CQI FDS (Field Data Specification) Working Group
Meeting Minutes
Monday, October 23, 2017

Call to Order

The meeting was called to order at 11:05 a.m. PDT by Chair Pete Jacobs (BMI).

Welcome, Roll Call, and Approval of 10/2/17 Meeting Minutes

Chair Pete Jacobs (BMI) welcomed members.

Organization	First Name	Last Name	WHPA Category	P=Present
Voting Members				
ACCA (Air Conditioning Contractors of America)	Donald	Prather	Contractor Association	P
BMI (BuildingMetrics Inc.)	Pete	Jacobs	Energy Efficiency Program Consultant	P
Daikin Applied	Skip	Ernst	HVAC Manufacturer	P
Energy Solutions	Jim	Hannah	Energy Efficiency Program Consultant	P
NCI (National Comfort Institute)	Ben	Lipscomb	Educator, Trainer	P
	Rob	Falke	Educator, Trainer	P
SCE (Southern California Edison)	Steve	Clinton	California IOU	P
Guest				
Green Link Mechanical	Jerry	Hernandez	Contractor (Nonresidential)	P
Staff				
Galawish Consulting Associates (Staff Support)	Elsia	Galawish	Energy Efficiency Program Consultant	P

There was a quorum for approval of the October 2, 2017, Meeting Minutes. Rob Falke (NCI) motioned to approve the minutes and Pete Jacobs (BMI) seconded the motion. All voting members present voted "aye." The 10/2/17 minutes were approved.

Agenda Review

Pete Jacobs (BMI) reviewed the agenda.

AGENDA TOPICS	DISCUSSION LEADER
Welcome, Roll Call, and Approval of 10/2/17 Meeting Minutes	PJacobs / EGalawish
Agenda Review	PJacobs
Review of Action Items from Last Meeting	
Questions or Comments on Best Practices from 10/2/17 Meeting • Temperature, Humidity, Static Pressure, and Electric Power Measurements	
Best Practices: • Airflow Measurements	
Next Steps for Working Group	
Action Items and Adjourn	PJacobs/EGalawish

Review of Action Items from Last Meeting

No comments or questions on the action items from 10/2/17 meeting.

Questions or Comments on Best Practices from 10/2/17 Meeting

No comments or questions on pressure temperature and kW measurements presentation from 10/2/17 meeting.

Best Practices – Airflow Measurements

Airflow measurement discussion focused on issues and best practices around making some of the field measurements that are embedded both in the installation data spec and in calculation procedures discussed at the previous Working Group Meeting. October 23 meeting presentation embedded below.

FD Spec Meeting
Presentation 10-23-17

Rob Falke (NCI) – I begin the discussion by laying the foundation for Airflow Measurement Interpretation (slide 6). Most of what is done in the field comes from the test-and-balance industry. There are also many other professionals that also do it, like commissioning engineer personnel, contractors, and EM&V folks, but there are people charged with quantifying the performance of the system. Sometimes it is just the air side, other times it is the water side. Most of the standards continue to be updated, but the standards that govern this have been around for over 50 years and are still relevant today.

Rarely does a single reading stand alone. After completion of measuring a system, the whole suite of measurement tasks has to be assessed—the numbers and calculations—to ensure they agree and are in unison. If not, there has to be a relook at the physics of the system and how it operates. This is key to taking measurements. There are many reports and differing opinions about field testing in the industry, but the bottom line is:

a) Accurate interpretation of measurements often requires the comparison of multiple readings; and to equipment specification, the whole system has to make sense.
b) Practice, judgment, and skill are critical; and this includes on-going education and training to execute accurate readings and to interpret the performance of a system.

Skip Ernst (Daikin Applied) agreed with these statements.

Rob Falke (NCI) – On Air Flow Measurement-Traverse Principles (slide 7), most airflow measurements sooner or later boil down to or relate to an airflow traverse principle. This is a principle most used to measure airflow. See illustration on Slide 7 of attached PPT. Holes are drilled into the duct – predetermined test sites. There are different methods—(1) equal-distance method or (2) log-Tchebycheff method—on where to put the probe to make measurements at different points across the duct. Velocity is recorded at each of those points, and then there is a scientific calculation that goes into deriving the average velocity and determining the CFM. This is the basic principle behind the traverse method.

Rob Falke (NCI) – On Air Flow Measurement-Equipment Supply Air (slide 8), for airflow leaving the equipment, one has to take a traverse at the right spot. There are rules, like ASHRAE Standard 111 provides guidance for a traverse. Measurement must be taken at a qualifying plane in the supply trunk duct.

Pete Jacobs (BMI) – In general, for most package RTU, it is very tough to get measurement on a qualifying plane in the supply trunk duct. For example, if the duct goes down, breaks off from the plane roof plan, and branches off, it is difficult to find a good place to make a traverse. Is this generally true? What are the members' experiences with such a situation?

Don Prather (ACCA) – A lot of times, you will have a main trunk where one can take a traverse. However, when a trunk branches off, one has to traverse all of the branches and then add up the branches.

Rob Falke (NCI) – Added that sometimes there are systems where there is no good place to get a good airflow measurement in the duct. However, there are methods, like what Don Prather (ACCA) mentioned above, that will suffice. Some other methods will be discussed later like plotting airflow using manufacturer's data and the TrueFlow plate.

Rob Falke (NCI) – On <u>Airflow Measurements-Balancing Hood Principles</u> (slide 9), airflow at the grilles where the air enters into the building is another requirement of this spec. Below is a summary of the basics of a hood and how it works.

1. The skirt at the top of the hood needs to be the right size and length to capture all the airflow of the register, directed evenly over the manifold.
2. The number of sensing points depends on the type of hood—about 12 to 40 different sensing points.

Basically, a traverse is done by the skirt of the hood capturing the airflow from the register, then the manifold measures and averages the FPM of the velocity of airflow. The CFM is derived by the product of the average velocity and the area of the manifold. This was created by Ernest Shortridge.

On <u>Airflow Measurements-Supply Air Entering the Building</u> (slide 10), when conditions are adequate, a balancing hood can be used to determine the supply air entering conditioning space. It can be measured using a calibrated commercial hood that can take a large number of readings with a skirt big enough to cover the supply and return grilles. Air volume of each supply grille is summed to find the total supply air entering the conditioning space. There are a number of new tools in the market and most of them compensates for back-pressure (the pressure drop created by the hood itself that may influence the measurement).

On <u>Airflow Measurements-Register Traverse</u> (slide 11), when a supply register is inaccessible, outside of the hood specifications, or in question, an airflow traverse is used to measure the airflow or verify the hood reading. The supply registers require an adjustment factor to correct for air velocity increase through the register.

On <u>Outdoor Air</u> (slide 12), measurement technique for estimating outdoor air depends on outdoor conditions.

a) For calm conditions, use a vane anemometer traverse.
b) For windy conditions, use a hotwire traverse—measure inside the hood just over the area of the inlet into equipment.
c) Can also estimate a traverse from outdoor air fraction and supply airflow rate.

Technicians have to know how to apply these techniques to each system since systems will be different. Certified air balancers are the best authority to set outdoor air values.

Don Prather (ACCA) – Warned about turbulence that could be present when using the hot wire traverse method. He suggests that one could use a smoke pencil to see if the air is going in or if there is any turbulence in the hood, and then use the hotwire method.

Skip Ernst (Daikin Applied) – We did this for outdoor monitoring stations and found a lot of probe locations that did not work before we found one that did work. In these cases, use sensors to see if measurement is *repeatable*. This does take a while to find something that is *repeatable*. This is indicative of problems you might find when doing airflow measurements. *Repeatable* means doing the test 5-10 times and getting about the same answer. Depending on the situation, if repeatable – ok; if not, it is an art to find a solution. ASHRAE 62.1 Standard for outdoor-monitoring-control-accuracy usually shoots for within 5%-10% accuracy depending on the product.

Jerry Hernandez (Green Link Mechanical) – Stressed that during economizer commissioning, he found that construction was not good. Stratification is a big deal. Using loggers with sensors, he noticed that mixed air sensors have to have a good location in order to have good measurement.

Pete Jacobs (BMI) – With the need to recognize how hard it is to get good mixed air measurements on RTUs, item c) above is the least appropriate method to use.

Rob Falke (NCI) – In general, the data is only as good as the placement of sensors.

Rob Falke (NCI) – Another test method used for economizers, the principles of an airflow traverse are applied to the air inlet or duct. These are usually used in kitchen exhaust return air and supply air.

Pete Jacobs (BMI) – We found a 2008 CEC Case study on ways to do acceptance testing on ventilation air. The study evaluated several different methods and found that the most accurate and repeatable one is the traverse method. This research seems to corroborate the standard practices in field—the traverse method.

Ben Lipscomb (NCI) – That is the only study that assessed all the methods so far.

Don Prather (ACCA) – This study was challenged by some in the industry because of the way they did the flow hood. We recommend using one or more methods to calculate outside air.

Rob Falke (NCI) – We would like to see some research done on measuring outside air by certified air balancers and would like to see the CEC go to certified, qualified professionals who are doing this in the field to help to establish ASHRAE standards.

Don Prather (ACCA) – California has new requirements on new equipment being installed. There are now better methods of reading outdoor air that is built into the equipment; however, they are more expensive.

Pete Jacobs (BMI) – With the traverse methods, as outside air fraction gets smaller and smaller, you get to the lower limit of the instrument and the air flow may not be measurable.

Skip Ernst (Daikin Applied) – Emphasized that the number of sensing points is critical, and the only way to know that one can be comfortable and that there are enough of them is to have a small enough difference between them.

Rob Falke (NCI) – There are industry standards that can be used, but I will discuss this issue offline with Skip Ernst (Daikin Applied).

Pete Jacobs (BMI) – The next class of measurements, <u>Supply Air at Unit-Additional Test Methods</u> (slide 14)—measuring supply air at the unit:

- *Hot Wire Traverse*: If you can find an appropriate location for measurement—the difficulty at times is finding a good measurement place on the main trunk coming off of the unit.
- *Fan Table Lookup (slide 15):* Using manufacturer's data—taking indirect measurements on the system and correlating back to the airflow as reported by manufacturers in their fan tables. The basic concept is discussed below.

The basic concept is measuring external static pressure on equipment and then looking at RPM of the fan and making adjustments for accessories as needed. Often tables are presented for external static pressure without any other elements inside the unit itself that provides additional pressure drop. So, if you have an element inside the unit such as an economizer, you have to add in the pressure drop associated with that particular portion of the system to the physical measurement of the external pressure on the unit. You then come up with corrected external static pressure and with the RMP. You can use the table on slide 16 to determine the airflow that the unit should be delivering.

Don Prather (ACCA) – There should be a clean coil and new operating conditions. Fan tables assume both wet and dry airflow.

Jerry Hernandez (Green Link Mechanical) – Raised the issue of measuring airflow and static pressure on commercial units with VAV controls and the adjustment needed to get the right airflow.

Pete Jacobs (BMI) – VAV systems and methods for evaluating those are outside the scope of this Working Group's efforts—constant volume system. One rarely hits the RPM or external static pressure in fan table and usually have to interpolate—weigh those various values to interpolate between values in table and the actual measured values. Slide 16 shows an example of the use of a fan table.

Skip Ernst (Daikin Applied) – With regard to fan curves vs. fan tables, I recommend using the fan curve rather than the fan table when you have to interpolate. If motor is close to fully loaded, you can also get fan amps to help verification.

Don Prather (ACCA) – Usually for packaged units, you can get fan tables from manufacturers but you may need model and serial number.

Pete Jacobs (BMI) – The advantage in using the fan curve is that you can follow the curve versus doing a linear interpolation from the table values.

Skip Ernst (Daikin Applied) and Don Prather (ACCA) agreed that there is a good chance that visualization will help and that fan curves make it easier to see how close you are.

Rob Falke (NCI) – Affirmed that the data is readily available and is different among manufacturers; some equipment is wet coil and some is dry coil.

Pete Jacobs (BMI) – Lab Data Comparison (slide 17) lists some investigations performed based on tests done on four different commercial RTUs. These tests were set up as horizontal flow. The tests were conducted by Robert Mowris & Associates, EM&V consultant to the CPUC, with me as an advisor to the project at the Intertek Lab in Texas. Actual airflow in system was measured according to ASHRAE Standard using a calibrated orifice. We have a publicly available dataset that included (1) the fan RPM and external static pressure measurements and (2) a lab measurement of airflow so that we could compare values out of the table to what was obtained in the lab. Lab Test Comparison (slide 18) represents an example a scatter plot of 3-ton RTU from the test. These are the results of conducting a series of testing faults and then measuring the impacts of fixing the faults. We have 31 sets of measurements: RMP, static pressure, and airflow. The results in the scatter plot were all over the map. Fan lookups in general were over-predicting by about 11%.

Don Prather (ACCA) – I notice in the scatter plot that the readings are high.

Skip Ernst (Daikin Applied) – I wonder how this could happen given that the fan laws are pretty predictable.

Ben Lipscomb's (NCI) questions and *Pete Jacobs' (BMI) answers*:

a) Did any of the internal pressure drops change as part of the fault testing and did you load up the coil or filter? *Some tests were done where we blocked off the face of evaporator. I am not sure those were part of the results but I will check on this.*
b) There was a pressure drop correction; and are you confident that any variation in internal static pressure drops—like accessories, economizers, heat exchangers, etc.—were accounted for correctly relative to the manufacturer's tables? *Yes, there was a curve in the manufacturer's literature used for pressure drop correction for economizers (closed dampers) and for wide open damper on the return side.*
c) Was the static pressure measurement below that damper or above? *Before the unit (static pressure entering the unit).*

Pete Jacobs (BMI) – This dataset is publicly available. It includes 600 individual tests across four different RTUs from three different manufacturers. You get a sense for how lab measurements compare with the fan tables. Take some time to do some more investigating to figure out what is going on and further research to understand the relative accuracy of the fan lookup tables.

Don Prather (ACCA) – I believe the fan speed and value could be off by 10% because they are based on computer simulations and not real measurements.

Ben Lipscomb (NCI) and Pete Jacobs (BMI) agreed that there is not really a wide variation on the imposed airflow or static on the unit.

Pete Jacobs (BMI) – TrueFlow Plates (slide 21) is another method that is sometimes used in commercial systems. It is a technology that was primarily developed for residential systems but has been used occasionally for commercial systems. TrueFlow plates are portable airflow measurement stations that replace filter racks. The plate has an array of static and velocity pressure ports to give an average velocity through the plate. It reads out to a readout device—micro manometer with some imbedded calculations—and produces the correct CFM. You can pack the filter rack with a series of plates and use them to measure total system airflow.

Don Prather (ACCA) – One has to know the static pressure of the duct in case they add more resistance.

Pete Jacobs (BMI) – Agreed, a correction is needed if the static pressure across the plate is different from the static pressure across the filter since it will affect the measurement. TrueFlow plates are not often used in the commercial units.

Rob Falke (NCI) – Energy raters use these in the residential sector.

Don Prather (ACCA) – It is one of the options under the ACCA HVAC installation standards.

Pete Jacobs (BMI) – The biggest issue with TrueFlow plates is that you have to watch for gaps around the plates so that the air is not bypassing the measurement elements and, as Don Prather (ACCA) mentioned earlier, that you make corrections for static pressure in case of pressure-drop differences.

Ben Lipscomb (NCI) – What is the technique used when using multiple TrueFlow plates? Is it feasible to connect all the tubes together with tees?

Pete Jacobs (BMI) – Typically, you would use just one micro manometer (expensive) and go from one plate to the next until all plates are measured. The device reads out in CFM and you simply sum the multiple readings. Regarding connecting the plates, I am not sure. Clearly, if one had an average velocity pressure reading across all elements, then you need to consider total surface area, and so forth, plus perform some additional calculations to make it work. Theoretically you could; however, the read-out device is not set up for this.

Pete Jacobs (BMI) – Summarized Pro Forma Uncertainty Specifications and Assumptions (slide 22) and Uncertainty Analysis Approach (slide 23). Uncertainty analysis was applied on the Test In/Test Out (TI/TO) values using specifications noted on slide 22 (variable description, typical instrument accuracy specification, and assumed uncertainty at 95% confidence). The results from 127 qualified field performance tests on HVAC systems using the draft ASHRAE 221P Standard protocol were used to run Monte Carlo simulations of the cooling system performance ratio (CSPr) and installed cooling system energy efficiency ratio (ICSeer). An Excel tool, Oracle Crystal Ball, was then used to evaluate the uncertainty of the results from the 127 tests.

Discussion of Slide 24: Sample Output Distribution of System EER

Don Prather (ACCA) – Resulting in 6-7.8 of EER centering around 6.8 uncertainty, all are ½ as efficient as they should be.

Pete Jacobs (BMI) – This was due to losses in the distribution system.

Ben Lipscomb (NCI) – That was one test on one unit; measured an installed cooling system efficiency of 6.8-6.9; the overall simulation was based on the uncertainty of the measurements across all 127 tests.

Rob Falke (NCI) – World needs qualified installation and testing personnel to get these results.

Pete Jacobs (BMI) – Using the Uncertainty Analysis Results (slide 25) and Significance of TI/TO Measurements (slide 26), the 127 field tests had an average CSPr of 72% and an average field-measured system efficiency of 6.5 SEER. Using manufacturer performance data to estimate capacity and efficiency resulted in estimated uncertainties of ± 8.1% for cooling performance ratio and ±.76 SEER at a 90% confidence level, while using generic performance data resulted in estimated uncertainties of 12.2% cooling performance ratio and ±0.95 SEER at a 90% confidence level. From this set of data, the difference in the TI/TO measurements were statistically significant indicating that the measurements are good enough to be used to document a unit's performance improvement. Typical TI was 43% of rated and typical TO was 85% of rated. Typical improvements are significant at 90% confidence.

Don Prather (ACCA) – This comes pretty close to what ACCA has been saying that if units/systems are not installed by the QI specifications, you are losing roughly 40-60% of rated efficiency out of the box (NIST Study commissioned by ACCA's Glenn Hourahan). Faults are additive with the exception of airflow which stands alone as a fault.

Rob Falke (NCI) – This test measures the deterioration of the performance of the system, quantifies it, and then field measurements are repeated after the improvement to document the improvement to the system performance. This test shows that there are a lot of opportunities for energy savings out there, similar to retro-commissioning.

Pete Jacobs (BMI) – Bottom line is we will have to continue researching improvements in Test Procedures; but more importantly, using best practices relating to field measurements can give an uncertainty that is tight enough to actually measure the improvement being made to the system.

Don Prather (ACCA) – I request that the vane manometer be added to the list.

Next Steps for Working Group

- Pete Jacobs (BMI) to finalize calculations protocols and procedures and write up results of best practices presentations and comments.
- Elsia Galawish (Staff) to distribute documents to WG members for an email vote.
- Final approved documents to be submitted by 10/31/17 and sent to the WHPA EC.

Action Items and Adjourn

No meetings until further notice—waiting the outcome of the WHPA restructuring.
The meeting adjourned at 12:35 p.m. PDT.

Submitted by Elsia Galawish, WHPA Staff, 415-482-1079
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