Appendix F

Visual Plume Analysis

GERALD DESMOND BRIDGE/LONG BEACH GENERATING PLANT VISIBLE PLUME ANALYSIS

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INTRODUCTION

The following provides the assessment of the Long Beach Generating Plant (Long Beach) turbine exhaust stack visible plumes. A modeling analysis for the turbines was completed based on information provided for full-load and part-load operating conditions. This analysis was completed to determine if the visible plumes would be expected to impact motorists on the adjacent Gerald Desmond Bridge. This modeling analysis and its conclusions are based on the modeling inputs used; if any of these inputs (meteorological data, exhaust data, modeling input data) are inaccurate, they could affect the results of this analysis.

SITE DESCRIPTION

The Long Beach plant includes seven separate Brown Boveri-Sulzer Model 11D gas turbines. These turbines are air cooled and equipped with steam/water injection. The steam/water injection, which is used for emissions control, is always operational. The turbines are operated in a combined cycle mode, with two steam turbines. The 7 turbine exhausts are sent to four 235.3-ft-high (71.7-m-high) stacks, with Units 1 and 2, Units 3 and 4, and Units 6 and 7 sharing exhaust stacks and Unit 5 having its own exhaust stack. Table 1 provides the exhaust parameters provided for modeling, which include full-load and one partial-load condition.

Table 1 – Turbine Exhaust Parameters

Parameter	HRSG Exhaust Parameters			
Stack Height	235.3 feet – All Stacks			
Stack Diameter	20 feet – All Stacks, except Unit 5 Stack at 15 feet			
Stack	**Moisture Content (% by Volume)**	**Moisture Content (% by Weight)**	**Exhaust Flow Rate (klb/hr)[a]**	**Exhaust Temp (°F)**
Full-Load Conditions				
Unit 1 &2	13.95	8.93	5,049	343
Unit 3 & 4	12.81	8.19	4,791	347
Unit 5	14.29	9.15	2,609	336
Unit 6 & 7	13.14	8.41	4,976	333
Partial-Load Conditions[b]				
Unit 1 &2	11.80	7.54	3,828	337
Unit 3 & 4	11.58	7.40	3,798	345
Unit 5	10.70	6.82	2,009	345
Unit 6 & 7	12.40	7.93	3,683	332

Source: Parsons, 2003.
Notes:
[a] Values estimated based on exhaust flow rates, exhaust temperatures, and moisture contents.
[b] Partial load conditions range from 75% to 81.7% load.

The Long Beach plant stacks parallel the Gerald Desmond Bridge and are located approximately 100 ft (30.5 m) from the bridge. The stack height is more than 15 ft (4.5 m) higher than the bridge deck height at its highest point, which is some distance east northeast from the Long Beach plant. The bridge deck height directly adjacent to the exhaust stacks ranges approximately 35 to 50 ft (10.6 to 15.25 m) below the height of the exhaust stacks.

METEOROLOGICAL DATA

The meteorological data used in the plume frequency modeling analysis is 1990 to 1995 HUSWO data available for Long Beach that was obtained from the National Climatic Data Center (NCDC, 2001). This HUSWO data set does not have complete data for hours from 11:00 p.m. to 5:00 a.m. daily. The data provided for these incomplete data hours is limited to dry bulb temperature readings. An attempt to include this incomplete data has been made based on a statistical identification of potential plume hours.

The meteorological data used to determine plume impact potential to the bridge deck is 1981 Long Beach meteorological data obtained from the South Coast Air Quality Management District (SCAQMD) website. This data has all of the meteorological parameters necessary to run the ISCST3 model.

VISIBLE PLUME MODELING ANALYSIS

Staff modeled the turbine exhaust plumes using the CSVP model with a 6-year meteorological data set from Long Beach. Table 2 provides the CSVP model visible plume frequency results.

Table 2 – Predicted Hours with Turbine Exhaust Steam Plumes Long Beach 1990-1995 Meteorological Data

Exhaust Stack	Modeled Plumes (hrs)	Percent
Full Load		
Units 1 & 2	21	0.050
Units 3 & 4	6	0.014
Unit 5	50	0.120
Units 6 & 7	13	0.031
Partial Load		
Units 1 & 2	1	0.002
Units 3 & 4	0	0
Unit 5	0	0
Units 6 & 7	6	0.014

*A total of 41,617 hours were modeled.

The predicted visible plume frequencies are very low, but they are higher than might be expected for the given turbine exhaust temperatures. The reason that any visible plumes are predicted is due to the fact that water/steam injection is used for nitrogen oxide (NO_x) emissions control, and that elevates the exhaust moisture content enough to predict plume formation under the most severe meteorological conditions. The partial-load operating conditions have lower exhaust moisture contents without substantially lower exhaust temperatures; therefore, the plume frequencies at partial load were predicted to be lower than at full-load operation. For the 1990 to 1995 meteorological data set modeled, the maximum temperature where a visible plume is predicted is

46.9 degrees Fahrenheit (°F) when the relative humidity is 100%, and the minimum relative humidity where a plume is predicted is 53% when the ambient temperature is 28.9°F.

The modeled meteorological data had 897 hours where the temperature was at or below 46.9°F. The incomplete meteorological data in this data set had a total of 716 hours where the temperature was at or below 46.9°F. Therefore, the maximum plume potential for Turbine 5 (worst-case turbine), assuming a similar distribution of relative humidity, would be 90 hours for the entire 1990 to 1995 period (52,583 hours), or approximately a 0.17% frequency.

The meteorological data from the CSVP modeling analysis indicates the Turbine 5 wind direction would be towards the bridge for 21 out of the 50 hours (42%) when plumes were predicted to occur. Twenty-two of the 50 hours (44%) were noted as calm wind conditions. Additionally, out of the 21 plume hours where the wind was directed towards the bridge, 10 of these (48%) were during hours where fog or rain was indicated to occur in that hour, and 6 of these (29%) were during hours where visibility was indicated to be less than 0.1-mile.

CONCENTRATION MODELING ANALYSIS

The CSVP modeling analysis data indicates that plumes could form under the worst-case meteorological conditions when the stack exhaust has diluted to between 13.4 to 6.8 g/m^3. These concentrations refer to the worst-case initial condensation point and end condensation point on the saturation curve. This means that when the initial stack concentration of 70.9 g/m^3 (Turbine 5) has been diluted to 13.4 g/m^3, it has the appropriate temperature and moisture content to begin condensation, and when the stack exhaust has diluted to less than 6.8 g/m^3, then the moisture content will be less than is necessary for condensation. For simplification, the intersection points with the saturation curve are used to describe when the plume will begin forming droplets and become visible and when the plume will stop forming droplets and no longer be visible. The Long Beach plant exhaust stacks were modeled using ISCST3 model using 1 year of Long Beach meteorological data obtained from the SCAQMD website. The base modeling input variables were obtained from existing ISCST3 modeling files (Parsons, 2003). This modeling analysis was performed to determine the worst-case modeled exhaust concentrations on the bridge deck.

This modeling analysis is considered to be conservative because the actual temperature and relative humidity of the hours modeled are not being considered in the determination of the worst-case concentrations. The plume height, and consequentially the determined concentration, is a function of ambient temperature; given the same exhaust conditions, the plume heights are higher when the ambient temperatures are lower. Additionally, ISCST3 has certain simplifying assumptions that allow very near field concentrations from a single large-diameter stack or from multiple stacks to be modeled at a higher concentration than their initial exhaust concentration (i.e., in violation of thermodynamic laws). Therefore, this modeling analysis is expected to result in a conservative estimate of the potential for visible plume occurrence on the bridge deck.

This ISCST3 modeling analysis indicates that the worst-case 1-hour moisture concentration on the bridge deck would be approximately 0.04 g/m^3, which would be much lower than the exhaust concentration necessary for a visible plume to occur. However, it should be noted that plumes, like odors, are more of an instantaneous phenomena. Using Turner's 1/5th power law adjustment, the worst-case instantaneous concentration, defined for these purposes as the maximum one second concentration, would be 5.14 times the maximum 1-hour concentration. This would mean that the instantaneous maximum bridge deck concentration would be on the order of 0.2 g/m^3, which is still well below exhaust concentration necessary for a visible plume to occur.

A model run with receptors located approximately 110 ft (33.5 m) above maximum bridge deck height (receptor height 100 m, 33 m above the bridge deck) indicates that the 1-hour worst-case plume concentration would be approximately 0.2 g/m^3 (instantaneous maximum 1.1 g/m^3). A model run with receptors located approximately 270 ft (82 m) above the bridge deck height (receptor height 150 m, 83 m above the bridge deck) indicates that the 1-hour worst-case plume concentration would be approximately 1.3 g/m^3 (instantaneous maximum 6.8 g/m^3). Finally, a model run with receptors located approximately 435 ft (132.5 m) above the bridge deck height (receptor height 200 m) indicates that the 1-hour worst-case plume concentration would be approximately 9.8 g/m^3 (instantaneous maximum 50.5 g/m^3). Therefore, the modeling indicates that visible plumes may be expected to begin to occur at approximately 270 ft (83 m) or higher above the bridge deck, but not on the bridge deck or even 110 ft (33 m) above the bridge deck.

This finding is consistent with the stack design of the power plant, which minimizes stack downwash, and the relatively high temperature and velocity of the exhausts that would cause significant plume rise.

CONCLUSIONS

Visible plumes from the Long Beach power plant are predicted to occur, but very infrequently. However, the visible plume heights are predicted to be well above the bridge deck and are not expected to interfere with bridge traffic visibility.

REFERENCES

NCDC (National Climatic Data Center). 2001. Hourly United States Weather Observations 1990-1995. Received from NCDC 2001.

Parsons. 2003. Full Load and Partial Load Turbine Exhaust Data and ISCST3 modeling input files. August 2003.

SCAQMD (South Coast Air Quality Management District). 2003. 1981 Long Beach Meteorological Data. http://www.aqmd.gov/metdata/. Downloaded 2003.