Felicia Miller

From: Will Walters <WWalters@aspeneg.com>
To: Felicia Miller <Fmiller@energy.state.ca.us>
Date: 3/12/2010 3:19 PM
CC: Jim Adams <Jadams@energy.state.ca.us>
Attachments: F4107D-6.6-10B Fogging Freq Curve.pdf; Data 10 cell back to back Clearsky.doc; Data 10 cell back to back.doc; F488-5.3-10B Fogging Freq CurveEstimate for Back t o back tower.pdf; CSVP Linearity Assumption.docx; Compute Dew Point Temp.pdf

Felicia,

I have reviewed the information provided by the applicant, all of which is attached below or provided as file attachments, and have the following notes and preliminary conclusions.

1) The revised cooling tower data was provided too late for staff to complete a revised modeling analysis in time for the workshop.
2) The revised cooling tower data was incomplete in respect to the original data response and what staff had thought the applicant had agreed to provide, instead of three ambient cases for each operating case they only provided one, which will cause staff additional effort to complete the modeling analysis and will impact the accuracy of staff's analysis.
3) The applicant provided data for two cooling tower designs, an unabated design and a partially abated design, it is staff's understanding that the partially abated design is not being proposed by the applicant and therefore will not be modeled by staff.
4) The applicant's analysis shows statistically inconsistent results. They indicate almost no visible plumes during the seasonal clear hours period, but show a visible plume frequency of almost 20 percent for all annual clear hours. This is an impossible result, the seasonal clear hour period includes the much colder winter period that is much more plume conducive, and so will have a higher frequency that the annual clear hours. There are obvious major errors in the applicant's approach based on these results.
5) Additionally, the limited modeling results provided are inconsistent with the fogging frequency curve provided. Based on the fogging frequency curve the overall plume frequency should be somewhere around 50 percent of all hours, while the applicant's modeling results notes only 10 percent.
6) Staff shared with the applicant our heat balance methodology that matches ambient conditions with exhaust conditions for the cooling tower through heat balance. The applicant did not follow this approach, or anything similar and appeared to have modeled a single ambient case for all ambient conditions. So their modeling results will not conform with staff's regardless of any other issues with methods and inputs.
7) The fogging frequency curve provided for the proposed tower suggests that plumes would be a frequent occurrence during seasonal clear daylight hours and supports the need for a KOP simulation.

I am willing to work with the applicant to help them fix the major issues with their visible plume analysis if they are interested. I will call in just after 10:30 on Tuesday to discuss this at the PSA workshop.

Will Walters, Aspen Environmental Group
818-597-3407 ext. 345

Will
Attached to this email are multiple documents and our CSVP modeling results using the new cooling tower data. Information included consist of:

1. The updated cooling tower parameters for the PHPP obtained from Kiewit/SPX consisting of the fogging curve and tower parameters for two cooling tower alternatives.
2. Memorandum in which I describe what I see as an inherent assumption of linearity between relative humidity and temperature in the CSVP model. We discussed this briefly in our phone call on Tuesday, March 9.
3. Campbell Scientific memorandum describing computation of moisture variables, including a plot of the relationship of temperature and relative humidity.
4. AECOM CSVP visible plume modeling results (below).

In our revised visible plume modeling, we did not simulate the 25 degree case since a temperature this low is such a rare event in Palmdale. The 98 degree case was also not run as summer daytime low humidity conditions in Palmdale are not conducive to visible plume formation. Plus, as I describe in my memorandum, I believe there is a bias (direction unknown) in CSVP for low humidity conditions typical of a hot summer day where the temperature is 98F. For all the cases simulated for the 64F conditions, visible plumes occur less than 20% of the time for all meteorological cases you use in your assessment.

In our plume dimension modeling results, we present the plume dimensions for the Maximum, 90th percentile, and median (50th percentile) plumes for two cooling tower designs. For our visual simulation, we propose to plot the median plume for the Wet Tower F488-5.3-10B for the PB13 scenario – 64F, 40%RH, Full Load with Duct Burner. Our simulation will therefore represent the median plume dimensions for the worst-case operating scenario. We used Victorville meteorological data for these simulations, consistent with what you used in the PSA.

Please note that our modeling results present information for the daytime clear skies case. There are too few occurrences of seasonal daytime clear sky conditions to develop representative percentile plume dimensions (i.e., only two hours for case PB13, Wet Tower F488-5.3-10B).

Wet Tower F488-5.3-10B		**Case PB8 - 64 degrees F, 40% RH - Full load, no DB**		**Case PB13 - 64 degrees F, 40% RH - Full load, with DB**	
Case	**Hours**	**Visible**	**%**	**Visible**	**%**
All hours	25361	2619	10.3%	1980	7.8%
Daylight	12662	2201	17.4%	1726	13.6%
Daylight Clear	11871	2185	18.4%	1716	14.5%
Seasonal Daylight Clear	5069	14	0.3%	2	0.04%

Clearsky F4107D-6.6-10B		**Case PB8 - 64 degrees F, 40% RH - Full load, no DB**		**Case PB13 - 64 degrees F, 40% RH - Full load, with DB**	
Case	**Hours**	**Visible**	**%**	**Visible**	**%**
All hours	25361	2291	9.0%	1815	7.2%
Daylight	12662	1969	15.6%	1613	12.7%
Daylight Clear	11871	1955	16.5%	1605	13.5%
Seasonal Daylight Clear	5069	7	0.1%	0	0.00%

Wet Tower F488-5.3-10B Plume Results, Daytime Clear

Hours

Plume Characteristics By Height:			
	Length (m)	Height (m)	Width (m)
Max	248	835	76
90%	144	547	66
50%	163	193	34

Clearsky F4107D-6.6-10B Plume Results, Daytime Clear Hours

Plume Characteristics By Height:			
	Length (m)	Height (m)	Width (m)
Max	139	839	64
90%	171	781	35
50%	56	218	28

Regards

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Will,

Attached is the cooling tower data we have for the two cooling towers being considered for Palmdale. Additionally, included in the email in which we got this data were the tower characteristics for 3 cases: PB4, PB8, and PB13. The formatting of that email was messy so I've cleaned it up here. We modeled cases PB8 and PB13 since those were the most typical temperature cases (both 64 degrees, PB8 without DB, PB13 with DB). The flow rates are given per cell (10 per tower)

Wet Tower F488-5.3-10B	98 F, 17% RH, 100% Load, Solar, no DB **Case PB4**	64 F, 40% RH, 100% Load, Solar, no DB **Case PB8**	64 F, 40% RH, 100% Load, Solar, with DB **Case PB13**
Moist Air Mass Flow Rate (lb/min)	83449.7	84649.6	84465.9
Wbout (F)	90.5	86.6	88.7
Dbout (F)	90.5	86.6	88.7
Heat Rejection (MMBTU/h)	1091	1520	1653
Dry Air Mass Flow Rate (lb/min)	80620	82112.3	81759.6

Clearsky F4107D-6.6-10B	**Case PB4**	**Case PB8**	**Case PB13**
Moist Air Mass Flow Rate (lb/min)	86636.5	87239.6	86942.7
Wbout (F)	90.1	86.1	88.2

Dbout (F)	92.1	87.2	89.3
Heat Rejection (MMBTU/h)	1091	1520	1653
Dry Air Mass Flow Rate (lb/min)	83793.4	84702.8	84237.8

Let us know if you need anything else.

Rich

Technical Note 16
22.12.00

CALCULATING DEW POINT FROM RH and AIR TEMPERATURE

SCIENTIFIC

Introduction

Dew point can be measured directly, to a high degree of accuracy, using traditional devices such as cooled mirror hygrometers, etc.

However, such devices are often very expensive, require regular maintenance and may need air pumps. They are also heavy on power consumption.

An alternative method, described in this Technical Note, uses relatively inexpensive RH and Temperature sensors, in conjunction with a Campbell Scientific datalogger, to calculate dew point. While end results may not be quite as accurate as traditional dedicated devices, they are acceptable for a wide range of applications.

Calculating Dew Point

Dew point temperature can be calculated by Campbell Scientific dataloggers as follows:

1. Measure the relative humidity (RH) and air temperature (T_a; units °C).
2. Compute the saturation vapour pressure (S_{vp}; units kPa) using Instruction 56.
3. Compute the vapour pressure (V_p; units kPa) from $V_p = RH * S_{vp} / 100$).
4. Compute the dew point (Td; units °C) from the inverse of a version of Tetens' equation, optimised for dewpoints in the range -35 to 50°C:

$$T_d = (C_3 * \ln(V_p / C_1)) / (C_2 - \ln(V_p / C_1))$$

where:

$C_1 = 0.61078$

$C_2 = 17.558$

$C_3 = 241.88$

Error in the Estimation of Dew Point

Teten's equation is an approximation of the true variation of saturated vapour pressure as a function of temperature. However, the errors in using the inverted form of the equation result in dew point errors much less than 0.1°C.

The largest component of error, in reality, comes from errors in the absolute calibration of the temperature and RH sensor.

Figure 1 shows how dew point varies as a function of temperature and humidity. It can be seen that the response is non-linear with respect to both variables. Errors in the measurement of RH and temperature thus form a complex function in relation to the resultant error in estimated dew point. In practise, the effect of errors in the calibration of air temperature can be taken to translate to an equivalent error in dew point, e.g. if the air temperature sensor is 0.2°C high, then the estimated dew point is approximately 0.2°C high. Figure 2 shows the errors in dew point as a function of a 'worst case' 5% error in the calibration of the RH sensor.

For sensors installed in the field there are additional errors associated with exposure of the sensor, e.g. sensors in unaspirated shields get slightly warmer than true air temperature in conditions of low wind speeds and high solar radiation. However, if the RH and air temperature sensors are installed in the same shield and are thus exposed identically, the estimate of dew point is not subject to the same error as the measurement of air temperature would be. This is because the temperature sensor will measure the actual temperature of the RH sensor, which is what is required for the derivation of air vapour pressure and thereby dew point.

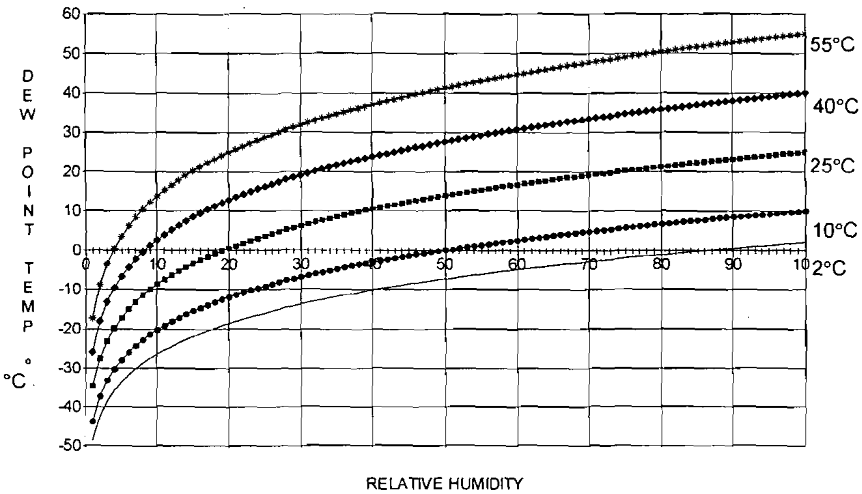

Figure 1. Dew Point Temperature over the RH Range for Selected Air Temperatures

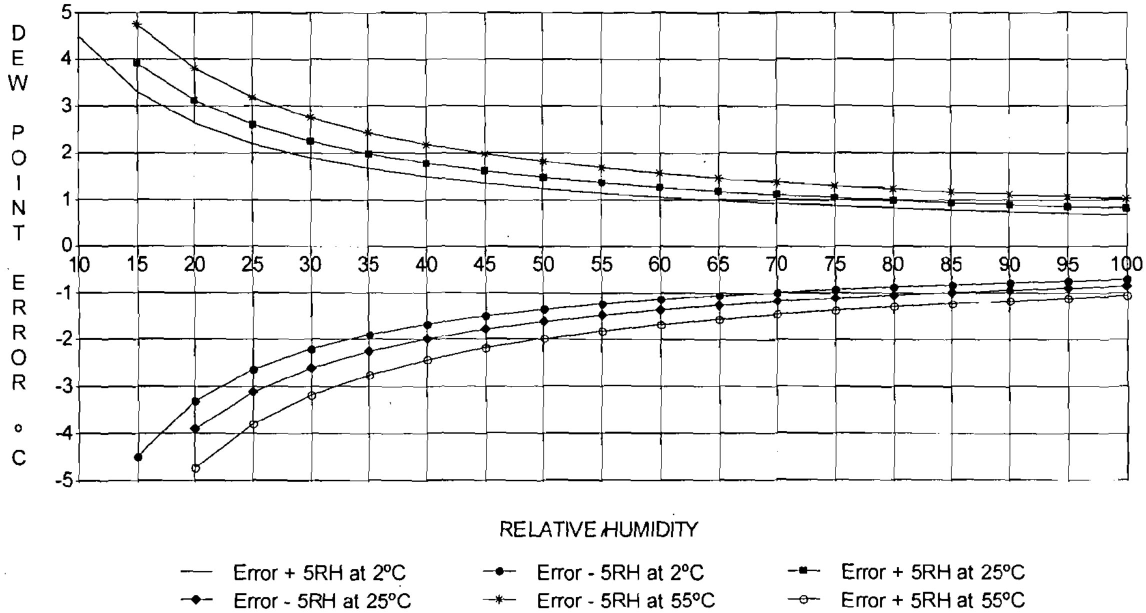

Figure 2. Effect of RH Errors on Calculated Dew Point (±5 RH Unit Error at Three Air Temperatures)

Program Example

```
;{CR10X}
;Program: Demonstration of DewPoint
;calculation
;This example uses an HMP45C Relative
;Humidity and Temperature probe/

*Table 1 Program
  01: 60   Execution Interval (seconds)
```

;First turn on power to the probe

```
1:  Do (P86)
 1: 41        Set Port 1 High
```

;Use Instruction 22 to force a 1 second settling delay

```
2:  Excitation with Delay (P22)
 1: 1         Ex Channel
 2: 0         Delay W/Ex (units = 0.01 sec)
 3: 100       Delay After Ex (units = 0.01 sec)
 4: 0         mV Excitation
```

;Measure RH and Temperature mV and multiply ;readings by 0.1

```
3:  Volt (SE) (P1)
 1: 2         Reps
 2: 5         2500 mV Slow Range
 3: 1         SE Channel
 4: 1         Loc [ RH        ]
 5: 0.1       Mult
 6: 0.0       Offset
```

;*Turn off power to the probe*

```
4:  Do (P86)
 1: 51        Set Port 1 Low
```

;*Subtract 40 from Temperature to scale to Celsius*

```
5:  Z=X+F (P34)
 1: 2         X Loc [ Air_Temp ]
 2: -40       F
 3: 2         Z Loc [ Air_Temp ]

6:  Saturation Vapor Pressure (P56)
 1: 2         Temperature Loc [ Air_Temp ]
 2: 4         Loc [ Sat_VP    ]
```

;*Now calculate Vapour pressure using*
;*VP = RH * Sat_VP / 100*
;*This equation can be entered directly for Edlog 6+.*
;*Instructions 7 - 8 show the instructions required for*
;*older versions of Edlog or keyboard entry.*

```
7:  Z=X*Y (P36)
 1: 4         X Loc [ Sat_VP     ]
 2: 1         Y Loc [ RH         ]
 3: 7         Z Loc [ WORK_1      ]
```

;*Multiply by 0.01 (equiv. to dividing by 100)*

```
8:  Z=X*F (P37)
 1: 7         X Loc [ WORK_1      ]
 2: .01       F
 3: 5         Z Loc [ VP         ]
```

;*Now estimate dew point using the equation:*
;*Dew_Temp = 241.88 * ln(VP/0.61078) / (17.558 -*
;*ln(VP/0.61078))*
;*This equation can be entered directly with Edlog 6+.*
;*Instructions 9 - 14 show the instructions required for*
;*older versions of Edlog or keyboard entry*

;*Multiply VP by 1/0.61078 (= 1.6373)*

```
9:  Z=X*F (P37)
 1: 5         X Loc [ VP         ]
 2: 1.6373    F
 3: 6         Z Loc [ WORK_R      ]

10:  Z=LN(X) (P40)
 1: 6         X Loc [ WORK_R      ]
 2: 6         Z Loc [ WORK_R      ]

11:  Z=X*F (P37)
 1: 6         X Loc [ WORK_R      ]
 2: 241.88    F
 3: 7         Z Loc [ WORK_1      ]

12  Z=F (P30)
 1: 17.558    F
 2: 0         Exponent of 10
 3: 8         Z Loc [ WORK_2      ]

13  Z=X-Y (P35)
 1: 8         X Loc [ WORK_2      ]
 2: 6         Y Loc [ WORK_R      ]
 3: 8         Z Loc [ WORK_2      ]

14  Z=X/Y (P38)
 1: 7         X Loc [ WORK_1      ]
 2: 8         Y Loc [ WORK_2      ]
 3: 3         Z Loc [ DEW_TEMP  ]
```

;*And now, as an example, store the time and hourly*
;*average*

```
15  If time is (P92)
 1: 0         Minutes (Seconds --) into a
 2: 60        Interval (same units as above)
 3: 10        Set Output Flag High

16  Real Time (P77)
 1: 110       Day,Hour/Minute

17  Average (P71)
 1: 1         Reps
 2: 3         Loc [ DEW_TEMP  ]

*Table 2 Program
  02: 0       Execution Interval (seconds)

*Table 3 Subroutines

End Program
```

Input Locations

```
1  RH          1 1 1
2  Air_temp    1 1 1
3  DEW_TEMP    1 1 1
4  Sat_VP      1 1 1
5  VP          1 1 1
6  WORK_R       1 3 2
7  WORK_1       1 2 2
8  WORK_2       1 2 2
9  _ ________  0 0 0
10 _________   0 0 0
11 _________   0 0 0
12 _________   0 0 0
13 _________   0 0 0
14 _________   0 0 0
15 _________   0 0 0
16 _________   0 0 0
27 ______   0 0 0
28 ______   0 0 0

-Program Security-
00
0000
-Mod
-Mode 4-
-Final Storage Area 2-
0
```

AECOM

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Memorandum

Date: March 10, 2010

To: Will Walters, Aspen Environmental

From: Howard Balentine

Subject: Assumed linearity of RH with Temperature in CSVP

Distribution: Rich Hamel Sara Head

Based on our conversation yesterday, I re-looked at my interpretation of how CSVP operates and still believe there is an inherent assumption of linearity between relative humidity and temperature in the CSVP model. The portion of the code I am questioning is below:

```
1       dt=(texit-ambt)/1000.
2       dh=(humex-humid)/1000.
3       icond=0
4       t1=0.
5       t2=0.
6       h1=0.
7       h2=0.
8       do i=1,1000
9       t=texit-dt*i
10      h=humex-dh*i
11      humsat=qsc(1,t,1013.)
12      if(icond.eq.0) then
13          if (h.gt.humsat) then
14          if(good_day) icount = icount + 1
15          goto 10
16          endif
17      else
18          if (h.le.humsat) goto 20
19      endif
```

1. In lines 1 and 2, the dt and dh variables are defined as 1/1000 of the difference between the stack exhaust values and ambient values. The individual dt and dh values, for a given value of i, are linked by the index i. Thus, CSVP makes an inherent assumption of linearity between a small change in humidity (dh) and a small change in temperature (dt).

2. In line 11, CSVP computes the saturation water content for the given t_i as CSVP steps through the temperature range between exhaust temperature and ambient temperature (DO I loop in line 8). The saturation vapor curve used is not in question.

3. In line 13, CSVP associates the computed saturation water content (humsat) for a given t_i value with the corresponding linked estimate of plume water content (h_i). This is a direct assumption that the value of t_i computed in line 9 corresponds to the value of d_i computed in line 10. Since the relationship between t_i and d_i is computed in a linear fashion, the CSVP model in this portion of the code assumes linearity between temperature and humidity during the comparison with saturated conditions in lines 13 and 18.

For most of the relative humidity range, linearity is a valid assumption. However, once the relative humidity drops below about 25%, the linearity assumption begins to break down. This is demonstrated in the attached PDF file from Campbell Scientific that includes a plot with curves of Relative Humidity versus Wet Bulb temperature for various temperatures. The plot of interest (Figure 1) is extracted below:

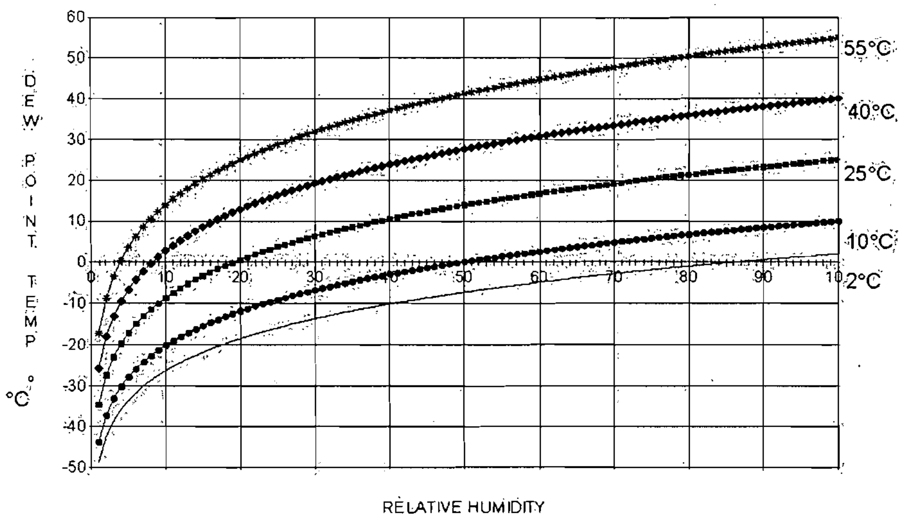
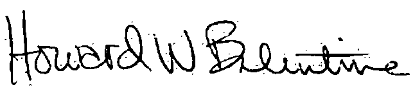


Figure 1. Dew Point Temperature over the RH Range for Selected Air Temperatures

Source: Cambpell Scientific, Technical Note 16, 22.12.00. Calculating Dew Point from RH and Air Temperature.

For projects in the desert such as the PHPP, ambient relative humidity can drop below 25% and so there will be a bias in CSVP due to the linearity assumption for these hours with low humidity. However, for many cases, this is not significant since under low humidity conditions, visible plumes are of lesser concern.



Howard Balentine, CCM, PE
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SPX
COOLING TECHNOLOGIES

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robert.fleming@spx.com

MARLEY FIELD ERECTED COOLING TOWER

TO:	Kiewit	DATE:	March 15, 2010
ATTN:	Glenn Milller	FROM:	Bob Fleming

PROJECT: Palmdale Clearsky Back to Back Plume Abated Tower

BUDGETARY SELECTION

DESIGN CONDITIONS:	Flow	120200 gpm
	Hot Water	98.23 °F
	Cold Water	79.93 °F
	Wet Bulb	71.09 °F
	Plume Abatement	**Yes , Clearsky**
TOWER DESCRIPTION:	Model	F4107D-6.6-10B
	Number of Cells	10
	Pump Head	38 ft
	Fan Diameter	28 ft
	Motor Size	10 @ 200 Hp
	Brake Horsepower	10 @ 200 Hp
	Evaporation	2452 gpm
	Drift Rate	0.0005 %
TOWER DIMENSION:	Tower Width	120 ft
	Tower Length	280 ft
	Tower Height	84 ft
	Fan Deck Height	70 ft
BASIN DIMENSION:	Basin Width	130 ft
	Basin Length	281.3 ft

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robert.fleming@spx.com

MARLEY FIELD ERECTED COOLING TOWER

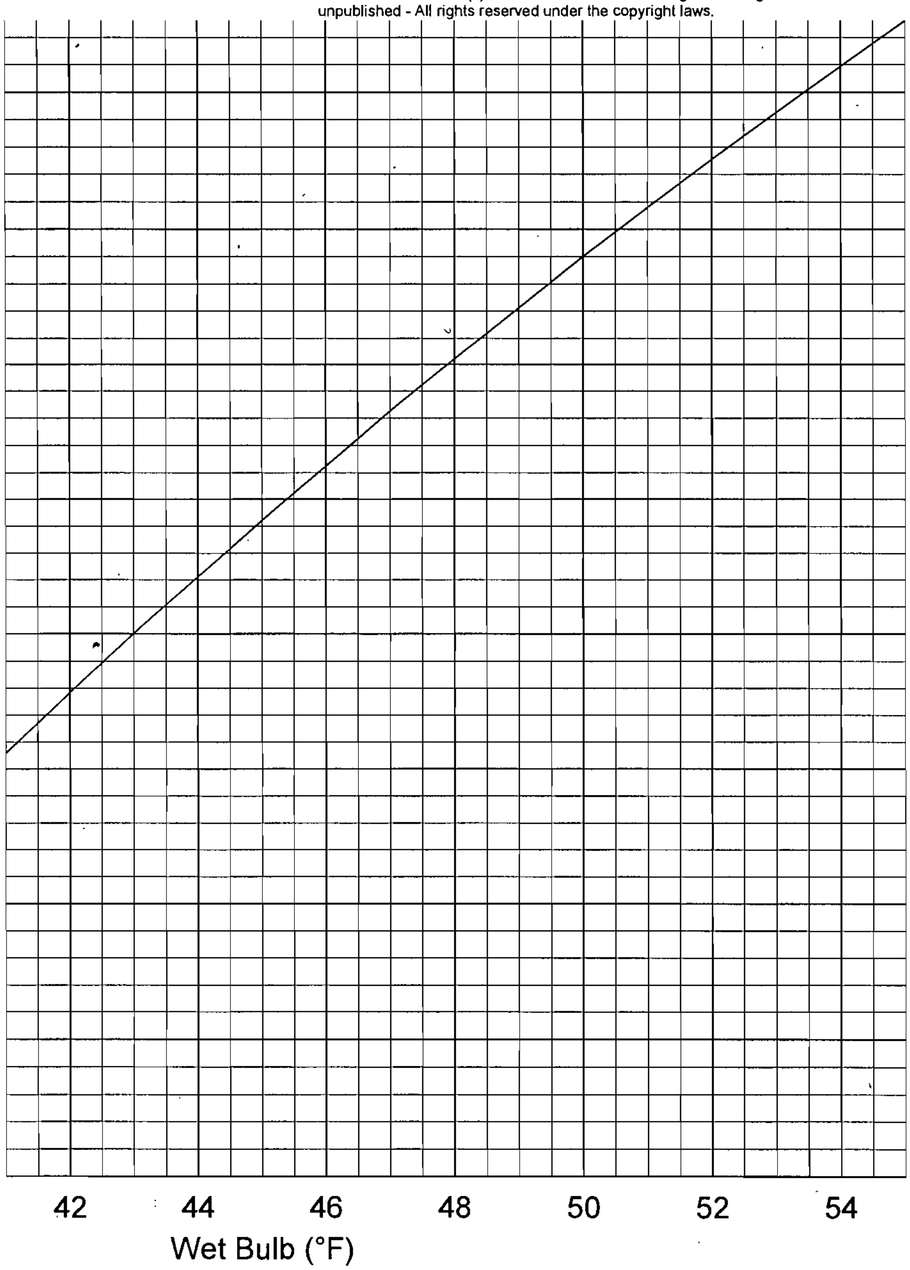
TO:	Kiewit	DATE:	March 15, 2010
ATTN:	Glenn Miller	FROM:	Bob Fleming

PROJECT: Palmdale Back to Back Non Plume Abated Tower Selection

BUDGETARY SELECTION

DESIGN CONDITIONS:	Flow	120200 gpm
	Hot Water	98.23 °F
	Cold Water	79.93 °F
	Wet Bulb	71.09 °F
	Plume Abatement	**None**
TOWER DESCRIPTION:	Model	F488-5.3-10B
	Number of Cells	10
	Pump Head	35.31 ft
	Fan Diameter	28 ft
	Motor Size	10 @ 200 Hp
	Brake Horsepower	10 @ 200 Hp
	Evaporation	2480 gpm
	Drift Rate	0.0005 %
TOWER DIMENSION:	Tower Width	96.67 ft
	Tower Length	240.7 ft
	Tower Height	59 ft
	Fan Deck Height	45 ft
BASIN DIMENSION:	Basin Width	107 ft
	Basin Length	251 ft

;y Curve for



SPX Cooling Technologies
TRACS Version 18-SEP-08

Model	F488-5.3-10B
Number of Cells	10
Motor Output	200HP
Motor RPM	1800
Fan	HP7336-7
Fan RPM	137
(Full Speed)	

Design Conditions:

Flow Rate	120200GPM
Hot Water	98.25°F
Cold Water	79.93°F
Wet-Bulb	71.09°F

Curve Conditions:

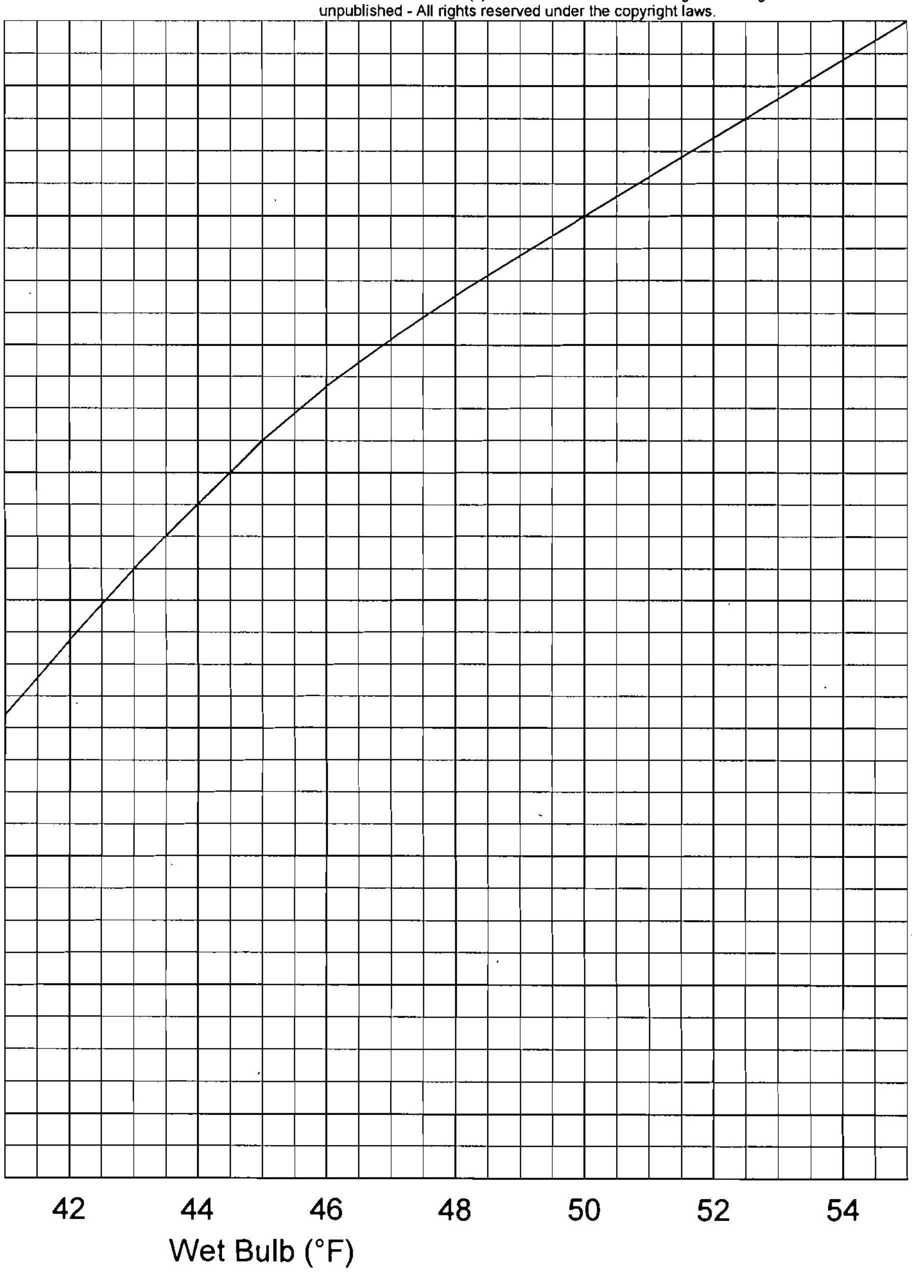
Fan Pitch	Constant
Flow Rate	120200GPM
(100% Design Flow)	

FOGGING FREQUENCY CURVE: The curve shown to the left is referred to as a 'Fogging Freqency Curve'. The Fogging Freqency Curve separates entering cooling tower conditions that produce fog at the discharge (Top-Left region of chart) from those that do not produce fog (Bottom-Right region of chart)

❶ 27.73 °F Range

Time: 14:52:14 Date: 03-04-2010 Drawn By: CJH

SPX Cooling Technologies
TRACS Version 18-SEP-08



Model	F4107D-6.6-10B
Number of Cells	10
Motor Output	200HP
Motor RPM	1800
Fan	HP7384-9
Fan RPM	119
(Full Speed)	

Design Conditions:

Flow Rate	120200GPM
Hot Water	98.25°F
Cold Water	79.93°F
Wet-Bulb	71.09°F

Curve Conditions:

Fan Pitch	Constant
Flow Rate	120200GPM
(100% Design Flow)	

FOGGING FREQUENCY CURVE: The curve shown to the left is referred to as a 'Fogging Freqency Curve'. The Fogging Freqency Curve separates entering cooling tower conditions that produce fog at the discharge (Top-Left region of chart) from those that do not produce fog (Bottom-Right region of chart)

❶ 27.73 °F Range

Time: 16:35:36 Date: 03-04-2010 Drawn By: CJH