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Memorandum

To: **Dockets** Date: November 13, 2007

From : **California Energy Commission** **Dale Edwards**
1516 Ninth Street
Sacramento CA 95814-5512

Subject: Visible Plume Modeling Analysis for Palomar Energy Center (01-AFC-24)

The attached Palomar Energy Center Cooling Tower and HRSG Exhaust Visible Plume Analysis by William Walters and Paula Hemmer has been docketed on this date because it was not previously docketed as part of the record for the Palomar Energy Center siting case (01-AFC-24). Staff only recently discovered that this document had not be docketed as the result of a request for the document related to the Inlet Air Chiller Amendment now in process for the Palomar Energy Center.

PALOMAR ENERGY PROJECT
COOLING TOWER AND HRSG EXHAUST
VISIBLE PLUME ANALYSIS

William Walters and Paula Hemmer

INTRODUCTION

The following provides staff's assessment of the Palomar Energy Project (PEP) cooling tower and heat recovery steam generator (HRSG) exhaust stack visible plumes. Staff completed a modeling analysis for the Applicant's proposed abated cooling tower and non-abated HRSG designs.

PROJECT DESCRIPTION

The Applicant has proposed one linear 7-cell conventional mechanical-draft wet cooling towers with drift eliminators. The Applicant proposes to minimize visual plumes through the use of a plume abated cooling tower. The cooling tower vendor and design is not finalized, but the Applicant has specified a revised plume abatement performance goal for the tower (Palomar 2002c). It is staff's understanding that the Applicant's revised design was reached by agreement with the City of Escondido to minimize cooling tower plume formation. The plume abated cooling tower will be abated by the addition of warm, dry air into the plume (i.e. wet/dry tower design). The air will be heated by dry air-to-water heat exchangers located at the top of the towers, above the water distribution level and below the fan deck. The circulated water returning from the condenser is used by the heat exchangers. Dampers regulate the flow of ambient air into heat exchangers. After flowing through the heat exchangers, the heated, dry air then mixes with the supersaturated cooling tower air to desaturate the exiting air plume. The plume abated design will abate plumes under most conditions, but visible plumes will still occur occasionally during cold and wet weather.

The project includes two separate turbine/heat recovery steam generator systems, each with separate exhaust stacks. Duct firing will be used for peaking operations. The Applicant has not proposed to use any methods to abate visible plumes from the HRSG exhausts.

COOLING TOWER VISIBLE PLUME MODELING ANALYSIS

EXISTING CONDITIONS

The Applicant has not identified other plume sources within the immediate vicinity of the PEP project site. However, the City of Escondido has identified visual plumes as a concern due to the visual impacts of the Ice-gen facility, which has a near constant visual water vapor plume source within in the City of Escondido.

METEOROLOGICAL DATA

The Applicant provided the meteorological data set, both raw data and processed data used in their plume analyses, from the Miramar Naval Air Station for the years 1997 to 1999 for the HRSG analysis, and the years 1995 through 2000 used in the revised cooling tower analysis. After a review of this data staff believes that there are minor problems with the Applicant's meteorological processing for the HRSG modeling analysis. Staff found that the data in the original raw meteorological file, using the CD144 daily hour basis of 0 to 23, was not converted properly when revised to a 1 to 24 daily hour basis. Additionally, there are incorrect values provided for hourly stability class (i.e. 343 hours with a stability class designation of "0", stability class designations of 7 for midday hours, etc.), and the flagged daylight hours are shifted one hour too early. These processing issues do not significantly affect the HRSG plume frequency analysis, and staff corrected some of these issues prior to completing the "staff" plume frequency analyses.

COOLING TOWER DESIGN PARAMETERS

Staff evaluated the Applicant's AFC (Palomar, 2001, Section 5.10), Data Adequacy Response VIS-5 Appendix B (g) (6) (F) (Palomar, 2002a, pp 5.10-28 – 5.10-30), Data Request Response #110 (Palomar, 2001b) and Revised Data Request Response #110 (Palomar, 2002c), and performed an independent psychrometric analysis to predict the frequency of visible plumes from the project's proposed abated wet cooling towers. The cooling tower design characteristics, presented below in Table 1, were determined through a review of the Applicant's AFC, DAR, and Data Request Responses.

Table 1 – New Cooling Tower Operating and Exhaust Parameters

Parameter	New Cooling Tower Design Parameters
Number of Cells	7 (1 @ 1 x 7)
Design Duty	1,250 MMBtu/hr
Water Return Temperature	110 °F
Water Supply Temperature	90 °F
Design Ambient Wet Bulb Temperature	77 °F
Design Ambient Dry Bulb Temperature	110 °F
Maximum Plume Abatement Design Point	50.5°F, 90.5% relative humidity

Source: AFC (Palomar 2001), DAR (Palomar, 2002a), Data Request Response #110 (Palomar 2002b), and revised Data Request Response #110 (Palomar 2002c).

Since the exact design and vendor of the cooling tower have not been finalized, the design variables for the cooling tower, with the exception of the abatement design point, are preliminary.

COOLING TOWER VISIBLE PLUME MODELING ANALYSIS

The Applicant provided a confidential fogging frequency curve for the plume abated cooling tower and modeling results determining plume frequency for the six years of Miramar meteorological data. Staff performed a separate analysis of the plume frequency potential based on the provided fogging frequency curve.

Table 2 presents the number of hours of plume formation predicted for the abated cooling tower, by staff and by the Applicant, based on the performance curves. These results indicate that the visible plume formation will mainly occur during the cold weather months, with the majority of plume formation occurring at night or early morning.

Table 2 – Predicted Hours with Cooling Tower Steam Plumes Miramar 1995-2000 Meteorological Data

	Available (hr)	Plume (hr)	Percent
Staff's Estimate			
All Hours	50,660	5,740	11.3%
Daylight Hours	26,963	1,431	5.3%
Nighttime Hours	23,697	4,309	18.2%
Seasonal Daylight No Rain No Fog Hours*	11,291	793	7.0%
Applicant's Estimate			
All Hours	50,660	5,760	11.4%
Daylight Hours	29,052	1,506	5.2%
Nighttime Hours**	21,554	4,254	19.7%
Seasonal Daylight No Rain No Fog Hours*	12,024	609	5.1%

*Seasonal conditions occur anytime from November through April.
**Determined through subtraction

The Applicant's results are slightly different from staff's due to a few minor differences in the assumptions used in the two analyses. The Applicant determined a mathematical equation for the plume fogging curve, while staff used the graphical curve provided in the revised data response to determine hourly plume potential. Additionally, the daylight hour assumptions were slightly different between staff and the Applicant, where the Applicant used a slightly broader interpretation of what constitutes a daylight hour. Finally, the Applicant discarded all plume hours with a relative humidity above 95%, as they reasoned that the visibility would be impacted during these hours, to determine seasonal daylight no rain no fog plume hours. While there are minor differences in the analysis approach and interpretation, both analyses indicate the same basic plume abatement potential for the cooling tower.

A plume frequency of 10% of seasonal (November through April) daylight no rain/fog hours is used as a plume impact study threshold trigger. The performance curve predicts plume frequencies less than greater then 10% of seasonal daylight no rain/fog hours, which would not trigger a study of the visual impacts of the plume from the cooling tower.

HRSG VISIBLE PLUME MODELING ANALYSIS

Staff evaluated the Applicant's AFC (**Palomar, 2001, Section 5.10**), Data Adequacy Response VIS-5 Appendix B (g) (6) (F) (**Palomar, 2002a, pp 5.10-28 – 5.10-30**), Data Request Response #111-114 (**Palomar, 2001b**) and performed an independent psychrometric analysis and dispersion modeling analysis. The Combustion Stack Visible Plume (CSVP) model was used to estimate the worstcase potential plume frequency, and provide data on predicted plume length, width, and height for each HRSG stack.

HRSG DESIGN PARAMETERS

Based on the stack exhaust parameters anticipated by the Applicant for each HRSG stack, the frequency and size of visual plumes can be estimated. The operating data for these stacks are provided in Table 3.

Table 3 – HRSG Exhaust Parameters

Parameter	**HRSG Exhaust Parameters**		
Stack Height	33.528 meters (110 feet)		
Stack Diameter	5.182 meters (17 feet)		
DUCT FIRING	**Case 1**	**Case 2**	**Case 3**
Ambient Temp	20°F	62°F	110°F
Turbine Load	100%	100%	100%
Duct Firing	Off	Off	Off
Exhaust Temperature	186°F	186°F	186°F
Exhaust mass flow rate	3,775,527 lbs/hr	3,517,961 lbs/hr	3,295,502 lbs/hr
Exhaust Molecular Weight	28.5 lbs/lb-mol (est.)		
Moisture Content (% by wt.)	5.06%	5.90%	7.36%
NO DUCT FIRING	**Case 1**	**Case 2**	**Case 3**
Ambient Temp	20°F	62°F	110°F
Turbine Load	100%	100%	100%
Duct Firing	On	On	On
Exhaust Temperature	193°F	193°F	193°F
Exhaust mass flow rate	3,767,000 lbs/hr	3,510,000 lbs/hr	3,287,000 lbs/hr
Exhaust Molecular Weight	28.5 lbs/lb-mol (est.)		
Moisture Content (% by wt.)	4.58%	5.43%	6.81%

Source: AFC (Palomar, 2001), Data Request Response #111 and 112 (Palomar 2002b).
Notes:
1. For CSVP the analysis, values were extrapolated or interpolated between data points as necessary.

HRSG VISIBLE PLUME MODELING ANALYSIS

Staff modeled the HRSG plumes using the CSVP model with a three-year meteorological data set, obtained from the National Climatic Data Center, for Miramar Naval Air Station. A problem with the stability class was noted in the Applicant supplied meteorological data. It appears the stability class was not properly calculated from the meteorological data file. This would have an impact on plume size determination but does not affect the plume frequency results. Table 4 provides the CSVP model visible plume frequency results.

Table 4 – Staff Predicted Hours with HRSG Steam Plumes
Miramar 1997-1999 Meteorological Data

No Duct Firing	**Available (hr)**	**Plume (hr)**	**Percent**
All Hours	26,280	392	1.5%
Daylight Hours	13,323	37	0.3%

Nighttime Hours	12,957	355	2.7%
Seasonal Daylight No Rain Hours*	5,807	35	0.6%
Duct Firing	**Available (hr)**	**Plume (hr)**	**Percent**
All Hours	26,280	1600	6.1%
Daylight Hours	13,323	211	1.6%
Nighttime Hours	12,957	1389	10.4%
Seasonal Daylight No Rain Hours*	5,807	179	3.1%

*Seasonal conditions occur anytime from November through April.

These results confirm that the visible plume formation will mainly occur during the cold weather months, with the majority of plume formation occurring at night or early morning. For the proposed HRSG, the maximum temperature where a visible plume is predicted for no duct firing is 48°F when the relative humidity is 100%. For duct firing, the maximum temperature where a visible plume is predicted is 54°F at 100% relative humidity.

The Applicant modeled the HRSG visible plume formation using CSVP. As shown in Table 5, staff's HRSG plume frequency results using CSVP are very similar to the Applicant's results.

Table 5 – Comparison of Predicted Hours with HRSG Steam Plumes

Seasonal Daylight No Rain *	**Applicant Results No Duct Firing**	**Applicant Results Duct Firing**	**Staff Results No Duct Firing**	**Staff Results Duct Firing**
Available	6,195	na	5,807	5,807
Plume Hours	104	na	36	179
Percentage	1.7%	7%	0.6%	3.1%

Source: DAR Vis-5 (Palomar, 2002a), Data Request Response #114 (Palomar 2002b).
* Seasonal conditions occur anytime from November through April.

The Applicant's available hours listed in Table 5 are higher because they assumed different sunrise and sunset hours.

A plume frequency of 10% of seasonal (November through April) daylight no rain/fog hours is used as a plume impact study threshold trigger. The CSVP model predicted plume frequencies less then 10% of seasonal daylight no rain hours, which would not trigger a study of the visual impacts of the plume from the HRSGs.

CONCLUSIONS

Visible plumes from the proposed PEP plume abated wet cooling tower exhaust are predicted to occur at a frequency that is less than the significance threshold of 10% of seasonal daylight no rain/fog hours. Therefore, a plume impact analysis of the cooling tower plumes will not be included in the Visual Resources section of the Staff Assessment.

Visible plumes from the HRSGs are predicted to occur at a frequency that is significantly less than the significance threshold of 10% of seasonal daylight no rain/fog hours. Therefore, a plume impact analysis of the HRSG plumes will not be included in the Visual Resources section of the Staff Assessment.

REFERENCES

Marley Cooling Tower (Marley) 2002. Estimated Fogging Frequency Performance Curve. May 13, 2002.

Palomar (Palomar Energy) 2001. Application for Certification, Volumes 1 and 2 (01-AFC-24), Docket Date November 21, 2001.

Palomar (Palomar Energy) 2002a. Data Adequacy Response (DAR), Docket Date February 5, 2002.

Palomar (Palomar Energy) 2002b. Data Request Responses Set 1, Docket Date April 8, 2002.

Palomar (Palomar Energy) 2002c. Revised Data Request Response #110, Docket Date July 24, 2002.