Advocates Priorities – ASRAC Commercial Unitary and Heat Pump Working Group

DRAFT: Subject to change

November 2, 2022

Topics for Discussion

Our goals: Better reflect total energy consumption and losses without unduly increasing test burden.

Topics:

- Request for clarification on the proposed IVEC equation
- Fan power during cold weather and fan-only ventilation operation
- Accounting for crankcase heating
- Control settings during testing
- Representative airflow for units larger than 240,000 Btu/h
- Leakage
- Economizer pressure drop

The Proposed Equation is a good starting point

- We like the concept and agree with:
  - Assuming oversizing
  - Not including the full-load test in IVEC
  - Assuming all models have an economizer
  - Using an appropriate airflow for the economizer capacity calculation
  - Properly accounting for the economizer contribution and airflow.
- We suggest some additional energy consumption and losses be determined with limited testing and calculation, such a crankcase heating and added to the denominator.
- We believe there are more hours of fan-only operation than the working group has assumed, so a separate term may be needed.
  - We will share our analysis of the spreadsheets to show why this week.
- We are still thinking about determining fan power for the economizer airflow.
  - Fan power cannot be calculated accurately using the fan laws, since this is a wire-to-air test. It may be possible to use the method in AMCA 214.
  - During full economizing, the full airflow and power does not include the return pressure drop but does include the OA damper. Do we assume that the total pressure drop is unchanged?

The Proposed Equation is a good starting point

- We like the concept and agree with:
  - Assuming oversizing
  - Not including the full-load test in IVEC
  - Assuming all models have an economizer
  - Using an appropriate airflow for the economizer capacity calculation
  - Properly accounting for the economizer contribution and airflow.
- We suggest some additional energy consumption and losses be determined with limited testing and calculation, such a crankcase heating and added to the denominator.

$$IVEC = \frac{\sum_{i=1}^{n} h_i Q_i}{\left(\sum_{i=1}^{n}\left[h_v(P_{IFV} + P_{CT}) + (h_{iEO} + h_{iIE})(P'_{IF} + P_{CT}) + h_{iIE}(P_C + P_{CD}) + h_{iC}(P_{IF} + P_{CT} + P_C + P_{CD})\right]\right) + \boldsymbol{CCH}\ Energy}$$

- *CCH Energy* is the annual crankcase heating energy determined by a method described later in this presentation.
- $h_v(P_{IFV} + P_{CT})$ represents hours of ventilation-only operation (hv) times the sum of the fan power during ventilation (P_{IFV}) and Controls Power (P_{CT})

Questions About the Equation

$$IVEC = \frac{\sum_{i=1}^{n} h_i Q_i}{\sum_{i=1}^{n}[(h_{iEO} + h_{iIE})(P'_{IF} + P_{CT}) + h_{iIE}(P_C + P_{CD}) + h_{iC}(P_{IF} + P_{CT} + P_C + P_{CD})]}$$

- How is the integrated economizer compressor and condenser power ($h_{iIE}(P_C + P_{CD})$) determined for the bands where the test temperature is higher than economizing temperatures?
- How is the cooling determined for each band?
  - Do the hours of operation (h_i) change, depending on the turndown capability of the refrigerant system, or is this baked into the degradation equation?
  - Are cooling hours where the load can be covered by the ventilation airflow included in Q_i?
- We are still thinking about determining fan power for the economizer airflow.
  - Fan power cannot be calculated accurately using the fan laws, since this is a wire-to-air test. It may be possible to use the method in AMCA 214.
  - During full economizing, the full airflow and power does not include the return pressure drop but does include the OA damper. Do we assume that the total pressure drop is unchanged?

Fan Power during cold weather and Fan-Only Ventilation Operation

Fan-only operation during cooling hours

- We believe that there significantly more hours of fan operation in cooling mode than the original analysis recognizes.
  - This will be discussed in the next slides.
- We want to work with the working group to determine if the quantity of actual hours is enough to include a term for fan-only operation in the IVEC equation.

Fan power during cold-weather operation

- We are open to the idea of creating a separate metric for fan power for fans in equipment that include furnaces.

Analysis of Fan-Only Hours During Cooling

Method of Analysis:

- Three building type spreadsheets were imported into Microsoft Access.
- The occupied hours where the OA temperature exceeded 50°F and there was less than 3% heating and cooling loads were counted.
- For the same OA greater than 50 °F, we counted the total hours and subtracted the unoccupied hours where there was <3% cooling load.
  - This value should closely match the total hours in the denominator of IVEC.
- Hours are still understated because multiple units in the prototypes were combined into one, so a cooling hour in one becomes a cooling hour in all when combined.
  - We will rerun some of the models with the units disaggregated to test the sensitivity.

Building Type	Climate Zone	Total Hours Where OA > 50°F	Unoccupied Hours Where Total Occupied Hours Where <3% Heating or Cooling Load	Total Cooling and Fan Operation Hours Where OA > 50°F	Total Occupied Hours Where <3% Heating or Cooling Load	Percent Fan-Only Hours
Warehouse	1A	8713	2556	6157	135	2.2%
Warehouse	2A	8089	3011	5078	388	7.6%
Warehouse	2B	7737	2676	5061	658	13.0%
Warehouse	3A	6583	3001	3582	600	16.8%
Warehouse	3B	6753	2664	4089	614	15.0%
Warehouse	3C	7959	4361	3598	811	22.5%
Warehouse	4A	4962	2488	2474	476	19.2%
Warehouse	4B	5376	2411	2965	578	19.5%
Warehouse	4C	4917	2731	2186	674	30.8%
Warehouse	5A	4196	2295	1901	563	29.6%
Warehouse	5B	4286	1991	2295	600	26.1%
Warehouse	5C	3651	2009	1642	411	25.0%
Warehouse	6A	3946	2227	1719	561	32.6%
Warehouse	6B	3640	1891	1749	649	37.1%
Warehouse	7	3332	1892	1440	463	32.2%
Warehouse	8	2650	1500	1150	461	40.1%
					Climate Zone Weighted Average:	**22.7%**

Analysis of Fan-Only Hours During Cooling (cont.)

Building Type	Climate Zone	Total Hours Where OA > 50°F	Unoccupied Hours Where Total Occupied Hours Where <3% Heating or Cooling Load	Total Cooling and Fan Operation Hours Where OA > 50°F	Total Occupied Hours Where <3% Heating or Cooling Load	Percent Fan-Only Hours
Retail-Standalone	1A	8665	761	7904	0	0.0%
Retail-Standalone	2A	8089	2354	5735	594	10.4%
Retail-Standalone	2B	7737	2752	4985	679	13.6%
Retail-Standalone	3A	6583	2007	4576	862	18.8%
Retail-Standalone	3B	6753	2364	4389	690	15.7%
Retail-Standalone	3C	7959	3005	4954	999	20.2%
Retail-Standalone	4A	4962	1643	3319	577	17.4%
Retail-Standalone	4B	5376	1542	3834	431	11.2%
Retail-Standalone	4C	4917	1743	3174	993	31.3%
Retail-Standalone	5A	4196	1472	2724	585	21.5%
Retail-Standalone	5B	4286	1298	2988	364	12.2%
Retail-Standalone	5C	3651	1108	2543	585	23.0%
Retail-Standalone	6A	3946	1452	2494	583	23.4%
Retail-Standalone	6B	3640	1106	2534	475	18.7%
Retail-Standalone	7	3332	1147	2185	464	21.2%
Retail-Standalone	8	2650	847	1803	334	18.5%
					Climate Zone Weighted Average:	**18.2%**

Building Type	Climate Zone	Total Hours Where OA > 50°F	Unoccupied Hours Where Total Occupied Hours Where <3% Heating or Cooling Load	Total Cooling and Fan Operation Hours Where OA > 50°F	Total Occupied Hours Where <3% Heating or Cooling Load	Percent Fan-Only Hours
Medium Office	1A	8713	3284	5429	5	0.1%
Medium Office	2A	8089	3156	4933	4	0.1%
Medium Office	2B	7737	2696	5041	9	0.2%
Medium Office	3A	6583	2593	3990	4	0.1%
Medium Office	3B	6753	2365	4388	5	0.1%
Medium Office	3C	7959	3148	4811	1536	31.9%
Medium Office	4A	4962	1899	3063	0	0.0%
Medium Office	4B	5376	1773	3603	0	0.0%
Medium Office	4C	4917	1896	3021	0	0.0%
Medium Office	5A	4196	1601	2595	0	0.0%
Medium Office	5B	4286	1352	2934	0	0.0%
Medium Office	5C	3651	1170	2481	0	0.0%
Medium Office	6A	3946	1479	2467	0	0.0%
Medium Office	6B	3640	1230	2410	0	0.0%
Medium Office	7	3332	1131	2201	0	0.0%
Medium Office	8	2650	863	1787	0	0.0%
					Climate Zone Weighted Average:	**2.8%**

- We will add additional building types when the version 12 spreadsheets are available.
- Medium office is always in cooling, because each unit serves a portion of the core.

Crankcase Heating (CCH) is a large and variable power consumer

- We recognize that the control of refrigerant migration is necessary.
- The power can vary widely. For two compressor manufactures, a 15-ton unit with two compressors:
  - Manufacturer A 180W (2 X 90W)
  - Manufacturer B 140W (2 X 70W)
  - Manufacturer B single variable-speed compressor 56W.
- Literature review indicates that CCH operates all hours the compressor is off, regardless of temperature.

- Compressor manufacturer A:

  "The crankcase heater must remain energized during compressor off cycles."
- Compressor manufacturer B:

  "Belt crankcase heaters are not self regulating; control must be applied to energize the belt heater once the compressor has been switched off."
- CUAC/HP Manufacturer 1:

  "The heaters will be energized when the compressor is not running providing the unit disconnect switch is closed."
- CUAC/HP Manufacturer 2:

  "When the compressor is "NOT" running, the heaters should be energized."

CCH is never completely captured in the test procedure, and often not at all

- Controls power (P_{CT}) only includes non-operating compressors. An example from AHRI 340/360 is shown.
  - Nothing is captured for units with single compressors.
  - Twinned compressors may shut off CCH for both during operation of one.
- There is no requirement to capture CCH as part of P_{CT}.
  - The components of P_{CT} are not described in the current test procedure.
  - CCH power is often on the compressor circuit, so would not be captured in P_{CT}.

Table G10. Example 5. Test Results

Test	Stage	Test OAT	Req OAT	Actual Percent Load	Test Net Cap	Test CFM (Std Air)	Cmpr (P_C) (Test)	Cond (P_{CD}) (Test)	Indoor (P_{IF}) (Test)	Control (P_{CT}) (Test)	EER (Test)
-	-	°F	°F	%	Btu/h	scfm	W	W	W	W	Btu/(W·h)
1	2	95.1	95.0	100.0	115,493	3354	8615	650	1050	100	11.09
2	2	81.3	81.5	106.7	123,267	3354	8073	650	1050	100	12.49
3	1	81.7	81.5	52.4	60,510	3354	3855	325	1050	150	11.25
4	1	67.6	68.0	53.3	61,536	3354	3588	325	1050	150	12.04
5	1	65.3	65.0	53.4	61,716	3354	3545	325	1050	150	12.17

"For tests 3, 4, and 5, the control power increased based on the use of a crankcase heater in the inactive compressor."

Estimated Annual Electricity Consumption of CCH

- Cooling only
- Based on the spreadsheets and Calculated for Medium Office, Standalone Retail, and Warehouse
- Assumptions for cooling only
  - All zero cooling hours are CCH-on time.
  - For partial cooling hours:
    - If >50%, CCH hours = 1 – cooling load %
    - If <50%, CCH hours = 1 – (2 X cooling load %)
  - Economizer hours were not considered and were treated as "compressor on" time.
  - Cooling power is the cooling percent load X the EER plus the fan power for that hour. Degradation was not considered.
- Analysis for heat pumps and economizers will be added.

		Climate-Zone Market Share Weighted Average Annual Values			
Builidng Type	Power Consumption of CCH	Cooling Electricity	CCH Operation Time	CCH Electricity	Increase in Energy Consumption With CCH
	W	kWh	Hours	kWh	%
Medium Office	180	15,622	6,378	1,148	9.3%
	140	15,622	6,378	893	7.2%
	56	15,622	6,378	357	2.9%
Standalone Retail	180	14,272	7,119	1,281	11.3%
	140	14,272	7,119	997	8.8%
	56	14,272	7,119	399	3.5%
Warehouse	180	8,610	7,670	1,381	28.0%
	140	8,610	7,670	1,074	21.8%
	56	8,610	7,670	430	8.7%

Annual CCH power compared to cooling and fan power for 180W, 140W and 56W

CCH Testing and Energy Calculation

- The annual CCH electricity use can be confirmed with testing, much like the Central Air Conditioner P_{off} test.
- The baseline (worst case) operating hours would be established in the test procedure.
- The actual operating hours will be determined and multiplied by the CCH power. The baseline "compressor off" hours will be part of the test procedure.
- When the operation is temperature dependent, a bin-hours chart would be part of the procedure.

Example CCH Bin Hours Chart

Temperature ^oF			Baseline Hours	Example Unit	
From	To	Percent	1400	Hours	
90	120	1%	14	0	
80	89.9	5%	70	0	
70	79.9	10%	140	0	
60	69.9	20%	280	280	
50	59.9	25%	350	350	
40	49.9	15%	210	210	
30	39.9	10%	140	140	
20	29.9	8%	112	112	
10	19.9	4%	56	56	
-30	9.9	2%	28	28	
			Total:	**1176**	Hours
			Watts:	**150**	W
			CCH Power:	**176400**	Wh

Example: The CCH is controlled to only operate at 70^{o}F or below and uses 150W.

Note: the numbers in the chart are not a proposal –they are for demonstration only

Testing with Default Control Settings

Default control settings

- There are currently no requirements to test equipment at their default control settings.
- Most replacement equipment will run at the default settings.
- The VRF test procedure limits the settings the manufacturer can specify in the Special Test Instructions to:
  - Compressor speed
  - Condenser fan speed
  - Outdoor valve position.
- We are reviewing manufacturer literature and will provide specific suggestions.

Examples of differences in default settings.

- Minimum Airflow:
  - Manufacturer A: 50% of full airflow
  - Manufacturer B: 66% of full airflow
- Supply air temperature:
  - Manufacturer C: 55^{o}F
  - Manufacturer D: Not less than 50^{o}F
- Head Pressure Control:
  - Manufacturer E: 66^{o}F outdoor air
  - Manufacturer F: When condensing temperature is less than 80^{o}F
- Supply air temperature limit for economizing:
  - Manufacturer G: 4^{o}F offset from SAT setting.
  - Manufacturer H: No offset value in the controls

13

Leakage

- Leakage has significant cost in colder climates
- We propose that manufacturers test leakage once for each cabinet size.
  - Test the negative pressure side per AHRI 1350 Appendix C6.1, Method 2, modified to include dampers in place and unsealed.
  - We will conduct further analysis of the spreadsheet data to determine the appropriate pressure and hours to calculate the added energy.
- We are working through how to include this in the metric.

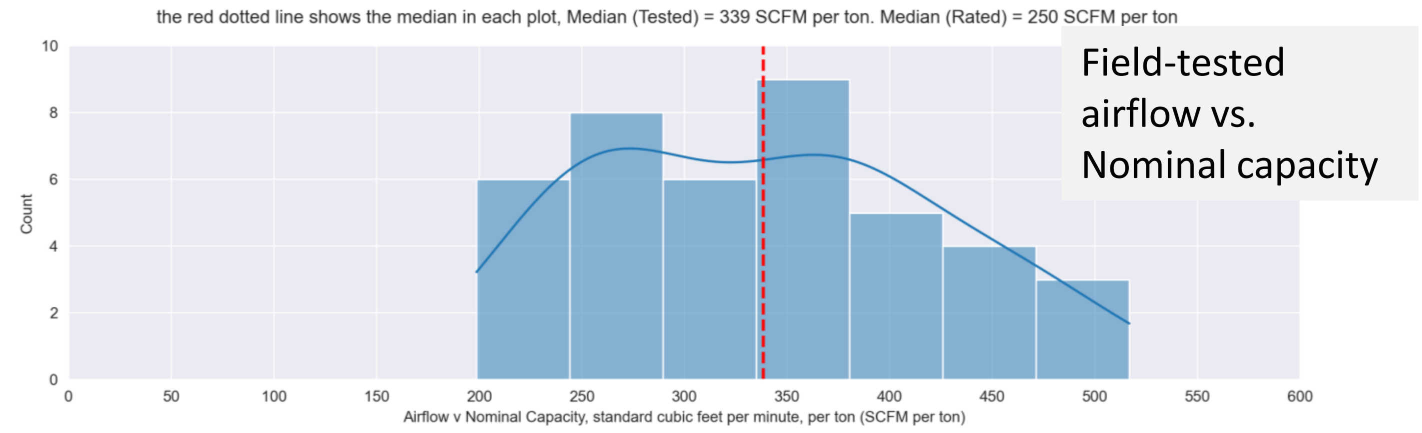
		Increased Gas Consumption		
Building Type	Climate Zone	Loss 100 scfm %	Loss 200 scfm %	Loss 600 scfm %
Warehouse	1A	0.0%	0.0%	0.0%
Warehouse	2A	11.5%	22.9%	68.8%
Warehouse	2B	6.2%	12.4%	37.3%
Warehouse	3A	2.1%	4.2%	12.5%
Warehouse	3B	4.1%	8.1%	24.3%
Warehouse	3C	4.3%	8.6%	25.7%
Warehouse	4A	1.5%	3.0%	8.9%
Warehouse	4B	2.3%	4.7%	14.1%
Warehouse	4C	1.3%	2.7%	8.0%
Warehouse	5A	1.1%	2.1%	6.4%
Warehouse	5B	1.3%	2.5%	7.6%
Warehouse	5C	1.1%	2.1%	6.3%
Warehouse	6A	1.5%	3.1%	9.2%
Warehouse	6B	1.0%	2.1%	6.3%
Warehouse	7	1.4%	2.8%	8.4%
Warehouse	8	0.7%	1.3%	3.9%
Climate Zone Weighted Average:		2.9%	5.9%	17.6%

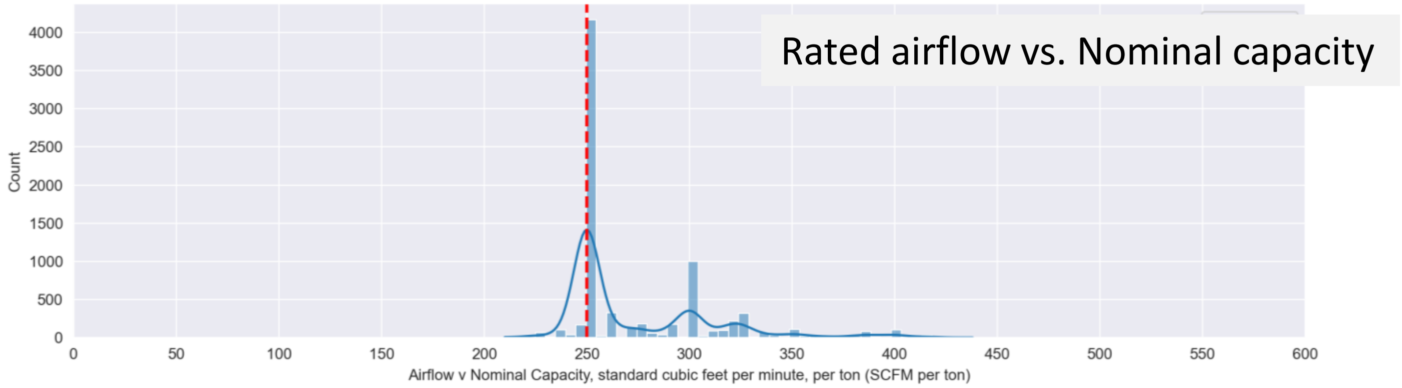
The percentage increased use gas dues to leakage, based on the SCFM of the leakage and the climate zone.

- 600 SCFM leakage for the spreadsheet’s 15-ton unit is representative of the leakage data for a 7.5-ton unit shown previously.
- Based on fan only on during heating operation and unoccupied.

Statistical analysis suggests that full-load rated airflow is low for larger units compared to real-world applications

CUAC/HPs with cooling capacity greater than 240 kBtu/h





	Field	Construct Connect	Rated
Number of records	41	19	7,754
Median	339	400	250
Standard deviation	85 (Broad)	74 (Broad)	37 (Skinny)
Skew	0.26	-2.44	1.54
Kurtosis	- 0.92	5.66	2.07

50, 60, 70, 80, 90, 95, 99th percentiles for rated airflow vs. nominal capacity < field-tested airflow vs. nominal capacity

Units (cfm/ton, scfm/ton)

Source: AHRI database accessed 03/23/2022 at 9:26 a.m. PDT

Economizer Pressure Drop

- We have been conducting research into how pressure drop changes based on changes in total airflow. It appears that for the outdoor airflow rate to remain the same, the pressure drop across the OA damper must remain the same.
  - Therefore, the negative pressure in the mixing box remains unchanged at all airflows.
  - We are working with others to confirm this is the case.
- We are also working on an analysis that shows the effect the variation in economizer pressure drop between models will have on IVEC.

Questions?