Evaporative Cooling Compliance Credit

California Statewide Utility Codes and Standards Program

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Current Code Requirements

- Evaporative Cooling
  - The ACM provides path for modeling evaporative cooling through optional 'System 9' (§3.3.5)
    - Stand-alone evaporative cooling systems, and
    - Evaporative cooling as pre-cooling for other systems
  - Inputs needed for modeling
    - Evaporative cooler fan capacity and brake horsepower (bhp)
    - Water pump capacity and brake horsepower (bhp)
    - Whether evaporative cooling is stand-alone or as pre-cooling
  - Default inputs provided
    - Direct cooling efficiency
    - Indirect cooling efficiency
    - Can be changed by user

Summary of Code Change Proposals

- Base Code:
  - Performance credits for high-efficiency evaporative cooling systems
    - Stand-alone indirect systems
    - Packaged/built-up hybrid systems with evaporative and Dx
  - Model qualifying systems with a “Total System EER” as calculated using independent laboratory testing
    - Using criteria defined in the Nonresidential Alternative Calculation Method (ACM)
      - Based on the Western Cooling Challenge criteria

Data / Findings

- Interviews with manufacturers/designers
- Western Cooling Challenge
- Simulation Software Review
  - DOE-2.x
  - EnergyPlus
  - Engineering Practice
- Association of Water Technologies Water Management Guidelines

Interview Summary

- Detailed interviews with manufacturers, designers, distributors
  - System types:
    - Direct, Indirect, Indirect/Direct, Hybrid evaporative + Dx
    - Few packaged products
    - Many built-up products designed to spec
  - System Efficiency:
    - 65-75% efficiency for direct systems
    - Can go as high as 120% of wet-bulb depression with newer indirect systems
  - Building Types:
    - Warehouses, big-box retail, industrial, data centers
  - System costs:
    - Varies depending on system type and usually reported in $/cfm
    - Designers have provided cost quotes of $3/cfm for direct units and $6-$9/cfm or higher for indirect and hybrid units
  - Water management
    - Timed sump flush
    - Conductivity sensors

Western Cooling Challenge

- Established by the Western Cooling Efficiency Center
- Goals:
  - 40% reduction in energy use and peak demand of roof-top units (RTUs) through
    - Development of new products and improvements to existing products
  - Target – RTUs between 3-20 tons, manufacturing capacity >500-units/yr
  - Extensive laboratory testing of equipment at several design conditions

Western Cooling Challenge

- Test Conditions

Test Conditions/ Criteria	ARI 340/360	WCC Peak	WCC Annual
Outside Air Condition (TdbºF/TwbºF)	95/75	105/73	90/64
Return Air Condition (TdbºF/TwbºF)	78/67	78/64	78/64
Min. Outdoor Ventilation (cfm/nominal-ton)	0	120	120
External Static (in WC)	0.2-0.75	0.7	0.7
Min Filtration	NA	MERV 7	MERV 7
Operating Mode	Full Capacity	Full Capacity	Full or Part Capacity

Source: Western Cooling Efficiency Center

Western Cooling Challenge

- Performance Thresholds

	WCC Peak Conditions	WCC Annual Conditions
Min Sensible Credited Capacity *(% sensible credited cooling at peak conditions)*	NA	80%
Min Sensible Credited EER *(kbtu/kWh)*	14	17
Max Supply Air Humidity	0.0092	0.0092
Max Water Use *(gal/ton-h)*	NA	4

- Testing done at independent labs
  - Results include variables above plus "Total System EER" that accounts for latent effects

Source: Western Cooling Efficiency Center

Evaporative Cooling Compliance Credits

Western Cooling Challenge

- First system to exceed the goals announced in Jan 2010
- Small commercial applications
- 5-ton RTU
- Manufacturer claims energy savings up to 60% compared to baseline system

		Specification	Performance	Units
Peak Conditions (105°F/73°F)	Total Credited Cooling	36–360	61.7	kBtu/h
	Sensible Credited Cooling	–	56.9	kBtu/h
	Power	–	2.84	kW
	Credited EER	–	21.7	Btu/Wh
	Sensible Credited EER	≥14.0	20.1	Btu/Wh
	Outlet Humidity	≤0.0092	0.00917	–
	* Water Use	–	1.83	gal/ton·h (sensible credited)
	Water Evaporation	–	1.50	gal/ton·h (sensible credited)
Surrogate Annual Conditions (90°F/64°F)	Total Credited Cooling	–	47.7	kBtu/h
	Sensible Credited Cooling	–	45.6	kBtu/h
	Mean Power	–	1.64	kW
	Credited EER	–	29.1	Btu/Wh
	Sensible Credited EER	≥17.0	27.8	Btu/Wh
	* Water Use	≤4.0	1.84	gal/ton·h (sensible credited)
	Water Evaporation	–	1.50	gal/ton·h (sensible credited)

Source: *Technical Report*
NREL/TP-5500-46524, November 2010

Water Usage of Evaporative Systems

- WCC criteria for max water consumption
  - 4 gal/ton-h at annual test conditions
- Association of Water Technologies (AWT) Green Task Force Best Practices Guidelines
  - Minimizing water usage, including using non-potable makeup water where available
  - Maximizing energy efficiency through maintaining clean heat-transfer surfaces
  - Extending the life cycle of equipment by controlling corrosion and mechanical deterioration of materials
  - Reducing carbon footprint of facilities personnel by integrating cooling water data mining into building management systems
  - Favoring materials and processes friendly to the environment and operator safety

Source: http://www.awt.org/IndustryResources/cooling_water_management.pdf

Simulation Software Review

- DOE 2.1E
  - Pros:
    - Can model both direct and indirect saturation effectiveness
    - Can model both stand-alone and DX integrated systems
  - Cons:
    - M-cycle indirect units with effectiveness greater than 1.0 limited to 1.0 effectiveness
    - Hybrid modeling assumes indirect and DX to be in the same airstream
      - Some newer hybrid evap+DX units have more options of mixing primary and secondary air streams as well as outdoor and return air
    - No account of water usage of the systems

Simulation Software Review

- EnergyPlus
  - Pros:
    - Modules to deal with direct, indirect and hybrid systems
    - Models evaporative pad characteristics (area, depth) that combined with mass flow rate of air calculates saturation effectiveness
    - Can input saturation effectiveness directly as well
    - Models both dry-coil and wet-coil evaporative coolers
    - Models water usage based on evaporative media characteristics
  - Cons:
    - Limited in modeling of some of the newer hybrid evap+DX units that have more options of mixing primary and secondary air streams as well as outdoor and return air
    - Run-time
    - Need for validation

Simulation Software Review

- Engineering Tools
  - Manufacturers have custom software used internally
    - Based on finite element or other first-principles modeling
    - Not available to designers/buyers
  - Engineering firms develop sizing guidelines based on manufacturer published data to meet loads

Limitations and Challenges

- Lack of field-verified performance
  - Even for units tested under laboratory conditions, not enough information available publicly about field performance of the same units
- Lack of unified standards for evaluating evaporative system efficiency
  - California Evaporative Cooler Efficiency Ratio (ECER) uses slightly different criteria than ASHRAE/ARI standards
    - ECER used for listing of equipment, but not for modeling performance
  - WCC has established criteria more suitable for western climates
    - Not the same as the ASHRAE/ARI or ECER metrics
    - WCC ‘EER’ metrics not the same as EER metric for DX systems

Energy Simulation Analysis

- Prototype small commercial building
  - 5760 sf, 3 zones (3 separate systems), office function
- Model hybrid Indirect Evap+Dx system using five approaches

Run#	System Type Modeled
1	PSZ w/EVAP PRE COOLER and INDIRECT EVAP COOL (85% eff) w/out Integrated Operation
2	PSZ w/EVAP PRE COOLER and INDIRECT EVAP COOL (85% eff) w/ Integrated Operation
3	PSZ w/EVAP PRE COOLER and INDIRECT EVAP COOL (100% eff) w/ Integrated Operation
4	PSZ w/ 17 EER (WCC Qualifying Criteria)
5	PSZ w/ 30 EER (Max EER allowed in EnergyPro)

Evaporative Cooling Compliance Credits

Simulation Results – Sample (CZ 12)

	Run#	Modeling Approach	S=Standard; P=Proposed	Cooling Energy	heat rejection	total	Compliance Margin	% Improvement Total
TDV Energy	R1	PSZ w/EVAP PRE COOLER and INDIRECT EVAP COOL w/OUT integrated Operation	S	132.53	0.00	412.14		
			P	62.39	0.00	355.71	56.43	13.69%
	R2	PSZ w/EVAP PRE COOLER and INDIRECT EVAP COOL (0.85) w/integrated Operation	S	132.53	0.00	412.14		
			P	49.10	0.00	342.43	69.71	16.91%
	R3	PSZ w/EVAP PRE COOLER and INDIRECT EVAP COOL (1.0) w/integrated Operation	S	133.36	0.00	413.06		
			P	43.96	0.00	337.29	75.76	18.34%
	R4	PSZ w/17 EER (WCC Annual EER target)	S	129.90	0.00	409.23		
			P	46.44	0.00	337.78	71.45	17.46%
	R5	PSZ w/30 EER (max allowable EER in EnergyPro)	S	129.90	0.00	409.23		
			P	21.07	0.00	312.40	96.82	23.66%
Source Energy	R1	PSZ w/EVAP PRE COOLER and INDIRECT EVAP COOL w/OUT integrated Operation	S	17.52	0.00	61.47		
			P	6.82	0.00	52.94	8.53	13.88%
	R2	PSZ w/EVAP PRE COOLER and INDIRECT EVAP COOL (0.85) w/integrated Operation	S	17.52	0.00	61.47		
			P	5.33	0.00	51.45	10.02	16.30%
	R3	PSZ w/EVAP PRE COOLER and INDIRECT EVAP COOL (1.0) w/integrated Operation	S	17.65	0.00	61.61		
			P	4.74	0.00	50.86	10.75	17.45%
	R4	PSZ w/17 EER and NO EVAP COOLER	S	17.12	0.00	61.02		
			P	5.01	0.00	50.77	10.24	16.79%
	R5	PSZ w/30 EER and NO EVAP COOLER	S	17.12	0.00	61.02		
			P	2.27	0.00	48.04	12.98	21.27%

Simulation Results

- Savings for modeling with “Total System EER” versus modeling using built-in evaporative cooling capability in DOE 2.x

	TDV Energy Savings	
	Compliance Margin	% Improvement Total
R3	PSZ w/EVAP PRE COOLER and INDIRECT EVAP COOL (100% Eff.) w/ Integrated Operation	
CZ03	11.30	18.71%
CZ09	12.32	20.76%
CZ12	10.96	18.34%
CZ13	13.40	22.19%
R5	PSZ w/30 EER (max allowable EER in EnergyPro)	
CZ03	14.42	24.11%
CZ09	14.86	25.38%
CZ12	14.00	23.66%
CZ13	15.59	26.20%

- Note: Manufacturer savings claims are substantially higher

Simulation Results

- Savings for modeling with “Total System EER” versus modeling using built-in evaporative cooling capability in DOE 2.x

TDV Energy Savings - R5 over R3		
CZ	Compliance Margin	% Improvement
CZ03	3.12	5.40%
CZ09	2.55	4.62%
CZ12	3.05	5.32%
CZ13	2.19	4.02%

- Proposed credit is thus conservative
  - But sends the right signals to encourage higher efficiency system designs

Specifics of Code Change Proposals

- Base Code
  - Compliance credit in the performance approach
  - Qualifying criteria
    - Meet the qualifying criteria for the Western Cooling Challenge
      - EER at three test conditions, water usage, cooling capacity…
    - Require active water control strategies
      - Conductivity sensors
  - Method for Modeling Credit
    - Using the DX model in compliance software
    - Model measured “Total System EER” of the unit at “WCC annual condition”
    - Limit modeling of EER to 30.0 max EER

Outstanding Issues

- ACM rules will be developed in coordination with overall ACM changes
  - Qualifying criteria
  - System capacity definition
  - System modeling descriptions
  - Compliance forms
- Develop acceptance testing

HVAC Baseline and Efficiency

QUESTIONS & COMMENTS