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Exhibit No.:
Witness: Jon A. Peterka

DIRECT TESTIMONY OF

JON A. PETERKA

SAN DIEGO GAS & ELECTRIC COMPANY

(WITCH FIRE)

BEFORE THE PUBLIC UTILITIES COMMISSION
OF THE STATE OF CALIFORNIA
June 5, 2009

SDGE

DIRECT TESTIMONY OF
JON A. PETERKA
SAN DIEGO GAS & ELECTRIC COMPANY

I. WIND SPEEDS AT TIME OF WITCH CREEK FIRE INITIATION

Q: Please state your name, company, and address.

A: My name is Jon A. Peterka, CPP, Inc., 1415 Blue Spruce Drive, Fort Collins, CO.

Q: Please state your title and describe your educational and professional background.

A: I am the Co-founder and President of CPP, Inc. I am also a Professor Emeritus in the Fluid Mechanics and Wind Engineering Program of the Department of Civil Engineering at Colorado State University in Fort Collins, Colorado. I earned my Bachelor's of Science and Masters of Science in Civil Engineering, Colorado State University, in 1964 and 1965, as well as a Ph.D. in Fluid Mechanics and Thermodynamics from Brown University in 1968. I am also a licensed professional engineer and a member of a number of professional engineering organizations. A complete list of my memberships, publications, professional history, experience in legal cases and other information related to my qualifications can be found in Appendix A.

I have more than 35 years experience in wind-engineering applications and research. During that time, I have evaluated over 1,000 buildings and structures for wind loads (local cladding pressures and/or frame forces and moments) primarily through wind tunnel testing; evaluated pedestrian wind climate for many of these buildings; measured forces on numerous other structures including towers, stacks, bridges and solar collectors; defined snow loads for many structures; investigated pollutant dispersion from buildings and stacks; determined heat transfer rates from structure surfaces in the wind; helped define siting criteria for wind energy projects as well as wind tunnel and field testing to assist in the development of wind turbine technology; and developed meteorological analysis procedures for power line rating. My research in wind engineering includes statistical characteristics of fluctuating pressures, adjacent building effects, wind flow around and downwind of buildings, natural ventilation, transport of snow and sand, and siting criteria for anemometers. I spent three years developing liquid rocket propulsion systems for the U.S. Army Missile Command. I also participate on the national committee which writes the national wind load standard ASCE 7, served on the Board of Directors of the Wind Engineering Research Council, and am currently the chairman of an American Society of Civil Engineers Standards committee on wind tunnel testing of structures.

Q: What investigations were you asked to perform related to the Witch Creek Fire?

A: We were asked by SDG&E to determine the mean and gust wind speed, as well as wind direction, at the time and location of the Witch Creek fire initiation in October 2007.

Q: Please summarize your investigation.

A: To obtain wind conditions at the Witch Creek fire initiation location, a two-pronged approach was utilized. First, a mesoscale model simulation was run to examine the winds near the surface from a regional perspective. Second, the local terrain was modeled and location-specific winds were measured in an atmospheric boundary layer wind tunnel to determine the impact terrain had on the wind flow. The results were then combined to generate a reasonable estimate of the winds at the fire initiation location and height of the power lines. Nearby wind measurements at four RAWS sites were reviewed, but were found to be unreliable and were not used in this analysis due to local shielding effects. We also examined the data from the weather station at the Ramona Airport and found it likewise unusable because of the distance between the area of origin of the Witch Fire and the Ramona Airport weather station and because the terrain is sufficiently different at the two sites such that readings from the Ramona Airport weather station are not representative of the Witch Fire area of origin.

Q: Can you describe your findings?

A: At the line height above ground of 20 meters (66 ft), the mean wind speed at the time of fire initiation was 25 m/s (56 mph). The wind was gusting between 35 m/s (78 mph) and 38 m/s (84 mph) based on the ESDU gust factor analysis at gust factors of 1.4 and 1.5. Winds were gusting to 39 m/s (87 mph) based on the original time series data obtained in the wind tunnel.

These peak gust estimates are within 10 and 3 percent, respectively, of the wind tunnel measured gust, indicating an acceptable match for this process.

Q: Did you also review the "Report of the Consumer Protection and Safety Division Regarding the Guejito, Witch and Rice Fires," dated September 2, 2008 and the "Supplemental Direct Testimony of the Consumer Protection and Safety Division Regarding the Formal Witch and Rice Fire Investigations," dated March 20, 2009?

A: Yes. In the report, the investigator assumes that the wind speeds noted at the time of fire initiation from various RAWS sites are representative of the wind conditions at the Witch site. For the reasons set forth above and explained more fully below, however, the wind speeds from the Julian, Pine Hills, Goose Valley, and Valley Center RAWS sites and the Ramona Airport site are not representative of the actual wind speeds at the Witch site and cannot be used to reliably determine whether the wind conditions at the Witch site were "common" or "uncommon" at the time of the fire start.

Q: You indicated that you also examined data from weather stations; which ones did you examine?

A. Observational data was obtained from the nearest Remote Automated Weather Station (RAWS), which was Julian (NWS ID: 045708), to examine local measured conditions. A Google Earth image annotated with the wind direction range at this station at the time of fire initiation is shown in Exhibit 10. In addition wind data from Pine Hills (NWS ID: not available), Goose Valley (NWS ID: 045724), Valley Center (NWS ID: 045734), and Ramona Airport (ASOS station RNM) were examined.

Q: Please describe the RAWS observations that you investigated at Julian.

A: For Julian, there are trees and structures visible upwind that shield the anemometer. Photographs of the anemometer are shown in Exhibit 11. The nearby building is not upwind for the fire initiation wind direction of about 85˚ azimuth (measuring from true north), but would shield the anemometer for winds from the NW-NE (roughly 315˚ - 45˚). There are some trees in close proximity just upwind and additional structures further upwind of the tower. Based on Exhibits 10 and 11, the nearby trees are likely to significantly shield the anemometer for fire initiation wind directions.

Time histories of the wind speed, wind direction, and gust factors (largest peak gust speed / mean speed) for Julian are shown in Exhibit 12. A wind rose is also shown to demonstrate the extent of the shielding. For the entire year of 2007, the wind direction is only measured from two directions WSW and ENE, indicating significant shielding and/or a problem with data acquisition. Even with the shielding, there should be more directions represented at this site. Generally, the mean wind speeds ranged from 10 mph to over 30 mph throughout the Santa Ana event, with gusts over 55 mph and prevailing wind directions from the ENE (80˚).

Gust factors were on average around 2.0 and as high as 12 from October 19-24, 2007, and on average 2.1 and as high as 15 over the entire year of 2007. Typically for open exposure, values are in the range of 1.4-1.6 for 3s gust to 10 min mean ratios and roughly 2.0 for fairly rough terrain. Julian data were not compared to the mesoscale speeds because of the shielding issues.

Q: Please describe the RAWS observations that you investigated at Pine Hills.

A: Pine Hills is also a RAWS station. Its location is shown in Exhibits 13a-13b, while photographs of the anemometer are shown in Exhibits 13c – 13e. There are large trees upwind in the sector for winds blowing from ENE (65˚) to ESE (115˚) for the Santa Ana event to partially shield the anemometer.

Time histories of the wind speed, wind direction, and gust factors (largest peak gust speed / mean speed) for Pine Hills are shown in Exhibits 13e – 13g. A wind rose is also shown to demonstrate the extent of the shielding in Exhibit 13h. For the entire year of 2007, the wind direction is only measured from two directions ESE and WNW, indicating significant shielding and/or a problem with data acquisition. Even with the shielding, there should be more directions represented at this site as evidenced by relatively clear exposure for many wind directions.

This site exhibited gust factors (Exhibit 13g) on average of 3.0 and as high as 11 from October 19-24, 2007; shielding from the large tree(s) to the east could be responsible for these values. The mean wind speeds (Exhibit 13e) ranged from 10 mph to 20 mph with gusts to 55-60 mph, while the prevailing wind directions varied from roughly NE (45˚) to E (90˚). Wind speeds were likely significantly larger for an unshielded observer located even a few 10s of feet away. There are also unusual flat tops (or missing data) to the mean data plot which further renders the data suspect. Pine Hills data were not compared to the mesoscale speeds because of these shielding and data quality issues.

Q: Please describe the RAWS observations that you investigated at Goose Valley.

A: For Goose Valley, there are trees visible upwind in Exhibit 15 that could shield the anemometer. Photographs of the anemometer are shown in Exhibit 16. The nearby building is not upwind for the fire initiation wind direction of about 70˚ azimuth, but would shield the anemometer for winds from the WNW-NW (roughly 290˚ - 315˚). Based on Exhibits 15 and 16, the nearby trees are likely to partially shield the anemometer for fire initiation wind directions.

Time histories of the wind speed, wind direction, and gust factors (largest peak gust speed / mean speed) for Goose Valley are shown in Exhibit 17. Generally, the mean wind speeds ranged from 5 mph to over 30 mph throughout the Santa Ana event, with gusts to 55 mph and prevailing wind directions from NE (45˚) to E (90˚).

The quality of the data was not ideal in that there was some data missing at the onset of the Santa Ana event. The data also suggests that there may be some sheltering causing unusually high gust factors (peak to mean ratios), as suggested above. Gust factors were on average around 2.4 and as high as 8 from October 19-24, 2007, and on average 2.7 and as high as 10 over the entire year of 2007. Typically for open exposure, values are in the range of 1.4-1.6 for 3-second gust to 10 min mean ratios and roughly 2.0 for fairly rough terrain. The high values observed at Goose Valley may also be due in part to how the data is sampled. For example, the peak wind speed observed may not necessarily correspond to the same 10 min period as the mean represents since the 10 min means are recorded on an hourly basis and the gust speed is the maximum instantaneous value measured anytime during that hour. However, from a statistical perspective, the average of the gust factors over a longer period of time should still be representative of the wind flow at that location, thus indicating that there is something influencing the higher values observed at Goose Valley, such as greater surface roughness (i.e. taller vegetation or obstacles), terrain variability, or a combination of these factors. Exhibits 15 and 16 indicate these factors are trees and buildings. Goose Valley data were not compared to the mesoscale speeds because of these shielding issues.

Q: Please describe the RAWS observations that you investigated at Valley Center.

A: Valley Center is also a RAWS station. Its location is shown in Exhibits 18a-18b, while photographs of the anemometer are shown in Exhibits 18c and 18d. There are sufficient trees and buildings upwind in the sector for winds blowing from NE (45˚) to ESE (115˚) for the Santa Ana event to partially shield the anemometer. This site exhibited gust factors on average of 2.4 and as high as 7 from October 19-24, 2007. The mean wind speeds ranged from 9 mph to 29 mph with gusts to 52mph, while the prevailing wind directions were from roughly NE (45˚) to ESE (115˚). There are also unusual flat tops to the mean data plot which further renders the data suspect. Time history plots are shown in Exhibits 19a-c. Valley Center data were not compared to the mesoscale speeds because of these shielding and data quality issues.

Q: Please describe the ASOS observations that you investigated at Ramona Airport.

A: The Ramona Airport ASOS station location is shown in Exhibit 14a-14b. Photographs of the site are shown in Exhibits 14c-14d. The site is in a relatively open field, with airport buildings, and suburban area upwind. This area is more open than any of the RAWS stations discussed above. Exhibits 14e-14g reveal that the mean wind speeds ranged from 14 mph to 36 mph with gusts to 53 mph throughout the Santa Ana event. The prevailing wind direction ranged from NE (50˚) to ESE (110˚). The gust factors were much more reasonable with values averaging 1.5 and peaking at 2.4 from October 19-24 indicating an anemometer exposure close to open country. The winds at a height of 10 m at this site have apparently mostly recovered from the rougher suburban area to the east for easterly winds. This data did suffer from some missing values during the event, which was not ideal. Exhibit 14h indicates there is probably a residual effect of mountainous terrain to the east that decreases wind speeds in comparison to a true open environment.

Q: Why wasn't the data from the RAWS or ASOS stations used in your analysis?

A: Two reasons. First, according to the World Meteorological Organization (WMO), wind data from Automated Weather Stations should be collected at a height of 10 m with any obstructions being 10-20 obstruction heights away, see Exhibit 1, References [1]-[3]. Similar guidance is provided in an anemometer siting guide developed by the Federal Aviation Administration, reference [4] in Exhibit 1. For example, if a building is 10m tall, then the wind sensor should be installed at a location 100-200 m away from the building to get usable wind speed and direction measurements. Currently the RAWS guidelines [5] recommend a height of 6 m (20 ft) with obstructions only one obstruction height away for wind data collection. At one obstruction height, distortion of the wind by the object may cause the speed and direction data to be useless. This suggests that many RAWS stations are poorly sited for wind data collection, according to the WMO and FAA standards. My experience also indicates this to be true.

When siting an anemometer in areas where the WMO and FAA requirements cannot be met, which includes many RAWS locations, a common way to measure unobstructed wind flow is to increase the height of the anemometer to 1.5 to 2.0 times the shielding obstacle height. To evaluate speeds below obstacle height, a second anemometer is used on the meteorological tower at the desired height. Use of only one anemometer located below the shielding obstacle height prevents evaluation of shielding magnitude and prevents the use of the data to represent geographical areas away from the anemometer site.

Second, the Ramona Airport data were too far from the Witch Creek fire origin site to be included in the wind tunnel model. The RAWS stations and the Ramona Airport station cannot be compared directly to the Witch Creek fire site because of differing terrain influences.

Q: How does the measured data compare to the mesoscale simulation?

A: The wind speeds which were generated by our mesoscale model are effective mean speeds and represent the largest mean speed recorded during the duration of the storm. The values labeled 75.0 mph and 18.0 mph are the largest and smallest values anywhere on the map of Exhibit 2.

The Julian mean speed is 33 mph, representing the largest mean speed recorded during the storm at this RAWS station. The value of the Julian measurement is about half the predicted value based on mesoscale simulation/wind tunnel analysis for the fire initiation site. The measurement is 5-10 mph less than that predicted by the mesoscale simulation for the anemometer location.

The Pine Hills mean speed ranges only up to about 19 mph while the mesoscale simulation indicates values near 45 mph. This difference might be due partially to terrain, but there is evidence of local shielding of the anemometer. This anemometer is not a good candidate for correction based on local shielding.

The Goose Valley mean speed is 34 mph, representing the largest mean speed recorded during the storm at this RAWS station. The value of the Goose Valley measurement is about half the predicted value based on mesoscale simulation and is consistent with our earlier discussion about potential shielding of this anemometer.

The Valley Center mean speed ranges only up to about 30 mph while the mesoscale simulation indicates values near 50 mph. This difference might be partially due to local terrain influences, but as demonstrated earlier, there is evidence of local shielding of the anemometer as well. This anemometer is not a good candidate for correction based on wind tunnel measured terrain influences because of local shielding.

The Ramona Airport ASOS wind speed data were lower than those predicted by the mesoscale simulation, as shown in Exhibit 14e with mean speeds of up to 36 mph, while the mesoscale simulation predicted speeds over 60 mph. It is possible that the local terrain is responsible for this difference.

II. TECHNICAL EXPLANATIONS REGARDING PROCESSES AND METHODOLOGY

Q: You said that you performed some mesoscale modeling, what is mesoscale modeling?

A: The Weather Research and Forecasting (WRF) model is a widely used numerical model developed under a collaborative partnership between the National Center for Atmospheric Research (NCAR), the National Oceanic and Atmospheric Administration (NOAA), the National Centers for Environmental Prediction (NCEP), and other institutions and organizations. It is a complex computer program that simulates the physical processes of the atmosphere. It is initiated using gridded atmospheric data appropriate for the time period to be simulated. Two such datasets that are often used include the National Centers for Environmental Prediction (NCEP) Rapid Update Cycle (RUC) analysis and the NCEP North American Regional Reanalysis. Both datasets are publicly available.

Q: What does the term mesoscale refer to?

A: Mesoscale refers to the physical size of the weather processes simulated in the WRF model. These weather systems are on the order of a few kilometers to several hundreds of kilometers in size, and fall between synoptic scale weather systems (approaching half the size of the US) and microscale (or turbulence scale) systems.

Q: How was mesoscale modeling performed in your investigation?

A: Four different simulations were run over the timeframe of 00:00 GMT October 19 (16:00 PST October 18) to 00:00 GMT October 25 (16:00 PST October 24) 2007. Each run used different parameterization schemes as outlined in Appendix B, and nested grids with grid size as small as 1 km. This was done to assess the impact of these schemes on the variability of predicted wind flow, and to select a "worst-case" scenario for further analysis. By "worst case" we mean the highest wind speed case that will induce the largest amplitude of transmission line wind load and line motion.

An overview of the wind speeds resulting from the mesoscale model analysis is shown in Exhibit 2. This Exhibit shows the largest wind speeds from the mesoscale simulation during the course of the storm.

Q: You also indicated that you did wind tunnel testing; why was wind tunnel testing necessary?

A: The Witch Creek fire initiation location is characterized by complex terrain. As a result, mesoscale modeling is incapable of fully resolving the near-surface terrain-induced flows due to the terrain smoothing within the model caused by the 1 km grid size. The effects of larger scale terrain features are fully represented in the simulation. Therefore, to determine the impacts the local terrain has on the wind at the fire initiation location, a wind tunnel simulation was conducted.

Q: How were the wind tunnel tests performed?

A: The tests were conducted in Boundary Layer Wind Tunnel 1 in the CPP, Inc. laboratory located in Fort Collins, CO. This wind tunnel was specifically designed to model atmospheric winds including winds over terrain. A detailed discussion of the simulation methodology can be found in Exhibit 1, references [8-12].

The terrain surrounding the initiation point was modeled at a scale of 1:5000, within the range suggested in Exhibit 1, references [11-12], on a test section (or turntable) 9.3 ft (2.8 m) in diameter. This represents a region 8.8 mi (14.1 km) in diameter at full scale. A round turntable is used to permit the approach wind direction to be varied by rotating the turntable. Terrain was also modeled upwind of the test turntable to ensure the boundary layer was fully developed and representative of flow over this terrain. Specifications of the wind tunnel and experimental setup are provided in Appendix C. The scaled terrain and test turntable are shown in Exhibit 3. Wind profiles were measured at four different locations for three different approach flow directions (45˚, 67.5˚, 90˚ east of north) and eight heights. Refer to Appendix C for details.

Q: How were wind tunnel velocity measurements made?

A: The AeroProbe velocity measurement probe is shown in Exhibit 3c. The probe measures fluctuating pressure at each of 5 holes on the probe tip. These measurements permit simultaneous measurement of three components of velocity at each instant in time. An alternative explanation is that the vector velocity magnitude and its two angles relative to a fixed axis are measured. A time series of these velocity magnitudes were measured at 250 samples per second model scale (equivalent to 4.38 s between samples at full scale) to provide a time series of velocities.

Q: How was the WRF simulation integrated with the wind tunnel data?

A: Four WRF runs were evaluated for integration with the wind tunnel data. Run 2 was selected as the "worst case" scenario with overall slightly higher wind speeds than the other runs that used RUC data. Run 4 experienced a period of slightly lower wind speeds at about the time of fire initiation, and was not used because of this characteristic, see Exhibit 4. With the objective of being conservative in assumptions to provide a scenario with highest line wind loads and motion, Run 2 was chosen for analysis and comparison. Exhibit 2 shows a wind map of the WRF wind speeds at 10 m above ground and the terrain modeled in the wind tunnel.

Winds at 250 m were selected to match up the wind tunnel and mesoscale model data to adjust the surface layer wind speeds to account for terrain effects. 250 m was selected for the match height between mesoscale model and wind tunnel because it is above the immediate influence of local terrain and below the height where features not represented in the wind tunnel become important such as turning of wind direction with increasing height.

Time histories of the WRF 250 m wind speeds for all four runs are shown in Exhibit 4. The wind tunnel data was normalized to its 250 m speed, and then multiplied by the 250 m wind speed observed in the Run 2 WRF simulation. The resulting wind speed profile was fit to a power law profile where:

$$U_z = U_{ref}\left(\frac{z}{z_{ref}}\right)^n$$

From this relationship the associated surface roughness (z_0) was determined, and was further used to calculate the wind speed at the line height of 20 m. This process was performed for the WRF wind speeds at the time of fire initiation (11:29am PST October 21 2007) and the time of the peak 250 m wind speed (05:40am PST October 22 2007). Exhibit 5 shows the WRF profile compared to the wind tunnel profile adjusted to the WRF 250 m speed for the initiation time. Likewise, Exhibit 6 compares the profiles at the time of the peak 250 m wind speed. The difference between these profile shapes represents the reason that the wind tunnel data is needed to define the near-ground detailed profile shape.

The resulting power law coefficient (n) and surface roughness (Z_0) values were found to be 0.12 (no units) and 0.02 m, respectively. These values are similar to those measured in open country terrain models.

Q: How was wind direction accounted for between WRF and wind tunnel data?

A: The WRF wind direction data was used to adjust the wind tunnel data to account for terrain effects. The WRF data resulted in a 250 m wind direction of 82.7°. Therefore, wind directions measured in the wind tunnel at the closest measurement direction (90°) were decreased by (90 – 82.7 = 7.3 degrees). Exhibits 7-8 show the wind direction profiles. It was found that the wind direction was influenced by terrain at the surface on the order of 1-2° in comparison to the direction at 250 m.

Q: How did you analyze wind gusts?

A: For analysis of wind speeds, it is useful to estimate the magnitude of expected maximum gust relative to the mean speed. This value is known as the Gust Factor = Vgust / Vaverage. For this purpose, we used a methodology as defined in Exhibit 1, reference [6-7]. This analysis procedure can account for changes in effective ground roughness length, Zo, upwind of a site. This procedure is also useful for estimating a peak gust speed based on output from a mesoscale model simulation.

Exercising this analysis at the site of the Witch Creek fire initiation yielded the information in Exhibit 9. Input information used to generate Exhibit 9 includes wind-tunnel profile measurements to define the effective roughness length Zo and mesoscale model output to determine effective mean wind speed and direction. Zo is a standard length parameter in meteorology used to describe the effect of surface features such as trees or buildings on the wind speeds. By effective mean wind speed we mean an average over 10 minutes to one hour. A range of mean velocity averaging times is shown on the abscissa of Exhibit 9 while the averaging times for various peak gusts are shown in curves in the graph. The Gust Factor is read from the ordinate. For mean velocity averaging times of 10 minutes to one hour, the gust factor for a 3-second gust ranges from about 1.4 to 1.5. In other words, we expect the peak 3-second gust to be about one and a half times the effective mean speed.

III. CONCLUSION

Q: What conclusions did you reach?

A: Based on the testing described above, we found that at a height of 20 meters (66 ft) above ground, the mean wind speed at the time of fire initiation was 25 m/s (56 mph). Winds were gusting between 35 m/s (78 mph) and 39 m/s (87 mph).