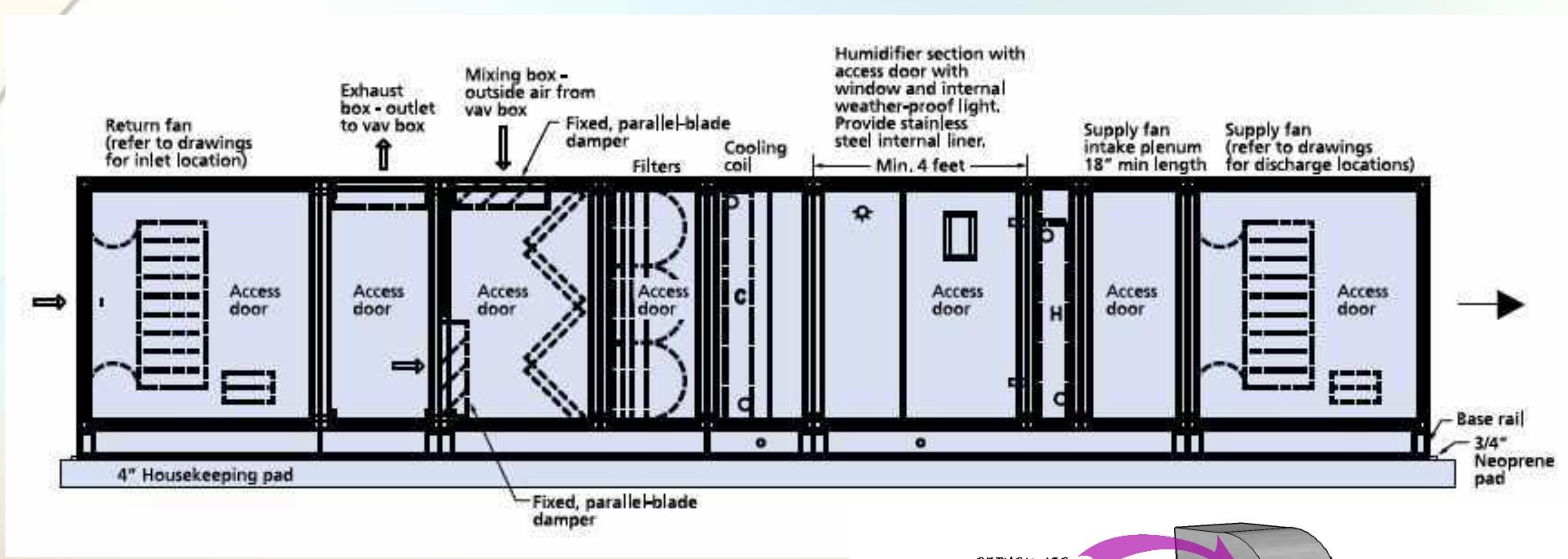


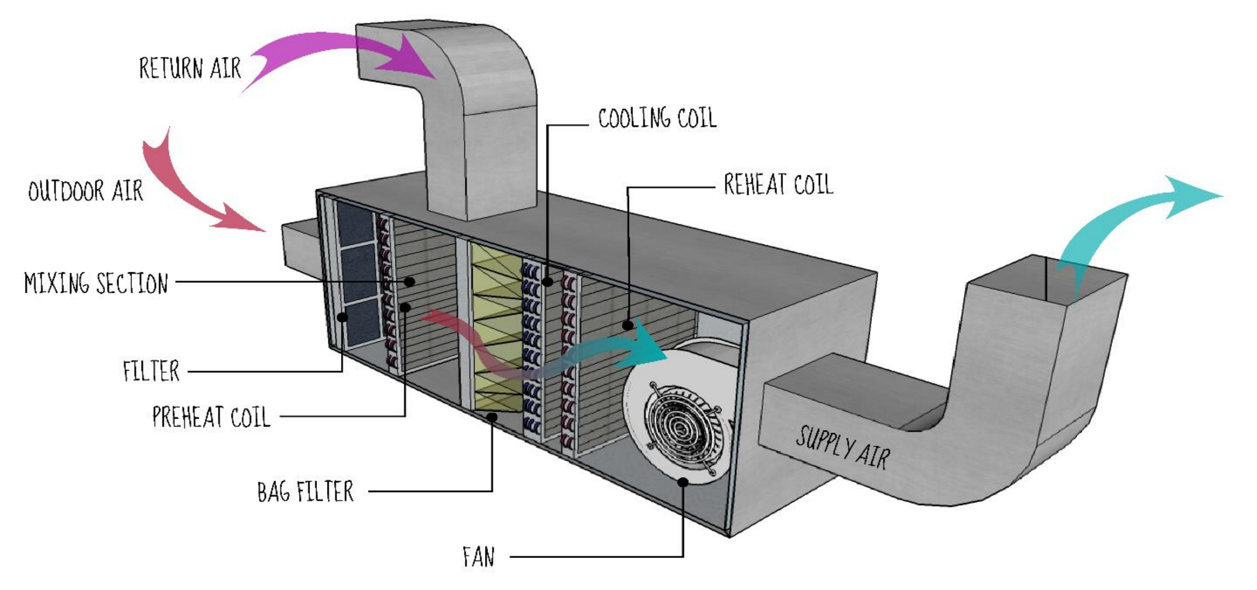
- Up stream of coils
- Down stream of coils
- Up stream of fans
- Down stream of fans
- Anywhere I can gain access to the unit
- Consider confined space issues

Considerations

- With an air handling system set to maximum design air and water flow, the following should be taken into consideration as the temperatures/coil performances are verified and recorded:

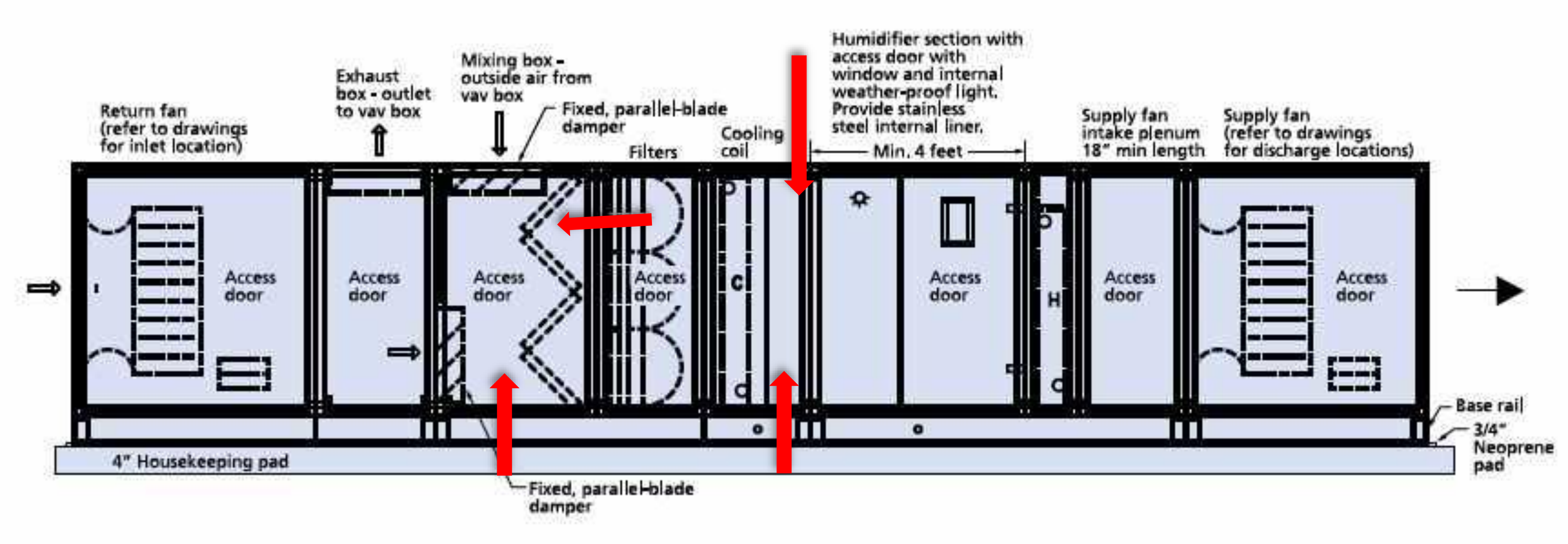
How does the outside air introduction in the unit effect the entering air temperature?





If the return air mixing plenum of the unit does not provide enough distance to properly mix the return and outside air, elevated or reduced return air temperatures may be recorded. If this is the case, a temperature traverse of the entering filter bank or some other location should be performed which will provide a reliable “average” entering air temperature. It is advised to continuously monitor the outside air temperature to verify there is not a significant change due to weather or time.

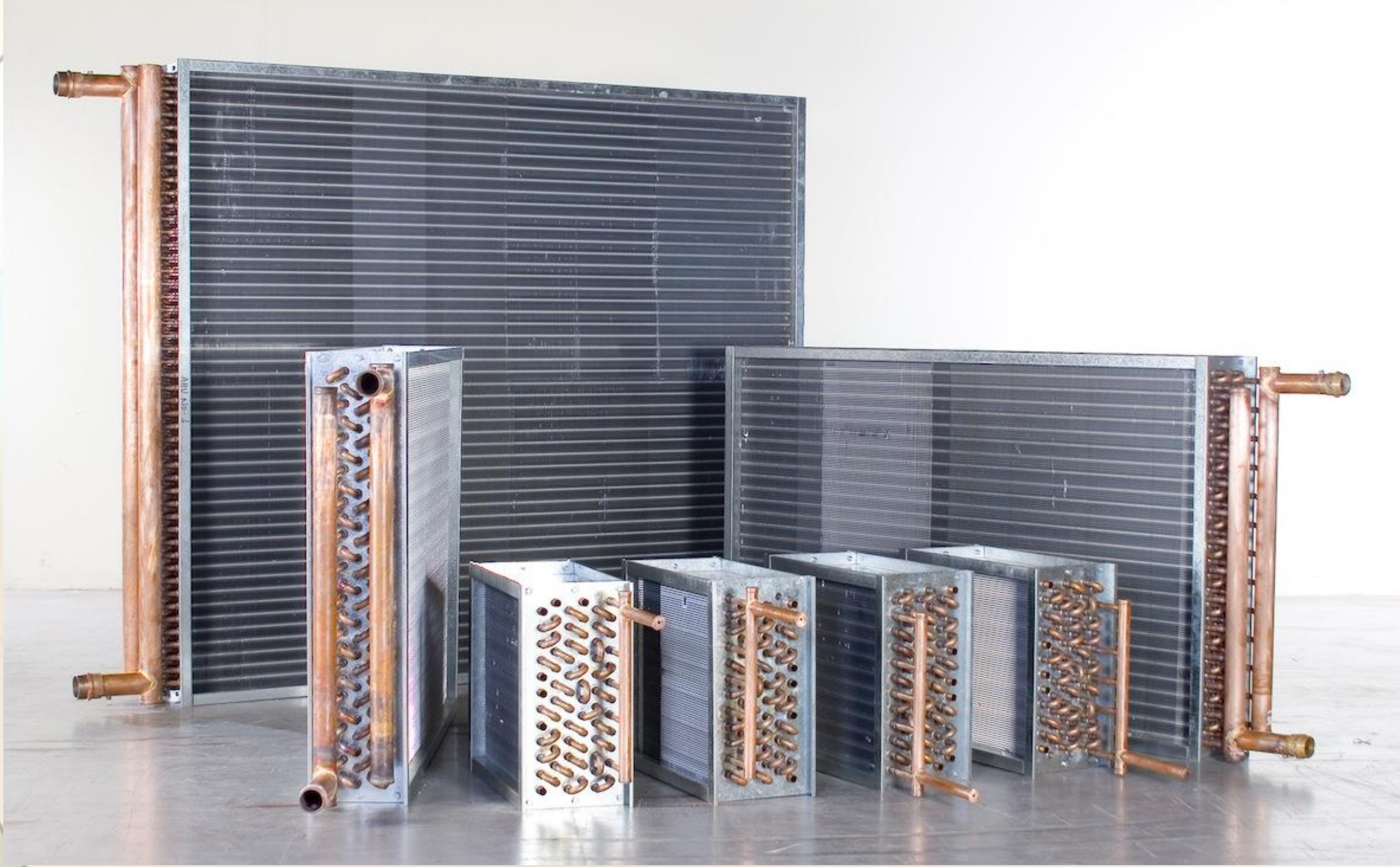
$$Tma = (\%RA \times Tra) + (\%OA \times Toa)$$



How does the continued operation of the air handling unit affect the return air temperature?

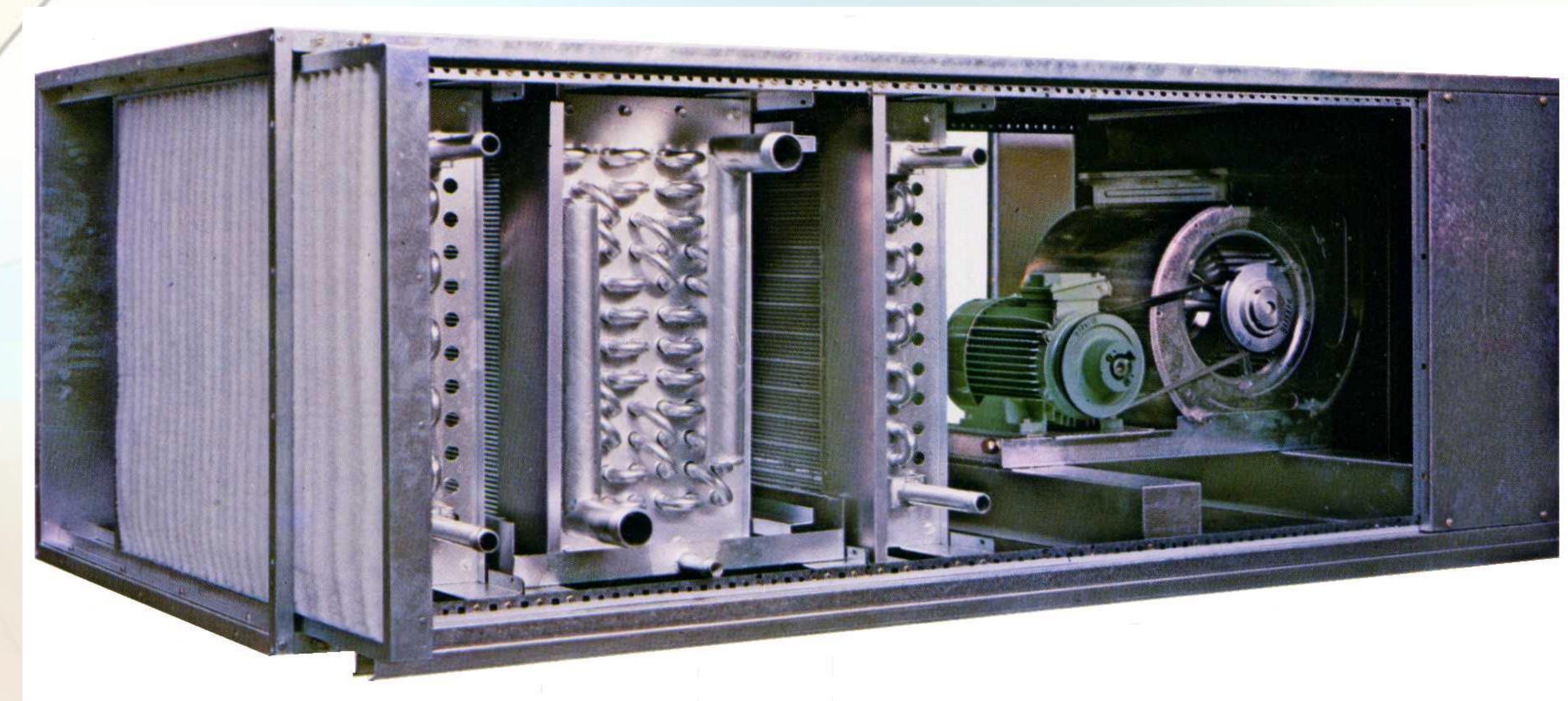
If the coil performance testing extends for a length of time and the occupied area served does not have significant heat load, the return air temperature may begin to fall which will have an impact on the final leaving air temperatures. This can be true for rooftop or fan coil units that may serve individual areas such as classrooms that are not occupied. This temperature may need to be monitored on a continuous basis to verify it is not falling/rising below/above design conditions.

How does the coil configuration affect the leaving air temperature?

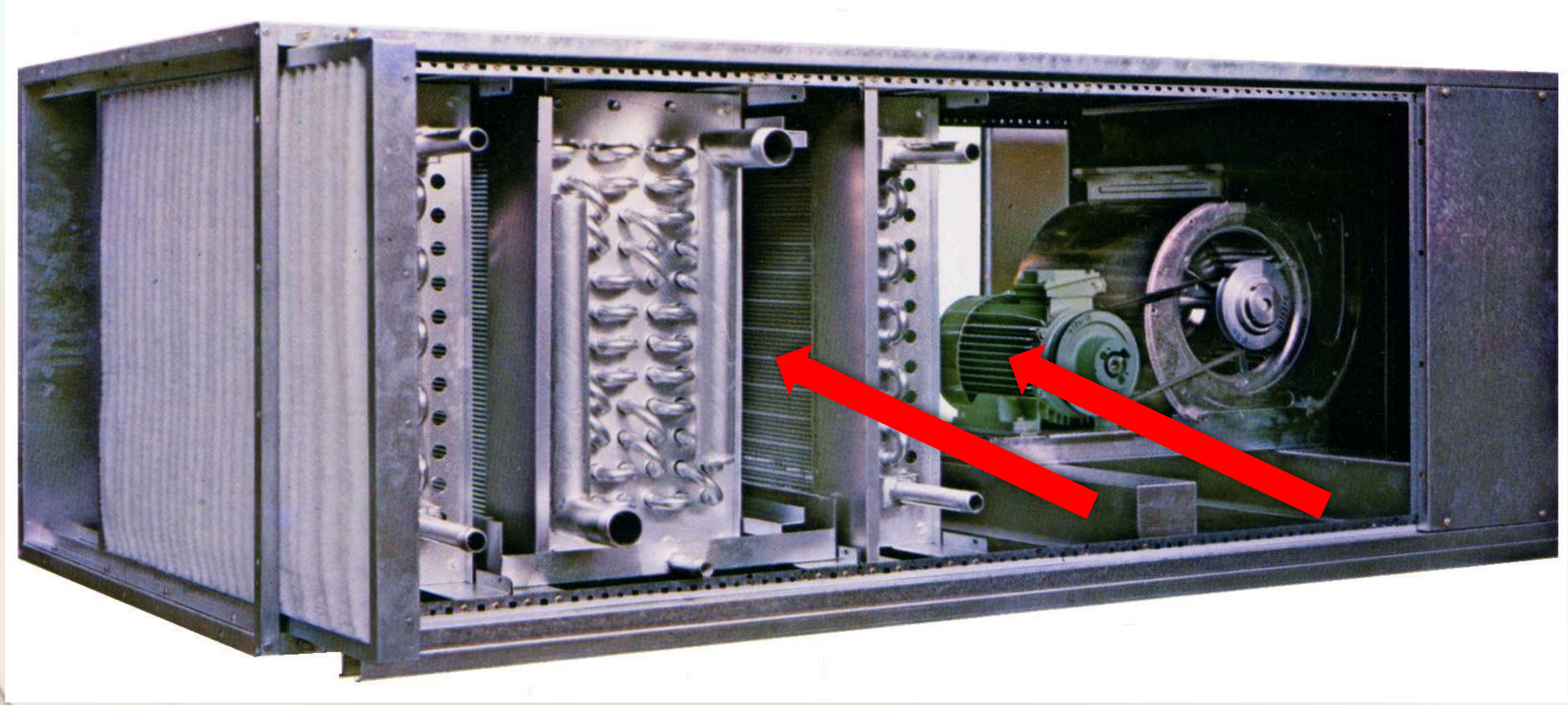


Depending upon the size of the unit, the coil header configuration may create a void before the actual cooling coil face. If the temperature probe being used is not long enough to extend past this area, this will have an adverse effect on the actual temperature meas

1. How does the location of the fan motor affect the leaving air temperature?



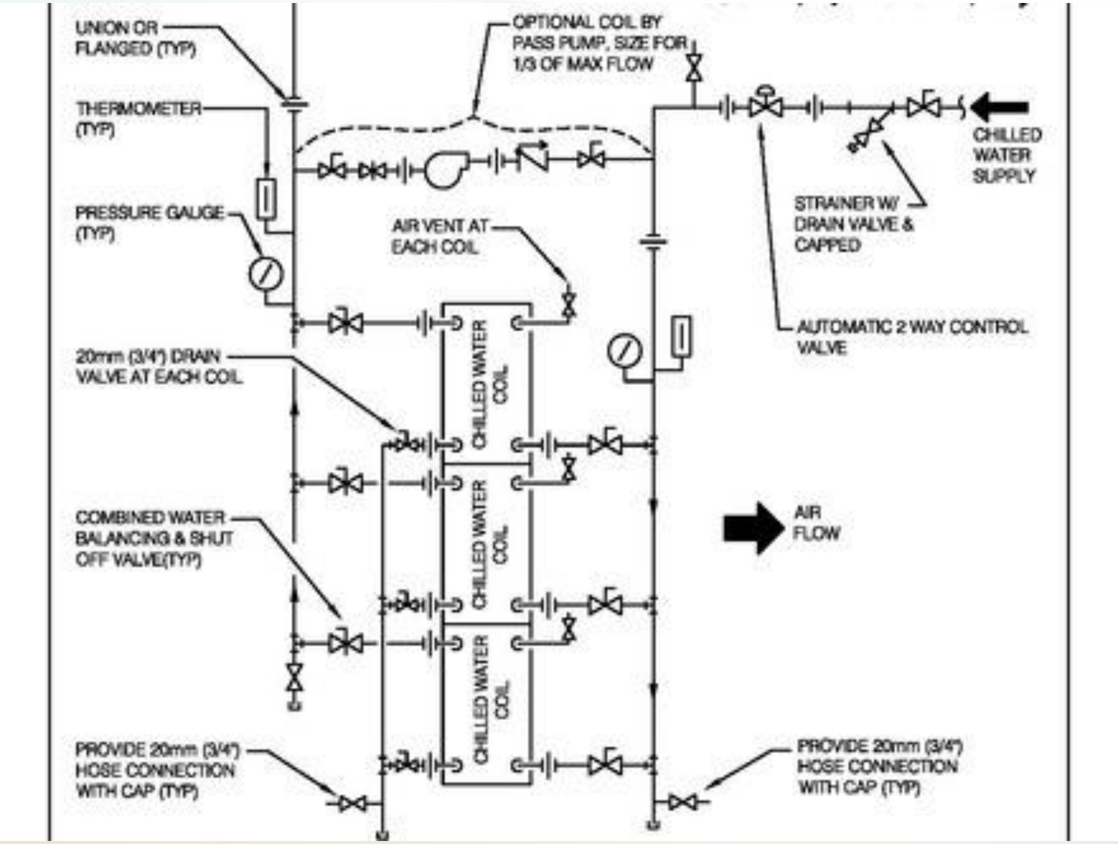
If the fan motor is located in the airstream, its location can impact the temperatures recorded in the field. Often an opening in the side of an air handling unit is created for collecting actual static pressures. This opening or penetration is utilized for gathering the coil leaving air temperature. But if a heat source, such as a motor, is in close proximity to the location where the temperature was recorded, this will adversely affect the reading. In both instances described earlier, inspections of the unit configuration can eliminate these issues. If the testing location does not eliminate this variable, then another test opening may need to be made or a temperature profile on the leaving coil face should be performed.



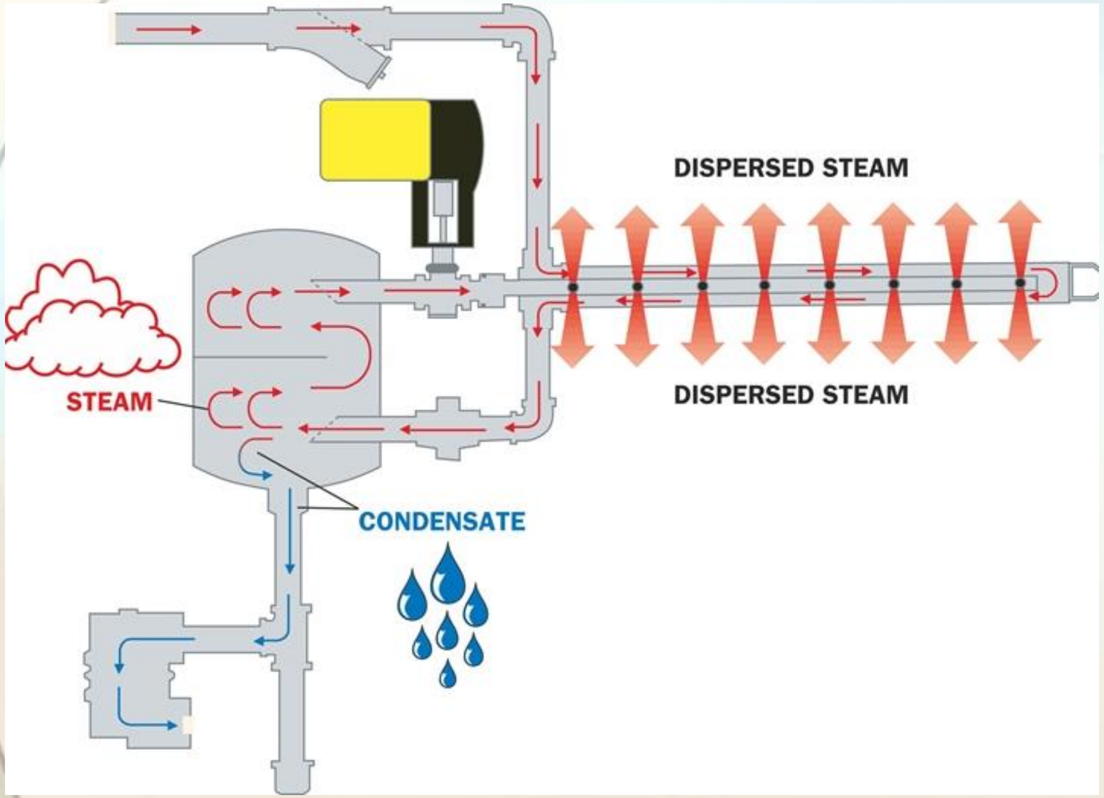
How may the coil configuration affect the leaving air and water temperatures?

Does the unit have a single or multiple, stacked coils?

Air handling units that have multiple coil banks can experience varying leaving air and water temperatures. If the outside air is introduced at the top of the unit and mixing is limited, the upper coil bank may experience elevated or reduced entering air temperatures. If the lower coil air and water temperatures are recorded and used as unit totals, the coil capacity calculations will not reflect actual conditions.



How will humidifiers affect the leaving air temperatures?
Are the humidifiers dry steam or microniser?



During coil performance testing, operation of humidifiers will affect the leaving air wet-bulb temperatures. Always verify that the actual field measured temperatures are recorded upstream of an active humidifier or disable the humidifier to eliminate this variable.

Questions / Conclusion

- The collection methods
  - Is all airside data repeatable?
- The location of the data collection points
  - Acceptable locations
  - Evaluate less desirable locations
- The unit configurations and how that may affect the final data
  - Review and evaluate
- The outside influences and how they may affect the final data
  - Building loading; changing conditions