CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE)

Draft Measure Information Template – Cooling Tower Water Savings

2013 California Building Energy Efficiency Standards

California Utilities Statewide Codes and Standards Team, April 20, 2011

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1. Purpose

Through Codes and Standards Enhancement (CASE) Studies, the California Investor Owned Utilities (IOUs) provide standards and code-setting bodies with the technical and cost-effectiveness information required to make informed judgments on proposed regulations for promising energy efficiency design practices and technologies. The IOUs began evaluating potential code change proposals in the fall 2009. Throughout 2010, the CASE Team (Team) evaluated costs and savings associated with each code change proposal. The Team engaged industry stakeholders to solicit feedback on the code change proposals, energy savings analyses, and cost estimates. This Draft CASE Report presents the IOU code change proposal for cooling tower water savings.

The contents of this report, including cost and savings analyses and proposed code language, were developed after taking into consideration feedback from the cooling tower and water treatment industries and the California Energy Commission (CEC), as well as recent guidelines such as ASHRAE 189.1 P, Standard for the Design of High Performance Green Buildings, Section 6: Water Use Efficiency, and the IAPMO Green Plumbing and Mechanical Code Supplement, 2010.

Although Part 6 of Title 24 includes mandatory energy efficiency requirements for heat rejection systems, there is currently no existing standard in Part 6 of Title 24 that directly addresses water use in cooling towers. The proposed measure aims to addressing the vexing challenge of standardizing water conservation practices in open, or evaporative, cooling towers. During this process two things have become clear from our research and feedback from industry stakeholders: 1) the vast majority of cooling towers over about 100 tons are equipped with conductivity- or flow-based controls intended to control the level of total dissolved solids (TDS) in the tower water, and 2) most towers are not operated in such a manner as to maximize cycles of concentration and minimize water losses.

This apparent contradiction likely stems from several factors. Managing water chemistry in cooling towers is a complex process. Cooling tower system water chemistry is managed to control three main concerns: scale, corrosion, and biological fouling. The proposed measure primarily affects the first two factors, which are a result of interactions between TDS, alkalinity, hardness, pH and temperature of the water. Achieving maximum cycles of concentration, while managing potentially harmful water quality elements, requires regular monitoring of system water, as well as an understanding the quality of local water entering the tower via the makeup water line. Water quality varies widely across the state, as well as from city block to city block, and sometimes day to day and season to season as local water suppliers balance supply and demand, utilizing multiple sources of water.

It is easy to see how the variability in makeup water quality and the complexity of managing tower system water, in combination with the high operational and financial cost of early failure of a cooling tower, can result in an overly conservative approach to tower bleed frequency. Our goals for this proposed code are two-fold: 1) to ensure that all towers covered by the code have the controls necessary to maximize cycles of concentration and minimize unintentional water losses such as leaks and unintentional overflow; and 2) to ensure that local water quality and maximum achievable cycles of concentration are understood and documented each time a new or replacement tower is installed.

2. Overview

2.1 Measure Title

Cooling Tower Water Savings

2.2 Description

This measure would apply to evaporative cooling towers 150 tons and larger, installed in new construction and replacement projects for commercial/ industrial/ institutional buildings covered under Title 24. Building types/ sectors most likely to be affected include those that have a cooling tower used for rejecting heat from an HVAC system (e.g., office building) or used for rejecting heat from process loads (e.g., manufacturing, food processing, etc.).

Although Part 6 of Title 24 includes mandatory requirements for heat rejection systems – specifically, fan speed control, tower flow turndown, and a limitation on centrifugal fan cooling towers - there is no existing standard in Part 6 of Title 24 that directly addresses water use in cooling towers.

The proposed cooling tower water savings measure requires the installation of controls that automate blowdown and chemical feed based on conductivity or flow rate, while maximizing cycles of concentration based on local water quality conditions. Building owners are required to calculate and document the maximum cycles of concentration based on local water quality conditions. The measure also requires installation of a flow meter on the makeup water line, an overflow alarm to prevent overflow of the sump in case of makeup water valve failure, and efficient drift eliminators.

2.3 Type of Change

The code will be incorporated into Part 6 of Title 24. The proposed language will be a mandatory measure in Section 112: Mandatory Requirements for Space-conditioning Equipment, and will require the addition of a new sub-section (e). Although Title 24 currently addresses energy savings in cooling towers, the following proposal is for a new mandatory measure that addresses cold water use in cooling towers. This will be the first time that Part 6 of Title 24 mandates cold water saving measures.

To implement the proposed measure as a mandatory measure, the Nonresidential Compliance Manual for Title 24 will need to be updated, as well as the mechanical systems compliance forms.

Because this is a mandatory requirement only, it will not affect calculation procedures or assumptions used in making performance calculations, nor will the Alternative Calculation Method (ACM) Approval Manual be affected.

2.4 Energy Benefits

The proposed measure does not address energy use directly; however, annual water savings and the associated embedded energy savings[1] were calculated.

Building climate-zone dependent analysis played a role in our overall computation of cost-effectiveness; however, due to the use of very localized water quality within those climate zones, a weighted statewide average was ultimately used to determine an average savings for the measure. This approach is outlined in detail in Section 3. Below, a single table summarizes the total average annual water and electrical savings for all measure requirements combined (including conductivity or flow-based controller, flow meter, overflow alarm and drift eliminator).

Table 1. Water and Electric Savings by Tower and Building

	Unit Definition	Water Savings (gal/yr)	Electricity Savings* (kwh/yr)	Demand Savings (kw)	Natural Gas Savings (Therms/yr)	TDV Electricity Savings	TDV Gas Savings
Per Unit Measure	350 ton cooling tower	86,114	859	n/a	n/a	n/a	n/a
Per Prototype Building	Office 117,000 sqft conditioned space	86,114	859	n/a	n/a	n/a	n/a

**Electricity savings represent embedded energy, or energy savings that occur as a result of saving water, i.e., the amount of energy required to produce, convey and treat a given quantity of water.*

The energy benefits presented in the Analysis and Results section of this report provides more detailed calculations.

Electrical demand savings in kW for a prototype building were not calculated because the code change would lead to water and embedded energy savings, for which there are no quantifiable direct electrical demand savings.

Time Dependent Valuation (TDV) savings were not calculated because the code change would not lead to direct energy savings. Demand values and TDV values for water and embedded energy savings are not available.

[1] For the purposes of this report, embedded energy is the energy required to produce, convey and treat a given quantity of water. The methodology used to calculate the statewide embedded energy in water was based on a 2006 Energy Commission PIER study, and is described further in section 3.3.

2.4.1 Assumptions

Following, is a summary of the assumptions for building characteristics, cooling equipment, and embedded energy used for modeling and analysis of cooling tower energy and water use.

Table 2. Building Characteristics and Embedded Energy Assumptions

Building size	117,000 sq ft of conditioned space
Occupancy type	Office
Cooling operation	6am – 6pm, 7 days per week[2]
Embedded Energy[3]	9,977 kWh/MG

Table 3. Chiller and Cooling Tower Capacity, and Condenser Water Flow Rate Assumptions

BCZ	Chiller capacity (tons)	Cooling tower capacity (tons)	CW (gpm)
3	242	281	700
4	242	281	700
6	240	280	694
7	239	280	691
8	281	325	811
9	281	325	811
10	242	281	700
12	291	337	841
13	292	339	845

[2] Per Table N2-8 in T24 ACM

[3] Population-weighted for Northern and Southern California using data from an Energy Commission PIER study (2006)

2.5 Non-Energy Benefits

The primary benefit of the proposed measure is water savings.

The measure will also result in increased energy efficiency and decreased chemical costs. Better management of cooling tower water will result in less scale and corrosion, improving heat transfer and extending the life of the cooling tower. Lower chemical use in tower water can also be expected.

Only water savings and chemical savings are quantified in this report.

2.6 Environmental Impact

The proposed measure is expected to decrease water consumption and associated embedded energy consumption, as well as direct energy consumption in cooling towers due to a decrease in scaling and improved heat transfer. In addition, increased cycles of concentration will result in less chemical use to treat cooling tower water.

No significant environmental impacts associated with implementing the measure are anticipated.

Table 4. Avoided Emissions (pounds/ yr)[4]

	NO_X	SO_X	CO	PM10	CO_2
Per Unit Measure	0.136	0.814	0.198	0.064	497
Per Prototype Building	0.136	0.814	0.198	0.064	497

Table 5. Impact on Materials (I = Increase, D = Decrease, NC = No Change)

	Mercury	Lead	Copper	Steel	Plastic
Per Unit Measure	NC	NC	NC	NC	NC
Per Prototype Building	NC	NC	NC	NC	NC

[4] Emissions factors are calculated based on embedded energy savings associated with cooling tower water savings and the following emissions factors (in pounds/ MWh): NOX (0.158); SOX (0.948): CO (0.230) ; PM10 (0.074): CO2 (578.960).

Table 6. Water Consumption

	On-Site (Not at the Powerplant) Water Savings (or Increase) (Gallons/Year)
Per Unit Measure[1]	86,114
Per Prototype Building[2]	86,114

Table 7. Water Quality Impacts

	Mineralization (calcium, boron, and salts)	Algae or Bacterial Buildup	Corrosives as a Result of PH Change	Others
Impact (I, D, or NC)	NC	NC	NC	N/A
Comment on reasons for your impact assessment	Increased cycles of concentration will decrease bleed water and increase concentration of total dissolved solids in the bleed water, resulting in not net effect over the life of the tower.	Increasing cycles of concentration does not directly affect algal or bacterial buildup	Concentrated water in tower tends to go more basic, and less corrosive	

2.7 Technology Measures

The proposed code change requires the installation of several types of equipment, all of which are widely available and commonly used in industry. All equipment is available from numerous manufacturers and distributors, and is manufactured in quantities that can meet increased demand associated with the code change.

2.7.1 Conductivity and/or Flow-based Controls

The table below lists a sample of conductivity- or flow-based controller manufacturers and distributors and their products. These industry representatives were contacted for quotes on their products.

Table 8. Conductivity and Flow-based Controller Manufacturers, Distributors, and Products

Manufacturer	Distributor	Sample Product
Advantage Controls	Advantage Controls	NanoTron C
Chemtrol	Santa Barbara Control Systems	CT 100
Lakewood Instruments	Metex Corporation	140
Aquatrac Instruments	Aquatrac Instruments	microFLEX
Seametrics	Howard E. Hutching Co. Inc.	PT35 Dual Pulse Timer

2.7.2 Documentation of Maximum Achievable Cycles of Concentration

This requirement does not require the purchase of equipment.

2.7.3 Flow Meter on Makeup Water Line

Turbine, insertion, and paddle wheel flow meters made of brass or stainless steel are appropriate to meet the code. Flow meters are readily available on the market. Manufacturers include, but are not limited to:

- Santa Barbara Controls/ Chemtrol
- Advantage Controls
- Lakewood Instruments

2.7.4 Overflow Alarm

Overflow alarms include a level switch and an electronic signaling device. Overflow alarm components manufacturers include, but are not limited to:

- Electronic sirens
  - Allen-Bradley
  - Federal Signal
  - Grainger

- Float switch
  - Flowline
  - Dwyer Instruments
  - Little Giant sold by Franklin Electric

2.7.5 Drift Eliminators

Drift eliminator manufacturers include, but are not limited to:

- Cooling Tower Depot
- Amertech Tower
- American Cooling Tower

2.7.6 Useful Life, Persistence, and Maintenance

Water savings will persist as long as these measures are installed and the responsible party for managing cooling tower water chemistry utilizes the measures. The measures are relatively simple to install. As outlined in the proposed code language, conductivity controllers should be maintained in accordance with manufacturer's specifications to minimize scale accumulation and maintain calibration.

The estimated useful life of each equipment type is summarized below.

Table 9. Estimated Useful Life for Proposed Measures

Measure	EUL (years)
Conductivity- or flow-based controller	10
Conductivity sensor	3
Max cycles calculation	n/a
Makeup flow meter	15
Overflow alarm	15
Drift eliminators	9

2.8 Performance Verification of the Proposed Measure

No additional performance verification, such as diagnostic testing or acceptance testing, is required for compliance with this measure.

2.9 Cost-Effectiveness

Below are the present value costs and savings associated with the proposed measures installed on a 350 ton cooling tower over the 15 year analysis period.

Table 10. Life Cycle Cost of Proposed Measures

a	b		c		d	e	
Measure Name	Additional Costs– Current Measure Costs (Relative to Basecase) ($)		PV of Additional Maintenance Costs (Savings) (Relative to Basecase) (PV$)		PV of **Water and Chemical** Cost Savings – Per Proto Building (PV$)	LCC Per Prototype Building ($)	
	Per Unit	Per Proto Building	Per Unit	Per Proto Building		(c+e)-f Based on Current Costs	(d+e)-f Based on Post-Adoption Costs
Cooling Tower Measures	$3,624	$3,624	$0	$0	$10,042	$(6,418)	$(6,418)

2.10 Analysis Tools

The proposed measures are mandatory measures. Analysis tools are not relevant because the measure will not be subject to whole building performance trade-offs.

2.11 Relationship to Other Measures

The cooling tower water savings measure is related to the existing cooling tower energy standards in Title 24, for which there are also proposed updates for 2013. These measures are complimentary in the sense that better management of water quality results in less scale and increased heat transfer, as well as water savings.

3. Methodology

The cooling tower water savings measure is a cold water-saving measure that will also provide embedded energy savings. There are five components to the proposed requirement:

1. installation of conductivity- or flow-based controller
2. documentation of maximum achievable cycles of concentration
3. installation of flow meter on the make-up water line
4. installation of overflow alarm
5. installation of efficient drift eliminators

Several components of the analysis apply to all or most measures and are summarized in Sections 3.1 and 3.2. Measure-specific analysis is addressed in subsequent sub-sections. For all measures, a 350-ton cooling tower was analyzed.

Note that some standard LCC methodologies do not apply: for example, there are no TDV or demand values, therefore the analysis has been altered appropriately.

3.1 Calculating Measure Costs

Installed measure costs were developed through phone calls to manufacturers and distributors. An "average least-cost option" for materials was determined by eliminating outlier costs and averaging the remainders. The average material cost was then adjusted to include the California sales tax rate, where applicable, and we also applied the cost basis adjustments for California electrical and plumbing materials from RS Means. Labor hours for installation were estimated based on input from manufacturers and distributors, and we used the RS Means Standard Union Labor Rate 2011, adjusted for the California cost basis, for electricians and plumbers to determine installation cost.

3.2 Cost of Water

Water cost savings were assumed to be $8.12/kgal. This represents the cost of water to the industrial sector in 2009 as presented in the *Black & Veatch 2009/ 2010 Water/ Wastewater Rate Survey*. The cost of water to the commercial sector in 2009 was $8.53. Because the relative tonnage of evaporative cooling towers in California for commercial versus industrial sectors is not known, the more conservative water cost assumption was used in the analysis.

The Black & Veatch Rate Survey includes typical monthly water and wastewater bills for commercial and industrial customers for the top 50 United States cities based on population. Our analysis uses the population-weighted industrial cost of water for California's eight largest cities as shown in the Black & Veatch report. Because commercial and industrial water cost projections could not be found, our analysis uses a constant water rate over the 15 year measure life. However, it is expected that this understates cost savings and that the cost of water will likely increase substantially over that time.

3.3 Embedded Energy

The conversion factor for embedded energy used in our analysis is 9,977 kWh/million gallons of water (MG). This factor was derived from a California Energy Commission PIER study (2006) and has been population-weighted for Northern and Southern California.

At the time of this report-writing, the California Public Utilities Commission (CPUC) was spearheading research and analysis to determine more granular values for embedded energy based on investor-owned utility (IOU) territory. The most recent data to come from the CPUC's effort was presented in January 2011 and shared the embedded energy associated with nine pilot water conservation projects implemented across the four IOU service territories in coordination with 18 regional water agencies. The purpose of the study was to determine if, and how, to include embedded energy savings in the IOU total resource cost (TRC) calculations for their energy efficiency programs.

Although the pilot programs resulted in the development of embedded energy values, there are a few significant limitations. In many cases, a portion of the energy supplied to move and treat water was supplied by a non-IOU energy utility. In those cases, no energy data was provided by the non-IOU agency, which sometimes represented over half of the energy profile. Also, a number of water, wastewater, and recycled water providers did not provide energy use data on numerous projects. In cases where data was missing from the analysis, the total energy intensity for that pilot was under-reported.

Due to the inconsistencies noted in the CPUC study, embedded energy values resulting from the study were not used in this Title 24 analysis.

3.4 Conductivity or Flow-based Controls

3.4.1 Calculating Statewide Baseline and Maximum Cycles of Concentration

The use of controls in combination with an understanding of maximum achievable cycles of concentration based on water quality is expected to result in maximization of cycles of concentration at any given tower. As discussed earlier in this report, maximum achievable cycles of concentration is dependent on local water quality conditions since mains water is consistently added to the tower system to make up for losses due to evaporation, blowdown and drift. Due to the variability of water quality conditions across the state, and sometimes even within municipalities, we are not proposing a requirement to achieve minimum cycles of concentration. However, in order to assess cost-effectiveness of the measure, expected average statewide savings were calculated based upon a statewide average baseline cycles of concentration and a population-weighted statewide maximum cycles of concentration.

Baseline Cycles

Hard data on average cycles of concentration was scarce. No data was available for towers that were not equipped with controls.

Chem-Aqua provided 10 data points from across California, which averaged 4.7 cycles. Several water quality companies indicated that it was unusual to encounter towers that were not using conductivity- or flow-based controls, and this would seem especially true for sites engaging the services of a water quality management company. Therefore, we consider these data points to be representative of towers using controls and to be biased towards those towers that are "better than average" in terms of management of water quality and use.

Average statewide cycles of concentration was presented in two documents. The first was as a 2006 Potential Best Management Practices report developed by Koeller and Company for the California Urban Water Conservation Council[5]. The Koeller report states that average cycles of concentration in California is three. A second source was a Pacific Gas and Electric Company code change proposal in which Chem-Aqua provided data that California towers average four cycles of concentration[6]. Again, we assume the latter is biased toward towers with "better than average" water quality management.

For this analysis, we assumed a statewide average of 3.5 cycles of concentration.

Maximum Cycles

In calculating the maximum achievable cycles of concentration based on local water quality, we considered three limiting factors related to water quality and cooling tower operation to prevent scaling and/or corrosion:

1. Silica levels must be maintained at ≤ 150 ppm
2. The Langelier Saturation Index should be maintained at ≤ 2.5 (see explanation of LSI below)
3. pH in new cooling towers using galvanized metal must be maintained at ≤ 8.3 until metal is passivated, which occurs after 3-6 months of operation

Water quality data was collected for 9 water utilities representing the 10 most populous California cities - approximately 25% of the state's population - and 9 building climate zones. Water quality data was found in Annual Water Quality Reports, also known as Consumer Confidence Reports, which are publicly available on water agency websites. Datapoints not found in these reports were collected by calling the water quality division of the utility. Agencies are not required to test for and report

[5] Riesenberger, James and Koeller and Company. "VII. Commercial – Industrial Cooling Water Efficiency" Potential Best Management Practices report to the California Urban Water Conservation Council (2006).

[6] Pacific Gas and Electric Company, "Cooling Tower code change proposal" (2002).

alkalinity, for example; however, they often do test for it and they were able to easily provide data over the phone or in an email. Some water agencies do not test for a certain water quality parameter and it is not available in print or by telephone. Additional detail regarding water quality data for each water utility is provided in Appendix X.

Determining max cycles of concentration for silica is simply a matter of multiplying the ppm of silica in the water and the cycles of concentration until it reaches a maximum of 150 ppm. For example, a cooling tower being fed by mains water containing 30 ppm can achieve 5 cycles of concentration before it needs to bleed system water to reduce the amount of silica in the tower.

A model based on the Langelier Saturation Index (LSI) was used to calculate maximum cycles of concentration for each water agency's local water conditions. The LSI indicates whether water will precipitate, dissolve, or be in equilibrium with calcium carbonate. LIS is a function of hardness, alkalinity, conductivity, pH and temperature and should be maintained at ≤ 2.5[7].

The LSI model used was in the form of an Excel spreadsheet and was provided by Chem-Aqua. The model requires the input of five water quality parameters – conductivity, alkalinity, calcium hardness, magnesium hardness, and silica – and once entered, allows the user to increase the cycles of concentration until the desired LSI is reached, which in this case was a maximum value of 2.5.

pH levels for new cooling towers made of galvanized metal was not addressed in the maximum cycles of concentration calculation since pH is only a concern for the first 3-6 months of the life of the cooling towers. Also, this proposal is not mandating that the tower achieve a specific minimum cycles of concentration - only that towers are equipped with the controls necessary to do so and that tower owners have calculated the maximum achievable cycles of concentration for their tower.

[7] Personal communication with Sam McManis, Chem-Aqua, August 25, 2010.

The average statewide maximum cycles of concentration, calculated for each water utility based on silica levels and LSI, resulted in a population-weighted average of 4.9 cycles, as shown below.

Table 11. Maximum Achievable Cycles of Concentration by Water Agency, Building Climate Zone and Hydrologic Region

Population Ranking	**City**	**Water Agency**	**Building Climate Zone(s)**	**Hydrologic Region**	**Maximum Cycles**
1	Los Angeles	LADWP	8,9	South Coast	3.90
2	San Diego	City of San Diego	7,10	South Coast	3.45
3	San Jose	SJ Muni WD/ Great Oaks Water	4	SF Bay/ Central Coast	6.20
4	San Francisco	SFPUC	3	San Francisco Bay	10.00
5	Fresno	City of Fresno	13	Tulare Lake	3.55
6	Long Beach	Long Beach	6,8	South Coast	3.60
7	Sacramento	City of Sacramento	12	Sacramento River	7.85
8	Oakland	EBMUD	3	San Francisco Bay	10.00
9	Santa Ana	Orange Co WD	8	South Coast	2.75
10	Anaheim	Orange Co WD	8	South Coast	2.85
				Population-weighted max cycles:	**4.9**

3.4.2 Modeling Energy Characteristics of Cooling Tower

We used EnergyPro to model a chiller/ cooling tower system in an office building in 9 California Building Climate Zones (3,4,6,7,8,9,10,12,13). These climate zones represent 89% of projected new construction of offices.

The building was modeled using the Title 24 ACM manual guidelines. A building of 117,000 square feet and 5 stories was modeled because it represent an appropriate application a chiller/ cooling tower cooling system of typical size (i.e., on the order of 250 tons or greater).

Table 12. Modeling Energy Characteristics of Cooling Towers by Building Climate Zone

Bldg Climate Zone	Occupancy Type	Area (Square Feet)	# of Stories	Chiller Capacity (tons)	Cooling Tower Capacity (tons)	Condenser Water Flow (gpm)	Cooling Operation
BCZ 3	Office	117,000	5	242	281	700	6am - 6 pm, 7 days/wk*
BCZ 4	Office	117,000	5	242	281	700	6am - 6 pm, 7 days/wk*
BCZ 6	Office	117,000	5	240	280	694	6am - 6 pm, 7 days/wk*
BCZ 7	Office	117,000	5	239	280	691	6am - 6 pm, 7 days/wk*
BCZ 8	Office	117,000	5	281	325	811	6am - 6 pm, 7 days/wk*
BCZ 9	Office	117,000	5	281	325	811	6am - 6 pm, 7 days/wk*
BCZ 10	Office	117,000	5	242	281	700	6am - 6 pm, 7 days/wk*
BCZ 12	Office	117,000	5	291	337	841	6am - 6 pm, 7 days/wk*
BCZ 13	Office	117,000	5	292	339	845	6am - 6 pm, 7 days/wk*

*per Table N2-8 in T24 ACM

Energy Pro provided the following information, which was used to model tower water use in the same 9 climate zones:

- Outside air dry bulb temperature
- Outside air wet bulb temperature
- Condenser water load
- Chiller load

Modeling cooling tower water use is explained in the next section.

3.4.3 Modeling Cooling Tower Water Use

Cooling tower water use was calculated using an Excel-based "cooling tower water use" model that determines evaporation and blowdown based on weather data, chiller and condenser water loads, drift and cycles of concentration. The model was developed by Baltimore Air Coil and refined by Taylor Engineering, an Alameda-based engineering firm with extensive experience modeling cooling towers. Baseline cycles of concentration and maximum cycles of concentration were inputted for each of the 9 building climate zones evaluated, resulting in a total of 18 model runs. The output value of the model was bleed (in gallons per minute), which was averaged across all 9 climate zones for the baseline cycles of concentration value, and again for the maximum cycles value. Savings was determined by the difference between the statewide average values for baseline and maximum cycles.

The loads that were input into the cooling tower water use model were based on tower sizes that ranged from 280 of 339 tons depending on the climate zone. In order to conduct life cycle cost analysis of a typical size, 350 ton tower, water savings was scaled-up in each climate zone. These values were population-weighted to calculate one statewide average value for savings, which was then extended for the entire analysis period of 15 years.

Water cost savings for a 350 ton cooling tower was scaled down to determine the smallest tower size for which the proposed measures would be cost-effective over 15 years. Based on interviews with Taylor Engineering, scaling results for a large tower to a small tower provides a reasonable estimate of the actual bleed rate to within 5%.

3.4.4 Calculating Chemical Cost Savings

Chemicals that inhibit scale are added to cooling tower water based on the bleed rate. The less water that is bled from a tower, the smaller the quantity of chemicals that is added to the system. Chemical cost savings for an individual cooling tower is therefore exactly proportional to the decreased bleed rate that results from increasing cycles of concentration. For the LCC analysis, we used the same modeling results described in section 3.4.3 to determine bleed savings, and the corresponding chemical savings (36%).

The chemical cost savings associated with reducing bleed by increasing cycles of concentration from 3.5 to 4.9 was calculated based on the following information:

- chemical concentration in towers is maintained at no less than 100 ppm, which is equivalent to ~1 gallon of chemical inhibitor per 12,000 gallons of bleed water[8]
- 10 pounds of chemical inhibitor/gallon
- cost of chemical inhibitor: $2.00/lb[9]

[8] Personal communication with Sam McManis, Chem-Aqua, April 13, 2011.

3.5 Documentation of Maximum Cycles of Concentration

This measure requires calculation and documentation of the maximum achievable cycles of concentration based on local water conditions. This measure is assumed to work in tandem with the conductivity- or flow-based controls and makeup water flow meter requirements to maximize cycles of concentration and no additional energy savings are associated with it.

This measure requires the building owner to:

- collect water quality data from local water supplier for the building covered by the code
- calculate maximum cycles of concentration using the Energy Commission supplied LSI calculator
- complete Compliance Form MECH 5C.

Time needed to complete this compliance process was estimated to be 2 hours and was included in the measure costs associated with this proposal.

3.6 Flow Meter on Make-up Water Line

This measure provides a number of water-efficiency benefits. A flow meter on the make-up water line effectively submeters the cooling tower, allowing the operator to know how much water the tower is using and facilitating the identification of excessive water use due to leaks, for example.

How a makeup flow meter detects leaks

- The cooling tower manufacturer specifications will have a formula that allow the calculation of water loss due to evaporation given a certain set of variables such as air temperature, humidity and incoming water temperature.
- If the rate of water loss is smaller than the rate of makeup water from the ball valve, then more water is flowing into the system than is being used for evaporation
- In that case, you have a leak and require cooling tower pipe leak location

We were unable to find data on the frequency and magnitude of cooling tower leaks and therefore did not attribute savings to this measure.

[9] Email quotation from Kirk Saunders, Wesco Chemicals, April 13, 2011.

3.7 Overflow Alarm

Unintended water losses can occur if the standard float valve that controls the flow of make-up water in the sump fails, resulting in overflow into the sewer line. The failure of the makeup water line control also results in uncontrolled dilution and no activation of chemical feed, putting the system at risk for scale. An overflow alarm prevents these losses from going undetected for days, weeks or longer. An overflow alarm system includes a float switch and an audible electronic signaling device or notification through a building management system (BMS). Industry contacts, including cooling tower manufacturers and water treatment companies, generally indicated that the prevalence of installed overflow alarms is very low.

We were unable to find data on the frequency and magnitude of sump overflow in cooling towers and therefore did not attribute savings to this measure.

3.8 Efficient Drift Eliminators

Efficient drift eliminators minimize losses due to drift, which is liquid water that is blown or splashed out of the tower during normal operations. Drift eliminators include secondary benefits, such as minimizing the spread of disease and preventing damage to adjacent property, such as parked cars, that would otherwise be splashed.

According to representatives of cooling tower manufacturers, water treatment companies and drift eliminator distributors, that most cooling towers have drift eliminators installed and the drift eliminators are likely to control drift losses to 0.005% or less[10]. Current practice for new tower installations is to include drift eliminators, and Evapco specifies equipment that limits losses to a maximum of 0.0001%[11].

The proposed code requirement specifies that drift eliminators that control drift losses to 0.002% of the circulated water volume for counterflow towers and 0.005% for cross-flow towers on all new and retrofit cooling towers. This is a “no incremental cost, no incremental savings” measure.

[10] Personal communication: Daryn Cline, Evapco, February 25, 2011, and James Scott, San Joaquin Chemical, February 25, 2011, Gary Hennis, American Cooling Tower, March 3, 2011.

[11] Personal communication, Daryn Cline, Evapco, February 25, 2011.

3.9 Summary Cost and Estimated Useful Life of Each Measure

The following table summarizes the installed cost and estimated useful life (EUL) of each measure requirement. Individual measure costs are not discounted. Total cost over 15 years, in present value terms, is provided in the last row of the table.

Table 13. Costs and Estimated Useful Lives of Proposed Measures

	Installed Cost (first year)	**EUL (years)**	**15 Year Cost**
Controller	$1,089	10	$2,178
Conductivity sensor	$164	3	$657
Max cycles calculation	$300	n/a	$300
Makeup flow meter	$653	15	$653
Overflow alarm	$351	15	$351
Drift eliminator	$0	9	$0
Total	$2,393		$4,139
Total (present value)			$3,624

4. Analysis and Results

The results of the analysis outlined above show that this measure is cost-effective for cooling towers 150 tons and larger.

Water savings for a 350 ton cooling tower are expected to be 1,289,764 gallons over 15 years as a result of decreasing bleed through increased cycles of concentration from 3.5 to 4.9, in addition to 1,940 gallons over 15 years as a result of increasing the efficiency of drift eliminators.

Reduction of bleed has the added benefit of decreasing chemical use, resulting in additional savings. In this case, chemical savings associated with increasing cycles of concentration from 3.5 to 5 on a 350 ton cooling tower is expected to total 1,075 pounds of chemicals over the life of the tower.

The proposed measure is expected to deliver $6,418 in net savings to the owner of a 350 ton cooling tower. The overall present value savings for the proposed measure over 15 years is $10,042, and the cost is $3,624.

Water savings will also result in annual embedded energy savings of 859 kWh, or 12,887 kWh over the lifetime of a 350 ton tower.

It is important to note that this analysis provides a conservative estimate of water savings and water cost savings for the following reasons:

- Only an industrial water rate was used, which was lower than the commercial water rate because we do not have a good estimate for what percentage of tower tonnage in California serves the commercial versus industrial sectors
- The water rate was held constant over the 15 year analysis. However, more likely than not, water rates will increase over the next 15 years.
- We modeled cooling tower energy use - and by extension, water use - for an office building and applied that to our analysis; however, cooling towers serving the industrial sector have longer operating hours and would experience higher savings as a result of these efficiency measures.

This analysis can be strengthened in several ways during the next code cycle:

- Data on projected water rates would allow more realistic projections of water cost savings
- Modeling energy use and water use for cooling towers serving an industrial load profile would provide a more accurate LCC results for that sector. The current exception being proposed for towers under 150 tons could likely be lowered for the industrial sector.
- Market data indicating the share of commercial versus industrial cooling tower tonnage would allow a more refined analysis of statewide savings

5. Recommended Language for the Standards Document, ACM Manuals, and the Reference Appendices

5.1 Code Change Language for Inclusion in Part 6 of Title 24

The proposed language will be a mandatory measure in Section 112: Mandatory Requirements for Space-conditioning Equipment, and will require the addition of a new sub-section (e):

(e) Evaporative or Open Cooling Towers. All evaporative or open cooling towers shall be equipped with the following:

1. Conductivity or Flow-based Controls. Towers shall include installation of controls that maximize cycles of concentration based on local water quality conditions. Controls shall automate system bleed and chemical feed based on conductivity, and/or in proportion to metered makeup volume, metered bleed volume, or bleed time. Conductivity controllers shall be maintained in accordance with manufacturer's specifications to maximize useful life and accuracy.
2. Documentation of Maximum Cycles of Concentration. Building owner shall document the maximum cycles of concentration based on local water quality conditions, using the Energy Commission-provided calculator. The calculator is intended to determine maximum cycles based on a Langelier Saturation Index (LSI) of 2.5 or less. Building owner shall document maximum cycles of concentration on Compliance Form MECH 5C, which shall be reviewed and signed by the Professional Engineer (P.E.) of Record.
3. Flow Meter. Towers shall include installation of a flow meter on the makeup water line.
4. Overflow Alarm. Towers shall include installation of an overflow alarm to prevent overflow of the sump in case of makeup water valve failure. Overflow alarm shall send an audible signal or provide an alert via the Building Management System to the tower operator in case of sump overflow.
5. Efficient Drift Eliminators. Towers shall be equipped with efficient drift eliminators that achieve drift reduction to 0.002% of the circulated water volume for counterflow towers and 0.005% for cross-flow towers.

   EXCEPTION to Section 112(e)(1-5): Towers under 150 tons are exempted from all requirements under Section 112(e).

5.2 Code Change Language for Title 24 Compliance Manual

To implement the proposed measure as a mandatory measure, the Nonresidential Compliance Manual for Title 24 will need to be updated in the following ways:

- Section 4.1.2 Mandatory Measures, will need add item number 12, Cooling Tower Water Saving Controls (§112), to the list of mandatory measures.
- A new section, 4.2.4 Cooling Tower Controls, would be added under Section 4.2: Equipment Requirements. Section 4.2.4 would reference §112 in Part 6 of Title 24, and would describe the methodology or tool required to calculate maximum achievable cycles of concentration in cooling towers based on local water conditions. It would also reference the appropriate compliance form.
- Section 4.5.1 Mandatory Measures, under Section 4.5 HVAC System Control Requirements, would require the addition of #7 Cooling Tower Water Savings Controls. Language would be developed that references §112 in Part 6 of Title 24, and would describe the methodology or tool required to calculate maximum achievable cycles of concentration in cooling towers based on local water conditions. It would also reference the appropriate compliance form.
- Section 4.10 Glossary/Reference would also be updated to include subsection 4.10.11, describing the water balance in evaporative cooling towers, and defining cycles of concentration and the Langelier Saturation Index (LSI).

5.3 Updates to the Mechanical Systems Compliance Forms

The mechanical systems compliance forms will also need to be modified.

- The MECH 1C: Certificate of Compliance: Add a new section to HVAC equipment efficiencies (§112) in the Note Blocks for Mechanical Mandatory Measures. The section will require verification of installation of the following:
    - controls that automate blowdown and chemical feed based on conductivity or flow rate
    - flow meter on the makeup water line
    - overflow alarm to prevent overflow of the sump in case of makeup water valve failure
    - efficient drift eliminators

A new form, MECH-5C: Maximum Cycles of Concentration, will be used to document maximum achievable cycles of concentration based on local water quality conditions. This can be inserted as subsection 4.11.8 or be added to the end of Section 4.11 as subsection 4.11.10.

5.4 Code Change Language for Existing Compliance Forms

The mechanical systems compliance forms would also need to be modified.

- The MECH 1C: Certificate of Compliance would be updated. A new section would be added to HVAC equipment efficiencies (§112) in the Note Blocks for Mechanical Mandatory Measures. The section would require verification of installation of the following:
  - controls that automate blowdown and chemical feed
  - flow meter on the makeup water line
  - overflow alarm to prevent overflow of the sump in case of makeup water valve failure
  - efficient drift eliminators

A new form, MECH-5C: Maximum Cycles of Concentration, will be used to document maximum achievable cycles of concentration based on local water quality conditions. This could be inserted as subsection 4.11.8 or be added to the end of Section 4.11 as subsection 4.11.10.

5.5 Code Change Language for Glossary

Glossary to come

6. Bibliography and Other Research

Sources to come.

7. Appendices

Appendices to come.