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Carrier
A United Technologies Company

April 12, 2012

CALIFORNIA ENERGY COMMISSION
Attention: Docket No. 12-BSTD-1
Dockets Office
1516 Ninth Street, MS-4
Sacramento, CA

Dear CEC Staff:

Carrier Corporation, a division of United Technologies has review the proposed 45 day language posted on the CEC web page as of Feb 24, 2012 and would like to file the following comments and proposed changes. We realize that the comments are late, but most of the comments are to correct minor wording errors and references. Any substantive comments have already been filed thru the combined industry comments from AHRI. I have included some of the comments submitted to AHRI for completeness.

In the document labeled 45-Day_2013_Standard_Consolidated.pdf.

In section 100.1 Definitions and Rules of Construction

On page 33 there is a definition that states.

> "Air Conditioner is an appliance that supplies cooled air to the space for the purpose of cooling object within the space"
>
> This is not technical correct as air conditioners provide conditions air that is both cooled and dehumidified to the space. We propose that the wording be changed to the following.
>
> "Air Conditioner is an appliance that supplies cooled and dehumidified air to the space for the purpose of cooling object within the space"

On page 34 a reference is made to AHRI 210/240 with addendum 1. AHRI has now released addendum 2 which should also be included with the reference. You can download the revised standard from the AHRI website.

On page 34 a reference is made to AHRI 550/590. This standard has been revised and the reference should be changed to AHRI 550/590 (I-P) – 2011. You can download the standard from the AHRI website.

Also on page 34 you should add AHRI Standard AHRI 1230-2010 with addendum 1: Performance Rating of Variable Refrigerant Flow (VRF) Multi-Split Air-Conditioning and Heat Pump Systems. Also you need to add the efficiency requirements to the Title 24 as defined in ASHRAE-2010 as currently in Title 24 there are not requirements.

On page 48 a definition for Integrated Energy Efficiency Ratio (IEER) has been added. I states the following;

"INTEGRATED ENERGY EFFICIENCY RATIO (IEER) is a single-number performance parameter based on part load EER expressing part load efficiency established by the ANSI/AHRI Standard (2007) for air conditioning equipment on the basis of weighted operation at various load capacities for the equipment as determined using the applicable test method in the Appliance Efficiency Regulations or Section 110.2. This parameter was developed by AHRI as an improvement over the previous part load performance parameter IPLV and has been in use since 1/1/2010."

The ANSI/AHRI Standard (2007) is missing the actual standard and the reference should be AHRI 340/360 without the data as the reference section contains the full details. The actual IEER is a metric that is now used on most packaged equipment and is referenced in AHRI 340/360, AHRI210/240 and AHRI 1230. Additional products are likely to be added. For ducted equipment the IEER has replaced the IPLV, but IPLV is still used as the metric for part load for chilled water equipment. The definition for IPLV is also not totally correct. I would recommend you just just use the official definition from AHRI 340/360 as noted below.

"INTEGRATED ENERGY EFFICIENCY RATIO (IEER) A single number cooling part-load efficiency figure of merit calculated per the method described in AHRI Standard 340/360. This metric replaces the IPLV for ducted and non-ducted units."

On page 48 there is a definition for integrated plart load valve (IPLV) which is now not correct. The IPLV is now only used for chillers as defined in AHRI 550/590. The definition should be changed to the official definition in AHRI 550/590 which is;

Integrated Part-Load Value (IPLV). A single number part-load efficiency figure of merit calculated per the method described in AHRI Standard 550/590 for use with chillers.

In section 110.2 MANDATORY REQUIREMENTS FOR SPACE CONDITIONING EQUIPMENT

In page 71 the standard requires that equipment met the efficiency requirements in table 110.2A thru 110.2G. There are products that are missing from the tables as well as new products that have been added to ASHRAE 90.1 that are not covered in the Title 24 requirements. The tables used are;

Table 110.2A - ELECTRICALLY OPERATED UNITARY AIR CONDITIONERS AND CONDENSING UNITS –MINIMUM EFFICIENCY REQUIREMENTS
Table 110.2B - UNITARY AND APPLIED HEAT PUMPS, MINIMUM EFFICIENCY REQUIREMENTS
Table 110.2C - AIR-COOLED GAS-ENGINE HEAT PUMPS
Table 110.2D - WATER CHILLING PACKAGES – MINIMUM EFFICIENCY REQUIREMENTS
Table 110.2E - PACKAGED TERMINAL AIR CONDITIONERS AND PACKAGED TERMINAL HEAT PUMPS – MINIMUM EFFICIENCY REQUIREMENTS
Table 110.2F - HEAT TRANSFER EQUIPMENT
Table 110.2G - PERFORMANCE REQUIREMENTS FOR HEAT REJECTION EQUIPMENT

I will cover the products that are missing from each table later in my comments. There are no requirements listed for the following products. These needed to be added to the Title 24 standard.

- Warm-air furnaces and combination warm-air furnaces/air conditioning units as defined in ASHRAE 90.1 table 6.8.1E
- Gas and Oil Fired Boiler as listed in ASHRAE 90.1 table 6.8.1F
- Electrical Operating Variable Refrigerant Flow Air Conditioners as listed in ASHRAE table 6.8.1I

- Electrical Operated Variable Refrigerant Flow Air to Air and Applied Heat Pumps as listed in ASHRAE table 6.8.1J
- Air Conditioners and Condensing Units Serving Computer Rooms as listed in table 6.8.1K

On page 72 the equation for the Kadj factor A is not shown correctly. The 4, 3, and 2 factors need to be shown in superscript as to indicate they are an exponent.

Current Equation format

A = 0.00000014592 * (LIFT)4 – 0.0000346496 * (LIFT)3 + 0.00314196 * (LIFT)2 – 0.147199 *(LIFT) +
3.9302

The correct format is;

$A = 0.00000014592 * (LIFT)^4 – 0.0000346496 * (LIFT)^3 + 0.00314196 * (LIFT)^2 – 0.147199 *(LIFT) +$
3.9302

On page 76 in table 110.2-A there are several things that need to be corrected.

- The requirement that minimum efficiencies after 1.1.2015 will be determined by Title 20 section will violate federal preemption if the levels exceed the before 1/1/2015 levels which are the federal minimums.
- The requirements for water cooled and evaporatively cooled products with capacities less than 240,000 Btu/hr are missing.
- The requirements for through the wall units are missing
- The requirements for high duct velocity units are missing
- The note a which states IEERs are only applicable to equipment with capacity modulation is incorrect and should be removed. The IEER requirement covers units with a single stage of capacity as defined in AHRI 340/360
- The table is show twice in the standard

On page 79 in table 110.2-B there are several things that need to be corrected.

- The requirements for through the wall units are missing
- The requirements for high duct velocity units are missing
- The requirements for water source heat pumps are missing
- The requirements for ground source heat pumps are missing

On page 123 it the standard allows factory installed economizers to be exempted from the Functional Testing if certified by the commission. The industry does not understand how this is done and procedures need to be released to show how this can be done.

On page 123 there are several new requirements that define requirements for covered processes which are based on the use on non-critical refrigeration systems, but are not applicable to CO2 supercritical based refrigerant systems. How will the new low GWP CO2 systems be certified to meet Title 24 requirements.

On page 184 in table 140.4-A it requires for climate zone 1 to have 115% better efficiency to eliminate an economizer. Climate zone 1 appears to be close to ASHRAE climate zone 7 where the efficiency

improvement is 72%. The number appears to be an error. The other numbers also do not appear to agree with the ASHRAE numbers that were justified and developed based on models. Using the ASHRAE climate zones and mapping to the California climate zones we would suggest the following valves. We recommend these be used, or we would like to see the justification for the other numbers which was never shared with the industry.

The proposed revisions are shown

Climate Zone	Title 24	ASHRAE 90.1
1	155%	72%
2	40%	65%
3	75%	65%
4	40%	64%
5	50%	74%
6	35%	32%
7	25%	32%
8	25%	32%
9	25%	32%
10	20%	32%
11	30%	32%
12	30%	32%
13	30%	32%
14	25%	32%
15	10%	32%
16	60%	72%

In most cases the Title 24 appears to be less restrictive than the ASHREAE 90.1 requirements. This is surprising as the energy rates in California are higher than used for ASHRAE 90.1 analysis.

In table 140.4-B it defines the requirements for high limit economizer controls. We have several comments regarding this table which most of the comments have already been communicated thru the AHRI industry comments. Carrier has done extensive studies using full building models based on the PNNL ASHRAE standard work models. Unlike the studies that were likely used to develop the requirements in the 45 day language, we used models based on minimum requirements for the ASHRAE 2010 standard including the new requirements on 2 speed fans and staging requirements defined in the 45 day language and in addendum AQ to ASGRAE 90.1. The details of the study were sent by AHRI, but are also included in the appendix to this document.

1. We support the elimination of the fixed enthalpy, electronic enthalpy and differential enthalpy for the California climates.
2. The high limit settings for the drybulb are higher than our study shows. For example with 75 F and the added heat of the full speed supply fan the actual leaving air temperature to the space will be higher than the modeled return air temperatures which will result in negative capacity contribution of the economizer. It is similar to the logic tht must have been used to develop the offset requirements for the differential drybulb. Another advantage of this is it will prevent high moisture levels being introduced to the space during raining days and mornings when moisture levels can be high. This is unique to DX constant volume systems where the load may not be high enough to turn on the mechanical cooling like variable volume systems. Based on our study we would recommend the following high limit optimal setpoints.

Climate Zone	Title 24	Optimal
1	75	66
2	73	67
3	75	65
4	73	66
5	75	67
6	71	69
7	69	66
8	71	69
9	71	69
10	73	69
11	75	69
12	75	69
13	75	69
14	75	69
15	75	69
16	75	69

3. The proposal includes some new requirements for differential drybulb which include an offset for the return air temperature. Our studies have confirmed that this is a good idea, but we found the offset valves can actual be a little higher has shown in the following table. We recommend the optimum valuves be used.

Climate Zone	Title 24	Optimal
1	0	9
2	2	6
3	0	9
4	2	8
5	0	6
6	4	6
7	6	6
8	4	6
9	4	6
10	2	6
11	0	6
12	0	6
13	0	6
14	0	6
15	0	6
16	0	9

4. The proposal includes some new requirements for tolerances are sensors. The Carrier study shows that the impact of the very tight tolerances as a very small impact on energy savings can not be economically justified. As shown in the study with the higher change over temperatures the incremental benefit to energy cost savings is very flat and changes in the drybulb change over setpoint due to tolerance has a very small impact. You can find the details in the appendix study summary. Based on this we recommend the following changes.

- The dry bulb tolerance should be changed from a +/- 1 F to a +/- 2 F with a range of 60 to 80 F temperatures
- The wetbulb temperature tolerance should be eliminated as it is not used in the requirements.
- The enthalpy tolerance should be change form with 1 Btu/lbm to +/- 3 Btu/lbm over a range of 20 to 36 Btu/lbm
- The humidity tolerance should be eliminated as it is not used in the requirements.
- A tolerance of +/- 3 F differential tolerance should be added to the differential drybulb sensor requirements.

5. The footnote b requires a selectable setpoint device to have setpoints within 2 F and 1 Btu/lbm. We suggest that the drybulb setpoint be 1 F.
6. In requirement D it require economizer and return dampers shall be certified to have a maximum leakage rate of 10 cfm.sf. We suggest that it be changed to the following to make it clear that leakage must be complied with for both the outside air and return air.

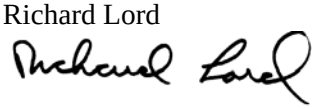
   > Damper leakage. Economizer outside and return dampers shall be certified to have a maximum leakage rate of 10 cfm/sf at 1.0 in. w.g. when tested in accordance with AMCA Standard 500.

7. In new standard requires sensor calibration it is not clear what is required. If the intent is to use field instrumentation carried in a service truck that is not itself calibrated and likely is out of calibration to calibrate a sensor that is factory calibrated there likely will be issues. To do it properly would require laboratory grade instrumentation that is calibrated routine against know standards. We recommend that factory certified calibration be acceptable if not preferred.

Again sorry that these comments are 1 day late, but the study of the economizer took considerable time and effort. Most of the changes are editorial other than the economizer high limit comments which were mostly covered in the AHRI industry comments.

If you have any questions please feel free to contact me.

Richard Lord



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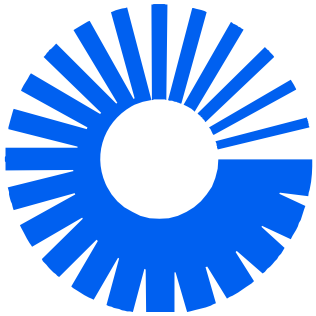

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TITLE 24-2013 ECONOMIZER REQUIREMENTS

Richard Lord 04-10-2012

Title 24 Economizer Change Background

- In the proposed 45 day language for the Title 24 Standard several changes are being made to the economizer requirements
  - Addition of accuracy requirements for high limit changeover devices
    - Dry bulb and wet bulb temperatures accurate to +/-1 F (at what temperature?)
    - Enthalpy accurate to with 1 Btu/lbm (? +/-)
    - Relative humidity accurate to within 5% (5% of what)
  - Revision to the high limit shutoff control requirements defined in table 140.4-B with both elimination of some options and changes in set points
    - Eliminated Fixed Enthalpy, Electronic Enthalpy, and Differential Enthalpy
    - Change is dry bulb set points and addition of offset to differential drybulb
- Lowered the threshold for economizers to 54,000 Btu/hr
- Revision in the economizer elimination table to be similar to ASHRAE 90.1
- Addition of 2 speed and fan staging requirements for >65K has been added
- In parallel to this ASHRAE 90.1 has also been looking at the same type of changes

Title 24 Economizer High Limit

TABLE 140.4-B AIR ECONOMIZER HIGH LIMIT SHUT OFF CONTROL REQUIREMENTS

Device Type[a]	Climate Zones	Required High Limit (Economizer Off When):	
		Equation[b]	Description
Fixed Dry Bulb	1, 3, 5, 11-16	$T_{OA} > 75°F$	Outdoor air temperature exceeds 75°F
	2, 4, 10	$T_{OA} > 73°F$	Outdoor air temperature exceeds 73°F
	6, 8, 9	$T_{OA} > 71°F$	Outdoor air temperature exceeds 71°F
	7	$T_{OA} > 69°F$	Outdoor air temperature exceeds 69°F
Differential Dry Bulb	1, 3, 5, 11-16	$T_{OA} > T_{RA}$	Outdoor air temperature exceeds return air temperature
	2, 4, 10	$T_{OA} > T_{RA}-2°F$	Outdoor air temperature exceeds return air temperature minus 2°F
	6, 8, 9	$T_{OA} > T_{RA}-4°F$	Outdoor air temperature exceeds return air temperature minus 4°F
	7	$T_{OA} > T_{RA}-6°F$	Outdoor air temperature exceeds return air temperature minus 6°F
Fixed Enthalpy[c] + Fixed Drybulb	All	$h_{OA} > 28$ Btu/lb[c] or $T_{OA} > 75°F$	Outdoor air enthalpy exceeds 28 Btu/lb of dry air[c] or Outdoor air temperature exceeds 75°F
~~Fixed Enthalpy[c]~~	~~4, 6, 7, 8, 9, 10 & 12~~	~~$h_{OA} > 28$ Btu/lb[b]~~	~~Outdoor air enthalpy exceeds 28 Btu/lb of dry air[b]~~
~~Electronic Enthalpy~~	~~All~~	~~$(T_{OA}, RH_{OA}) > A$~~	~~Outdoor air temperature/RH exceeds the "A" set point curve[c]~~
~~Differential Enthalpy~~	~~All~~	~~$h_{OA} > h_{RA}$~~	~~Outdoor air enthalpy exceeds return air enthalpy~~

[a] Only the high limit control devices listed are allowed to be used and at the setpoints listed. Others such as Dew Point, Fixed Enthalpy, Electronic Enthalpy, and Differential Enthalpy Controls are prohibited in all climate zones. ~~Fixed Enthalpy Controls are prohibited in climate zones 1, 2, 3, 5, 11, 13, 14, 15 & 16.~~

[b] Devices with selectable (rather than adjustable) setpoints shall be capable of being set to within 2°F and 2 Btu/lb of the setpoint listed.

~~[b]~~[c] At altitudes substantially different than sea level, the Fixed Enthalpy limit value shall be set to the enthalpy value at 75°F and 50% relative humidity. As an example, at approximately 6000 foot elevation the fixed enthalpy limit is approximately 30.7 Btu/lb.

~~[c] Set point "A" corresponds to a curve on the psychometric chart that goes through a point at approximately 75°F and 40% relative humidity and is nearly parallel to dry bulb lines at low humidity levels and nearly parallel to enthalpy lines at high humidity levels.~~

Title 24 Sensor Accuracy Requirements

G. **Sensor accuracy.** Outdoor air, return air and supply air sensors shall be calibrated within the following accuracies.

   i. Drybulb and wetbulb temperatures accurate to ±1°F

   ii. Enthalpy accurate to within 1 Btu/lb

   iii. Relative humidity accurate to within 5%

H. **Sensor calibration data.** Sensor calibration data of sensors used for control of economizer shall be plotted on sensor performance curve.

I. **Sensor high limit control.** Sensors used for the high limit control shall be located to prevent false readings, e.g. properly shielded from direct sunlight.

J. **Relief air system.** Relief air system shall be designed to provide up to 100% outside air without over-pressurizing the building

ASHRAE 90.1 Study

- In the following pages you will find the result of the work that Carrier has to analysis the high limit set points and set point accuracy
- The basic study which is very detailed is being done for ASHRAE 90.1 change evaluations, but has been adapted to the 16 Title 24 climate zones.
- What I did is take the ASHRAE 90.1 standard model for a 5,000 ft2 office building and use it to model a 7 ton rooftop equipped with the 2 speed fan and staging requirements defined by ASHRAE 90.1 and Title 24 proposed changes including the ASHRAE requirement for 2 speed economizers
- I then ran the model for each of the 17 climate zones starting at a high limit of 55 F and ramped it up to 80 F
- I also mapped the ASHRAE climate zones to the Title 24 16 climate zones so that we can use the data for analysis of title 24.
- I used an energy cost of $.1032/kWh which is the ASHRAE standard work number. California will likely be more like $.16/kWh but I was not sure if there is a defined number for analysis so I used the ASHRAE US average.

Study Scope

We looked at the following items.

- Drybulb change over setpoints and drybulb sensor accuracy
- Differential drybulb setpoint and accuracy
- Enthalpy changeover setpoints and accuracy

General Comments on Tolerances

- As noted earlier the Title 24 change proposal includes requirements on accuracy.
  - Drybulb and wetbulb temperatures accurate to ±1°F
  - Enthalpy accurate to within 1 Btu/lb
  - Relative humidity accurate to within 5%

- Neither the wetbulb or humidity are used in the requirements for economizer high limits and should be removed. Yes they may be used to determine enthalpy, but there already is a tolerance on enthalpy.
- The bulb temperature has an accuracy of +/- 1 F which is too tight and not cost justified as will be shown in the following study
- Typically when an accuracy is specified for temperature it is over a given range of temperatures. As the proposal only requires switching at a range of 69 to 75 F the accuracy should also include a range of 60 to 80 F
- The enthalpy is not properly specified. We are assuming it is required to be +/- 1 Btu/lbm which is also too tight and not economically justified as will be shown in the following study.
- The enthalpy should also include an accuracy range of around 25 to 35 Btu/lbm
- Not sure why there is a requirement on setpoint capability which is larger than the accuracy requirements. Does not make sense.

Inconsistent Tolerances

- Although the wetbulb tolerance is not need you can compare the +/1 F wetbulb and drybulb temperature impact on enthalpy
  - For example take 65 F drybulb/65 F wetbulb with 63 F drybulb/63 F wetbulb and the change in enthalpy is 30.06 Btu/lbm to 28.572 Btu/lbm for a change of 1.488 Btu/lbm.
  - The enthalpy tolerance is +/- 1 Btu/lb which would require 50% tighter tolerances on the drybulb and wetbulb temperatures

- You can do the same analysis for the relative humidity tolerance of 5%. Starting with 65 F drybulb and 100% RH and then looking at 63 F (-2 F = +/- 1 F) and 90% RH (-10% = +/-5%) the enthalpy change is 30.06 Btu/lbm to 27.203 Btu/lbm for a change of 2.857 Btu/lbm is 2.8 times the tolerance for the enthalpy

- Conclusion is the specific tolerances do not agree with the end result tolerance for Btu/lbm

Drybulb Setpoint and Tolerance Analysis

- Using the model of the 5,000 ft2 building we ran the model for the 7 ton units in all 17 ASHRAE climate zones from 55 F changeover temperature to an 80 F changeover temperature

- The units for the building was a 7 ton rooftop with the new staging requirements defined for ASHRAE 90.1 and Title 24 including the 2 speed fan and 2 stage economizer

- The unit was run with an external static of 1 inch.

- I calculated the change in cooling energy cost as a function of the change in drybulb high limit.

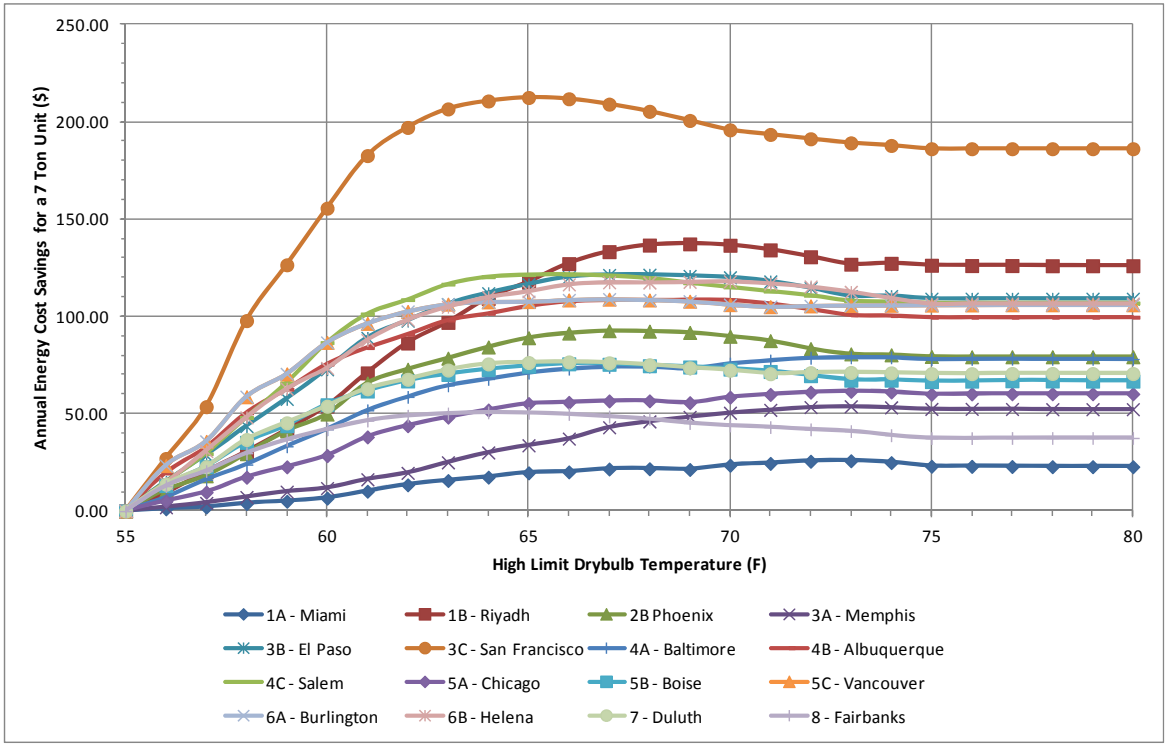
Drybulb Changeover Results

- The following table shows the energy cost savings for each climate zone as a function of the drybulb changeover setpoint
- The values are annualized energy cost savings relative to 55 F changeover for the 7 ton system based on an energy cost of 0.1032 $/kwh

ASHRAE Climate Zone	ASHRAE Benchmark City	Title 24 Climate Zone	Drybulb Changeover temperature (F)																											
			55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
			Savings vs 55 F	Savings vs 55 F	Savings vs 55 F	Savings vs 55 F	Savings vs 55 F	Savings vs 55 F	Savings vs 55 F	Savings vs 55 F	Savings vs 55 F	Savings vs 55 F	Savings vs 55 F	Savings vs 55 F	Savings vs 55 F	Savings vs 55 F	Savings vs 55 F	Savings vs 55 F	Savings vs 55 F	Savings vs 55 F	Savings vs 55 F	Savings vs 55 F	Savings vs 55 F	Savings vs 55 F	Savings vs 55 F	Savings vs 55 F	Savings vs 55 F	Savings vs 55 F	Savings vs 55 F	Savings vs 55 F
			$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$
1A	1A - Miami		0.00	1.12	2.01	3.88	5.02	6.63	10.15	13.46	15.66	17.39	19.63	20.11	21.56	21.71	21.32	23.52	24.48	25.57	25.82	24.88	23.00	22.94	22.86	22.77	22.77	22.76
1B	1B - Riyadh		0.00	9.11	20.12	30.37	41.62	53.93	70.90	86.31	96.90	109.23	117.53	127.06	133.19	136.60	137.21	136.53	134.12	130.58	126.78	127.20	126.20	126.11	126.11	126.00	125.97	125.97
2A	2A - Houston		0.00	5.01	9.41	18.58	24.43	29.53	34.48	41.23	46.50	49.43	52.25	53.20	54.18	54.19	53.53	56.00	57.50	58.61	58.87	58.19	56.71	56.69	56.69	56.69	56.69	56.69
2B	2B Phoenix		0.00	10.77	18.08	29.43	41.13	49.78	65.74	72.81	78.52	84.25	89.05	91.40	92.58	92.38	91.73	89.78	87.52	83.44	80.68	80.22	79.36	79.24	79.24	79.24	79.24	79.24
3A	3A - Memphis		0.00	1.97	4.18	7.18	9.93	11.83	16.29	19.62	25.00	30.08	33.78	37.21	43.04	46.03	48.38	50.47	51.96	53.37	53.77	53.25	52.44	52.47	52.41	52.33	52.31	52.31
3B	3B - El Paso	6,8,9,10,11,12, 13,14,15	0.00	15.01	28.61	43.60	57.61	72.83	88.97	97.76	106.31	111.92	116.45	120.20	121.29	121.36	120.76	120.08	117.93	114.51	110.43	110.41	109.03	109.00	109.03	109.00	109.00	109.00
3C	3C - San Francisco	3	0.00	27.01	53.60	97.81	126.45	155.55	182.57	197.03	206.54	210.60	212.40	211.75	208.98	205.30	200.60	195.79	193.43	191.20	189.10	187.77	186.09	186.09	186.09	186.09	186.09	186.09
4A	4A - Baltimore		0.00	6.93	16.08	23.86	33.22	42.01	51.72	58.62	64.55	67.85	71.05	73.13	74.04	74.19	73.25	75.77	77.32	78.74	78.92	78.95	78.03	78.13	78.19	78.15	78.11	78.09
4B	4B - Albuquerque		0.00	19.54	32.62	50.41	62.55	75.44	83.95	90.76	98.08	101.53	105.35	107.80	108.49	108.41	108.62	108.42	106.61	103.77	100.77	100.41	99.58	99.57	99.55	99.57	99.57	99.57
4C	4C - Salem	4	0.00	14.71	29.44	48.03	65.82	86.52	101.23	108.56	116.53	120.35	121.39	121.61	120.92	119.65	117.24	115.06	112.94	110.80	108.02	107.51	106.87	106.89	106.89	106.88	106.87	106.87
5A	5A - Chicago		0.00	5.15	9.72	17.36	22.69	28.46	38.06	43.81	48.23	51.88	55.17	55.81	56.55	56.58	55.65	58.46	59.87	61.05	61.49	61.16	59.96	60.17	60.22	60.21	60.19	60.19
5B	5B - Boise		0.00	13.13	22.77	35.26	43.83	54.56	61.60	66.85	70.18	72.68	74.38	75.62	75.41	74.65	73.99	72.89	71.66	69.56	67.25	67.26	66.52	66.70	66.87	66.86	66.76	66.76
5C	5C - Vancouver	5	0.00	23.32	35.79	58.71	70.47	86.59	96.40	102.51	106.23	107.44	107.56	108.42	108.84	108.39	107.76	106.02	104.96	105.37	105.63	105.66	105.80	105.89	105.97	105.97	105.97	105.97
6A	6A - Burlington		0.00	7.40	14.84	26.63	33.47	41.38	49.68	54.04	58.34	61.98	64.64	65.45	65.86	65.46	63.82	61.68	59.82	60.97	61.18	61.00	60.29	60.28	60.28	60.28	60.28	60.28
6B	6B - Helena	2	0.00	14.43	30.82	48.14	62.80	73.47	87.84	98.25	104.91	109.89	112.89	116.44	117.50	117.36	117.70	117.97	116.85	115.31	112.59	109.43	106.49	106.65	106.59	106.57	106.57	106.57
7	7 - Duluth	1,7	0.00	13.77	22.76	36.74	45.31	53.84	62.81	67.68	72.42	75.57	76.26	76.58	76.13	75.12	73.58	72.33	70.52	71.07	71.20	70.97	70.56	70.56	70.64	70.65	70.60	70.60
8	8 - Fairbanks		0.00	12.80	20.50	29.69	36.61	41.96	46.48	48.98	50.06	50.71	50.40	49.85	48.54	47.28	45.21	43.98	43.12	41.96	41.03	38.96	37.43	37.43	37.51	37.53	37.53	37.53

Drybulb Changeover Results

- This is the same data but plotted to show where the peak energy savings occurs and that the curve in the range of the setpoints is very flat.
- From this you can see that many of the Title 24 changes are higher than the peak energy savings changeover setpoint and could lowered.
- This has an advantage of protecting the space from humidity problems on days with high relative humidity
- Also it shows that you can change the setpoints with very little impact on operating cost which indicates the tolerance is not as critical as assumed when a +/- 1 F tolerance was specified.



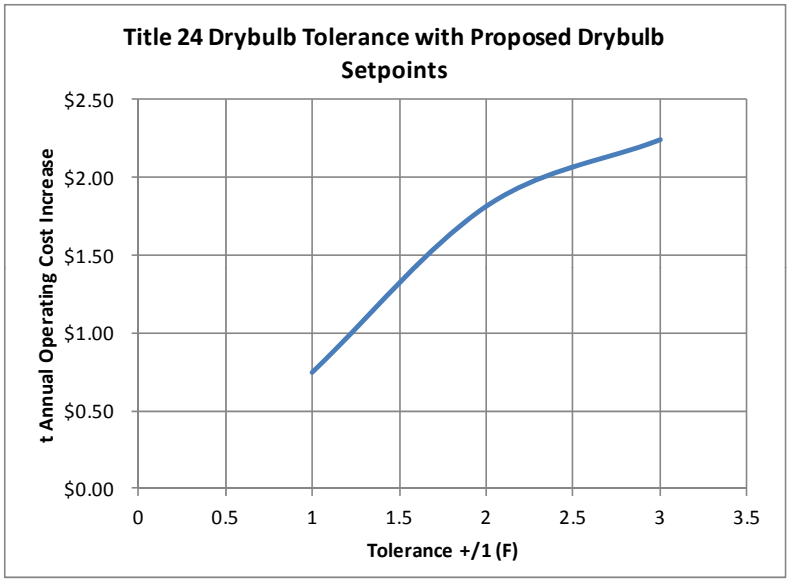
Drybulb Tolerance

- Using the analysis I think looked at +/- tolerances of 1, 2, and 3 F and the impact on operating cost.
- I used the Title 24 setpoints which results in some cases the savings actually increasing with the increased tolerances

California Climate Zone	City	HDD	CDD	ASHRAE Climate Zone	Title 24 Drybulb Setting	Optimum Setting	Energy Cost Savings vs Nominal Setpoint Title 24 Setpoint					
							+/- 1 F		+/- 2 F		+/- 3 F	
							-1 F	+1 F	-2 F	+2 F	-3 F	+3 F
1	Arcata	5297	5	7	75	66	$0.41	$0.00	$0.64	$0.08	$0.51	$0.09
2	Sata Rosa	4001	712	6B	73	67	($2.72)	($3.15)	$4.26	($6.10)	$5.39	($5.94)
3	Oakland	3383	276	3C	75	65	$1.68	$0.00	$3.01	$0.00	$5.11	$0.00
4	Sunnyvale	2676	558	4C	73	66	$2.78	($0.51)	$4.92	($1.15)	$7.04	($1.13)
5	Santa Maria	3541	323	5C	75	67	($0.14)	$0.09	($0.17)	$0.17	($0.43)	$0.17
6	Los Angeles	1699	963	3B	71	69	$2.15	($3.42)	$2.83	($7.50)	$3.43	($7.52)
7	San Diego	1220	617	3B	69	66	$0.60	($0.68)	$0.53	($2.83)	($0.55)	($6.24)
8	El Toro	1512	879	3B	71	69	$2.15	($3.42)	$2.83	($7.50)	$3.43	($7.52)
9	Burbank	1699	963	3B	71	69	$0.60	($0.68)	$0.53	($2.83)	($0.55)	($6.24)
10	Riverside	3165	1711	3B	73	69	$4.09	($0.02)	$7.50	($1.40)	$9.65	($1.43)
11	Red Bulff	3104	1974	3B	75	69	$1.38	($0.03)	$1.40	($0.00)	$5.49	($0.03)
12	Sacramento	3285	1345	3B	75	69	$1.38	($0.03)	$1.40	($0.00)	$5.49	($0.03)
13	Fresno	2682	2258	3B	75	69	$1.38	($0.03)	$1.40	($0.00)	$5.49	($0.03)
14	China Lake	3135	2816	3B	75	69	$1.38	($0.03)	$1.40	($0.00)	$5.49	($0.03)
15	El Centro	1392	4476	3B	75	69	$1.38	($0.03)	$1.40	($0.00)	$5.49	($0.03)
16	Mt Shasta	6455	699	7	75	69	$1.38	($0.03)	$1.40	($0.00)	$5.49	($0.03)
						average	$1.24	($0.75)	$2.20	($1.82)	$4.12	($2.25)
					highest negative cost		($0.75)		($1.82)		($2.25)	

Drybulb Tolerances

- Taking the prior chart you can then plot the operating cost increase as a function of the 1, 2, and 3 F tolerance



- As you can see if we doubled the tolerance to +/- 2 F the operating cost on average only increased $1.75 per year for the 7 ton system
- Assuming a base cost for the sensor of $20 and that the +/-1 F tolerance would double the cost it would have a payback of 11.4 years using the ASHRAE 90.1 power cost. This is well beyond a reasonable payback.
- **We recommend to tolerance be increased to +/-2 F for a temperature range of 60 to 80 F ambient temperatures**

Enthalpy Setpoint and Tolerance

- The title 24 proposal only allows enthalpy and temperature combined high limit setpoint which is a good approach.
- The use of enthalpy control is beneficial for constant volume systems that do not control the leaving air temperature like VAV systems to prevent indoor humidity and moisture problems during high humidity days which can occur on raining days or early in the morning when economizers are often used.
- The use of the 28 Btu/lbm setpoint is a accepted limit based on years of use to prevent moisture issues in the space, so I would not recommend it be change even though the study sometimes show so changes could be made.
- In the following page you will find the results of the study where I just varied the enthalpy from 20 to 36 Btu/lbm

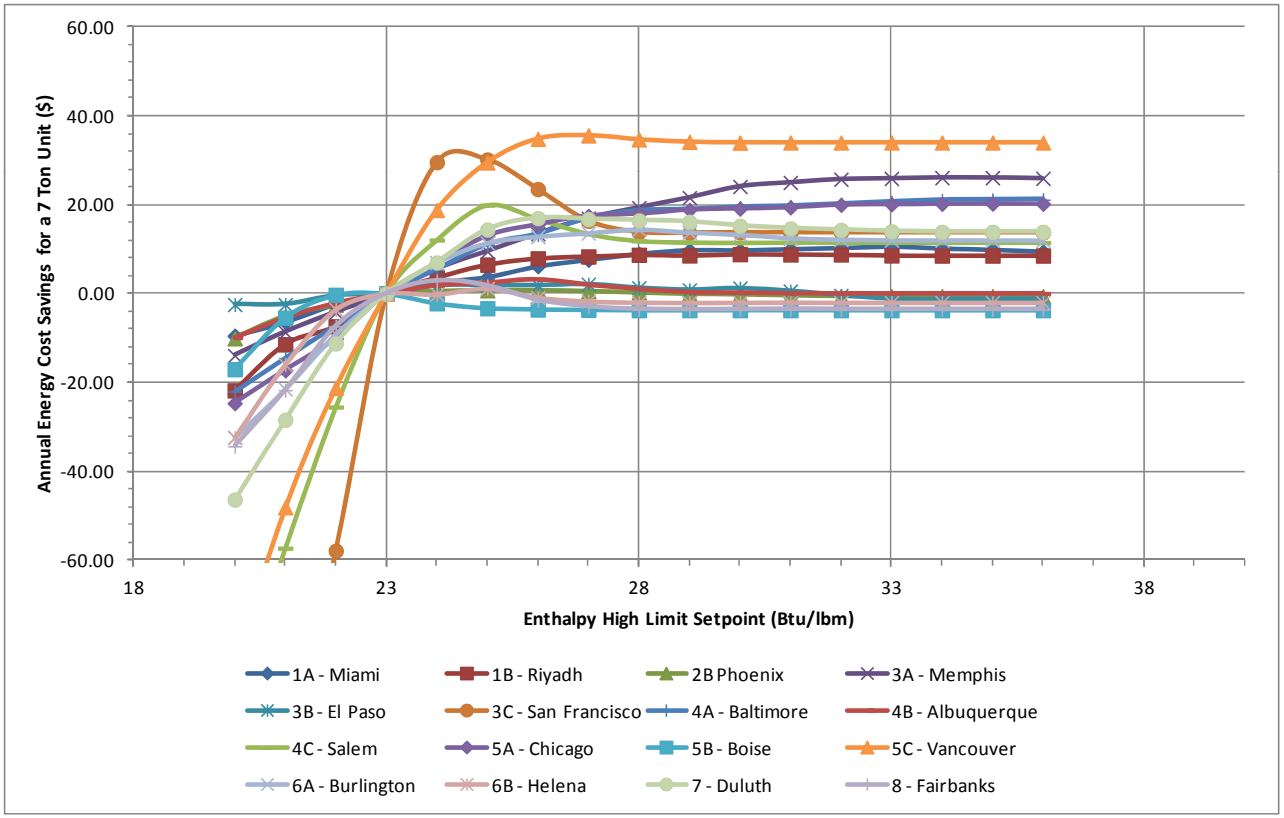
Enthalpy Changeover Energy Savings Results

- The following is a summary for each climate zone showing the annualized energy savings for the 7 ton unit with fixed enthalpy control relative to a 23 Btu/lbm setpoint
- The red values are the peak savings point, ignoring any issues with space humidity

ASHRAE Climate Zone	ASHRAE Benchmark City	Title 24 Climate Zone	Fixed Enthalpy Changeover Value (Btu/lbm)																
			20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
			Savings vs 23 Btu/lbm	Savings vs 23 Btu/lbm	Savings vs 23 Btu/lbm	Savings vs 23 Btu/lbm	Savings vs 23 Btu/lbm	Savings vs 23 Btu/lbm	Savings vs 23 Btu/lbm	Savings vs 23 Btu/lbm	Savings vs 23 Btu/lbm	Savings vs 23 Btu/lbm	Savings vs 23 Btu/lbm	Savings vs 23 Btu/lbm	Savings vs 23 Btu/lbm	Savings vs 23 Btu/lbm	Savings vs 23 Btu/lbm	Savings vs 23 Btu/lbm	Savings vs 23 Btu/lbm
			$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$
1A	1A - Miami		-9.48	-6.39	-2.40	0.00	2.44	3.73	6.15	7.61	8.95	9.80	9.77	10.03	10.29	**10.62**	10.20	9.90	9.48
1B	1B - Riyadh		-21.78	-11.41	-7.36	0.00	3.60	6.52	7.94	8.36	8.74	8.61	8.87	**8.81**	8.81	8.59	8.57	8.57	8.57
2A	2A - Houston		-18.13	-10.50	-5.39	0.00	3.69	8.03	10.54	13.58	16.76	18.61	19.41	19.61	19.81	**20.10**	19.90	19.71	19.50
2B	2B Phoenix		-10.03	-5.07	-2.49	0.00	0.58	0.74	**0.85**	0.54	0.26	-0.04	-0.19	-0.32	-0.57	-0.57	-0.57	-0.57	-0.57
3A	3A - Memphis		-13.92	-8.68	-4.23	0.00	5.51	9.49	13.46	16.97	19.33	21.60	24.10	25.00	25.73	25.90	**26.09**	26.08	25.93
3B	3B - El Paso	6,8,9,10,11,12, 13,14,15	-2.46	-2.45	-0.46	0.00	1.85	1.92	1.90	**2.13**	1.31	0.84	1.25	0.56	-0.41	-1.25	-1.31	-1.31	-1.31
3C	3C - San Francisco	3	-153.87	-108.52	-57.83	0.00	29.57	30.16	23.51	16.37	**13.87**	13.69	13.77	13.77	13.77	13.77	13.77	13.77	13.77
4A	4A - Baltimore		-22.03	-14.53	-7.27	0.00	5.39	10.96	13.31	16.81	18.57	18.85	19.37	19.62	20.09	20.56	20.95	21.05	**21.11**
4B	4B - Albuquerque		-9.90	-5.43	-2.11	0.00	1.87	2.48	**3.20**	2.04	1.07	0.34	0.23	0.09	0.06	0.06	0.06	0.06	0.06
4C	4C - Salem	4	-90.32	-57.24	-25.51	0.00	12.07	**19.91**	16.82	13.47	11.87	11.53	11.48	11.50	11.50	11.50	11.50	11.50	11.50
5A	5A - Chicago		-24.65	-17.28	-10.11	0.00	6.89	13.00	15.56	17.50	**17.96**	18.87	19.13	19.40	19.99	20.10	20.19	20.23	20.19
5B	5B - Boise		-17.01	-5.41	-0.28	**0.00**	-2.16	-3.28	-3.58	-3.63	-3.70	-3.71	-3.71	-3.71	-3.71	-3.71	-3.71	-3.71	-3.71
5C	5C - Vancouver	5	-83.37	-48.08	-21.19	0.00	18.80	29.52	34.83	**35.60**	34.68	34.15	33.99	34.00	34.00	34.00	34.00	34.00	34.00
6A	6A - Burlington		-32.34	-21.47	-9.12	0.00	6.96	11.38	12.83	13.61	**14.43**	13.77	13.28	12.49	12.18	12.04	12.00	12.00	11.97
6B	6B - Helena	2	-32.37	-15.95	-3.57	0.00	-0.16	**1.18**	-0.88	-1.71	-2.01	-2.01	-2.01	-2.01	-2.01	-2.01	-2.01	-2.01	-2.01
7	7 - Duluth	1,7	-46.32	-28.39	-11.23	0.00	7.01	14.42	**16.98**	16.75	16.47	16.16	15.27	14.67	14.35	14.03	13.90	13.90	13.90
8	8 - Fairbanks		-34.35	-21.72	-7.37	0.00	**2.85**	1.74	-1.50	-2.96	-3.58	-3.58	-3.58	-3.58	-3.58	-3.58	-3.58	-3.58	-3.58

Peak Enthalpy Changeover Setpoint

- The following is a plot of the energy savings
- Again it shows that in the range of a 28 Btu/lbm setpoint that the curves are flat and changes or tolerances will not have a big impact.



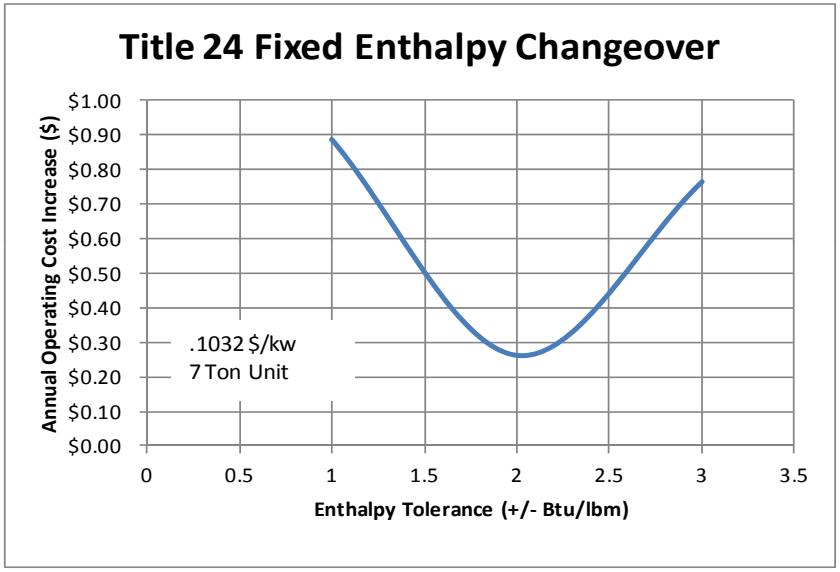
Enthalpy Setpoint Tolerance Study

- Using the model I looked at the energy cost impact for +/- 1, 2, and 3 Btu/lbm tolerances relative to a 28 Btu/lbm setpoint

City	HDD	CDD	ASHRAE Climate Zone	Title 24 Enthalpy Setting	Optimum Setting	Energy Cost Savings vs 28 Btu/lbm Setpoint					
						+/-1 Btu/lbm		+/-2 Btu/lbm		+/-3 Btu/lbm	
				Btu/lbm	Btu/lbm	-1	+1	-1	+1	-1	+1
Arcata	5297	5	7	28	26	($0.28)	$0.31	$0.51	($1.20)	($2.05)	($1.80)
Sata Rosa	4001	712	6B	28	25	($0.30)	$0.00	$1.13	$0.00	$3.19	$0.00
Oakland	3383	276	3C	28	28	($2.51)	$0.17	$9.65	($0.09)	$16.30	($0.09)
Sunnyvale	2676	558	4C	28	25	($1.60)	$0.34	$4.95	($0.39)	$8.04	($0.37)
Santa Maria	3541	323	5C	28	27	($0.92)	$0.52	$0.15	($0.69)	($5.16)	($0.68)
Los Angeles	1699	963	3B	28	27	($0.82)	$0.47	$0.59	($0.06)	$0.61	($0.74)
San Diego	1220	617	3B	28	27	($0.82)	$0.47	$0.59	($0.06)	$0.61	($0.74)
El Toro	1512	879	3B	28	27	($0.82)	$0.47	$0.59	($0.06)	$0.61	($0.74)
Burbank	1699	963	3B	28	27	($0.82)	$0.47	$0.59	($0.06)	$0.61	($0.74)
Riverside	3165	1711	3B	28	27	($0.82)	$0.47	$0.59	($0.06)	$0.61	($0.74)
Red Bulff	3104	1974	3B	28	27	($0.82)	$0.47	$0.59	($0.06)	$0.61	($0.74)
Sacramento	3285	1345	3B	28	27	($0.82)	$0.47	$0.59	($0.06)	$0.61	($0.74)
Fresno	2682	2258	3B	28	27	($0.82)	$0.47	$0.59	($0.06)	$0.61	($0.74)
China Lake	3135	2816	3B	28	27	($0.82)	$0.47	$0.59	($0.06)	$0.61	($0.74)
El Centro	1392	4476	3B	28	27	($0.82)	$0.47	$0.59	($0.06)	$0.61	($0.74)
Mt Shasta	6455	699	7	28	26	($0.28)	$0.31	$0.51	($1.20)	($2.05)	($1.80)
					average	($0.88)	$0.39	$1.43	($0.26)	$1.52	($0.76)
			maximum cost increase			($0.88)		($0.26)		($0.76)	

Enthalpy Tolerances

- Taking the prior chart you can then plot the operating cost increase as a function of the 1, 2, and 3 Btu/lbm tolerance



- As you can see if we triple the tolerance to +/- 3 Btu/lbm that the operating cost increase vs. zero tolerance is only $.76 per year.
- Vs the 1 Btu/lbm tolerance the 3 Btu/lbm tolerance is actual lower in energy cost impact as the 28 Btu/lbm is not the optimum
- **We recommend to tolerance be increased to +/-3 Btu/lbm for a range of enthalpy of temperature range of 25 to 35 Btu/lbm enthalpies**

Differential Drybulb Setpoint and Tolerances

- It is well know that a differential drybulb control with accurate sensors can provide the greatest savings in a dry climate like California.
- New to the proposal for Title 24 is to offset this by 0 to 6 F lower return air temperatures.
- Again we used the 5 ton model to analysis the setpoints and tolerances for differential drybulb changeover
- We ran the analysis from with a return air offset of -3 F to 15 F using the following high limit
  - High Limit – OAT>RAT-Offset

Differential Drybulb Offset Analysis

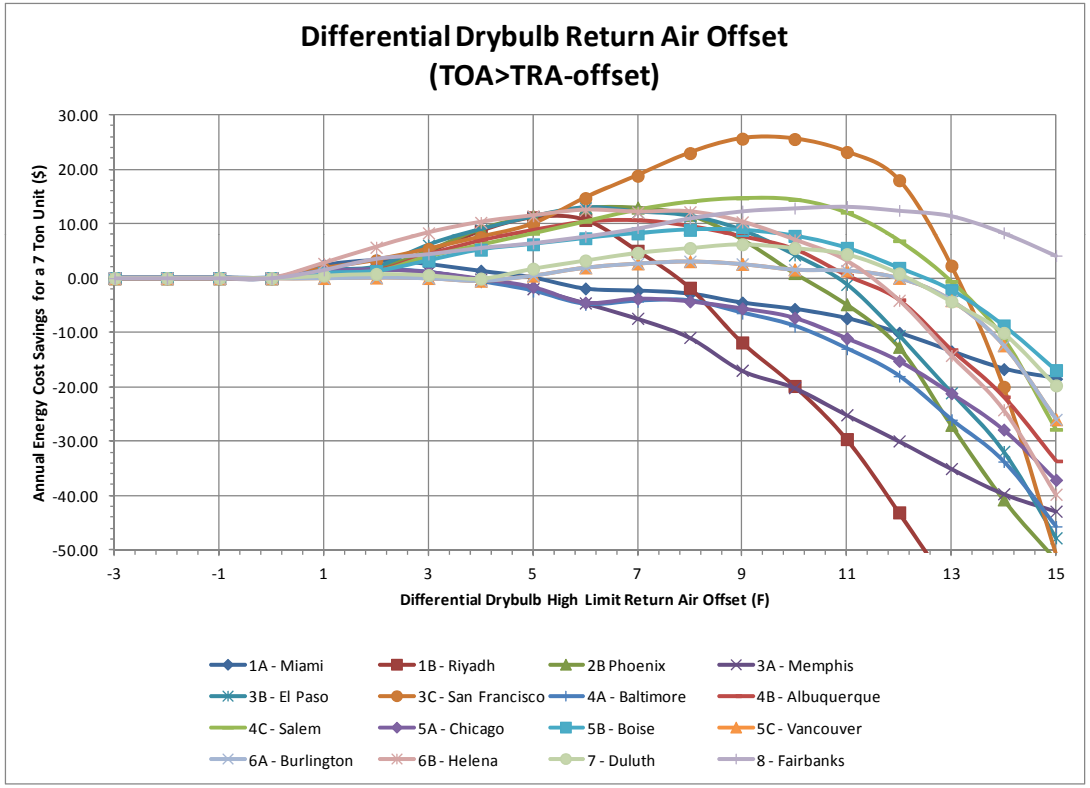
- The following shows the results of the offset analysis for the differential drybulb changeover cost savings relative to 0 F offset

ASHRAE Climate Zone	ASHRAE Benchmark City	Title 24 Climate Zone	Drybulb Changeover temperature (F)																	
			-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
			Savings vs 0 F $	Savings vs 0 F $	Savings vs 0 F $	Savings vs 0 F $	Savings vs 0 F $	Savings vs 0 F $	Savings vs 0 F $	Savings vs 0 F $	Savings vs 0 F $	Savings vs 0 F $	Savings vs 0 F $	Savings vs 0 F $	Savings vs 0 F $	Savings vs 0 F $	Savings vs 0 F $	Savings vs 0 F $	Savings vs 0 F $	Savings vs 0 F $	Savings vs 0 F $
1A	1A - Miami		0.00	0.00	0.00	0.00	2.41	**3.33**	2.65	1.37	0.16	-1.90	-2.28	-2.82	-4.50	-5.67	-7.38	-10.07	-13.46	-16.73	-18.49
1B	1B - Riyadh		0.00	0.00	0.00	0.00	1.38	1.31	4.78	8.65	**11.16**	10.71	5.03	-1.76	-11.83	-19.83	-29.61	-43.07	-57.63	-74.73	-92.22
2A	2A - Houston		0.00	0.00	0.00	0.00	1.87	**2.42**	1.91	0.07	-1.61	-3.13	-3.14	-4.44	-6.70	-10.04	-13.95	-21.04	-26.49	-31.52	-37.64
2B	2B Phoenix		0.00	0.00	0.00	0.00	1.11	1.79	5.08	9.08	11.44	**12.98**	12.98	11.63	7.17	0.94	-4.81	-12.64	-26.97	-40.68	-51.77
3A	3A - Memphis		0.00	0.00	0.00	0.00	1.22	**1.71**	1.18	-0.18	-1.95	-4.56	-7.40	-10.91	-16.95	-20.13	-25.13	-29.93	-35.02	-39.64	-42.85
3B	3B - El Paso	6,8,9,10,11,12, 13,14,15	0.00	0.00	0.00	0.00	1.47	2.04	6.05	8.90	11.23	**12.92**	12.14	11.38	8.76	4.25	-1.17	-10.55	-21.08	-31.85	-47.75
3C	3C - San Francisco	3	0.00	0.00	0.00	0.00	1.77	3.27	5.37	7.52	9.96	14.71	18.82	22.98	**25.63**	25.57	23.18	18.00	2.29	-19.99	-50.60
4A	4A - Baltimore		0.00	0.00	0.00	0.00	1.16	**1.47**	1.04	-0.66	-2.39	-4.83	-4.28	-4.20	-6.44	-8.84	-12.98	-18.02	-26.03	-33.71	-45.65
4B	4B - Albuquerque		0.00	0.00	0.00	0.00	1.08	1.46	4.35	6.97	8.86	10.42	**10.71**	9.65	7.75	5.40	0.55	-3.96	-13.14	-21.80	-33.60
4C	4C - Salem	4	0.00	0.00	0.00	0.00	0.74	1.21	3.98	6.09	8.20	10.42	12.58	14.05	**14.72**	14.43	12.08	6.87	-0.60	-11.06	-27.82
5A	5A - Chicago		0.00	0.00	0.00	0.00	1.23	**1.61**	1.10	-0.12	-1.64	-4.51	-3.77	-4.27	-5.58	-7.28	-11.05	-15.21	-21.17	-27.84	-37.08
5B	5B - Boise		0.00	0.00	0.00	0.00	0.94	1.28	3.22	5.23	6.22	7.34	8.22	**8.89**	8.84	7.76	5.56	1.87	-2.22	-8.71	-16.91
5C	5C - Vancouver	5	0.00	0.00	0.00	0.00	0.03	0.10	0.01	-0.49	0.48	1.95	2.71	**3.10**	2.61	1.59	1.39	0.04	-4.08	-12.36	-25.96
6A	6A - Burlington		0.00	0.00	0.00	0.00	0.71	1.03	0.74	-0.32	1.50	3.64	4.71	**5.12**	4.29	2.40	-0.61	-4.49	-11.04	-16.77	-25.06
6B	6B - Helena	2	0.00	0.00	0.00	0.00	2.72	5.67	8.31	10.25	11.45	**12.48**	12.12	12.18	10.32	7.02	3.16	-4.09	-14.21	-24.18	-39.74
7	7 - Duluth	1,7	0.00	0.00	0.00	0.00	0.46	0.76	0.55	-0.09	1.73	3.23	4.65	5.53	**6.22**	5.53	4.40	0.85	-4.29	-10.07	-19.72
8	8 - Fairbanks		0.00	0.00	0.00	0.00	1.53	3.58	4.43	5.59	6.45	7.68	9.15	11.01	12.32	12.88	**13.18**	12.45	11.45	8.33	4.15

- The red bold test is the peak energy savings and the red box is the title 24 recommend offset.
- In general greater offsets can be used than proposed in the title 24 table.

Peak Differential Drybulb Offset Setpoint

- The following is a plot of the energy savings for the differential drybulb changeover relative to the return air offset of 0 F.



- This has more of a peak than pure drybulb, but there is a flat spot for each climate zone of 4 to 5 F.

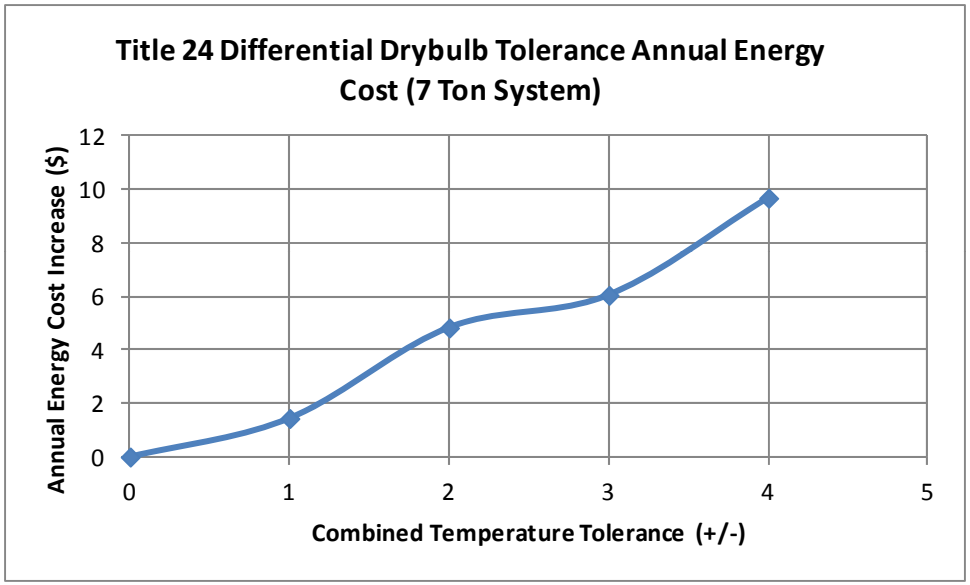
Differential Drybulb Tolerance Study

- The following is the results of the tolerance study with 1, 2, 3, and 4 tolerance +/- tolerance relative to the peak offset temperature.

California Climate Zone	City	HDD	CDD	ASHRAE Climate Zone	Title 24 Drybulb Setting	Optimum Setting	Energy Cost Savings vs Nominal Setpoint							
							+/- 1 F		+/- 2 F		+/- 3 F		+/- 4 F	
							-1 F	+1 F	-2 F	+2 F	-3 F	+3 F	-4 F	+4 F
1	Arcata	5297	5	7	0	9	($0.69)	($0.69)	($1.57)	($1.82)	($2.99)	($5.37)	($4.49)	($10.51)
2	Sata Rosa	4001	712	6B	2	6	($1.03)	($0.36)	($0.46)	($0.30)	($4.17)	($2.16)	($6.81)	($5.46)
3	Oakland	3383	276	3C	0	9	($2.65)	($0.06)	($6.81)	($2.45)	($10.93)	($7.63)	($15.67)	($23.34)
4	Sunnyvale	2676	558	4C	2	9	($0.67)	($0.29)	($2.14)	($2.63)	($4.29)	($7.84)	($6.52)	($15.32)
5	Santa Maria	3541	323	5C	0	8	($0.39)	($0.49)	($1.15)	($1.51)	($2.63)	($1.71)	($3.59)	($3.06)
6	Los Angeles	1699	963	3B	4	6	($1.69)	($0.78)	($6.35)	($1.54)	($6.88)	($4.16)	($10.88)	($8.67)
7	San Diego	1220	617	3B	6	6	($1.69)	($0.78)	($6.35)	($1.54)	($6.88)	($4.16)	($10.88)	($8.67)
8	El Toro	1512	879	3B	4	6	($1.69)	($0.78)	($6.35)	($1.54)	($6.88)	($4.16)	($10.88)	($8.67)
9	Burbank	1699	963	3B	4	6	($1.69)	($0.78)	($6.35)	($1.54)	($6.88)	($4.16)	($10.88)	($8.67)
10	Riverside	3165	1711	3B	2	6	($1.69)	($0.78)	($6.35)	($1.54)	($6.88)	($4.16)	($10.88)	($8.67)
11	Red Bulff	3104	1974	3B	0	6	($1.69)	($0.78)	($6.35)	($1.54)	($6.88)	($4.16)	($10.88)	($8.67)
12	Sacramento	3285	1345	3B	0	6	($1.69)	($0.78)	($6.35)	($1.54)	($6.88)	($4.16)	($10.88)	($8.67)
13	Fresno	2682	2258	3B	0	6	($1.69)	($0.78)	($6.35)	($1.54)	($6.88)	($4.16)	($10.88)	($8.67)
14	China Lake	3135	2816	3B	0	6	($1.69)	($0.78)	($6.35)	($1.54)	($6.88)	($4.16)	($10.88)	($8.67)
15	El Centro	1392	4476	3B	0	6	($1.69)	($0.78)	($6.35)	($1.54)	($6.88)	($4.16)	($10.88)	($8.67)
16	Mt Shasta	6455	699	7	0	9	($0.69)	($0.69)	($1.57)	($1.82)	($2.99)	($5.37)	($4.49)	($10.51)
						average	($1.44)	($0.65)	($4.83)	($1.62)	($6.05)	($4.48)	($9.40)	($9.68)
						variation	($1.44)		($4.83)		($6.05)		($9.68)	

Differential Drybulb Tolerance Study

- The following is a plot of the prior chart on differential tolerances



- We feel that a combined tolerance for the differential of +/- 3F would be appropriate. This is slightly tighter than combined error of two sensors with a +/- 2 F but it would encourage the development of differential sensors.
- We are checking with suppliers of sensors to get their feedback, but even a +/-4 F would not be much of a cost penalty.

Overall Recommendations

- Consider some decrease in the fixed drybulb setpoints as most appear to be higher than the peak value.
- Consider some increase to the offset for the differential drybulb
- Remove the requirement for wetbulb and humidity sensors accuracy as they are not used in the requirements
- Increase the drybulb tolerance to +/- 2 F for fixed drybulb and add a range requirement of 60 to 80 F
- Add a requirement for differential drybulb tolerance of +/- 3 F tolerance with a range of 0 to 15 F
- Increase the enthalpy tolerance to +/- 3 Btu/lbm with a range of 25 to 35 Btu/lbm