Measure Information Template: Residential Evaporative Cooling

2008 California Building Energy Efficiency Standards

Proposer: Southern California Gas Company (SCG)
Date: May 8, 2006 (Revised August 16, 2007)

CONTENTS

Purpose

This document proposes changes in how evaporative coolers are modeled under the Title 24 Residential Building Standards. ACM modeling rules for evaporative cooling have not recently been updated and do not reflect Title 20 Appliance Standards that took effect in January 2006. Updated ACM rules and eligibility criteria are needed to provide a viable framework for evaluating evaporative coolers within Title 24.

Acknowledgements

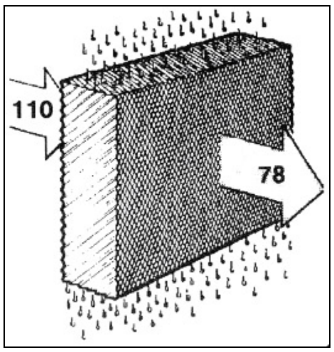
Southern California Gas Company (SGC) sponsored this code change proposal. Key SCG personnel included Jerine Ahmed, A.Y. Ahmed, and Lance DeLaura. Marc Hoeschele of Davis Energy Group led the development of this proposal and Ken Nittler of Enercomp provided software development expertise with funding from the Energy Commission's PIER program.

We would also like to acknowledge the input and support of Energy Commission staff during the development of this proposal. Roger Palmer and Yun Kim of Adobe Air offered valuable industry feedback on key elements of the proposal. Tom Pape and Karl Kurka of the California Urban Water Conservation Council provided valuable input in crafting language addressing water use issues.

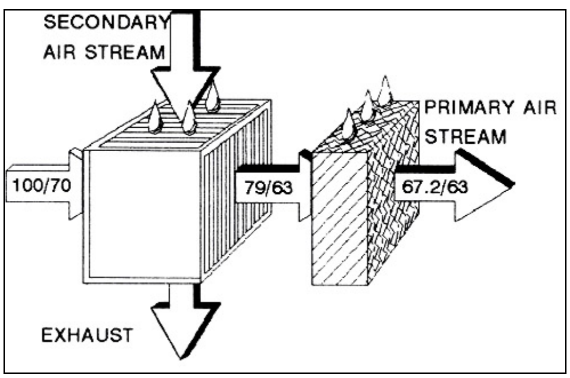
Overview

Description

Evaporative cooling offers significant energy and demand benefits over conventional vapor compression cooling by substituting blower(s) and pump(s) for energy intensive compressors and air handling components. The technology is best suited for dry climates where direct or indirect/direct cooling of the supply air stream can occur without compromising indoor comfort. Evaporative cooling can fully eliminate air conditioning in mild climates or in intelligently designed homes in more severe cooling climates. The potential of evaporative cooling to play a key role in California's energy future is improving as newer homes increasingly incorporate measures reducing cooling loads.



Direct Evaporative Cooler



Indirect-Direct Evaporative Cooler (sensible 1st stage pre-cooling of outdoor air, followed by direct 2nd stage cooling)

The key performance descriptor is saturation effectiveness, ε, defined as:

$$\varepsilon = \frac{t_{db} - t_s}{t_{db} - t_{wb}} \qquad \text{Equation 1}$$

where, t_{db} and t_{wb} = outdoor dry and wet bulb temperatures, respectively, and

t_s = supply air temperature

A saturation effectiveness of 100% indicates the system is providing supply air at a temperature equivalent to the outdoor wet bulb temperature. Direct evaporative systems, which pass outdoor air through wetted media, typically achieve an effectiveness of 70-90%, while indirect-direct systems (which indirectly pre-cool outdoor air prior to the direct stage) can achieve an effectiveness of over 100%.

Type of Change	This proposed change is a compliance option for the Residential Standards. ACM modeling rules would also be changed to allow for hourly modeling of evaporative cooler performance. The need for modeling changes is dependent upon how the proposed change is ultimately implemented. Although evaporative cooling is currently addressed under the 2005 Standards, it is not accurately handled. The proposed modification has been developed to deliver reasonable compliance credits for evaporative cooling while maintaining strict eligibility criteria to insure appropriate application of the technology. The Residential Standards, ACM Manual, Residential Manual, and compliance forms would all need to be updated to reflect this proposal.
Energy Benefits	Field studies have shown that evaporative coolers can provide energy and peak demand savings exceeding 50% in many cases (see Appendix A). Current modeling of evaporative cooling prescribes an 11 "SEER" for direct units and 13 "SEER" for indirect-direct units in comparison to the 13 SEER vapor compression standard. Unfortunately the ACM degrades evaporative cooler performance with outdoor temperature in the same manner as vapor compression equipment. This is clearly incorrect. The net impact of these assumptions results in energy impacts ranging from neutral to negative relative to the standard 13 SEER air conditioner. The goal of this proposal is to improve the modeling rules for evaporative cooling and also to offer reasonable compliance credits for the technology. A secondary goal is to offer a true hourly modeling approach that fully credits the technology under a Tier II Standards option.
Non-Energy Benefits	In many California climates, a properly sized evaporative cooler has the potential to maintain indoor temperature and relative humidity at levels within the ASHRAE comfort envelope in a well designed home. Sizing and proper equipment application is a critical design step in insuring the installed equipment meets the comfort requirements. Evaporative coolers are 100% outdoor air systems and provide filtered outdoor air to the conditioned space, improving indoor air quality.

Environmental Impact	Evaporative coolers utilize water to provide highly efficient space cooling. In contrast to "recreational" water consuming appliances, evaporative coolers provide significant societal benefits including electrical demand savings, reduced carbon, NOx and SOx emissions, and elimination of refrigerant-based cooling systems. Partially offsetting evaporative cooler water use is the reduction in water consumption at electrical generating facilities. A recent NREL study estimates roughly 4.5 gallons of water are consumed per kWh of energy produced in California (Torcellini et al, 2003). This number is high since it includes hydroelectric facilities with significant evaporation from lakes and reservoirs. A more reasonable value for combustion turbine power plants is approximately 0.5 gallons of water use per kWh. The California Urban Water Conservation Council (CUWCC) is concerned about residential water consumption. As a result of discussions with CUWCC, a project review meeting was held in April 2006 at the Energy Commission with the CUWCC, Energy Commission staff, AdobeAir, SCG, and Davis Energy Group. A key goal of the meeting was to insure that best practices in water conservation be applied to evaporative cooling. It was also agreed in this meeting that the Title 20 Appliance Standards are the appropriate mechanism to address evaporative cooler water use in a more quantitative manner. In the 1990's, Davis Energy Group completed several monitoring projects of system efficiency and water use (see Appendix A). Most of these studies involved systems with bleed lines that continually divert a fraction of the system's pumped water to neighboring landscaping, or to drains. Bleed systems, which are notoriously unreliable if not properly installed and maintained, are not included as a viable water maintenance system under this proposal. Automatic pump down systems (current best practice) that consume ~15% less water than bleed systems, are required under the proposed eligibility criteria for evaporative coolers. AdobeAir, one the leading manufacturers of evaporative cooling equipment, has prepared a position paper on water use issues and overall cooler energy efficiency (see Appendix B). Their analysis looks at both typical water use and how water use varies with climate.
Technology Measures	Measure Availability and Cost Not required for compliance option. Useful Life, Persistence and Maintenance Over the years, many low cost "swamp coolers" have resulted in evaporative cooler installations that often fail prematurely. Higher quality direct and indirect-direct EC's have higher quality rigid media and more durable components that should extend equipment life. Maintenance is a key component of extending the life of the equipment and insuring consistent performance over time. EC mechanical components are relatively simple, providing homeowners the option to perform routine seasonal maintenance (e.g. sump and media inspection/cleaning).

Performance Verification	Evaporative cooling systems require performance verification and/or commissioning to the same extent required by vapor compression equipment. We do not recommend a HERS rater inspection. Key installation verification issues include: 1. Operation of attic up ducts or other suitable method for providing for relief air from the house 2. Operation verification of sump dump system (no bleed systems allowed) 3. Verification of proper float level setting relative to the overflow drain 4. The overflow drain must drain to a exterior location easily observable by the homeowner, unless local code prohibits 5. Demonstration of uniform media wetting 6. Installation of a winter closure device that provides an adequate air barrier between the evaporative cooler and the duct system (or conditioned space, if non-ducted installation)
Cost Effectiveness	Not required.
Analysis Tools	Hourly evaporative cooling algorithm has been added to a research version of the MP7 simulation program. The proposed algorithm is simple and can be added to other approved compliance models.
Relationship to Other Measures	Evaporative cooling is most applicable in well-designed houses where cooling loads have been minimized by implementing with cooling reduction technologies such as passive solar design, spectrally selective glazing, low internal gain interior design (fluorescent lighting, efficient appliances, etc), and attic radiant barrier or cool roof technologies.

Methodology

The current 2005 Title 24 treatment of evaporative coolers conservatively assumes an 11 "SEER"[1] for direct systems and a 13 "SEER" for indirect-direct systems. With the January 2006 NAECA boost in air conditioner efficiency to 13 SEER, the 2005 methodology will result in a penalty to evaporative cooling under Title 24. This penalty arises because the ACM degrades evaporative cooler performance on an hourly basis exactly in the same manner as vapor compression equipment, despite the fact that evaporative cooler performance is independent of outdoor dry bulb temperatures.

Historically the Commission has proceeded cautiously with evaporative cooling to avoid a situation where evaporative coolers could be used to achieve a significant compliance credit for use in trading off with other measures. After completion of the home, the evaporative cooler could be removed and a replacement air conditioner could be installed with a resulting non-compliant home.

The goal of this proposal is to provide a reasonable credit for evaporative and tie performance to equipment characteristics, building loads, and weather. We believe that evaporative cooling needs to

[1] "SEER" in quotations is used in this document to refer to a Btu/Watt-hour efficiency for evaporative cooling systems, while SEER refers to standard vapor compression equipment rated performance.

be more fairly recognized in the Building Standards, since the technology has significant potential for providing efficient space cooling in many applications. In addition, the Building Standards are driving builders towards products such as spectrally selective glazing and attic radiant barriers that create a strong synergy with evaporative cooling (Lower cooling loads => reduced evaporative cooler run time => less moisture addition => improved indoor comfort). Effective January 2006, Title 20 Appliance Standards require all manufacturers to "test and list"[2] their products for sale in California. These factors, as well as the prospect of increasing on-peak electrical rates, support the need for more equitable treatment of evaporative cooling in the Residential Standards.

The implementation approach for evaporative coolers involves integrating an hourly algorithm into the ACM. Davis Energy Group worked with Enercomp to implement an hourly evaporative cooling model in MICROPAS with funding support from the Energy Commission's PIER program. The required inputs for the MICROPAS model are the Title 20 parameters: system *maximum airflow*, *effectiveness* at full speed, and *total system power*. The algorithm to calculate hourly EC cooling capacity is shown in Equation 2.

$$ClgCap = 1.08 * Q * (Tin - (Tdb - \varepsilon * (Tdb - Twb)))$$ Equation 2

Where,
- Q = airflow (cfm)
- Tin = indoor dry bulb temperature
- Tdb = outdoor dry bulb temperature
- ε = system effectiveness* (fraction)
- Twb = outdoor wet bulb temperature

* *System effectiveness is expressed in terms of "media saturation efficiency" or "cooling efficiency", depending upon equipment type, according to Title 20 appliance listing regulations.*

For those hours where the calculated "ClgCap" exceeds the building load, "true hourly" electrical energy consumption can be directly calculated based on *total system power* and the fractional hourly run time required to satisfy the load.

There are two performance issues that the proposed modeling methodology should address. The first issue relates to rising indoor relative humidity during periods with extended EC operation. Since modeling of indoor air moisture levels[3] is a complicated process beyond the capability of standard building simulation models, we are proposing a simplified algorithm to prohibit evaporative cooler operation during hours when extended operation under unfavorable conditions is likely. The algorithm will filter based on outdoor wet bulb temperature and disallow EC operation when outdoor wet bulb temperatures exceed 70°F. The second performance issue relates to evaporative cooler capacity limitations. Since evaporative coolers are 100% outdoor air systems with capacity limited by outdoor wet bulb temperature, they are more prone to experience diminished cooling capacity than a conventional vapor compression system.

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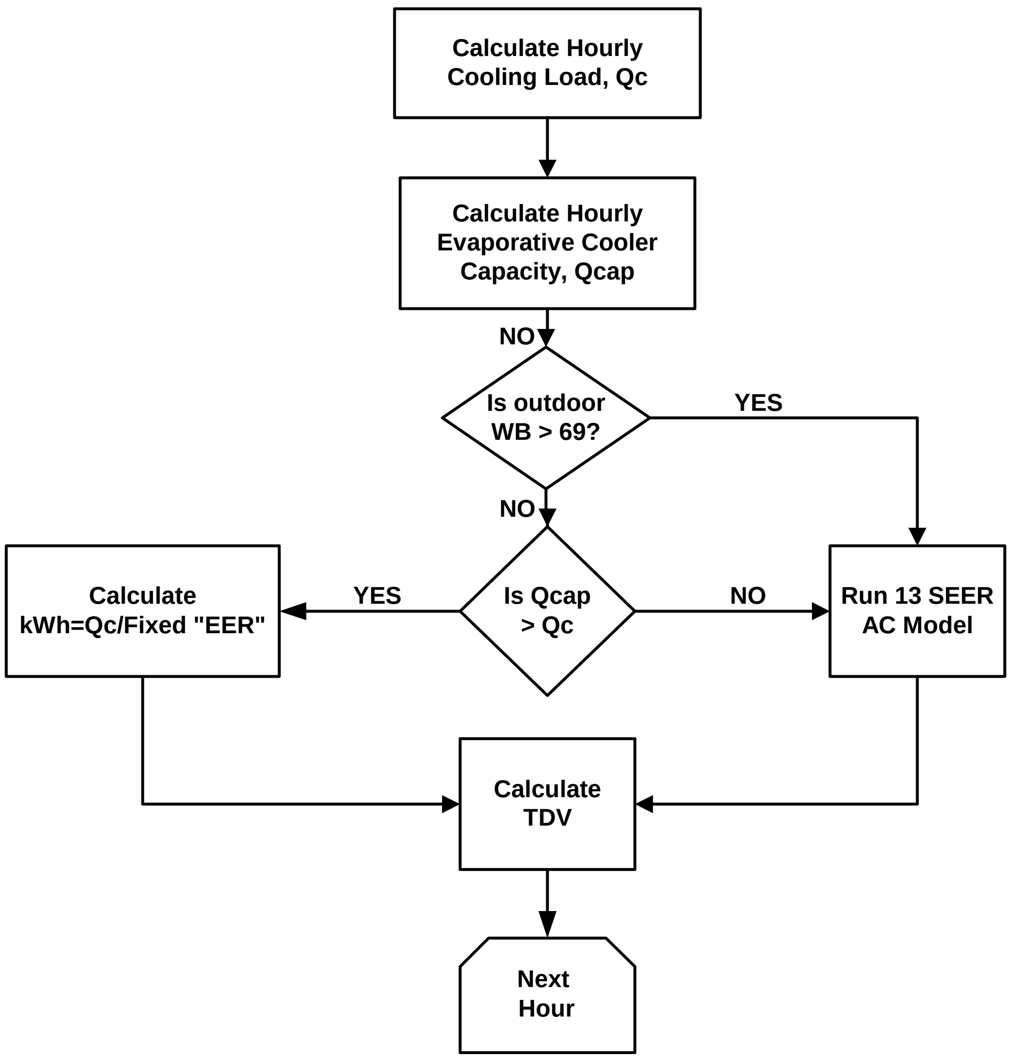
[2] Key listing requirements will include system effectiveness, full speed supply airflow, and total power at 0.3 E.S.P.

[3] Factors include moisture migration through the envelope, internal generation and absorption, and external sources/sinks such as an evaporative cooler (moisture addition) or air conditioner (moisture removal).

Each hour with calculated load, the algorithm will check both outdoor wet bulb temperature and also that the cooling capacity ("ClgCap") is greater than the calculated house cooling load. If either of these filters disallows EC operation, the program assumes that the hourly cooling load is met by a 13 SEER air conditioner (i.e. zero credit for that hour). If the filters allow evaporative cooler operation, a fixed Btu/Watt-hour efficiency (or "EER") is applied to determine hourly energy use. This fixed EER approach is used to limit the potential evaporative cooler compliance credit. Calculated hourly energy use is then valued based on the TDV value for that hour. The flow chart shown below depicts the modeling approach.



The proposed modeling methodology deviates from current ACM modeling rules for conventional air conditioning by requiring the user to model a specific evaporative cooler unit for Title 24 compliance. If the specified equipment being modeled is significantly undersized, or of low evaporative efficiency, the compliance run results will demonstrate reduced compliance credit. The proposed methodology provides feedback insuring that the specified equipment is both adequately sized and of sufficient efficiency for the load.

Analysis and Results

The hourly custom MICROPAS7 program (with 2008 TDV values) was used to simulate performance in climate zones 2 – 15. Runs were completed with on a prototype 1,600 ft^2 home[4] with equally distributed glazing and envelope parameters meeting climate zone prescriptive requirements. Assumed performance characteristics for single and two-stage evaporative coolers modeled are shown in Table 1. Single stage performance was based on expected performance results for direct evaporative units tested under the Title 20 standard. Two-stage performance is based on an indirect-direct unit soon to enter the market.

Table 1: Evaporative Cooler Performance Characteristics

Parameter	Direct	Indirect-Direct
Airflow (cfm)	1700	1550
Power (Watts)	595	600
Effectiveness (%)	80%	110%

Table 2 summarizes simulation results for the direct and indirect-direct modeling based on the 1,600 ft^2 prototype house and the EC performance assumptions shown in Table 1. Introduction of the wet bulb filter and fixed "EER" assumptions (11 for direct and 13 for indirect-direct) significantly reduce savings estimates relative to a true hourly modeling approach. Mean projected savings over the 15 climate zones average 12% for direct units and 30% for indirect-direct. Savings estimates weighted by the standard cooling budget range from 9% (direct) to 28% (indirect-direct), indicating generally lower percentage savings in the hotter zones. A plot of projected cooling and total (heating + cooling + water heating) budget savings by climate zone are included in Appendix C[5].

Additional runs were completed to assess how compliance credits could be used in terms of tradeoffs within the Title 24 process. For mild climate zone 8 and hot climate zone 14, additional runs were completed added glazing area in 10 ft^2 increments to each of the four cardinal orientations. Figure 1 plots results showing the compliance impacts for both direct and indirect-direct EC's in climate zone 8. For a direct EC, approximately 22 ft^2 of glazing can be added to each cardinal orientation before the compliance margin equals zero. For the more efficient indirect-direct EC, approximately 26 ft^2 of glazing can be added to each cardinal orientation. Figure 2 plots similar data for CZ14. In this hotter zone, the impact of adding glazing is greater per ft^2 than in CZ8; however a larger initial compliance credit allows more glass to be added to each cardinal orientation (~28 ft^2 for direct and 57 ft^2 for indirect-direct).

[4] Performance results will vary with house loads, EC cooling capacity, and weather characteristics.
[5] The graphs depict the % reduction from the standard design in both the cooling TDV budget and the total (heating, cooling, and water heating) budget.

Table 2: Evaporative Cooler Performance Projections

Climate Zone	Standard Cooling TDV/(ft²-yr)	Proposed Cooling TDV/(ft²-yr)		Cooling Compliance Margin TDV/(ft²-yr)		Cooling Compliance Margin (%)	
		Direct	Indirect-Dir	Direct	Indirect-Dir	Direct (%)	Indirect-Dir (%)
2	8.58	7.36	5.47	1.22	3.11	14%	36%
3	2.05	1.73	1.43	0.32	0.62	16%	30%
4	2.95	2.62	2.24	0.33	0.71	11%	24%
5	2.56	2.11	1.82	0.45	0.74	18%	29%
6	2.72	2.32	1.95	0.40	0.77	15%	28%
7	3.04	2.66	2.43	0.38	0.61	13%	20%
8	8.92	7.97	6.63	0.95	2.29	11%	26%
9	14.29	13.44	11.84	0.85	2.45	6%	17%
10	24.91	22.17	16.13	2.74	8.78	11%	35%
11	31.76	28.95	19.64	2.81	12.12	9%	38%
12	16.80	15.91	11.56	0.89	5.24	5%	31%
13	37.24	34.89	27.00	2.35	10.24	6%	27%
14	37.46	31.99	21.04	5.47	16.42	15%	44%
15	78.23	73.19	59.10	5.04	19.13	6%	24%
16	11.27	8.94	7.40	2.33	3.87	21%	34%

Figure 1: Impact of Added Glazing on Compliance Margin (CZ 8)

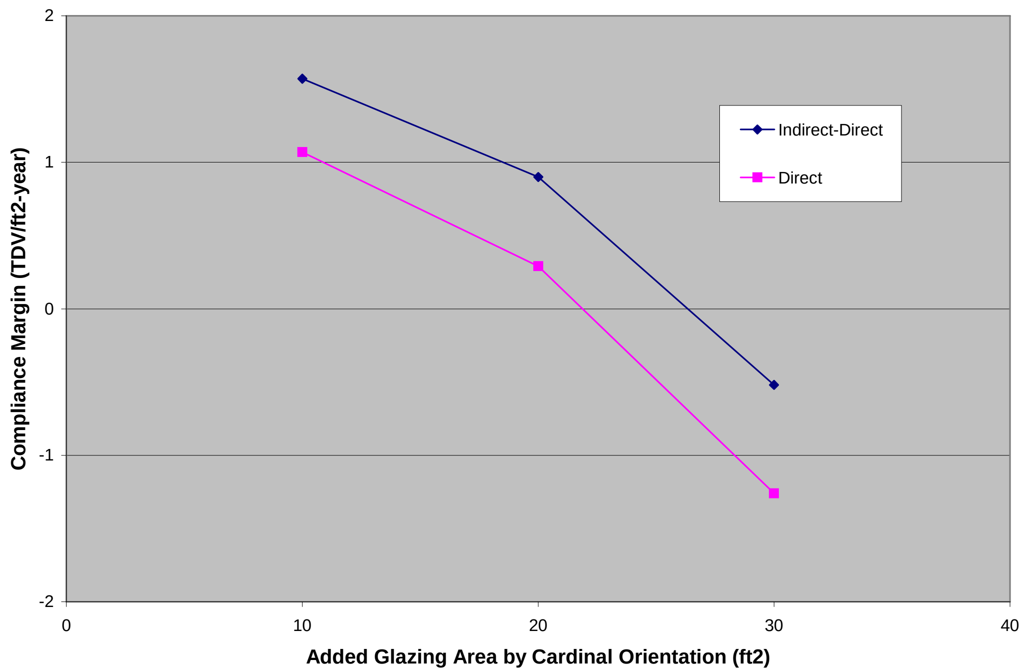
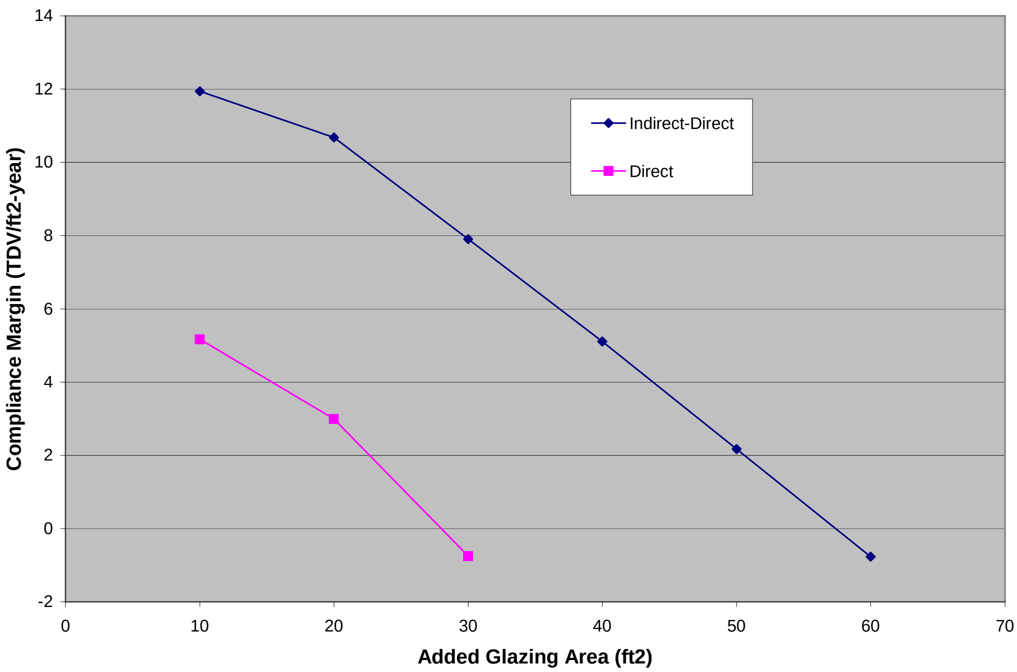


Figure 2: Impact of Added Glazing on Compliance Margin (CZ 14)



Recommendations

The proposed methodology presented in this template significantly improves the accuracy of the ACM modeling rules for evaporative coolers. The proposed approach ties tested performance parameters with hourly weather conditions and calculated hourly loads. By simulating the performance of a specific piece of equipment, sizing and effectiveness impacts are recognized in the compliance process. The original recommendations presented in May 2006 offered energy credits as shown in Table 2 for both direct and indirect-direct coolers. Based on concerns expressed by the California Energy Commission relating to indoor humidity concerns with direct evaporative coolers, the proposed credits will only be available for indirect and indirect-direct coolers that meet the proposed eligibility criteria. Direct evaporative coolers and indirect/indirect-direct coolers that do not meet the proposed eligibility criteria will be treated as minimum efficiency air conditioners for compliance purposes.

Based on the analysis completed in this project, we recommend the following:

1. The 2008 ACM should use Title 20 performance data (effectiveness, airflow, and power) to model evaporative coolers on an hourly basis using the algorithm presented in the Methodology section of this template. Indirect and indirect-direct evaporative cooler efficiencies should be fixed 13 “EER” and should not be degraded with changing outdoor or indoor conditions. The projected cooling savings (~30% for indirect and indirect-direct) are consistent with the original Title 24 treatment of evaporative coolers.

2. In the future reconsider allowing “true hourly” modeling of evaporative coolers under Tier II Standards approach. This would eliminate the fixed EER assumption proposed in Recommendation #1, and would provide full credit for evaporative cooler performance. True hourly modeling is valuable for various new construction energy efficiency programs that require “X%” beyond Title 24, as well as for Federal tax credit benefits.
3. The Commission should reassess a credit for direct evaporative units as monitoring data (primarily indoor humidity) becomes available in new production homes.
4. Proposed eligibility and sizing criteria are outlined below.

Material for Compliance Manuals

<u>Eligibility Criteria</u>

1. Eligible equipment shall be listed under Title 20 Appliance Standards.
2. The equipment manufacturer shall certify to the Commission that water use does not exceed 7.5 gallons per ton hour based on the Title 20 Appliance Standards testing criteria.
3. Equipment shall be permanently installed (no window or portable units).
4. Installation shall provide for automatic relief of supply air from the house with maximum air velocity through the relief dampers not exceeding 800 fpm (at the Title 20 rated airflow). Pressure relief dampers and ductwork shall be distributed to provide adequate airflow through all habitable rooms. For installations with an attic, ceiling dampers shall be installed to relieve air into the attic, and then to outside through attic vents. For installations without an attic, sidewall relief dampers are acceptable.
5. To minimize water consumption, bleed systems shall not be allowed.
6. A water quality management system (either “pump out” or conductivity sensor) is required. “Pump out” systems can either be integral to the evaporative cooler or they can be accessories that operate on a timed interval. The time interval between dumps shall be set to a minimum of six hours of cooler operation. Longer intervals are encouraged if local water quality allows.
7. Only the more water-efficient indirect and indirect-direct evaporative coolers with Title 20 listed saturation (or cooling) efficiency of 75%, or greater, are eligible for credits under this proposal. Direct evaporative coolers and coolers not meeting these criteria will be modeled in the ACM as a minimum efficiency (13 SEER) central air conditioner.
8. Automatic thermostats are required. On/off control is not allowed.
9. If evaporative cooler duct system is shared with a heating and/or cooling system, the installed duct system shall employ backdraft dampers at the evaporative cooler supply.
10. The installing contractor must provide a winter closure device that substantially blocks outdoor air from entering the indoor space.
11. The size of the water inlet connection at the evaporative cooler should not exceed 3/8”.
12. Unless local code prohibits, the sump overflow line shall not be directly connected to a drain and shall be terminated in a location that is normally visible to the building occupants.

Question and Answer Format

1. How are applications with vapor compression cooling systems and evaporative cooling systems handled?

In situations where both evaporative cooling system(s) and vapor compression system(s) are installed in a house, the sizing of the evaporative cooler will dictate the magnitude of the credit. The hourly model will insure that an evaporative cooler sized to meet most of the cooling loads will generate a higher credit than one sized to meet a small fraction of the design cooling load.

2. How do you model multiple evaporative coolers on one house?

In situations with multiple evaporative coolers, effectiveness inputs should be averaged, and airflow and power inputs should be totaled. Performance characteristics of each piece of equipment should be individually listed on the compliance forms

3. How should evaporative cooling systems be sized?

The following methodology should be used to select the appropriate evaporative cooler for a specific application. For dual system applications (conventional air conditioning and evaporative cooling), the evaporative cooler should be sized to meet a significant fraction of the design cooling load[6].

Complete a Manual J sizing calculation (or comparable sizing method) using a 78°F indoor temperature. Infiltration and latent contribution to the design cooling load should be eliminated from the design load since an evaporative cooler is a 100% sensible cooling system that pressures the house with supply air. Evaporative cooler capacity (ClgCap) should be calculated using the following equation:

$$ClgCap = 1.08 * (78° – (t_{db} - \varepsilon * (t_{db} - t_{wb}))) * Q$$

Where:
- t_{db} = outdoor design dry bulb temperature (ASHRAE 1%)
- t_{wb} = coincident outdoor wet bulb temperature
- ε = Title 20 listed effectiveness (saturation effectiveness for direct evaporative coolers and cooling effectiveness for two-stage evaporative coolers)
- Q = Title 20 listed air flow rate (cfm)

ASHRAE 1% design data for selected California locations are shown below.

[6] Whether that fraction is 70%, 80%, or 90% depends upon factors including climate, occupant comfort expectations, and expected cooling operating costs.

		ASHRAE 1% Design Conditions		
Location	Climate Zone	Design Dry Bulb	Coincident Wet Bulb	Wet Bulb Depression
ALAMEDA NAS	3	80	64	16
MOUNTAIN VIEW	4	83	64	19
PASO ROBLES AP	4	96	66	30
SAN JOSE	4	84	66	18
LOS ANGELES AP	6	83	67	16
BURBANK VLY PUMP	9	94	68	26
ONTARIO AP	10	99	68	31
RIVERSIDE FS 3	10	99	68	31
SAN BERNARDINO	10	101	69	32
MARYSVILLE	11	101	70	31
RED BLUFF AP	11	102	68	34
FAIRFIELD FS	12	96	68	28
SACRAMENTO AP	12	98	70	28
STOCKTON AP	12	97	69	28
BAKERSFIELD AP	13	101	70	31
FRESNO AP	13	100	70	30
LANCASTER	13	101	67	34
LEMOORE NAS	13	100	71	29
MERCED AP	13	99	69	30
BARSTOW	14	103	69	34
VICTORVILLE PUMPS	14	100	64	36
MOUNT SHASTA	16	88	61	27

Bibliography and Other Research

1. ASHRAE Standard 55-2003, Thermal Environmental Conditions for Human Occupancy, American Society of Heating, Refrigerating and Air-Conditioning Engineers, 2003.
2. 2001 ASHRAE Handbook, Fundamentals. American Society of Heating, Refrigeration, and Air Conditioning Engineers. 2001.
3. ANSI/ASHRAE Standard 133-2001, Method of Testing Direct Evaporative Air Coolers, American Society of Heating, Refrigerating and Air-Conditioning Engineers, February 2000.
4. Bourne, R. 1998. Evaporative Cooling, Natural Cooling for Dry Climates, E Source Technical Update, 1998.
5. California Energy Commission. 2005. California's Water – Energy Relationship. CEC-700-2005-011-SF.
6. Davis Energy Group. 1993. SMUD Indirect/Direct Evaporative Cooler Monitoring Report. Project report to the Sacramento Municipal Utility District.
7. Davis Energy Group. 1995. Indirect/Direct Evaporative Cooler Monitoring Report. Project report to Pacific Gas & Electric Company.
8. Davis Energy Group. 1995b. Indirect-Direct Evaporative Cooler (IDEC) Development Project Final Report. California Energy Commission ETAP project final report.

9. Davis Energy Group. 1998. Field Evaluation of Residential Indirect-Direct Evaporative Cooling in PG&E's Transitional Climates. Project report to Pacific Gas & Electric Company.
10. Huang, J. and H. Wu. 1992. Measurements and Computer Modeling of the Energy Usage and Water Consumption of Direct and Two-Stage Evaporative Coolers. Proceedings, 1992 ACEEE Summer Study.
11. Kinney, L. 2004. Modern Evaporative Coolers. Sept/Oct Home Energy Magazine, Berkeley, California.
12. NAEEEP, 2001. Minimum Energy Performance Standards, Evaporative Coolers. National Appliance and Equipment Energy Efficiency Program. Australia, March 2001. (http://www.energyrating.gov.au/library/pubs/profile-evapac2001.pdf)
13. Torcellini, P., N. Long, and R. Judkoff. Consumptive Water Use for Power Production. NREL/CP-550-35190. Golden, Colorado: National Renewable Energy Laboratory. November 2003.
14. Watt, J.R., et al. 1986. *Evaporative Air Conditioning Handbook, Second Edition*. Chapman and Hall Publishers.

Appendix A: Detailed Monitoring Results Summary

House Floor Area	Site Location	Seasonal Avg EER	Peak kW Demand	Indoor Conditions* Temp(°F)	RH (%)	Water Use Gal/hr (gal/day)
DIRECT EVAPORATIVE COOLERS						
1994 TurboCool Monitoring (SCE) **						
1600	Cathedral City	17.9	1.1	75.8	65.5%	2.9 (32)
1200	Palm Desert	19.1	1.1	76.7	64.9%	10.9 (150)
Average		**18.5**	**1.1**			
TWO-STAGE EVAPORATIVE COOLERS						
1993 MasterCool Monitoring (SMUD) **						
1400	Sacramento	14.1	1.5	77.2	63%	24 (186)
884	"	28.3	0.6	77.6	63%	7 (42)
1230	"	22.0	1.1	76.7	64%	10 (68)
1700	"	18.2	1.6	77.9	59%	12 (28)
1058	"	10.3	1.1	74.2	67%	2 (13)
1860	"	16.5	1.9	80.8	55%	8 (29)
Average		**18.2**	**1.3**			
September 1994 IDEC Monitoring (CEC)						
1600	Sacramento	43.2	0.7	77.5	64.1%	8.4 (26)
1300	Sacramento	51.5	0.7	80.2	65.3%	8.2 (33)
1300	Davis	26.7	0.7	78.0	73.7%	8.7 (12)
1000	Esparto	38.0	0.7	75.5	69.9%	7.4 (27)
1000	Cathedral City	86.4	0.7	79.1	54.0%	7.0 (33)
1500	Cathedral City	51.7	0.7	80.9	60.8%	10.4 (58)
Average		**47.9**	**0.7**			
1995 IDEC Monitoring (PG&E)						
1300	Davis	27.2	0.7	72.4	67.0%	10.1 (34)
1000	Esparto	30.8	0.7	73.8	74.0%	5.2 (53)
Average		**29.0**	**0.7**			
1998 IDAC Monitoring (PG&E)						
1607	Walnut Creek	26.0	1.1	76.7	61.3%	4.9 (21)
1637	Walnut Creek	18.0	1.1	73.4	65.9%	4.5 (27)
1649	Walnut Creek	23.5	1.2	75.9	56.6%	5.1 (11)
2030	Walnut Creek	19.3	1.1	72.7	52.1%	4.4 (3)
Average		**21.7**	**1.1**			

"*" average indoor temperature and RH during system operation

"**" indicates contractor installed bleed system

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Appendix B: Adobe Position Paper on Evaporative Cooler Energy Efficiency and Water Consumption – April 24, 2006

Evaporative cooling technology has been used for thousands of years, some say since the ancient Egyptian days. Since then the technology has made remarkable advances in many aspects: water delivery, air supply, evaporative effectiveness, and to the water conditioning system. However, there is one thing that has not changed in the core of the technology since the ancient days: evaporative cooling depends on the outside weather condition (dry and wet bulb temperatures). Not only cooling capacity depends on outdoor conditions, but also the water usage rate of the evaporative cooler. This is best illustrated based on analysis using the hourly MICROPAS weather file for Climate Zone 13 (Fresno).

July 29th: Hour 17
Outdoor Dry Bulb Temperature: 103 F
Outdoor Wet bulb Temperature: 64 F
House Cooling Load: 28,500 Btu/hr
Evaporative Cooler Capacity: > 50,000 Btu/hr
Projected Average Electric Demand: 0.7 kW
Water usage: 3.83 gallon/ton-hr
Projected 13 SEER AC Average Demand: 3.9 kW

August 1st: Hour 13
Outdoor Dry Bulb Temperature: 103 F
Outdoor Wet bulb Temperature: 76 F
House Cooling Load: 15,418 Btu/hr
Evaporative Cooler Capacity: ~18,000 Btu/hr
Projected Average Electric Demand: 1.0 kW
Water usage: 7.97 gallon/ton-hr
Projected 13 SEER AC Average Demand: 2.0 kW

The difference lies in the outdoor wet bulb temperature (64F vs. 76F). There will be days in areas such as Fresno and Palm Springs that evaporative cooling may not be sufficient to satisfy the cooling requirements. In more extreme areas, we recommend dual cooling systems (evaporative cooling and conventional air conditioning). Customers will use conventional air conditioning when evaporative cooling cannot meet the demand. As new homes become more efficient, the need for supplemental conventional air conditioning in many situations will be reduced. Also, customers can install portable or mini-split AC system for specific zones in the house to complement the use of evaporative cooling. There are many possibilities to mix and match technologies to reduce the impact of cooling operation on overall statewide electrical demand. In any case, using energy efficient evaporative cooling will reduce energy use, peak demand, and green house gas emissions!

There are several options that exist for water-conditioning systems. One is the conventional bleed-off approach that diverts a portion of the sump water from the media supply line, to a drain. A more advanced approach is the automatic drain system that drains the water from the sump every six hours of operation. The bleed-off system is cheap and if maintained correctly, it is an effective method of maintaining descent water quality in the system. However, more often than not, the bleed-off would be neglected and will become clogged. The drain system on the other hand will require less maintenance and will be consistent on its operation. On average, automatic drain system will save 15% of water usage over bleed-off system.

We believe evaporative cooling should be used more in appropriate applications. Yes, evaporative cooling will use water. Some coolers may use more water than others by its design and price point. Evaporative cooling units with rigid media will use approximately 25 to 35% less water than conventional aspen pads units. However, we believe aspen pad coolers have their place in the market. Even aspen pad evaporative cooling units will provide significant electrical energy savings relative to conventional air conditioning system.

Davis Energy Group provided Adobe with a full-year hourly weather and cooling loads file for the 1,600 ft^2 prototype house (climate zone 13) used in their Measure Information Template submittal. We took the hourly loads and computed hourly water use for the 1,600 ft^2 prototype house and a scaled up 2,200 ft^2 prototype house. We modeled an Adobe direct evaporative cooler with 12” rigid media. (WHC762) This particular unit can be considered water efficient because of its use of rigid media and an automatic drain system. Table 1 summarizes performance projections.

Table 1: Project Performance (Climate Zone 13)

	1,600 ft^2 house	2,200 ft^2 house
Conventional AC kWh/year	1,934	2,662
Evaporative Cooler kWh/year	524	735
Evaporative Cooler Water Use (gals/year)	5,006	8,351
Water Use: Gallons/ton-hour	3.02	3.71

Evaporative cooling may never replace conventional air conditioning. However, promoting highly energy efficient technologies with reduced green house gas emission impacts is an important part of moving to a more sustainable energy future.

If you have any questions, please let me know. Thank you.

Sincerely,

Yun Kim
Product Engineer
Adobe Air

Appendix C: Evaporative Cooler Savings Projections by Climate Zone