HVAC Airflow Measurement Issues for Programs and Evaluators

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ABSTRACT

The widely used Temperature Split Method (TSM) for assessing cooling system airflow is a less-than-ideal diagnostic technique. A 2002 comparison study of TSM and direct measurement[1] showed that for every 100 cases of directly measured low airflow, the TSM correctly diagnosed approximately 30 cases and misdiagnosed airflow as optimal in 70 cases where the direct measurements indicated less than optimal. Other research show that when the Temperature Split Method is used to infer flow rates there are errors of at least 20% in many cases with some ranging up to 200%[2] relative to direct measurements. Despite these findings, Heating, Ventilation, and Air Conditioning (HVAC) tune-up programs and, in some cases, energy codes have adopted the TSM to diagnose insufficient airflow and remediate the issue.

This paper challenges the continued use of the Temperature Split Method compared to direct airflow measurements. The challenge is supported by 224 side-by-side comparisons of the TSM to direct flow measurements, which were conducted as part of a recent evaluation of a refrigerant charge and airflow program. Of the 146 cases where measured airflow was low, the TSM only correctly diagnosed 21. Furthermore, of the 174 cases where the TSM produced a passing diagnostic result, only 48 had measured airflow that was in the optimal range. These findings should be considered in an overall transition away from the Temperature Split Method and toward more reliable means to diagnose and correct the issue of insufficient airflow in existing and new air conditioners.

Energy Impact of Airflow Inefficiencies

All air conditioning systems have a range of air flow rates where they function most efficiently—an "optimal" range of operating airflow rates. All systems operated with airflow rates significantly under the optimal range can suffer substantial capacity and efficiency loss with decreasing flow, and such systems comprise a notable portion of the air conditioner population. Systems operated in hot-humid climates that have significant dehumidification loads have dehumidification performance degradation at high airflows. Air conditioners operated in hot-dry conditions, where dehumidification loads can be less than system design, have a higher optimal range and less performance penalty for flows above the range. As such, correcting insufficient airflow for both existing systems and new installations of small direct-expansion cooling systems has long been identified as an energy and demand saving measure.

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[1] Proctor and Bowen. 2002. "What Can 13,000 Air Conditioners Tell Us?"

[2] Palmiter, Larry and Francisco, Paul. 2000. "Development of a Simple Device for Field Air Flow Measurement of Residential Air Handling Equipment."

Traditional air conditioner installation and service approaches have failed to address the basic energy efficiency problems found in residential air conditioners. Service performed by technicians is rarely checked, and work is governed by "check lists" that often provide inadequate guidance. The standard AC tune-up is much less valuable than it should be, and customers are often left with air conditioners that have incorrect refrigerant charge and airflow, resulting in reduced capacity and lowered efficiency[3].

In order to capture potential energy savings, programs and energy codes have been developed to measure and remediate inefficiencies associated with airflow and refrigerant charge. Utilities in California, Nevada, Arizona, Massachusetts, Rhode Island and Wisconsin all offer incentives to contractors to allow them to offer free or discounted service for customers that have refrigerant charge and airflow tests and corrections done on their AC units. Several other states have educational programs and others may be currently adopting these types or similar types of programs[4]. In California, 2005 energy code required some air conditioners in newly constructed homes and change-outs of systems in existing homes to have refrigerant charge and airflow verification, although not in all climate zones and this requirement could be avoided through alternate compliance paths. Many of these programs and codes allow the use of the Temperature Split Method (TSM) as the airflow diagnostic and some programs use the TSM exclusively as verification diagnostic of proper system airflow.

The use of the TSM in energy codes and energy conservation programs is standard practice as an airflow diagnostic method despite the TSM being identified in as early as 2000 as having large uncertainties[2] and proving to be inadequate[1] as a diagnostic method in 2002. It is difficult to estimate the number of applications of this diagnostic method, given the existence of California code compliance options that allow the avoidance of the diagnostics completely, as well as the issue of residential non-compliance itself. From 2004 to 2008, approximately 200,000 air conditioner units participating in energy saving programs may have been tested using the TSM in California, according to reports and data publicly available from the California Measurement Advisory Council and the California Public Utilities Commission.

The TSM is not a direct method of measuring airflow, but rather an HVAC system diagnostic that produces a qualitative assessment of airflow condition. The TSM returns a qualitative result, which is widely accepted to translate into either a "pass" or "fail." It should be noted that the TSM also attempts to differentiate between a high airflow failure and a low airflow failure.

This paper shows TSM is not fulfilling its diagnostic function by reviewing the findings of these past studies and presenting more recent results to support this claim. The tests in this study of 224 air conditioners revealed that the TSM was correct in only 75 cases when compared to direct flow measurements.

This paper seeks to prove that the TSM is an inadequate diagnostic tool for assessing cooling system airflow and, in many cases, leaves systems outside of their optimal performance airflow range. While clearly illustrating the deficiencies of the TSM, this paper does not attempt to estimate or forecast the negative energy impacts or lost opportunities resulting from non-optimal system performance produced by using the TSM in past programs or code. The study also does not quantify the future potential energy savings of using a reliable method to replace the TSM.

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[3] Proctor, John. 2003. "Innovative Peak Load Reduction Program CheckMe! Commercial and Residential AC Tune-Up Project."

[4] Consortium for Energy Efficiency. 2005 "Residential HVAC Programs National Summary, Consortium for Energy Efficiency"

Testing Adopted Airflow Measurement Methods

Methods of direct airflow measurement and ventilation requirements have been well studied and summarized in recent literature[5]. However, the most prevalent method of airflow diagnostics being used by Heating, Ventilation, and Air Conditioning (HVAC) tune-up programs -- and as a code minimum -- is the inaccurate Temperature Split Method (TSM), (promulgated by a major HVAC manufacturer, and embedded into California's Title 24 Energy Standards in the 2001 revisions).

A 2008 evaluation of Program X, conducted by the lead author's firm, used both the program-required Temperature Split Method as well as direct flow measurements on residential air conditioners from an HVAC tune-up program. The tests were conducted through the spring and summer of 2008 in inland California and focused on the hotter climates far inland where program activity and program claimed savings was greatest. The program and tests are described below.

Program Description

The HVAC measures implemented in Program X target the HVAC service and replacement market for residential and small commercial customers. The program provided incentives based on the degree of improvement in HVAC system performance. Each system was tested as part of the contractor intake process and deficiencies were identified. The deficiencies were addressed, and the system was then tested again by a verification service provider (VSP) to ensure proper performance. The program paid a smaller incentive to customers whose systems showed no deficiencies in the pre-test and the program did not claim any savings for those systems. The program also encouraged quality installation of system replacements, both for replacements on burnout and for early replacement of units identified as deficient in the testing process.

Many HVAC programs, Program X included, operate through VSPs who provide incentives to HVAC contractors. The contractors can use the incentive they receive to provide their services free of charge to customers, or they may choose to charge customers for some portion of the service cost. Each VSP is required to adhere to standards established by the utility, though a variety of different refrigerant charge and airflow test methods are allowed and are used in the field by the different VSPs and their contractors.

The Evaluation

This section provides a discussion and description of the two methods used in this study: (1) the Temperature Split Method (TSM), (2) the direct airflow method using a flow grid. Program X required airflow verification of contractor corrections using the TSM. The TSM diagnostic is intended to allow program contractors to diagnose and improve airflows and to provide a metric for VSPs to verify that flow is in the optimal range for a large percentage of program units. In addition, this evaluation of Program X utilized direct flow measurements using an orifice plate flow grid and digital manometer. The device uses a supply static pressure probe and a grid of pressure measurement locations that can replace residential air handler filters in air handler filter slots or filtered return grilles. The flow grid is described in a following section.

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[5] Wray, Craig, et al. 2002. "Practical Diagnostics for Evaluating Residential Commissioning Metrics." and McWilliams, Jennifer. 2002. "Review of Airflow Measurement Techniques."

Temperature Split Method

Assessing cooling system airflow using the Temperature Split Method is an incomplete and potentially misleading diagnostic assessment. While an in-range temperature split is an indicator of system health, like blood pressure or heart rate in human beings, it does not tell the whole story and it is possible for a poorly functioning unit to have an in-range temperature split. The method is reliant upon, that other than non-optimal airflow, the system is functioning properly and any number of system maladies when combined with low system airflow can yield a false positive.

For every 100 cases of directly measured low airflow, the TSM is likely to correctly diagnose only 30 of them and miss diagnose 70 cases, according to published studies[6]. Other research show that when the Temperature Split Method is used to infer flow rates there are errors relative to direct measurements of 20% in many cases with some ranging up to 200%[7]. Although the Temperature Split Method does not prove to be accurate, many energy codes and HVAC tune-up programs have adopted this technique as their standard to find and eliminate airflow issues. The Temperature Split Method that has been adopted by state codes and that has chosen for field verification of some refrigerant charge and airflow efficiency programs is extremely simplified. The TSM assumes a constant sensible cooling capacity regardless of conditions, when the actual cooling capacity of an air conditioner is significantly affected by ambient temperature.

The Temperature Split Method is the standard method used by contractors of Program X. The measurements required by TSM are likely collected using various instruments, the simplest of these instruments being thermocouples used to measure dry bulb temperatures and then applying a wet sock to take readings of wet bulb temperature. This method generally stays well-calibrated in the field but could produce unreasonable readings if the wet-bulb readings are not recorded in a time series; also there is an issue that drier conditions can cause rapid evaporation and readings taken after five minutes may be essentially equal to dry bulb. Many lower cost temperature and humidity meters have diminished accuracy for wet-bulb temperature and slow response time in moving air. Actual accuracy can be worse if there is unknown bypass or flow stratification issues particularly in packaged units.

Unlike a gas furnace or an electric resistance heater, the output of an air conditioner varies considerably; thus, target temperature split is not constant, as it varies with return air wet- and dry-bulb temperatures and the air temperature entering the condenser coil. The ambient temperature inversely affects the sensible cooling capacity of air conditioners and the TSM should logically have multiple target tables for varying ambient temperatures and return air conditions. A temperature based airflow diagnostic method utilizing multiple target lookup tables was designed in 1994[8]. However, by 2001 energy codes and efficiency programs adopted and continue to allow for the use of the Temperature Slit Method (TSM) that only uses one lookup table, and does not take ambient conditions into effect[1]. The TSM as defined for many programs and for this study uses one table of target temperature splits based on the return air conditions. The target temperature split table (from the 2005 California Residential ACM Approval Manual) is shown below.

The actual temperature split between supply and return dry bulb was calculated as shown in the steps below and compared against the target split as outlined in the California Title 24 2005 Residential Alternative Calculation Method (ACM) Approval Manual.

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[6] Proctor and Bowen. 2002. “What Can 13,000 Air Conditioners Tell Us?”

[7] Palmiter, Larry and Francisco, Paul. 2000. “Development of a Simple Device for Field Air Flow Measurement of Residential Air Handling Equipment.”

[8] Carrier Corporation, 1994. “Charging Procedures for Residential Condensing Units”

1. Calculate the Actual Temperature Split as follows:
   Actual Temperature Split = $T_{return,\ db} - T_{supply,\ db}$
2. Determine the Target Temperature Split using the appropriate tables from the 2005 Title 24 Residential ACM. (Table RD3 is presented below)

Table 1: Temperature Split Method (TSM) Target Table

Return Air Dry–Bulb (ºF) ($T_{return,\ db}$)	Return Air Wet-Bulb (ºF) ($T_{return,\ wb}$)																										
	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
70	20.9	20.7	20.6	20.4	20.1	19.9	19.5	19.1	18.7	18.2	17.7	17.2	16.5	15.9	15.2	14.4	13.7	12.8	11.9	11.0	10.0	9.0	7.9	6.8	5.7	4.5	3.2
71	21.4	21.3	21.1	20.9	20.7	20.4	20.1	19.7	19.3	18.8	18.3	17.7	17.1	16.4	15.7	15.0	14.2	13.4	12.5	11.5	10.6	9.5	8.5	7.4	6.2	5.0	3.8
72	21.9	21.8	21.7	21.5	21.2	20.9	20.6	20.2	19.8	19.3	18.8	18.2	17.6	17.0	16.3	15.5	14.7	13.9	13.0	12.1	11.1	10.1	9.0	7.9	6.8	5.6	4.3
73	22.5	22.4	22.2	22.0	21.8	21.5	21.2	20.8	20.3	19.9	19.4	18.8	18.2	17.5	16.8	16.1	15.3	14.4	13.6	12.6	11.7	10.6	9.6	8.5	7.3	6.1	4.8
74	23.0	22.9	22.8	22.6	22.3	22.0	21.7	21.3	20.9	20.4	19.9	19.3	18.7	18.1	17.4	16.6	15.8	15.0	14.1	13.2	12.2	11.2	10.1	9.0	7.8	6.6	5.4
75	23.6	23.5	23.3	23.1	22.9	22.6	22.2	21.9	21.4	21.0	20.4	19.9	19.3	18.6	17.9	17.2	16.4	15.5	14.7	13.7	12.7	11.7	10.7	9.5	8.4	7.2	5.9
76	24.1	24.0	23.9	23.7	23.4	23.1	22.8	22.4	22.0	21.5	21.0	20.4	19.8	19.2	18.5	17.7	16.9	16.1	15.2	14.3	13.3	12.3	11.2	10.1	8.9	7.7	6.5
77	-	24.6	24.4	24.2	24.0	23.7	23.3	22.9	22.5	22.0	21.5	21.0	20.4	19.7	19.0	18.3	17.5	16.6	15.7	14.8	13.8	12.8	11.7	10.6	9.5	8.3	7.0
78	-	-	-	24.7	24.5	24.2	23.9	23.5	23.1	22.6	22.1	21.5	20.9	20.2	19.5	18.8	18.0	17.2	16.3	15.4	14.4	13.4	12.3	11.2	10.0	8.8	7.6
79	-	-	-	-	-	24.8	24.4	24.0	23.6	23.1	22.6	22.1	21.4	20.8	20.1	19.3	18.5	17.7	16.8	15.9	14.9	13.9	12.8	11.7	10.6	9.4	8.1
80	-	-	-	-	-	-	25.0	24.6	24.2	23.7	23.2	22.6	22.0	21.3	20.6	19.9	19.1	18.3	17.4	16.4	15.5	14.4	13.4	12.3	11.1	9.9	8.7
81	-	-	-	-	-	-	-	25.1	24.7	24.2	23.7	23.1	22.5	21.9	21.2	20.4	19.6	18.8	17.9	17.0	16.0	15.0	13.9	12.8	11.7	10.4	9.2
82	-	-	-	-	-	-	-	-	25.2	24.8	24.2	23.7	23.1	22.4	21.7	21.0	20.2	19.3	18.5	17.5	16.6	15.5	14.5	13.4	12.2	11.0	9.7
83	-	-	-	-	-	-	-	-	-	25.3	24.8	24.2	23.6	23.0	22.3	21.5	20.7	19.9	19.0	18.1	17.1	16.1	15.0	13.9	12.7	11.5	10.3
84	-	-	-	-	-	-	-	-	-	25.9	25.3	24.8	24.2	23.5	22.8	22.1	21.3	20.4	19.5	18.6	17.6	16.6	15.6	14.4	13.3	12.1	10.8

3. Calculate the difference between the actual and target values as follows:
   Actual Temperature Split – Target Temperature Split
4. If the absolute value of the difference is less than or equal to 3 than the system has adequate airflow.
   a. If the difference is greater than 3, the airflow is too low.
   b. If the difference is less than -3, it is unlikely that the airflow is too high. Most likely the capacity is low on the system.

Direct airflow measurement

The industry standard at this time, the Palmiter and Francisco (2000) reference papers, include field tests that compare the flow plate method to the Temperature Split Method and also the fan assisted flow meter method. We did not use the fan assisted flow meter in our study, due to the longer amount of time required in the field to perform this test.

Orifice Plate Air Handler Flow Meter "Flow Grid". The flow grid technology was designed for measuring airflow in residential air handler systems. This technology consists of a perforated plastic plate installed in the place of the HVAC filter and allows for a measurement of the pressure difference between the stagnation pressure and static pressure at the plate to be taken; this pressure difference determines the flow. This direct airflow measurement method utilizes a static pressure probe, flow grid, and digital pressure gauge to measure the airflow across a wet evaporator coil. The procedure used in the evaluation of Program X was as follows:

Find the Normal Static Operating Pressure (NSOP):

1. A static pressure probe was installed into the supply plenum and connected to the digital pressure gauge (see schematic below).
2. The cooling system was run for at least 15 minutes to ensure measurements were taken over a wet evaporator coil.
3. The digital pressure gauge was used to record the NSOP over 2 to 3 minutes and then averaged the results. The digital pressure gauge stores this value.

Find the Flow Grid System Operating Pressure (TFSOP):

1. The filter is replaced with the flow grid TrueFlow metering plate (shown below)[9].

Figure 1: Orifice Plate Air Handler Flow Meter "Flow Grid"

2. The digital pressure gauge is used to measure the TFSOP and the adjusted CFM. Readings are taken for 5 minutes and three sets of measurements are recorded and averaged.

Fan-Assisted Flow Meter "Reference" (Not used in study). This method calculates NSOP in the same way described for the flow plate method, but calculates the airflow in CFM using a duct blower fan to match the operating pressure. The duct blower fan is attached to the air handler cabinet (see below)[10] and the fan speed is adjusted until the pressure in the ducts as recorded by the digital pressure gauge is equal to the NSOP. The airflow through the duct blaster fan is then determined by measuring the pressure drop across the fan and using the manufacturer's calibrations for the pressure drop to flow relationship. Both the Fan-Assisted Flow Meter method and the Orifice Plate Method are direct flow airflow measurement methods, and both are able to estimate the total system airflow, including flow through the air handler and duct leakage, if installed in the air handler cabinet. Sometimes the fan or the flow plate is installed at the return grille where they do not measure the total system airflow, instead measuring the total airflow less the return leakage which happens downstream of the measurement location.

[9] Image from: The Energy Conservatory, "TrueFlow® Air Handler Flow Meter Operation Manual."

[10] Image from: The Energy Conservatory, "Minneapolis Duct Blaster Operation Manual."

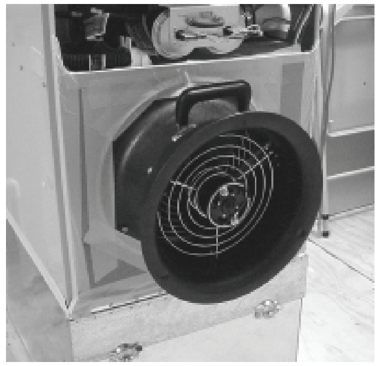

Figure 2: Fan Assisted Flow Meter "Reference" (Not used in study)

Uncertainties of Airflow Techniques Relative to the Flow Grid. According to the studies, the TSM is not very accurate and the fan-assisted flow meter method was not practical for this study. Flow measurements can be inaccurate in certain air flow geometries, but, in general, the flow grid and fan-assisted flow meter perform better than the Temperature Split Method. The true reference method is an inline flow meter which is only practical in laboratory settings. The TSM and the flow plate method both take about 15 minutes to perform. Field research showed that when the data collected for the TSM is used to infer flow rates there was a mean difference of 29% from the flow plate method. These calculations for flow rate are not presented in this paper which is focused on the diagnostic description of the TSM. There were differences of at least 20% in many cases with some ranging up to 200%[11], with some error likely due to assumptions required to produce quantitative results. In laboratory settings, the fan-assisted flow meter method, which takes significantly longer at around 1 hour to perform, has a mean difference of only 7% from the flow plate method[5]. In the Palmiter and Francisco (2000) study of 74 houses, preliminary comparisons of the fan-assisted flow meter to airflows using the flow plate and grid found measurements with a mean difference of 17% with less than 5% flow difference in 54% of the houses. Plenum static pressure errors may be reasons for the difference but this was not stated in the report. Francisco (2001)[12] indicates that measurement accuracy is not affected by upstream flow disturbances, such as 90º bends in the return duct as close as 3 inches (75mm) to the plate. The flow grid has a manufacturer stated measurement accuracy of plus or minus 7% under ideal installation conditions, which is supported by the literature.

Airflow measurements using the flow plate and grid showed a negative bias of 9% to 14% relative to fan-assisted flow meter measurements, according to a more recent study of measurement techniques by Lawrence Berkeley National Laboratory (LBNL). It is unlikely that the bias is due to flow bypass because the rigid plate was taped to the air handler in each test; still the reason for the bias is unknown. Although the bias was within measurement deviations reported by Palmiter and Francisco (2000), the LBNL study did not expect to find such a consistent bias.

Based on the evaluator's field experience using the orifice plate flow grid, all biases tend to be low. The openings on the flow grid pipes are all normal to the flow in a filter slot, but filtered returns and flow turbulence would likely account for many non-normal flow components which may be partially measured or "unseen" by the flow grid. As a result, there is an understanding that the "flow

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[11] Palmiter, Larry and Francisco, Paul. 2000. "Development of a Simple Device for Field Air Flow Measurement of Residential Air Handling Equipment."

[12] Francisco, Paul. 2001. "The Current state of Duct Leakage Measurements: Field Evaluations of Five Methods."

grid flow" is likely lower than actual system airflow and the difference needs to be quantified by future study.

Measurements used in this comparison study

For direct measurement in the evaluation, an orifice plate air handler flow meter was used to measure air flow from the system fan. The orifice metering plate was installed at the air handler cabinet or in a filter slot as close to the air handler blower as possible. Most residential systems have a filter slot at the return grille or a filter slot built into the blower compartment directly upstream of the blower. The metering plate was installed in one of these two locations. If there were multiple returns, a metering plate was installed at each one simultaneously. One potential issue is the affect of duct leakage on the flow measurements when the grid is placed at a return grille. A standard four percent positive adjustment is made for all filtered return grille measurements, per the instructions of the device manufacturer. The comparison measurements made for the return temperature for the TSM were always in the same locations as the flow grid placement. Effectively the flow measurement and the TSM should be "seeing" the same airflow on a given system, even though return duct leakage flows were not quantified. Once the orifice metering plate was in place, the system fan was turned on and the entering air velocity and the exiting air velocity through the metering plate were measured to obtain fan air flow using a digital differential pressure gauge. Five readings were taken and recorded over a period of about 10 minutes. The measured airflow was compared to required airflow in order to determine low airflow.

The evaluation method for the TSM used a high accuracy humidity and temperature meter to record wet- and dry-bulb temperatures for both supply and return intakes, thus measuring enthalpy in each airstream, and enabling computation of cooling achieved, and of extant cooling capacity under time-varying conditions. The air temperature sensors were placed in or near the center of the airstreams at points where the air was well mixed. Several measurement error considerations were made in the process of specifying the field instruments. The evaluation utilized a meter typically used to calibrate temperature and humidity sensors and chosen for its high accuracy and fast response. A schematic of the typical measurement points is illustrated below.

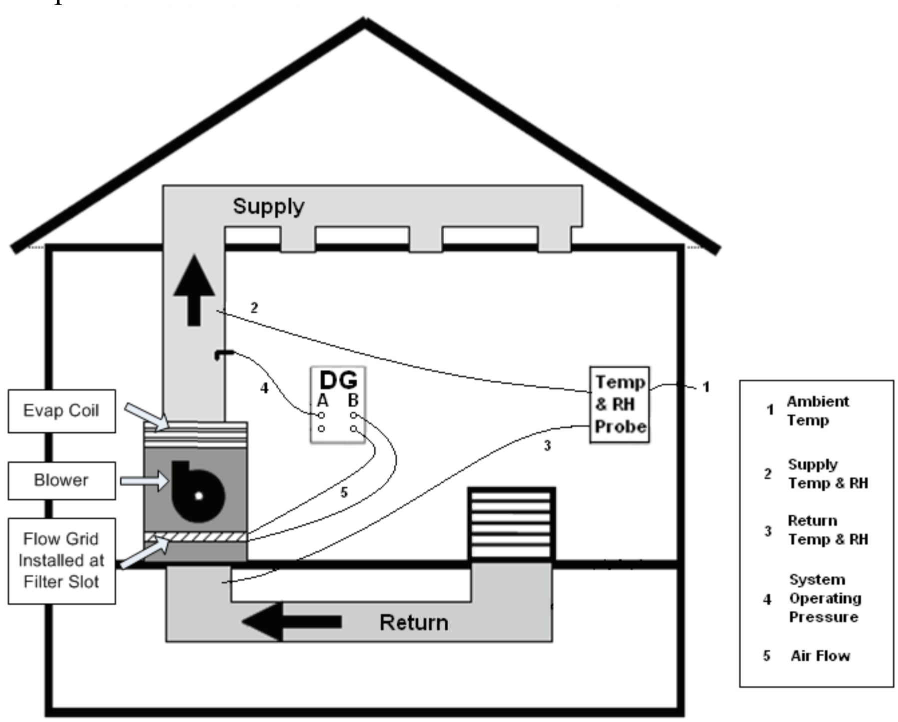

Figure 3: Test Measurement Locations for a "Typical" System

Given the measurement uncertainties, the evaluators set the minimum of the optimal range of measured airflow to 325 cubic feet per minute of air per ton of cooling (cfm/ton) and set the upper limit to 400 cfm/ton. The range was defined based on knowledge that the flow measurement device was not perfect and installation configuration issues tend to bias the method low. The TSM diagnoses as defined previously were then compared to the flow measurements based on this definition of the optimal range of airflow.

Results

The result of testing 224 units that were part of a recent refrigerant charge and airflow program demonstrates that the TSM airflow diagnostic produced only 75 correct results relative to direct flow measurement. Test methods, as described in the previous section, were conducted through the spring and summer of 2008 all across inland California and focused on the hotter climates far inland where program activity and program claimed savings was greatest. All systems served residences with typically one system per residence and installed capacity ranged in size from 1.5 to 5 tons. Of the 146 cases where actual flow measurements were low, only 21 were correctly diagnosed as low airflow by the TSM. Furthermore, of the 174 cases where the TSM produced a passing diagnostic result, only 48 had a measured airflow that was within the optimal range. The results are presented below in Table 2, divided into nine potential outcome categories. The three categories where TSM was correct relative to direct measurements are the bottom left, center, and top-right cells. For example a low airflow measurement with a corresponding low TSM diagnosis would be allocated to that category. The other cells represent the six failure modes of TSM relative direct measurement with the most notable being the 108 cases of low measured airflow with a corresponding TSM diagnosis of “pass”.

Table 2: Airflow Measurement and Temperature Split Method Diagnostic Outcomes

		TSM Test Outcome (Qualitative)			
		Fail Low	Pass	Fail High	**Totals**
Flow Measurement Outcome (CFM/ton)	Fail Over (flow>400)	0	18	6	**24**
	Pass (325<flow<400)	2	48	4	**54**
	Fail Under (flow<325) "Low Airflow"	21	108	17	**146**
	Totals	**23**	**174**	**27**	**224**

Research and experts agree that the TSM diagnostic is insufficient and the results of this recent study further support those assertions. The diagnostic should be eliminated from programs and pushed for elimination from code by new construction and replacement programs being evaluated relative to code. Figure 4 shows the data in similar outcome sections as Table 1 with the measured airflows plotted on the y-axis. The highlighted cells represent the six failure modes of the TSM relative to direct measurement.

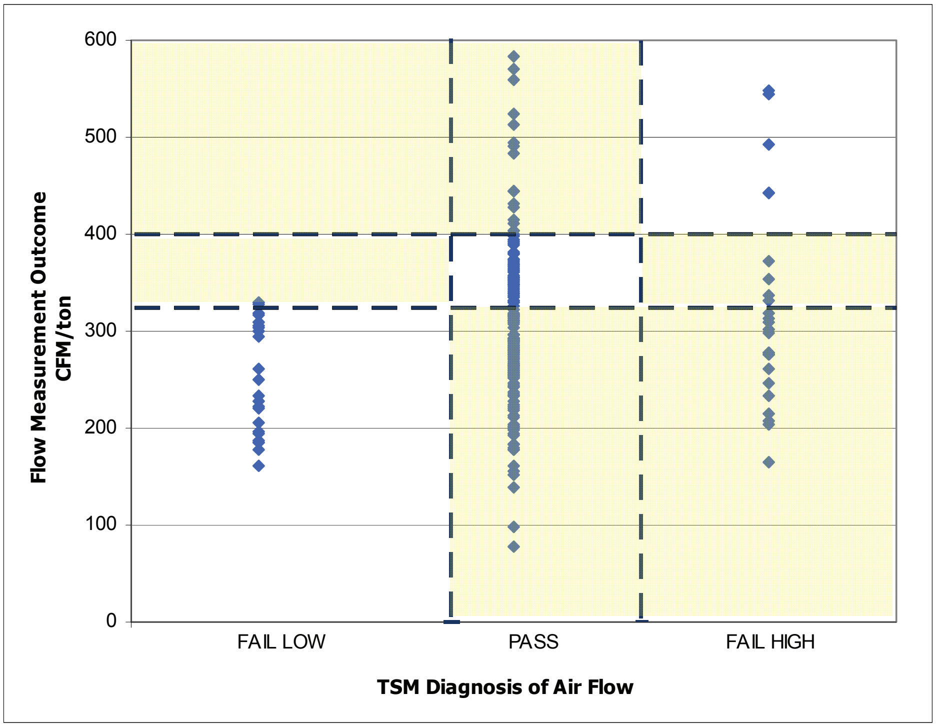

Figure 4: Measured Airflow Versus Temperature Split Method Diagnostic Outcome

Conclusions

In this study the temperature split test was inaccurate (149 times) more than it is accurate (75 times) based on 224 direct comparisons performed as part of an evaluation of refrigerant charge and airflow corrections. Based on this result and the supporting literature cited, we recommend that the TSM should be abandoned as a code or program metric in its currently promulgated and simplified form. In contrast, direct flow measurements, while not ideal, offer a reasonable diagnostic that in practice tends to avoid the issue of missed opportunities given the low flow bias of commonly available instrumentation. In this evaluation, there were 51 cases where installing the flow grid was impossible, over 20 of these cases would be solved by having a smaller grid option than the smallest of two provided in the commercial kit. It would thus be technically feasible for contractors to use direct measurements in over 80% of cases. Some investment would be required to increase the applicability rate of the flow grid method to that of the TSM.

The equipment used to measure the parameters required by TSM in this study is more accurate and expensive than the sensors used by contractors. Our measurement equipment costs approximately $1700 compared to the standard field practice equipment cost of approximately $250. The flow grid package used is a commercial product that costs about $800 for contractors who already own the standard digital manometer and about $1500 for the full package. The time to perform the TSM and flow grid method is roughly equal. As a program requirement for verification data collection, direct flow testing equipment for all verification service providers is both technically and financially feasible. The financial feasibility of the method for contractors may be dependent on their work volume and willingness of programs to supplement costs. Many programs offer contractor education in complete agreement with this paper's findings, but this training is somewhat in vain until programs, evaluators, and code abandon the TSM as being acceptable and steps are taken to adopt direct airflow measurements.

Other topics for consideration

In addition to the findings and conclusions of this paper, other important topics should be the subject of evaluation studies and program design considerations, these include:

- Directly measured system airflow targets for programs and codes do not always account for the pressure drop in actual installations or the climatic differences of hot-dry conditions relative to hot and humid conditions.
  - The 400cfm/ton for wet coils target is based on manufacturer defaults at one half inch water column of pressure drop and design. Manufacturers sometimes list flows for off-design pressure drops and most air condition systems in existing homes, especially with loaded filters, tend to have higher than design pressure drop.
  - The California energy code actually reduced the measured flow target from 400 cfm/ton to 350cfm/ton from 2005 to 2008 code. It is unclear if the change is to account for the issue of higher than design pressure drop in real systems, but ideally the targets could be based on measured pressure drops and provide the airflow per ton target range of optimal operation.
- Given the potentially low bias revealed in literature and our experience of measurements with the flow grid, an adjustment factor should be considered for development.
- Program designs may have to consider offering testing equipment rebates or offering volume "awards" of test equipment and free equipment to low-volume contractors serving hard-to-reach markets. From the contractor's perspective, test equipment investments may be further justified by multi-year program cycles and the ability to use the same equipment for existing air conditioners as well as new installations.
- Some investment could be made to add to the flow grid kit that would increase the applicability rate to greater than 90%.
- Cases not applicable for a method such as the flow grid could be reference to the verification service provider for backup method testing. Backup methods like the fan-assisted flow meter would be required to address all system airflow measurements on the air conditioner population.
- Proprietary methods for airflow diagnostics should undergo similar comparison to direct flow measurements. The data being collected by this current evaluation and others present an initial opportunity for the proprietary algorithm results to be compared to the flow measurements.

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Acknowledgements

The authors would like to thank all who reviewed and provided input to this paper, the staff who performed the tests, and all others who assisted in the effort. Special thanks to a staff member who performed all these tasks! Additional acknowledgements should be granted to the California ratepayers who participated in the study and all others as they ultimately funded this important research.