Comments for the 2013 Title 24 Energy Code

Subject: TSI Incorporated Concerns & Comments with regard to proposals outlined in the ***2013 standards update pre-rulemaking document to Title 24 energy standards in Appendix RA3 – Residential Field Verification and Diagnostic Test Protocols***. The document can be found in the following link http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/2011-11-07_workshop/review/Draft_Language/Staff_Proposed_Draft_Language-Appendices/RA-3.pdf

Concern: Proposed removal of flow hoods for use in measurement of supply and/or return flow in residential settings, based on conclusions published by researchers Iain S. Walker, Ph. D. and Craig P. Wray, P. Eng. (and others) in LBNL publications 45959, 47382 and 51551.

TSI Comments: TSI contends that the basis for removal of flow hoods and exclusive endorsement of "powered" flow hoods as an accepted airflow measurement technique in section RA3.3.2.1.2 is made on the basis of an incomplete reading and analysis of available data**.** We have shown below why TSI's commercial capture hoods (a.k.a. flow hoods) when used correctly perform within accepted standards for most if not all residential flow measurement applications.

TSI Recommendation: Include capture hoods with flow conditioning/diffuser screen as an acceptable method to measure airflow in residential HVAC applications.

To prove that some "Commercial Capture Hoods" perform acceptably well to qualify for most residential flow measurement applications, two sources will be cited:

1) ASHRAE Publication KC-03-1-2 entitled "Evaluation of Flow Capture Techniques for Measuring HVAC Grille Airflows" authored by Iain S. Walker, Ph. D. and Craig P. Wray, P. Eng;

2) Data taken at the LBNL "Multi-Branch [Residential] Laboratory Test Apparatus" by Charlie Wright, Staff Mechanical Engineer, TSI, Inc. as assisted and witnessed by Iain S. Walker, Ph. D. and Craig P. Wray, P. Eng. using TSI's Model 8373 "Commercial Capture Hoods" equipped with a standard accessory Flow Conditioning Screen. (June 2001)

Drawing from these two resources, we will **clearly demonstrate** that the TSI Models 8371/8373 AccuBalance Capture Hoods – when used with the available accessory Flow Conditioning Screen (TSI p/n 1080165) – perform well enough to qualify for five of the six "Accuracy Requirements for Residential Flow Hood Applications" identified by the LBNL researchers Walker and Wray.

Reference	Claim	TSI Comment
ASHRAE publication KC-03-1-2 - Page 6, paragraph 2	"The results in Table 2 show that the flow hood … …error was reduced to less than 10% when the diffuser screen was used."	TSI agrees that diffuser screen (Conditioning screen) can significantly improve accuracy to within acceptable levels
ASHRAE publication KC-03-1-2 - Page 8, paragraph 4, sub-head "**Flow Hood 1, Round One**."	"The tests on the multi-branch system were performed with the diffuser screen in place… For the 11 grilles of the multi-branch system, the mean error was 0.5 L/s (1 cfm, 1%) and the RMS error was 2.5 L/s (5 cfm/ 5%). These results show how the use of the diffuser screen combined with careful placement can give good results for this flow hood ." … "These results show that the diffuser screen makes the flow hood less sensitive to placement over the grille and improves accuracy."	TSI agrees with the statement – this should be a good basis for including flow hoods with a conditioning screen/diffuser screen as an acceptable air flow measurement technique
ASHRAE publication KC-03-1-2 - Page 9, paragraph containing sub-head "**Flow Hoods 1 through 5, Round Two**", sentence 2:	"The diffuser screen used with Flow Hood 1 is again shown to have significant benefits, particularly for individual grille measurements."	TSI concurs with claim
ASHRAE publication KC-03-1-2 - Table 5, page 9, titled "**Multi-Branch Test Results for Commercial Flow Hoods**		Examination of data in table 5 relating to "Hood 1 + diffuser screen" shows measurements at each of the 11 diffusers. Errors for these measurements range from a minimum of 0% to a maximum of 8.2% of reading. **Please note that all errors are less than 8.5% of reading.**
ASHRAE publication KC-03-1-2 - Table 5, page 9, titled "**Multi-Branch Test Results for Commercial Flow Hoods**		Tabulated data for "Hood 1 + diffuser screen" shows **"Mean Difference" = -3% and "RMS Difference" = 5%.**
Reference	**Claim**	**TSI Comment**
ASHRAE publication KC-03-1-2 - Page 11,	"Using the single value of k = *0.055* results in bias errors less than	if true for this technique, must also be true for

paragraph 3 under the sub-heading "**Supply Basket Hoods**", sentences 2 and 3:	3% and RMS errors of about 10%. These results indicate that using a single value for *k* gives **reasonable results for most flow hood applications**."	"Commercial Capture Hoods" (bias error -3%, RMS error 5%). And if, as authors indicate, "***but even for that*** (duct leakage estimates) ***test, the 5% bias is very close to being acceptable***", then surely the "Hood 1 + diffuser screen" must be even more acceptable, because it has demonstrated a smaller bias error (-3% of reading)
ASHRAE publication KC-03-1-2 - Page 12, paragraph containing sub-head "**Bag Filling**" in section entitled "**FIELD EVALUATION OF NEW TECHNIQUES**" Sentences 2 and 3	"Compared to the reference flow hood , the bias was -5% and the RMS uncertainty was 11%. These results indicate… the results of bag testing **can be used for almost all grille airflow diagnostics**, with the exception of the requirement for duct leakage estimates (***but even for that test, the 5% bias is very close to being acceptable***)."	If authors' claim is true for this technique, must also be true for "Commercial Capture Hoods" (bias error -3%, RMS error 5%). And if, as authors indicate, "***but even for that*** (duct leakage estimates) ***test, the 5% bias is very close to being acceptable***", then how much more must the "Hood 1 + diffuser screen" be <u>very close to being acceptable for that measurement</u>, because it has demonstrated a smaller bias error (-3% of reading).

From the above we can clearly conclude that using a flow hood with a flow conditioning/diffuser screen gives results that are acceptable for airflow measurement in residential HVAC applications

Additionally, the data in the Appendices from the June 2001 measurements performed at LBNL clearly demonstrate the suitability of the Accubalance 8371/8373 for residential HVAC airflow measurement

Conclusion and Recommendation:
Based upon the clear evidence presented above TSI would strongly recommend inclusion of flow hood with conditioner/diffuser screen as a recognized airflow measurement technique under Title 24 rules.

Appendices

Appendix 1

From the ASHRAE publication KC-03-1-2, we quote or cite the following:

a) Table 1. (page 2)

TSI comment: If it can be proven that a "Commercial Capture Hood" demonstrates measurement accuracy capability within +/- 10% (when compared to the "Active flow hood " utilized by the LBNL researchers), then that "Commercial Capture Hood" qualifies to be used for 5 of the 6 Applications identified in Table 1 – that is, all applications except "Determining duct leakage".

b) Page 6, paragraph 2 under the sub-head "**Flow Hood 1**", sentences 1 and 2:

"The results in Table 2 show that the flow hood … …error was reduced to less than 10% when the diffuser screen was used."

c) Page 8, paragraph containing the sub-head "**Flow Hood 1, Round One**."

"The tests on the multi-branch system were performed with the diffuser screen in place… For the 11 grilles of the multi-branch system, the mean error was 0.5 L/s (1 cfm, 1%) and the RMS error was 2.5 L/s (5 cfm/ 5%). These results show how the use of the diffuser screen combined with careful placement can give good results for this flow hood ." … "These results show that the diffuser screen makes the flow hood less sensitive to placement over the grille and improves accuracy."

d) Page 9, paragraph containing sub-head "**Flow Hoods 1 through 5, Round Two**", sentence 2:

"The diffuser screen used with Flow Hood 1 is again shown to have significant benefits, particularly for individual grille measurements."

e) Table 5, page 9, Entitled "**Multi-Branch Test Results for Commercial Flow Hoods** "

Examination of data in table 5 relating to "Hood 1 + diffuser screen" shows measurements at each of the 11 diffusers. Errors for these measurements range from a minimum of 0% to a maximum of 8.2% of reading. Please note that all errors are less than 10% of reading.

f) Table 5, page 9. Further observations:

Tabulated data for "Hood 1 + diffuser screen" shows "Mean Difference" = -3% and "RMS Difference" = 5%.

g) Page 11, paragraph 3 under the sub-heading "**Supply Basket Hoods**", sentences 2 and 3:

"Using the single value of $k = 0.055$ results in bias errors less than 3% and RMS errors of about 10%. These results indicate that using a single value for *k* gives **reasonable results for most flow hood applications**." (bold added for emphasis)

TSI comment: "bias errors" here are akin to "Mean Difference" in Table 5. Note that errors on the same scale or larger here are characterized as being "**reasonable results for most flow hood applications**". If true for the "Supply Basket Hoods", must also be true for "Commercial Capture Hoods".

h) Page 12, paragraph containing sub-head "**Bag Filling**" in section entitled "**FIELD EVALUATION OF NEW TECHNIQUES**" Sentences 2 and 3

"Compared to the reference flow hood , the bias was -5% and the RMS uncertainty was 11%. These results indicate… the results of bag testing **can be used for almost all grille airflow diagnostics**, with the exception of the requirement for duct leakage estimates (***but even for that test, the 5% bias is very close to being acceptable***)." (bold and italics added for emphasis)

TSI comment: Note here that the authors claim that -5% bias and 11% RMS error (uncertainty) indicate that this method "**can be used for almost all grille airflow diagnostics**". Again, if true for this technique, must also be true for "Commercial Capture Hoods" (bias error -3%, RMS error 5%). And if, as authors indicate, "***but even for that*** (duct leakage estimates) ***test, the 5% bias is very close to being acceptable***", then how much more must the "Hood 1 + diffuser screen" be <u>very close to being acceptable for that measurement</u>, because it has demonstrated a smaller bias error (-3% of reading).

Appendix 2

From data taken at the LBNL "Multi-Branch [Residential] Laboratory Test Apparatus" by Charlie Wright, Staff Mechanical Engineer, TSI, Inc. as assisted and witnessed by Iain S. Walker, Ph. D. and Craig P. Wray, P. Eng. using two different "Commercial Capture Hoods". This test system is described by Walker and Wray on page 5 of the ASHRAE paper. The description is briefly excerpted here: "The multi-branch laboratory tests used a full-scale duct system that is representative of many residential duct systems. It has a single return and eleven supply grilles, with a total flow of about 564 L/s (1,200 cfm)… All the grilles are the same size (400 mm x 190 mm, 15.5 in. x 7.5 in.)… The reference flow for each grille was determined using the active flow hood ."

Data was taken in June, 2001 on this same system using the same "active hood" as the reference flow standard. Tables A and B below tabulate the results of tests using a TSI Model 8373 AccuBalance Capture Hood equipped with the Flow Conditioning Screen (called a "diffuser screen" in the LBNL literature).

Table A
Multi-Branch Test Results for AccuBalance + Flow Conditioning Screen
Testing for effect of centering/uncentering of Hood on Diffuser

					Error [%]	Error [%]	Error [%]
	Reference Flow	Diffuser Centered	Diffuser In Corner	Diffuser Centered Along Edge	Diffuser Centered	Diffuser In Corner	Diffuser Centered Along Edge
Flow System Supply Boot #	LBNL Powered Capture Hood [cfm]	AccuBalance w/Screen [cfm]	AccuBalance w/Screen [cfm]	AccuBalance w/Screen [cfm]	AccuBalance w/Screen [% of flow]	AccuBalance w/Screen [% of flow]	AccuBalance w/Screen [% of flow]
1	145	138.5	141.3	141.7	-4.5	-2.6	-2.3
2	63	68	67	67.3	7.9	6.3	6.8
3	47	49.5	49.3	49.5	5.3	4.9	5.3
6	150	151.3	145.5	149	0.9	-3.0	-0.7
7	99	107.5	108.5	105.4	8.6	9.6	6.5
8	165	158.8	166.2	168.4	-3.8	0.7	2.1

Notice at all flows and all alignment/misalignment (centering) conditions, errors are less than 10% of reference flow and less than 7% when the hood is centered along the edge.

Table B
Multi-Branch Test Results for AccuBalance + Flow Conditioning Screen
All eleven diffusers tested with Hood Centered on diffuser

			Error [%]
	Reference Flow	Diffuser Centered	Diffuser Centered
Flow System Supply Boot #	LBNL Powered Capture Hood [cfm]	AccuBalance w/Screen [cfm]	AccuBalance w/Screen [% of flow]
1	145	138.5	-4.5
2	63	68	7.9
3	47	49.5	5.3
4	136	134.2	-1.3
5	86	88.4	2.8
6	150	151.3	0.9
7	99	107.5	8.6
8	165	158.8	-3.8
9	99	105.2	6.3
10	138	135.6	-1.7
11	81	86.4	6.7
Total:	1209	1223.4	1.2
9 & 11 Captured Together	180	185.8	3.2

Note: “Diffuser Centered” data repeated from Table A for diffusers 1, 2, 3, 6, 7, and 8.

Further note: All errors are 8.6% or less of reference flow measurement, including the Total flow and including the unusual case where diffusers 9 and 11 were measured simultaneously (this was possible because of their physical proximity to each other).

Table C
Single-Branch Results, AccuBalance + Flow Conditioning Screen
Supply Boot #2, No Grille

						Error [%]	Error [%]	Error [%]
Reference Flow	**Diffuser Centered**	**Reference Flow**	**Diffuser In Corner**	**Reference Flow**	**Diffuser Centered Along Edge**	**Diffuser Centered**	**Diffuser In Corner**	**Diffuser Centered Along Edge**
(Brandt Nozzle)	**AccuBalance w/Screen**	**(Brandt Nozzle)**	**AccuBalance w/Screen**	**(Brandt Nozzle)**	**AccuBalance w/Screen**	**AccuBalance w/Screen**	**AccuBalance w/Screen**	**AccuBalance w/Screen**
[cfm]	**[cfm]**	**[cfm]**	**[cfm]**	**[cfm]**	**[cfm]**	**[% of flow]**	**[% of flow]**	**[% of flow]**
107.7	115	111.0	120	112.3	121	6.7	8.1	7.8
107.7	113	111.0	118	111.8	119	4.9	6.3	6.5
107.7	119	111.0	117			**10.5***	5.4	
111.5	118					5.8		

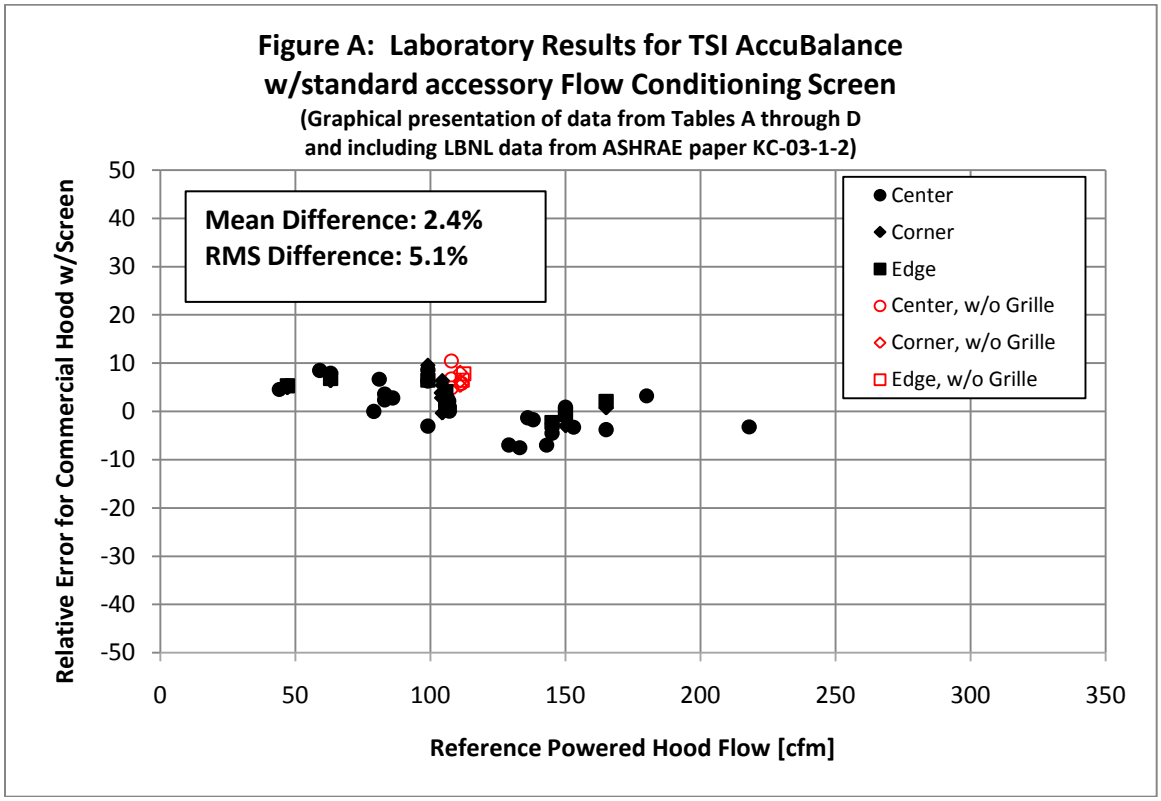
*Notice that one reading exceeds 10% error by the smallest of margins (one cfm).

TSI Comment: **"No Grille" is not a normal measurement condition in the field. In other words, the only measurement by the AccuBalance + Flow Conditioning Screen that is in error by more than 10% is on a measurement not normally encountered in the field.**

Table D
Single-Branch Results, AccuBalance + Flow Conditioning Screen
Supply Boot #2, Grille Flow Facing "Front", Edges Sealed, Fully Open

						Error [%]	Error [%]	Error [%]
Reference Flow	Diffuser Centered	Reference Flow	Diffuser In Corner	Reference Flow	Diffuser Centered Along Edge	Diffuser Centered	Diffuser In Corner	Diffuser Centered Along Edge
(Brandt Nozzle) [cfm]	AccuBalance w/Screen [cfm]	(Brandt Nozzle) [cfm]	AccuBalance w/Screen [cfm]	(Brandt Nozzle) [cfm]	AccuBalance w/Screen [cfm]	AccuBalance w/Screen [% of flow]	AccuBalance w/Screen [% of flow]	AccuBalance w/Screen [% of flow]
107.0	107	104.1	107	105.7	108	0.0	2.8	2.2
106.7	107	104.3	111	105.7	106	0.3	6.4	0.3
106.7	109	104.3	104	105.7	110	2.2	-0.3	4.1
		104.3	110				5.4	

Accuracy of all flows within 6.5%



Summary: TSI AccuBalance + Flow Conditioning Screen tested in a wide variety of measurement conditions (range of flow rates, different hood-to-diffuser centering , with and without grille). **55 of 56 data points agreed with flow standard within 10%.** Comparison to other capture hoods tested in similar conditions (see graphs below, taken from LBNL publication #47382) demonstrates the clear superiority of the TSI AccuBalance + Flow Conditioning Screen

and its ability to perform within +/-10% of LBNL's flow standard. This proves its capability to be used for 5 of the 6 Residential Flow Measurement Applications identified by LBNL.

Therefore, all commercial capture hoods must <u>not</u> be disallowed for use in complying with Title 24 residential air flow measurement requirements.

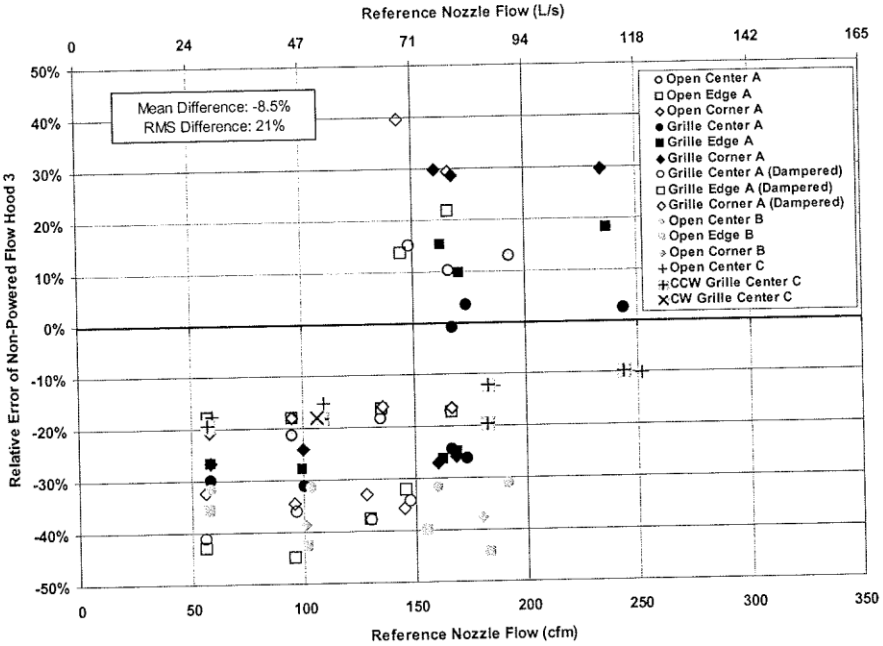


Figure 7. Standard flow hood 12 laboratory test results

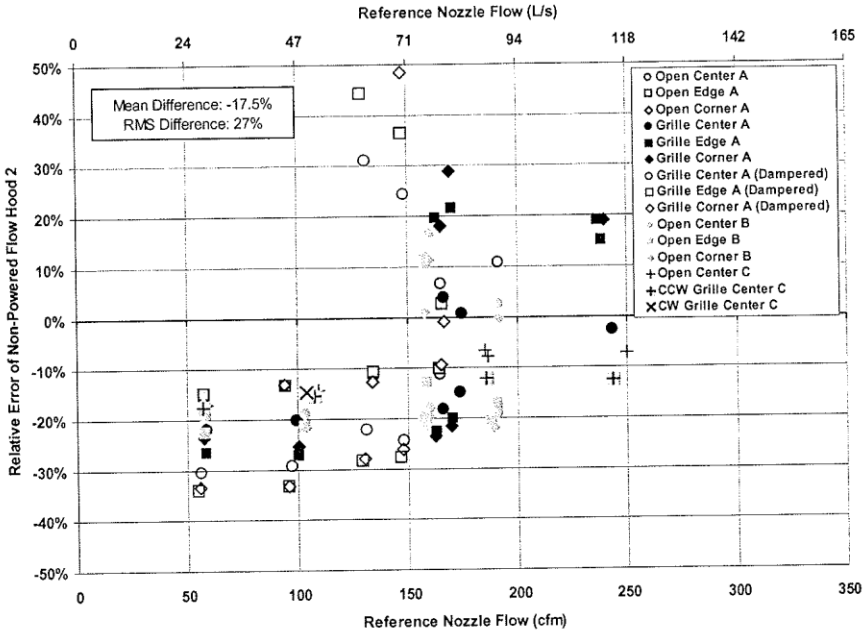


Figure 8. Standard flow hood 13 laboratory test results