# Docket No. E-100, Sub 179

## William E. Powers on Behalf of NC WARN et al.

## Exhibit 1 (Part 1 of 2)

Docket No.: R.20-11-003
Exhibit No.:
Witness: Bill Powers, P.E.
Commissioner: Marybel Batjer
ALJ: Brian Stevens

**BEFORE THE PUBLIC UTILITIES COMMISSION**

**OF THE STATE OF CALIFORNIA**

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| Order Instituting Rulemaking to Establish Policies, Processes, and Rules to Ensure Reliable Electric Service in California in the Event of an Extreme Weather Event in 2021. | Rulemaking 20-11-003 (Filed November 19, 2020) |

# PREPARED OPENING TESTIMONY OF BILL POWERS, P.E. ON BEHALF OF THE PROTECT OUR COMMUNITIES FOUNDATION

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Dated: January 11, 2021

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# OPENING TESTIMONY OF BILL POWERS, P.E.
# ON BEHALF OF THE PROTECT OUR COMMUNITIES FOUNDATION

**PLEASE STATE YOUR NAME, PLACE OF EMPLOYMENT, AND BUSINESS ADDRESS.**

My name is Bill Powers, P.E. I am the owner and principal of Powers Engineering, located at 4452 Park Boulevard, Unit 209, San Diego, CA 92116.

**PLEASE DESCRIBE YOUR QUALIFICATIONS FOR PROVIDING THIS TESTIMONY.**

I am a registered professional engineer, with extensive knowledge and experience in the fields of energy and environmental engineering, air emissions control, and regional energy planning. A copy of my resume is included as **Exhibit A** to this testimony.

**WHAT IS THE PURPOSE OF THIS TESTIMONY?**

I submit this opening testimony on behalf of The Protect Our Communities Foundation ("PCF") who provides testimony (PCF Presentation), pursuant to Rule 14.3 of the Commission's Rules of Practice and Procedure, on actions the Commission can adopt by April 2021 to increase energy supply and decrease demand during the peak demand and net demand peak hours in the event that a heat storm similar to the August 2020 storm occurs in the summer of 2021.

My testimony details that California already has adequate energy supplies for the summer of 2021 with available resources. Consistent with the Scoping Memo's focus "on those actions that the Commission can adopt by April 2021 and that the parties can implement before or during the summer of 2021,"[1] the short-term focus of the Commission should be on crafting measures to avoid further financial burdens on California's ratepayers caused by the activities of wholesale sellers and traders in the markets administered by the California Independent System Operator (CAISO).

[1] R.20-11-003, Assigned Commissioner's Scoping Memo and Ruling (December 21, 2020), p. 1.

The Assigned Commissioner's focus on procurement must be accompanied by effective and aggressive use of the Commission's and the CAISO's existing authority to assure reliability, including measures to prevent physical and economic withholding and gaming. The August 2020 blackouts should not be used as justification to fast-track new gas-fired procurement for the summer of 2021, especially without a factual record that supports any new procurement.

## I. AVAILABLE EVIDENCE INDICATES THAT THE MISMANAGEMENT OF AMPLE SUPPLIES CAUSED THE AUGUST 2020 BLACKOUTS, NO EVIDENCE SUPPORTS THE NEED FOR ADDITIONAL SUPPLY TO BE PROCURED FOR THE SUMMER OF 2021.

The mismanagement of ample supplies by CAISO during mid-August 2020 led to such substantial load and supply impacts that it compromised grid reliability and resulted in rolling blackouts on August 14-15, 2020. The blackouts were initiated at actual demand levels below the CAISO's forecast 1-in-2 peak demand for the summer of 2020.[2] There was nothing exceptional or historic about the demand on the grid at the time of the blackouts. The Commission requires the load serving entities (LSE) to procure adequate resources to meet CAISO's summer peak demand forecast. As a result, ample supplies of electricity were available and under contract to meet demand on August 14-15, 2020. However, in the immediate wake of the blackouts, and prior to any investigation, CAISO identified inadequate supply as the primary cause of the blackouts and dismissed improper market activity as a contributing factor.[3]

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[2] CAISO, *2020 Summer Loads and Resources Assessment*, May 15, 2020, p. 3 (Forecast summer 1-in-2 peak = 45,907 MW); CAISO Today's Outlook website (click on Demand) (August 14, 2020 blackout initiated (18:36) = 45,716 MW; August 15, 2020 blackout initiated (18:20) = 44,662 MW), available at http://www.caiso.com/TodaysOutlook/Pages/default.aspx.

[3] Dale Kasler, *California power prices have skyrocketed. Is this normal — or more Enron-style 'manipulation'?*, Sacramento Bee (August 19, 2020) ("But top ISO officials have said they've seen no evidence of anything improper. They're convinced the heat wave is largely driving conditions on the grid . . . Berberich said the commission has failed to implement a strict 'resource adequacy' regulation that would force the utilities to procure a greater share of their power in advance."), available at https://www.sacbee.com/news/california/article245048140.html.

The December 21, 2020 Scoping Memo and Ruling accepts CAISO's initial and erroneous claim of a supply shortage at face value, framing the factual inquiry to increasing supply and reducing demand for the summer of 2021. This testimony explains why no physical supply shortage exists that must be addressed with additional fast-track bilateral gas contracts, or any other procurement not already in the procurement pipeline, for the summer of 2021. The Commission should instead focus on identifying and rectifying CAISO supply management deficiencies and lax resource adequacy contract terms[4] prior to the summer of 2021 to ensure that all resources already under contract are delivered to and used for the benefit of California's ratepayers. The Commission should also focus on enforcing General Order 167 and its authority under Section 761 et seq. to ensure sufficient generation resources are available and their output delivered for use by California ratepayers. Focusing on delivery and use by Californians of the electricity resources for which they have already contracted comports with the Commission's recognition that issues of "(1) safety, (2) reliability, (3) load and supply impact, and (4) cost allocation"[5] are properly included within the scope of this proceeding. Without ensuring the availability and delivery of those electricity resources already under contract, the Commission cannot ensure safety and reliability or assess load and supply impact appropriately.

[4] CAISO Department of Market Monitoring, *Import Resource Adequacy* (September 10, 2018), p. 1 ("Resource adequacy imports are not required to be resource specific or to represent supply from a specific balancing area, but only that they be on a specific intertie into the ISO system. Further, scheduling coordinators are only required to submit energy bids for resource adequacy imports in the day-ahead market. Imports can be bid at any price and do not have any further obligation to bid into the real-time market if not scheduled in the day-ahead energy or residual unit commitment process."), available at http://www.caiso.com/documents/importresourceadequacyspecialreport-sept102018.pdf.

[5] R.20-11-003, Assigned Commissioner's Scoping Memo and Ruling (December 21, 2020), p. 2.

The events of August 14-15, 2020 and the immediate reaction to pursue expensive supply as the only solution, recapitulate precisely the well-known pattern from the 2000-01 Energy Crisis.[6] In preparing for summer 2021, the Commission and California should take every action within their power to avoid being herded into expensive and unnecessary electricity contracts once again.

The August 2020 blackouts were accompanied by extremely profitable price gouging by sellers throughout the West. In proceedings at FERC initiated in October 2020, immediately after the publication of the October 6, 2020 Preliminary Root Cause Analysis (PRCA), a large number of sellers have disclosed – and attempted to justify – prices during and after the blackout period that exceeded the $1,000/MWh soft cap in the Western Interconnect.[7] All three large California utilities have intervened at FERC to request unwinding of these transactions and refunds.[8] The cost impacts on California ratepayers were unjust and unreasonable. FERC has not yet acted.

The Department of Market Monitoring at the CAISO (DMM) has intervened at FERC and requested that FERC provide guidance going forward on the use of non-generator costs to justify high bids (bilateral contract prices and published indices).[9] FERC has not yet acted. Notably, neither the CAISO nor the DMM have addressed price gouging and the possibility of

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[6] *See, generally*, Morgan Stanley Capital Group Inc. v. PUD Number 1 of Snohomish County, 554 US 527 (2008); Snohomish v. FERC, 471 F.3d 1053 (9th Cir. 2006) and cases cited at 471 F.3d at 1067-68.
[7] *See e.g.* ConocoPhillips, Docket ER21-40; Tenaska Power Services, ER21-42; Exelon, ER21-43; Mercuria, ER21-46; Tucson Electric Power (Fortis), ER21-47; UNS Electric, Inc. (Fortis), ER21-48; BP Energy, ER21-51-001; Public Service Company of New Mexico, ER21-52; Mesquite Power (IIF), ER21-55; El Paso Electric (IIF), ER21-61-001; Guzman Energy, ER21-56; Shell Energy North America, ER21-57; TransAlta Energy Marketing, ER21-58; Brookfield Renewable Trading and Marketing, ER21-59; PacifiCorp, ER21-60; Uniper Global Commodities North America, ER21-62; Macquarie Energy, ER21-64; Tri-State Generation and Transmission Association , ER21-65; EDF, ER21-135.
[8] FERC Docket No. ER21-40-000, Comments of SCE (October 28, 2020); Comments of PG&E (October 28, 2020); Motion to Intervene filed Out-of-Time by SDG&E (November 2, 2020).
[9] FERC Docket No. ER21-40-000, Comments of the CAISO DMM (October 28, 2020).

market manipulation for purposes of revenue and profit maximization in any of the preliminary reports or analyses to date. The Commission should address the pricing issues arising from the CAISO's conduct of its markets and should examine the utilities' filings and evidence about price gouging before it potentially compounds the problem by ordering additional unneeded procurement for the summer of 2021.

This supply can be diminished through withholding – physical or economic – or through actions that make it otherwise unavailable. Thus to ensure the availability and actual delivery of all the supply that Californians have already paid for, the Commission should focus on actions to ensure the availability and delivery of the currently-contracted-for supply, rather than order additional procurement to be purchased.

With proper management by CAISO of available supply, and new supply additions scheduled to be online by the summer of 2021, CAISO will have up to 9,000 MW of additional supply available in the summer of 2021 beyond what it had available on the afternoon of August 14, 2020. The composition of the additional supply is described in Section II. 1,000 MW of DR can also be added by the summer of 2021 by enrolling residential customers with smart thermostats in opt-out smart thermostat DR programs, as discussed in Section III.

## II. UP TO 9,000 MW OF ADDITIONAL SUPPLY WILL BE AVAILABLE TO CAISO IN THE SUMMER OF 2021 WITHOUT NEW PROCUREMENT.

### A. CAISO's Curtailment of Exports Would Add Up To 4,500 MW of Additional Supply.

Ongoing investigation, summarized in the October 6, 2020 PRCA,[10] the October 9, 2020 CAISO August Heatwave Update (Update), and the November 24, 2020 DMM Report on System and Market Conditions, Issues and Performance: August and September 2020 (DMM

[10] The Final PRCA has not been released at the time this opening testimony was prepared.

Report), do not support the CAISO's initial conjecture about the cause of the blackouts. The PRCA indicates that a CAISO "software error" enabled thousands of MW of power to be exported from CAISO to neighboring states as blackouts were called by CAISO in California.[11] The amount of power being exported at the time of the blackouts on August 14th and 15th 2020 was far in excess of the demand reduction achieved with the rolling blackouts. According to the CAISO's own data, about 4,500 MW of power was being exported from CAISO to neighboring states when CAISO called a 1,000 MW rolling blackout on August 14th.[12] About 3,500 MW of power was being exported to neighboring states on August 15th when CAISO initiated a 470 MW rolling blackout.[13]

The DMM, the entity within CAISO whose role is to assure that the market functions properly, claims to have been unaware until recently that, contrary to CAISO's tariff, CAISO would allow exports to continue under potentially tight CAISO supply conditions.[14] Is this a "software error" or a policy choice to promote exports in the name of regional grid integration? If the former, steps should be taken to correct the error, at no cost to consumers. If the latter, it needs to be corrected before consumers spend money for new procurements that would purport to pay exporters for "opportunity costs" associated with foregone exports.

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[11] PRCA, p. 13-14 ("After a review of the August 14 event, it was discovered that a prior market enhancement was inadvertently causing the CAISO's RUC process to mask the load under-scheduling and convergence bid supply effects, reinforcing the signal that more exports were supportable.").
[12] *Id.* at p. 100.
[13] *Id.* at p. 100.
[14] CAISO DMM, *Report on system and market conditions, issues and performance: August and September 2020* (November 24, 2020), p. 71 ("Prior to the August heat wave, the CAISO tariff and business practice manuals described day-ahead market exports not supported by specific generation being clearly prioritized below CAISO load in real-time. Therefore, it was DMM's understanding that CAISO already had such a carefully defined process in place. Now, it is DMM's understanding that CAISO may not have such a procedure and that its policy may not be aligned with export curtailment policies of other western balancing areas.").

In its FERC Comments, the DMM describes plausible scenarios for "exports" chasing high prices throughout the West, including re-import into California through devices such as megawatt laundering and wash trades.[15] Was it a software error, or a "market enhancement" through which sellers exploited the opportunity to remove available supplies from California at the expense of California consumers? These revelations do not inspire confidence that CAISO possesses or uses adequate internal market controls to manage exports or guard against price gouging under conditions of tight supply. A thorough investigation needs to provide answers to these questions before California load-serving entities and their retail customers are compelled to pay more to purchase existing power supplies.[16]

Several parties to this proceeding, including PCF, PG&E, TURN, UCAN, and CEJA, have attributed the continued exporting of large amounts of power out-of-state as the primary cause of August 14-15, 2020 rolling blackouts.[17] The DMM concurs and its December 18, 2020 presentation specifically finds that "Exports increased demand above levels that could be supported by physical generation."[18] The Commission should support the DMM's recommendation that "Further changes and clarifications in the rules and processes for limiting and curtailing exports should be discussed and pursued."[19] Curtailing exports during tight

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[15] FERC Docket No. ER21-40-000, Comments of the Department of Market Monitoring of the California Independent System Operator Corporation (October 28, 2020), p. 5-6, 8-9.
[16] No new construction can occur before June 2021, so any Commission order for more procurement will simply constitute an order to buy from currently existing supply.
[17] R.20-11-003, PG&E Reply Comments (December 10, 2020), p. 10-11; CEJA et al Reply Comments (December 10, 2020), p. 3; TURN Opening Comments (November 30, 2020), p. 4-5; UCAN Opening Comments (November 30, 2020), p. 1-2.
[18] CAISO DMM, *Report on System and Market Conditions, Issues and Performance: August and September 2020* (December 18, 2020), PowerPoint p. 16, available at http://www.caiso.com/Documents/Presentation-Report-MarketConditions-Issues-Performance-August-September2020-Dec18-2020.pdf
[19] *Id.* at p. 21.

supply conditions will boost supply in the summer of 2021 by at least 3,500 MW, at no cost to the California ratepayer.

The Commission should intervene at FERC to support the utilities' demands for refunds, to support the DMM's requests both for the clear guidance sought by the DMM that prohibits self-referential cost justification for high bids, and a reduction of the caps from $1,000/MWh to $500/MWh, based on the SCE formula.[20] The Commission should also direct the CAISO to develop clear scheduling and other market protocols to prioritize retail load within California over exports under tight supply conditions. PCF recommends that this proceeding incorporate an examination of the protocol revisions needed to prioritize the needs of California customers and the adequacy of retail service in California, as California Public Utilities Code Section 345.5(b)(5) requires.[21]

The efficacy of this practice has already been demonstrated by CAISO. The curtailment by CAISO of exports during peak hours on August 18, 2020 and September 6, 2020 enabled CAISO to meet significantly higher peak loads than those it experienced on August 14-15, 2020 without resorting to rolling blackouts,[22] thereby ensuring the safety and reliability of the system.

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[20] FERC, Docket No. ER21-40-000, SCE Comments (October 28, 2020), fn. 14, p. 5 ("During the August events, natural gas prices were in the range of $13.50/mmBtu, GHG prices were less than $18/ton, and data from Hitachi Powergrids Velocity Suite indicate no generation within the CAISO has an incremental heat rate above 30,000 Btu/kWh. Assuming a conversion factor of 0.0531148mtCO2e/mmBtu, then, conservatively, no generation within the CAISO had a marginal cost that exceeded $440/MWh. (30 mmBtu/*13.5/mmBtu + 30*0.0531148mtCO2e/mmBtu*$18/ton = $433.68/MWh).").

[21] Pub. Util. Code, § 345.5, subd. (b)(5) ("Independent System Operator shall manage the transmission grid and related energy markets in a manner that is consistent with all of the following . . . Conducting internal operations in a manner that minimizes cost impact on ratepayers to the extent practicable and consistent with the provisions of this chapter.").

[22] CAISO Today's Outlook (click on Demand) (August 14, 2020 peak (17:00) = 46,777 MW; August 14, 2020 blackout initiated (18:36) = 45,716 MW; August 15, 2020 peak (18:00) = 44,913 MW; August 15, 2020 blackout initiated (18:20) = 44,662 MW; August 18, 2020 peak (16:00) = 47,067 MW; September 6, 2020 peak (16:40) = 46,864 MW), available at http://www.caiso.com/TodaysOutlook/Pages/default.aspx.

**B. OTC Unit Performance Should Be Carefully Scrutinized.**

CAISO speculates that no manipulation of supply sources contributed to the blackouts because, based on its (anecdotal) polling of generators, the generator outages that occurred were legitimate.[23] However, over 1,400 MW of SoCal OTC capacity, nearly 40 percent of the total SoCal OTC capacity, was unavailable when the 1,000 MW rolling blackout were initiated by CAISO on August 14th with demand at 45,716 MW.[24] In contrast, all of the SoCal OTC units were available to meet the substantially higher peak demand on September 6, 2020, increasing OTC supply by over 1,000 MW.

Section 761.3 requires generators to record plant status information daily and to maintain a Control Operator Log, a "formal record of real time operating events as well as the overall status of the generating units" under the operator's control and to report the reasons for any unit curtailments to the CPUC and the CAISO.[25] Yet CAISO has declined to provide the reasons that the generators must officially record, from the formal reporting requirements for the outages of the SoCal OTC units that were unavailable on August 14-15, 2020.[26]

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[23] CAISO DMM, *Report on System and Market Conditions, Issues and Performance: August and September 2020* (November 24, 2020), p. 22 ("DMM has reviewed major outages which occurred on August 14 and 15. Based on data available to DMM *at this time*, there is no indication that on these days any outages were falsely declared at strategic times in order to allow generation owners to profit from higher prices.").

[24] **Exhibit B**: R.19-11-009, Response of CAISO to Data Request Number PCF-CAISO-2020RA-02 by Protect Our Communities Foundation (November 16, 2020); R.20-11-003, PCF Reply Comments (December 10, 2020), p. 5.

[25] Pub. Util. Code § 761.3, subd. (e) ("…[The generator] shall provide a monthly report to the Independent System Operator that identifies any periods during the preceding month when the unit was unavailable to produce electricity or was available only at reduced capacity. The report shall identify the reasons for any such unscheduled unavailability or reduced capacity. The Independent System Operator shall immediately transmit the information to the Oversight Board and the commission."); CPUC General Order 167, Appendix B (applicable to all thermal units in California over 50 megawatts).

[26] **Exhibit B**: R.19-11-009, CAISO, Response of the California Independent System Operator Corporation to Data Request Number PCF-CAISO-2020RA-02 by Protect Our Communities Foundation (November 16, 2020).

More concerning, the DMM's assertion that there were no deliberate outages does not appear to be based on a review of the Control Operator Logs, if indeed they are still maintained. The Control Operator Log specifically must include a record of "communications between the facility and outside entities including but not limited to the Independent System Operator (ISO), scheduling coordinators or headquarters facilities…"[27] This information would shed light on the actual dispatch instructions received by the plant operators, as well as other communications about operation and dispatch. The Commission should activate its reporting and enforcement mechanisms and both demand and then publish monthly CAISO "after action" outage reports for all California-based generation.

The primary purported purpose for utilizing outdated and high environmental impact OTC units in the past has been to provide additional supply during peak demand periods. A critical fact that the Commission must examine and understand involves why those plants could not perform on August 14-15 and why they could perform on September 6. A 40 percent unavailability rate at the hour of critical need is clearly unacceptable.

### C. Properly Maintained Utility-Owned Combined Cycle Units Adds 500 MW in Summer of 2021.

California investor-owned utilities (IOU) own a total of five combined cycle power plants: PG&E's Colusa Generating Station (August NQC = 595 MW) PG&E's Gateway Energy Station (August NQC = 523 MW), SCE's Mountainview Energy Center (August NQC = 1,110 MW), SDG&E's Palomar Energy Center (August NQC = 566 MW), and SDG&E's Desert Star Energy Center (August NQC = 419 MW).[28]

[27] CPUC General Order 167, Appendix B, p. 35.
[28] CAISO, Final Net Qualifying Capacity Report for Compliance Year 2020 (xls) (December 15, 2020), available at http://www.caiso.com/planning/Pages/ReliabilityRequirements/Default.aspx.

Two of these five utility-owned combined cycle power plants, Gateway Energy Center and Desert Star Energy Center, experienced substantial forced outages on August 14th and 15th, 2020. On August 14th, at the start of the 1,000 MW rolling blackout at 6:36 pm, Gateway was experiencing a partial curtailment of 180 MW.[29] At this same time, Desert Star was experiencing a partial curtailment of 280 MW.[30] The combined curtailment at these two combined cycle plants was approximately 460 MW when the rolling blackout was initiated on August 14th.[31]

On August 15th at the start of the 470 MW rolling blackout at 6:20 pm, Gateway was experiencing a partial curtailment of 164 MW.[32] Desert Star was experiencing a partial curtailment of 130 MW.[33] The combined curtailment at these two combined cycle plants was approximately 300 MW when the rolling blackout was initiated on August 15th. The high forced outage rate at utility-owned combined cycle plants, with two of five combined cycle plants substantially impacted, materially reduced available supply at the time the rolling blackouts were initiated on August 14th and 15th, 2020.

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[29] CAISO August 13-16, 2020 outage summary (xls) CAISO, Outage Data for August 13-16 and Responses to Stakeholder Questions (September 11, 2020), available at http://www.caiso.com/Documents/OutageData-August13-16-Responses-StakeholderQuestions.html; http://www.caiso.com/Documents/ISO-Stage-3-Emergency-Declaration-Lifted-Power-Restored-Statewide.pdf.

[30] *Ibid.*

[31] **Exhibit C**: T. Popik – Foundation for Resilient Societies, *August 2020 Blackouts in CAISO*, PowerPoint, (November 5, 2020), p. 16, available at https://www.nerc.com/comm/RSTC/EGWG/Foundation_for_Resilient_Societies_EGWG_Sept_29_2020_r2%20(002).pdf.

[32] CAISO August 13-16, 2020 outage summary (xls) CAISO, Outage Data for August 13-16 and Responses to Stakeholder Questions (September 11, 2020), available at http://www.caiso.com/Documents/OutageData-August13-16-Responses-StakeholderQuestions.html; http://www.caiso.com/Documents/ISORequestedPowerOutagesFollowingStage3EmergencyDeclarationSystemNowBeingRestored.pdf.

[33] *Ibid.*

**D. New Supply – Already in Development – Adds 2,400 MW by Summer 2021.**

There is no dispute that 2,100 MW of storage and hybrid storage resources and approximately 300 MW solar and wind resources, already under development by LSEs, will be online by the summer of 2021.[34] This additional supply, already under contract and paid for by California ratepayers, should be factored into any modeling or analyses of supply shortages before the Commission orders additional procurement.

**E. Shedding Load at 3% Operating Reserve Margin Adds 1,500 MW of Supply.**

CAISO insists it must maintain 3,000 MW of reserves and initiate controlled load shedding if it drops below that reserve level.[35] 3,000 MW of reserves equates to approximately 6 percent at a peak demand of 45,000 MW, the approximate peak loads on August 14th and 15th. The insistence on maintaining at least a 6 percent operating reserve margin contradicts CAISO's stated operating practice, that it will initiate controlled load shedding when operating reserves reach 3 percent.[36] The capacity difference between a 6 percent operating reserve margin and 3 percent operating reserve margin, at a demand of 45,000 MW, totals 1,500 MW, an amount of resources that would have clearly covered the 1,000 MW of rolling blackouts the CAISO called on August 14th and the 470 MW of rolling blackouts the CAISO called on August 15th.

An issue that must be addressed before the summer of 2021 is CAISO's real-time accounting of available capacity on its public website. The available capacity data on the public website indicated that CAISO initiated the rolling blackout on August 15, 2020 at an operating

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[34] PRCA, p. 64.
[35] Jeff St. John, *California's Shift from Natural Gas to Solar Is Playing a Role in Rolling Blackouts*, GreenTech Media (August 17, 2020), p. 4 ("'For those who say we can rely on our reserves, you are wrong,' Berberich said in response to criticism that CAISO called its emergencies while it still had reserve generation capacity available. CAISO must retain its roughly 3,000 megawatts of reserve capacity to prevent the possibility of an even more widespread grid collapse, which could occur if a power plant were to drop offline or a key transmission line were to be forced out of service, he said.").
[36] R.20-11-003, PCF Opening Comments (November 30, 2020), p. 4.

reserve margin of approximately 9 percent.[37] Yet the calculated real-time operating reserve margin displayed on a separate CAISO website was showing an operating reserve margin at or below 6 percent.[38] CAISO does not clarify the basis for this discrepancy in the PRCA or in its data request responses to PCF in the resource adequacy proceeding, R.19-11-009. The Commission should request clear and consistent information be provided to all of California before the CAISO decides to shed load at reserve levels above 3 percent.

### F. 9,000 MW of Additional Supply Is Already Available to CAISO for Summer 2021 with No Further Procurement Action by the Commission.

Curtailing exports (4,500 MW), accounting for new supply already in development for summer 2021 (2,400 MW), assuring all utility-owned combined cycle units are available when needed (500 MW), and following established NERC and CAISO protocol on initiating controlled load shedding at a 3% operating reserve margin (1,500 MW) would collectively add approximately 9,000 MW of supply to the supply-demand balance faced by CAISO on the afternoon of August 14th. 9,000 MW of this additional supply can be obtained at no cost to ratepayers.

## III. REDUCING DEMAND

### A. Reversing Attrition in DR Programs Adds 1,000 MW by Summer 2021.

The PRCA also indicates that the most likely focus of any new supply for the summer of 2021 will involve "demand side" resources such as demand response (DR).[39] However, CAISO has resisted expanding use of DR resources in the past, despite DR's prioritization at the top of the Loading Order for new resources. CAISO's institutional resistance to DR has been effective.

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[37] **Exhibit D**: Calculation of real-time operating reserve margin during August 15, 2020 rolling blackout, D. Marcus, September 22, 2020.
[38] CAISO OASIS database, Ancillary Services, Actual Operating Margin (accessed January 11, 2021): http://oasis.caiso.com/mrioasis/logon.do.
[39] PRCA, p. 65.

In 2012, CAISO identified 2,296 MW of DR at its disposal to offset demand at the summer peak.[40] In 2020, CAISO identified only 1,339 MW of DR available for this purpose.[41] Had CAISO simply maintained the amount of DR available to it in 2012 through the summer of 2020, it would have possessed an additional 957 MW of DR to deploy on August 14th and 15th as an alternative to calling rolling blackouts.

The Commission should take advantage of available but underutilized DR assets, increase incentives, reduce dispatch activity limits, and clarify its expectations regarding when programs are dispatched, to replenish this nearly 1,000 MW of the formerly available DR capacity by the summer of 2021. Over one million of California homes with central air conditioning (A/C) currently have smart thermostats installed.[42] Yet only a fraction of these homes are enrolled in IOU DR programs.[43] These customers form an obvious pool of candidates to reduce residential central A/C loads during heat waves, and should be enrolled immediately in IOU DR programs.

Enrollment for all customers with smart thermostats should be "opt-out" programs, following the approach used by the IOUs with their opt-out residential customer TOU tariffs. Opt-out DR programs – involving those customers already equipped with low-cost smart thermostats for cycling of central A/C units[44] – can achieve 95 percent participation.[45] For the DR programs to maximize their potential, they must be structured as opt-out programs.

SCE achieved an average of 1 MW reduction per 1,000 participating smart thermostat customers in the first hour of deployment (5 to 6 pm) over several heat waves in the summer of

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[40] CAISO, *2012 Summer Loads and Resources Assessment* (March 15, 2020), Table 1, p. 4.
[41] CAISO, *2020 Summer Loads and Resources Assessment* (May 15, 2020), p. 5.
[42] R.20-11-003, Google Opening Comments on Order Instituting Rulemaking (November 30, 2020), p. 3.
[43] *Ibid.*
[44] Portland General Electric, Smart Thermostat Program website, available at https://www.portlandgeneral.com/residential/energy-savings/thermostats/smart-thermostat-programs.
[45] FERC, *A National Assessment of Demand Response Potential* (October 2009), Table 1, p. 24.

2019.[46] The average SCE peak load reduction in the first hour was more than 50 MW and involved over 50,000 residential customers.[47] Based on these results, adding a million new residential customers in the CAISO control area has the potential to achieve a demand reduction of 1,000 MW.

Payments to smart thermostat participants should be decoupled for CAISO market prices to assure these DR resources play no role in driving marginal pricing in CAISO markets during heat waves. Customers should be paid a fixed price per annum for a limited number of dispatches, whether or not these DR resources are dispatched. For example, customers would be paid $50 in the form of a bill credit for up to 10 dispatches of up to 4 hours duration each in 2021.

The onerous dispatchability requirements that CAISO has placed on DR resources should also be relaxed to increase available DR capacity when it is needed. In the case of residential A/C load reduction via smart thermostat control, this DR resource should be scheduled for dispatch in the day-ahead market two hours before the day-ahead forecast net peak. Scheduling DR resources in the day-ahead market is fundamentally no different than dispatching slow-start resources (OTC units) a day in advance to assure they are operating at capacity when peak loads occur the following day.

### B. Reliability of CAISO Day-Ahead Forecasts in Heat Waves Must Be Improved.

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[46] SCE, *Southern California Edison Smart Energy Program: 2019 Load Impact Evaluation*, PowerPoint (May 4, 2020), p. 5 (Summer 2019 average, 5-6 pm, number of customers = 52,239, average load reduction = 1.02 kW, total load reduction = 52,239 customers x 1.02 kW per customer = 53,284 kW (53.3 MW).).

[47] *Ibid.*

The facts show that CAISO ordered the rolling blackouts at demand levels that were less, at 45,716 MW and 44,524 MW respectively, than the CAISO summer 2020 forecast 1-in-2 one-hour peak load of 45,907 MW.[48,49] Augmenting supply for the summer of 2021, when availability of supply was not the cause of August 2020 blackouts, will not prepare California to ensure reliability during any heat waves that might occur in 2021. Authorizing CPM procurement to augment supply, when supply constraints were not a cause of the August 14-15, 2020 rolling blackouts, would conflict with the Commission's statutory obligation to ensure just and reasonable rates.

This proceeding should examine closely the accuracy of CAISO's day-ahead forecasts in the week following the August 14-15, 2020 blackouts. The day-ahead forecast for Monday, August 17th, was nearly 5,000 MW higher, at 49,825 MW, than the actual peak of 45,094 MW. The next day, August 18th, the day-ahead forecast was 3,300 MW higher, at 50,485 MW, than the actual peak of 47,067 MW.[50] CAISO asserts that extraordinary voluntary conservation is the reason for the discrepancy between these day-ahead forecasts and the actual peak demand,[51] implying that the forecasts were accurate and the exceptional voluntary conservation was unanticipated.

These exceptionally high day-ahead demand forecasts created near-panic in California in the wake of blackouts on August 14th and 15th. The CAISO provides no evidence to support its

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[48] CAISO, *2020 Summer Loads and Resources Assessment* (May 15, 2020), p. 3.
[49] CAISO, CAISO Today's Outlook (click on Demand) (see "demand trend" curves for August 14, 2020 and August 15, 2020), available at http://www.caiso.com/TodaysOutlook/Pages/default.aspx..
[50] *Ibid.* (see "demand trend" curves for August 17, 2020 and August 18, 2020).
[51] CAISO/CPUC/CEC, *Preliminary Root Cause Analysis* (October 6, 2020), p. 39 ("As a result of the conservation messaging and awareness created by the State of Emergency, the state was successful in significantly reducing peak demand by as much as 4,000 MW (compared to day-ahead forecasts) on August 17 through 19.").

position that unexpected voluntary conservation was the only reason for the large difference between the day-ahead forecasts on August 18th and 19th and actual peak demand on those days. The Commission should examine whether the forecasts themselves were highly inaccurate. The Commission should corroborate whether the CAISO possesses the capability to conduct accurate day-ahead forecasts during heat waves, as the efficient allocation of supply resources depends largely on those day-ahead forecasts.

The day-ahead demand forecasts of large California public utilities, LADWP and SMUD, and investor-owned utilities in neighboring states that were subject to the same heat wave (Arizona Public Service, Tucson Electric Power, NV Energy) should be evaluated to determine if the CAISO high day-ahead forecasts for August 17-19, 2020 were an outlier or were consistent with the day-ahead forecasts of major California public utilities and IOUs in neighboring states. This information should be used to assess whether CAISO's day-ahead forecasts for the August 17-19, 2020 period were erroneously high. If so, action must be taken to improve the accuracy of CAISO day-ahead forecasts in the midst of heat waves, and not allow erroneously high forecasts to be used to justify supplemental CPM procurement for the summer of 2021.

## IV. TO ENSURE SAFETY AND RELIABILITY – THE COMMISSION MUST ADDRESS INADEQUATE CAISO GRID MANAGEMENT THAT MAY COMPROMISE SUMMER 2021 GRID RELIABILITY.

Actual historic blackouts in the CAISO control area have been caused by mismanagement of available supply, and not by a shortage of supply. For example, inadequate CAISO grid management in SDG&E service territory has led to three major blackouts in the last decade. These blackouts are summarized in Table 1.

**Table 1. Major blackouts in SDG&E service territory, 2010-2020**

| Year | Impact | Cause |
|---|---|---|
| 2010 April | 250,000 customers lose power in San Diego | Improper action by CAISO operators, ordering SDG&E to shed 290 MW. Attributed by FERC to inadequate training and lack of documented operating procedure.[52] |
| 2011 Sept | Regional blackout: SDG&E, Imperial Irrigation District, Baja California | Insufficient local generation online on highest demand day of year. Largest OTC plant (1,000 MW) and combined cycle plant (600 MW) in San Diego area not producing power when major transmission line shut down,[53] led to trip of San Onofre Nuclear Generating Station and regional blackout. |
| 2020 August | Rolling blackouts at modest summer loads | CAISO orders blackout in SDG&E territory with demand less than 3,800 MW (all-time SDG&E peak = 4,890 MW)[54] |

Inadequate management of available supply has been the cause of these blackouts, not lack of supply. The focus of Commission efforts to minimize the potential for a repeat of the blackouts of 2020 must be on CAISO grid management and market practices, and not on simply adding more supply while largely ignoring the management and market issues.

[52] FERC, *In re California Independent System Operator Corporation, Docket No. IN13-4-000, Order Approving Stipulation and Consent Agreement* (December 14, 2012), p. 2 ("The investigation examined possible violations of the NERC Reliability Standards by CAISO surrounding a Disturbance in the San Diego area of the state of California on March 31-April 1, 2010 (the Disturbance). CAISO admitted to the violations set forth below and agreed to pay a civil penalty of $200,000 to the United States Treasury.").
[53] NERC/FERC, *Arizona-Southern California Outages on September 8, 2011 – Causes and Recommendations* (April 27, 2012), p. 25, 33, 50 ("CAISO, the TOP for SDG&E and SCE, did not have any alarms specifically tied to the operation of the SONGS separation scheme either. CAISO only has alarms for when Path 44 exceeds its Path rating, but had no ability to monitor the SONGS separation scheme, set at 3,100 MW (8,000 amps). After the loss of H-NG, which caused Path 44 to exceed its Path rating, CAISO operators were primarily concerned with returning flows on Path 44 to below the Path rating of 2,500 MW, but believed they had 30 minutes to do so. Unlike Path ratings, the separation scheme would not allow CAISO operators 30 minutes to reduce flows on Path 44. CAISO did attempt to dispatch additional generation within SDG&E to reduce flows on Path 44. The other method to reduce flows would have been to manually shed load in SDG&E in time to prevent operation of the SONGS separation scheme. SDG&E estimates that it could have shed approximately 240 MW in between two and two-and-a-half minutes. However, SDG&E was never instructed to shed load and was unaware of the need to shed load.").
[54] R.20-11-003, PCF Reply Comments (December 10, 2020), p. 4.

## V. CONCLUSION

Proper management by CAISO of available supplies in the summer of 2021 will add up to 9,000 of supply capacity to meet peak loads with no new procurement. 1,000 MW of DR resources can also be added by the summer of 2021 by enrolling residential customers who have already added smart thermostats in IOU opt-out smart thermostat programs.

To summarize the programmatic recommendations for 2021 to avoid blackouts, ensure safety and reliability and to avoid price gouging, the Commission should:

(A) Assure that supply-side resources within the CAISO are available to serve CAISO loads by:

(1) prioritizing California loads over exports, a CAISO responsibility;

(2) enforcing generator operation and maintenance standards including enhanced monitoring and reporting under GO 167, a CAISO and Commission responsibility;

(3) completing storage and renewable projects already under contract for 2021, a Commission and California LSE responsibility;

(4) Completing a thorough and professional root cause analysis to determine, among other things, appropriate behaviors by scheduling coordinators, a CAISO/Commission/CEC responsibility;

(5) if necessary reform contract terms to establish the priority for serving California retail load, without paying for rents associated with exports, withholding or other forms of market power that create the appearance of scarcity, a CAISO and Commission joint responsibility.

(B) Assure that demand is accurately forecasted and managed within existing programs and technologies by:

(1) Complying with existing requirements for load shed events at 3 percent reserve level, a CAISO responsibility;

(2) Improving load forecasting, a CAISO responsibility;

(3) Reversing attrition of demand response programs including smart thermostats, a Commission responsibility;

The central focus of the Commission should be on measures to avoid the safety and reliability disruptions and the further financial burdens on California ratepayers caused by the activities of wholesale sellers and traders in CAISO markets. Focusing on procuring new gas-fired procurement without addressing the generation outages and the market flaws that allowed up to 4,500 MW of exports at a time of high demand cannot assure grid reliability or sufficient safety in the summer of 2021.

Respectfully submitted,

/s/ Bill Powers, P.E

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Dated: January 11, 2021

# EXHIBIT A:

# Bill Powers Resume

# BILL POWERS, P.E.

## PROFESSIONAL HISTORY

Powers Engineering, San Diego, CA 1994-
ENSR Consulting and Engineering, Camarillo, CA 1989-93
Naval Energy and Environmental Support Activity, Port Hueneme, CA 1982-87
U.S. Environmental Protection Agency, Research Triangle Park, NC 1980-81

## EDUCATION

Bachelor of Science – Mechanical Engineering, Duke University
Master of Public Health – Environmental Sciences, University of North Carolina

## PROFESSIONAL AFFILIATIONS

Registered Professional Mechanical Engineer, California (Certificate M24518)
Registered Professional Engineer, Missouri (Certificate 2018039156)
American Society of Mechanical Engineers
Institute of Electrical and Electronics Engineers

## TECHNICAL SPECIALTIES

Thirty-five years of experience in:

- Air quality and utility commission proceedings - expert witness
- Distributed solar photovoltaics (PV) siting and regional renewable energy planning
- Power plant cooling system conversion and air emission control assessments
- Combustion equipment permitting, testing and monitoring
- Air pollution control equipment retrofit design/performance testing
- Petroleum refinery air engineering and testing
- Latin America environmental project experience

## RECENT AIR QUALITY AND UTILITY COMMISSION PROCEEDINGS

**Compressor Station Gas Turbine Air Emission Controls**. Assessed the air emission controls and siting issues related to two proposed pipeline compressor station projects in the vicinity of Nashville, Tennessee utilizing Solar Turbines, Inc Titan gas turbines. The result, based on application of a Reasonably Available Control Technology (RACT) requirement, was the reduction of the proposed air permit nitrogen oxides (NOx) emission limit from 25 parts per million (ppm) to 9 ppm.

**Combined Heat and Power Plant Gas Turbine Air Emission Controls**. Evaluated the air emission controls proposed for a combined heat and power (CHP) plant at Duke University that would utilize Solar Turbines, Inc Titan gas turbine. Applicant proposed a 25 ppm $NO_x$ limit using dry low-$NO_x$ combustion as Best Available Control Technology (BACT) in its Certificate of Public Convenience and Necessity (CPCN) application to the North Carolina Utilities Commission. Argued that $NO_x$ BACT for the CHP plant should be use of selective catalytic reduction (SCR) to achieve a 2 ppm $NO_x$ emission limit. Applicant withdrew its CPCN application.

**SDG&E 36-Inch Transmission Pipeline.** Expert witness for non-profit client advocating that existing 16-inch pipeline did not require replacement with new $600 million 36-inch pipeline. Underscored in testimony that SDG&E had recently completed extensive inline inspection of existing 16-inch pipeline and found that pipeline was in good condition for long-term operation at 512 psig transmission pressure. Demonstrated that reduction of pressure to 320 psig would not increase safety of existing pipeline, as ILI could no longer be done periodically at lower pressure. Commission accepted this reasoning and denied SDG&E's application.

**Cove Point LNG Export Terminal.** Expert witness in two separate administrative proceedings before the Maryland Public Service Commission, in 2014 and 2017, regarding air permit conditions for the proposed Cove Point LNG export. The plant site is located in a non-attainment area for ozone. Testimony addressed deficiencies in the proposed air emission limits and proposed control technology for combustion equipment – including gas turbines, auxiliary boilers, and flares, fugitive emission sources, and marine loading vapor recovery systems.

**Corpus Christi LNG Expert Terminal.** Expert witness in Texas Commission on Environmental Quality contested air permit proceeding in 2013 before the State Office of Administrative Hearings. Testimony addressed deficiencies in the proposed control technology for compressor-drive gas turbines, flares, and fugitive emission sources, and marine loading vapor recovery systems.

## DISTRIBUTED SOLAR PV SITING AND REGIONAL RENEWABLE ENERGY PLANNING

**Roadmap to 100 Percent Local Solar by 2030 in the City of San Diego.** Author of the May 2020 *Roadmap to 100 Percent Local Solar Build-Out by 2030 in the City of San Diego* strategic energy plan for San Diego. The *Roadmap* outlines a strategy to maximize the use of solar energy and battery storage in the City of San Diego (City) to provide 100 percent clean electricity to all San Diegans by 2030. The City's Climate Action Plan sets a mandatory target of 100 percent clean electricity by 2035. The *Roadmap* describes how the City can best deliver lower-cost electricity and provide local job growth by choosing local solar power paired with battery storage, complemented by smart energy efficiency and demand response programs, to reach 100 percent clean energy.

**North Carolina Clean Path 2025 Plan.** Author of the August 2017 *North Carolina Clean Path 2025* strategic energy plan for North Carolina. *NC Clean Path 2025* implements local solar power, battery storage, and energy efficiency measures to rapidly replace fossil fuel-generated electricity in the state. The plan is substantially less costly than the $40 billion expansion of natural gas infrastructure, nuclear power, and transmission infrastructure being planned for North Carolina. Implementation of *NC Clean Path 2025* would reduce power generated by coal- and natural gas-fired plants by about 60 percent by 2025, and 100 percent by 2030. All in-state coal-fired plants would be closed and gas-fired plants would be used only for backup supply. Existing transmission and distribution infrastructure would be maintained and not expanded.

**Bay Area Smart Energy 2020 Plan.** Author of the March 2012 *Bay Area Smart Energy 2020* strategic energy plan for the nine-county region surrounding San Francisco Bay. This plan uses the zero net energy building targets in the *California Energy Efficiency Strategic Plan* as a framework to achieve a 60 percent reduction in GHG emissions from Bay Area electricity usage, and a 50 percent reduction in peak demand for grid electricity, by 2020. The 2020 targets in the plan include: 25 percent of detached homes and 20 percent of commercial buildings achieving zero net energy, adding 200 MW of community-scale microgrid battery storage and 400 MW of utility-scale battery storage, reduction in air conditioner loads by 50 percent through air conditioner cycling and targeted incentive funds to assure highest efficiency replacement units, and cooling system modifications to increase power output from The Geysers geothermal production zone in Sonoma County.

**Solar PV technology selection and siting for SDG&E Solar San Diego project.** Served as PV technology expert in California Public Utilities Commission proceeding to define PV technology and sites to be used in San Diego Gas & Electric (SDG&E) $250 million "Solar San Diego" project. Recommendations included: 1) prioritize use of roof-mounted thin-film PV arrays similar to the SCE urban PV program to maximize the installed PV capacity, 2) avoid tracking ground-mounted PV arrays due to high cost and relative lack of available land in the urban/suburban core, 3) and incorporate limited storage in fixed rooftop PV arrays to maximizing output during peak demand periods. Suitable land next to SDG&E substations capable of supporting 5 to 40 MW of PV (each) was also identified by Powers Engineering as a component of this project.

**Rooftop PV alternative to natural gas-fired peaking gas turbines, Chula Vista.** Served as PV technology expert in California Energy Commission (CEC) proceeding regarding the application of MMC Energy to build a 100 MW peaking gas turbine power plant in Chula Vista. Presented testimony that 100 MW of PV arrays in the Chula Vista area could provide the same level of electrical reliability on hot summer days as an equivalent amount of peaking gas turbine capacity at approximately the same cost of energy. The preliminary decision issued by the presiding CEC commissioner in the case recommended denial of the application in part due to failure of the applicant or CEC staff to thoroughly evaluate the PV alternative to the proposed turbines. No final decision has yet been issued in the proceeding (as of May 2009).

**San Diego Smart Energy 2020 Plan.** Author of October 2007 *San Diego Smart Energy 2020*, an energy plan that focuses on meeting the San Diego region's electric energy needs through accelerated integration of renewable and non-renewable distributed generation, in the form of combined heat and power (CHP) systems and solar photovoltaic (PV) systems. PV would meet approximately 28 percent of the San Diego region's electric energy demand in 2020. Annual energy demand would drop 20 percent in 2020 relative to 2003 through use all cost-effective energy efficiency measures. Existing utility-scale gas-fired generation would continue to be utilized to provide power at night, during cloudy weather, and for grid reliability support.

## COOLING SYSTEM CONVERSION AND POWER PLANT EMISSION CONTROL ASSESSMENTS

**Closed-Cycle Cooling Alternative at California Nuclear Plant.**
Lead engineer on review of Bechtel assessment of wedgewire screens and closed-cycle cooling for Diablo Canyon nuclear plant. Demonstrated that wedgewire screens were not likely to be effective in substantially reducing entrainment at the site, and that lower cost closed-cycle retrofit alternatives could be utilized to allow a "cost reasonable" cooling tower retrofit. Plume-abated back-to-back cooling towers located in secondary parking lots to the southeast of the turbine building were identified as the most cost-effective alternative.

**Closed-Cycle Cooling Alternative at Florida Nuclear Plant.**
Evaluated closed cycle cooling tower feasibility assessment for Turkey Point Nuclear Units 3 and 4. Closed-cycle cooling would replace the existing closed-cycle cooling canals. Wet cooling towers for Units 3 and 4 are feasible and could be operational within four years of submittal of applications for the necessary permits.

**Utility Boilers – Conversion of Existing Once-Through Cooled Boilers to Wet Towers, Parallel Wet-Dry Cooling, or Dry Cooling.** Provided expert testimony and preliminary design for the conversion of four natural gas and/or coal-fired utility boilers (Unit 4, 235 MW; Unit 3, 135 MW; Unit 2, 65 MW; and Unit 1,65 MW) from once-through river water cooling to wet cooling towers, parallel wet-dry cooling, and dry cooling. Major design constraints were available land for location of retrofit cooling systems and need to maintain maximum steam turbine backpressure at or below 5.5 inches mercury to match performance capabilities of existing equipment. Approach temperatures of 12 °F and 13 °F were used for the wet towers. SPX Cooling Technologies F-488 plume-abated wet cells with six feet of packing were used to achieve approach temperatures of 12 °F and 13 °F. Annual energy penalty of wet tower retrofit designs is approximately 1 percent. Parallel wet-dry or dry cooling was determined to be technically feasible for Unit 3 based on straightforward access to the Unit 3 surface condenser and available land adjacent to the boiler.

**Utility Boiler – Assessment of Air Cooling and Integrated Gasification/Combined Cycle for Proposed 500 MW Coal-Fired Plant.** Provided expert testimony on the performance of air-cooling and IGCC relative to the conventional closed-cycle wet cooled, supercritical pulverized coal boiler proposed by the applicant. Steam Pro™ coal-fired power plant design software was used to model the proposed plant and evaluate the impacts on performance of air cooling and plume-abated wet cooling. Results indicated that a conservatively designed air-cooled condenser could maintain rated power output at the design ambient temperature of 90 °F. The IGCC comparative analysis indicated that unit reliability comparable to a conventional pulverized coal

unit could be achieved by including a spare gasifier in the IGCC design, and that the slightly higher capital cost of IGCC was offset by greater thermal efficiency and reduced water demand and air emissions.

**Utility Boiler – Assessment of Closed-Cycle Cooling Retrofit Cost for 1,200 MW Oil-Fired Plant.** Prepared an assessment of the cost and feasibility of a closed-cycle wet tower retrofit for the 1,200 MW Roseton Generating Station. Determined that the cost to retrofit the Roseton plant with plume-abated closed-cycle wet cooling was well established based on cooling tower retrofit studies performed by the original owner (Central Hudson Gas & Electric Corp.) and subsequent regulatory agency critique of the cost estimate. Also determined that elimination of redundant and/or excessive budgetary line items in owners cost estimate brings the closed-cycle retrofit in line with expected costs for comparable new or retrofit plume-abated cooling tower applications.

**Nuclear Power Plant – Assessment of Closed-Cycle Cooling Retrofit Cost for 2,000 MW Plant.** Prepared an assessment of the cost and feasibility of a closed-cycle wet tower retrofit for the 2,000 MW Indian Point Generating Station. Determined that the most appropriate arrangement for the hilly site would be an inline plume-abated wet tower instead of the round tower configuration analyzed by the owner. Use of the inline configuration would allow placement of the towers at numerous sites on the property with little or need for blasting of bedrock, greatly reducing the cost of the retrofit. Also proposed an alternative circulating cooling water piping configuration to avoid the extensive downtime projected by the owner for modifications to the existing discharge channel.

**Power Plant Dry Cooling Symposium – Chair and Organizer.** Chair and organizer of the first symposium held in the U.S. (May 2002) that focused exclusively on dry cooling technology for power plants. Sessions included basic principles of wet and dry cooling systems, performance capabilities of dry cooling systems, case studies of specific installations, and reasons why dry cooling is the predominant form of cooling specified in certain regions of North America (Massachusetts, Nevada, northern Mexico).

**Ameren Missouri Coal Units – Causes of Opacity and Opacity Reduction Alternatives.** Lead engineer to assess the root causes of opacity exceedances and evaluate potential alternatives to eliminate opacity violations from the Labadie, Meramec, and Rush Island power plants.

**Utility Boilers – Evaluation of Correlation Between Opacity and $PM_{10}$ Emissions at Coal-Fired Plant.** Provided expert testimony on whether correlation existed between mass $PM_{10}$ emissions and opacity during opacity excursions at large coal-fired boiler in Georgia. EPA and EPRI technical studies were reviewed to assess the correlation of opacity and mass emissions during opacity levels below and above 20 percent. A strong correlation between opacity and mass emissions was apparent at a sister plant at opacities less than 20 percent. The correlation suggests that the opacity monitor correlation underestimates mass emissions at opacities greater than 20 percent, but may continue to exhibit a good correlation for the component of mass emissions in the $PM_{10}$ size range.

**IGCC as BACT for Air Emissions from Proposed 960 MW Coal Plant.** Presented testimony on IGCC as BACT for air emissions reduction from 960 MW coal plant. Applicant received air permit for a pulverized coal plant to be equipped with a baghouse, wet scrubber, and wet ESP for air emissions control. Use of IGCC technology at the emission rates permitted for two recently proposed U.S. IGCC projects, and demonstrated in practice at a Japanese IGCC plant firing Chinese bituminous coal, would substantially reduce potential emissions of $NO_x$, $SO_2$, and PM. The estimated control cost-effectiveness of substituting IGCC for pulverized coal technology in this case was approximately $3,000/ton.

**Analysis of Proposed Air Emission Limits for 600 MW Pulverized Coal Plant.** Project engineer tasked with evaluating sufficiency of air emissions limits and control technologies for proposed 600 MW coal plant Arkansas. Determined that the applicant had: 1) not properly identified $SO_2$, sulfuric acid mist, and PM BACT

control levels for the plant, and 2) improperly utilized an incremental cost effectiveness analysis to justify air emission control levels that did not represent BACT.

**Eight Pulverized Coal Fired 900 MW Boilers – IGCC Alternative with Air Cooling.** Provided testimony on integrated gasification combined cycle (IGCC) as a fully commercial coal-burning alternative to the pulverized coal (PC) technology proposed by TXU for eight 900 MW boilers in East Texas, and East Texas as an ideal location for CO2 sequestration due to presence of mature oilfield CO2 enhanced oil recovery opportunities and a deep saline aquifer underlying the entire region. Also presented testimony on the major increase in regional consumptive water use that would be caused by the evaporative cooling towers proposed for use in the PC plants, and that consumptive water use could be lowered by using IGCC with evaporative cooling towers or by using air-cooled condensers with PC or IGCC technology. TXU ultimately dropped plans to build the eight PC plants as a condition of a corporate buy-out.

**Utility Boilers – Retrofit of SCR and FGD to Existing Coal-Fired Units.**
Expert witness in successful effort to compel an existing coal-fired power plant located in Massachusetts to meet an accelerated $NO_x$ and $SO_2$ emission control system retrofit schedule. Plant owner argued the installation of advanced $NO_x$ and $SO_2$ control systems would generate > 1 ton/year of ancillary emissions, such as sulfuric acid mist, and that under Massachusetts Dept. of Environmental Protection regulation ancillary emissions > 1 ton/year would require a BACT evaluation and a two-year extension to retrofit schedule. Successfully demonstrated that no ancillary emissions would be generated if the retrofit $NO_x$ and $SO_2$ control systems were properly sized and optimized. Plant owner committed to accelerated compliance schedule in settlement agreement.

**Utility Boilers – Retrofit of SCR to Existing Natural Gas-Fired Units.**
Lead engineer in successful representation of interests of California coastal city to prevent weakening of an existing countywide utility boiler $NO_x$ rule. Weakening of $NO_x$ rule would have allowed a merchant utility boiler plant located in the city to operate without installing selective catalytic reduction (SCR) $NO_x$ control systems. This project required numerous appearances before the county air pollution control hearing board to successfully defend the existing utility boiler $NO_x$ rule.

**Biomass Plant $NO_x$ and CO Air Emissions Control Evaluation.** Lead engineer for evaluation of available nitrogen oxide ($NO_x$) and carbon monoxide (CO) controls for a 45 MW Aspen Power biomass plant in Texas where proponent had identified selective non-catalytic reduction (SNCR) for $NO_x$ and good combustion practices for CO as BACT. Identified the use of tail-end SCR for $NO_x$ control at several operational U.S. biomass plants, and oxidation catalyst in use at two of these plants for CO and VOC control, as BACT for the proposed biomass plant. Administrative law judge concurred in decision that SCR and oxidation catalyst is BACT. Developer added SCR and oxidation catalyst to project in subsequent settlement agreement.

**Biomass Plant Air Emissions Control Consulting.** Lead expert on biomass air emissions control systems for landowners that will be impacted by a proposed 50 MW biomass to be built by the local East Texas power cooperative. Public utility agreed to meet current BACT for biomass plants in Texas, SCR for $NO_x$ and oxidation catalyst for CO, in settlement agreement with local landowners.

**Combined-Cycle Power Plant Startup and Shutdown Emissions.** Lead engineer for analysis of air permit startup and shutdown emissions minimization for combined-cycle power plant proposed for the San Francisco Bay Area. Original equipment was specified for baseload operation prior to suspension of project in early 2000s. Operational profile described in revised air permit was load following with potential for daily start/stop. Recommended that either fast start turbine technology be employed to minimize start/stop emissions or that "demonstrated in practice" operational and control software modifications be employed to minimize startup/shutdown emissions.

## NON-WIRES ALTERNATIVES TO TRANSMISSION LINES

**Ameren Missouri Mark Twain 345 kV Transmission Line.** Responsible for evaluating: 1) the expected peak load growth of Ameren Missouri (MO) in general and in Northeast MO specifically over the next decade, 2) the likelihood of wind projects moving forward in the Northeast MO over the next decade, 3) the feasibility and cost of reconductoring with high capacity composite conductors the three 161 kV line segments that would experience NERC violations if 450 to 500 MW of wind power was constructed in Northeast MO, and 4) the feasibility and cost-effectiveness of substituting local solar for wind power to allow Ameren MO to meet its 2021 Renewable Portfolio Standard (RPS) obligation without building the proposed 345 kV transmission line or upgrading the three existing 161 kV lines interconnecting at the Adair Substation.

**American Transmission Corporation Badger-Coulee 345 kV Line.** Responsible for evaluating: 1) the expected peak load growth of Wisconsin utilities over the next decade, and 2) the feasibility and cost-effectiveness of alternatives including load management, energy efficiency, local solar, biogas, and energy storage as viable no-wires alternatives to the proposed ATC Badger-Coulee 345 kV transmission line.

**San Diego Gas & Electric Wood Pole to Steel Pole Replacement Project.**
Lead engineer assessing need and alternatives to replacement of existing wooden 69 kV poles with larger steel 69 kV poles as a response to the fire hazard potential of wooden poles in rural, high fire risk areas. Wooden poles in good condition and not a source of fire ignition. Utility would continue to shut off power to customers during low humidity, high wind conditions. Prepared alternative, solar with batteries for the ~10,000 affected customer meters, to allow customers to ride-through high fire hazard preventive grid power shut-offs at far less cost than replacing wood poles with steel poles.

**San Diego Gas & Electric 500 kV Sunrise Transmission Line.**
Lead engineer assessing the validity of load growth forecasts used by the utility to justify the need for the 500 kV line, and for developing a no-wires alternative, net-metered solar power with some battery support, to meet the identified reliability need at little or no net cost to the utility customer base.

## COMBUSTION EQUIPMENT PERMITTING, TESTING AND MONITORING

**EPRI Gas Turbine Power Plant Permitting Documents – Co-Author.**
Co-authored two Electric Power Research Institute (EPRI) gas turbine power plant siting documents. Responsibilities included chapter on state-of-the-art air emission control systems for simple-cycle and combined-cycle gas turbines, and authorship of sections on dry cooling and zero liquid discharge systems.

**Air Permits for 50 MW Peaker Gas Turbines – Six Sites Throughout California.**
Responsible for preparing all aspects of air permit applications for five 50 MW FT-8 simple-cycle turbine installations at sites around California in response to emergency request by California state government for additional peaking power. Units were designed to meet 2.0 ppm $NO_x$ using standard temperature SCR and innovative dilution air system to maintain exhaust gas temperature within acceptable SCR range. Oxidation catalyst is also used to maintain CO below 6.0 ppm.

**Kauai 27 MW Cogeneration Plant – Air Emission Control System Analysis.** Project manager to evaluate technical feasibility of SCR for 27 MW naphtha-fired turbine with once-through heat recovery steam generator. Permit action was stalled due to questions of SCR feasibility. Extensive analysis of the performance of existing oil-fired turbines equipped with SCR, and bench-scale tests of SCR applied to naphtha-fired turbines, indicated that SCR would perform adequately. Urea was selected as the SCR reagent given the local availability of urea. Unit is first known application of urea-injected SCR on a naphtha-fired turbine.

**Microturbines – Ronald Reagan Library, Ventura County, California.**
Project manager and lead engineer or preparation of air permit applications for microturbines and standby boilers. The microturbines drive the heating and cooling system for the library. The microturbines are

certified by the manufacturer to meet the 9 ppm $NO_x$ emission limit for this equipment. Low-$NO_x$ burners are BACT for the standby boilers.

**Hospital Cogeneration Microturbines – South Coast Air Quality Management District.**
Project manager and lead engineer for preparation of air permit application for three microturbines at hospital cogeneration plant installation. The draft Authority To Construct (ATC) for this project was obtained two weeks after submittal of the ATC application. 30-day public notification was required due to the proximity of the facility to nearby schools. The final ATC was issued two months after the application was submitted, including the 30-day public notification period.

**Gas Turbine Cogeneration – South Coast Air Quality Management District.** Project manager and lead engineer for preparation of air permit application for two 5.5 MW gas turbines in cogeneration configuration for county government center. The turbines will be equipped with selective catalytic reduction (SCR) and oxidation catalyst to comply with SCAQMD BACT requirements. Aqueous urea will be used as the SCR reagent to avoid trigger hazardous material storage requirements. A separate permit will be obtained for the $NO_x$ and CO continuous emissions monitoring systems. The ATCs is pending.

**Peaker Gas Turbines – Evaluation of $NO_x$ Control Options for Installations in San Diego County.**
Lead engineer for evaluation of $NO_x$ control options available for 1970s vintage simple-cycle gas turbines proposed for peaker sites in San Diego County. Dry low-$NO_x$ (DLN) combustors, catalytic combustors, high-temperature SCR, and $NO_x$ absorption/conversion ($SCONO_x$) were evaluated for each candidate turbine make/model. High-temperature SCR was selected as the NOx control option to meet a 5 ppm $NO_x$ emission requirement.

**Hospital Cogeneration Plant Gas Turbines – San Joaquin Valley Unified Air Pollution Control District.**
Project manager and lead engineer for preparation of air permit application and Best Available Control Technology (BACT) evaluation for hospital cogeneration plant installation. The BACT included the review of DLN combustors, catalytic combustors, high-temperature SCR and $SCONO_x$. DLN combustion followed by high temperature SCR was selected as the $NO_x$ control system for this installation. The high temperature SCR is located upstream of the heat recovery steam generator (HRSG) to allow the diversion of exhaust gas around the HRSG without compromising the effectiveness of the $NO_x$ control system.

**1,000 MW Coastal Combined-Cycle Power Plant – Feasibility of Dry Cooling.**
Expert witness in on-going effort to require use of dry cooling on proposed 1,000 MW combined-cycle "repower" project at site of an existing 1,000 MW utility boiler plant. Project proponent argued that site was two small for properly sized air-cooled condenser (ACC) and that use of ACC would cause 12-month construction delay. Demonstrated that ACC could easily be located on the site by splitting total of up to 80 cells between two available locations at the site. Also demonstrated that an ACC optimized for low height and low noise would minimize or eliminate proponent claims of negative visual and noise impacts.

**Industrial Cogeneration Plant Gas Turbines – Upgrade of Turbine Power Output.**
Project manager and lead engineer for preparation of Best Available Control Technology (BACT) evaluation for proposed gas turbine upgrade. The BACT included the review of DLN combustors, catalytic combustors, high-, standard-, and low-temperature SCR, and $SCONO_x$. Successfully negotiated air permit that allowed facility to initially install DLN combustors and operate under a $NO_x$ plantwide "cap." Within two major turbine overhauls, or approximately eight years, the $NO_x$ emissions per turbine must be at or below the equivalent of 5 ppm. The 5 ppm $NO_x$ target will be achieved through technological in-combustor $NO_x$ control such as catalytic combustion, or SCR or SCR equivalent end-of-pipe $NO_x$ control technologies if catalytic combustion is not available.

**Gas Turbines – Modification of RATA Procedures for Time-Share CEM.**
Project manager and lead engineer for the development of alternate CO continuous emission monitor (CEM) Relative Accuracy Test Audit (RATA) procedures for time-share CEM system serving three 7.9 MW turbines located in San Diego. Close interaction with San Diego APCD and EPA Region 9 engineers was required to receive approval for the alternate CO RATA standard. The time-share CEM then passed the annual RATA without problems as a result of changes to some CEM hardware and the more flexible CO RATA standard.

**Gas Turbines – Evaluation of $NO_x$ Control Technology Performance.** Lead engineer for performance review of dry low-$NO_x$ combustors, catalytic combustors, high-, standard-, and low-temperature selective catalytic reduction (SCR), and $NO_x$ absorption/conversion ($SCONO_x$). Major turbine manufacturers and major manufacturers of end-of-pipe $NO_x$ control systems for gas turbines were contacted to determine current cost and performance of $NO_x$ control systems. A comparison of 1993 to 1999 "$/kwh" and "$/ton" cost of these control systems was developed in the evaluation.

**Lead engineer for evaluation for proposed combined cycle gas turbine $NO_x$ and CO control systems.**
Project was in litigation over contract terms, and there was concern that the GE Frame 7FA turbine could not meet the 3 ppm $NO_x$ permit limit using a conventional combustor with water injection followed by SCR. Operations personnel at GE Frame 7FA installatins around the country were interviewed, along with principal SCR vendors, to corroborate that the installation could continuously meet the 3 ppm $NO_x$ limit.

**Gas Turbines – Title V "Presumptively Approvable" Compliance Assurance Monitoring Protocol.**
Project manager and lead engineer for the development of a "presumptively approval" $NO_x$ parametric emissions monitoring system (PEMS) protocol for industrial gas turbines. "Presumptively approvable" means that any gas turbine operator selecting this monitoring protocol can presume it is acceptable to the U.S. EPA. Close interaction with the gas turbine manufacturer's design engineering staff and the U.S. EPA Emissions Measurement Branch (Research Triangle Park, NC) was required to determine modifications necessary to the current PEMS to upgrade it to "presumptively approvable" status.

**Environmental Due Diligence Review of Gas Turbine Sites – Mexico.** Task leader to prepare regulatory compliance due diligence review of Mexican requirements for gas turbine power plants. Project involves eleven potential sites across Mexico, three of which are under construction. Scope involves identification of all environmental, energy sales, land use, and transportation corridor requirements for power projects in Mexico. Coordinator of Mexican environmental subcontractors gathering on-site information for each site, and translator of Spanish supporting documentation to English.

**Development of Air Emission Standards for Gas Turbines - Peru.** Served as principal technical consultant to the Peruvian Ministry of Energy in Mines (MEM) for the development of air emission standards for Peruvian gas turbine power plants. All major gas turbine power plants in Peru are currently using water injection to increase turbine power output. Recommended that 42 ppm on natural gas and 65 ppm on diesel (corrected to 15% $O_2$) be established as the $NO_x$ limit for existing gas turbine power plants. These limits reflect $NO_x$ levels readily achievable using water injection at high load. Also recommended that new gas turbine sources be subject to a BACT review requirement.

**Gas Turbines – Title V Permit Templates.** Lead engineer for the development of standardized permit templates for approximately 100 gas turbines operated by the oil and gas industry in the San Joaquin Valley. Emissions limits and monitoring requirements were defined for units ranging from GE Frame 7 to Solar Saturn turbines. Stand-alone templates were developed based on turbine size and $NO_x$ control equipment. $NO_x$ utilized in the target turbine population ranged from water injection alone to water injection combined with SCR.

**Gas Turbines – Evaluation of $NO_x$, $SO_2$ and PM Emission Profiles.** Performed a comparative evaluation of the $NO_x$, $SO_2$ and particulate (PM) emission profiles of principal utility-scale gas turbines for an independent power producer evaluating project opportunities in Latin America. All gas turbine models in the 40 MW to 240 MW range manufactured by General Electric, Westinghouse, Siemens and ABB were included in the evaluation.

**Stationary Internal Combustion Engine (ICE) RACT/BARCT Evaluation.** Lead engineer for evaluation of retrofit $NO_x$ control options available for the oil and gas production industry gas-fired ICE population in the San Joaquin Valley affected by proposed RACT and BARCT emission limits. Evaluation centered on lean-burn compressor engines under 500 bhp, and rich-burn constant and cyclically loaded (rod pump) engines under 200 bhp. The results of the evaluation indicated that rich burn cyclically-loaded rod pump engines comprised 50 percent of the affected ICE population, though these ICEs accounted for only 5 percent of the uncontrolled gas-fired stationary ICE $NO_x$ emissions. Recommended retrofit $NO_x$ control strategies included: air/fuel ratio adjustment for rod pump ICEs, Non-selective catalytic reduction (NSCR) for rich-burn, constant load ICEs, and "low emission" combustion modifications for lean burn ICEs.

**Development of Air Emission Standards for Stationary ICEs - Peru.** Served as principal technical consultant to the Peruvian Ministry of Energy in Mines (MEM) for the development of air emission standards for Peruvian stationary ICE power plants. Draft 1997 World Bank $NO_x$ and particulate emission limits for stationary ICE power plants served as the basis for proposed MEM emission limits. A detailed review of ICE emissions data provided in PAMAs submitted to the MEM was performed to determine the level of effort that would be required by Peruvian industry to meet the proposed $NO_x$ and particulate emission limits. The draft 1997 WB emission limits were revised to reflect reasonably achievable $NO_x$ and particulate emission limits for ICEs currently in operation in Peru.

**Air Toxics Testing of Natural Gas-Fired ICEs.** Project manager for test plan/test program to measure volatile and semi-volatile organic air toxics compounds from fourteen gas-fired ICEs used in a variety of oil and gas production applications. Test data was utilized by oil and gas production facility owners throughout California to develop accurate ICE air toxics emission inventories.

## AIR ENGINEERING/AIR TESTING PROJECT EXPERIENCE – GENERAL

**Reverse Air Fabric Filter Retrofit Evaluation – Coal-Fired Boiler.** Lead engineer for upgrade of reverse air fabric filters serving coal-fired industrial boilers. Fluorescent dye injected to pinpoint broken bags and damper leaks. Corrosion of pneumatic actuators serving reverse air valves and inadequate insulation identified as principal causes of degraded performance.

**Pulse-Jet Fabric Filter Performance Evaluation – Gold Mine.** Lead engineer on upgrade of pulse-jet fabric filter and associated exhaust ventilation system serving an ore-crushing facility at a gold mine. Fluorescent dye used to identify bag collar leaks, and modifications were made to pulse air cycle time and duration. This marginal source was in compliance at 20 percent of emission limit following completion of repair work.

**Pulse-Jet Fabric Filter Retrofit - Gypsum Calciner.** Lead engineer on upgrade of pulse-jet fabric filter controlling particulate emissions from a gypsum calciner. Recommendations included a modified bag clamping mechanism, modified hopper evacuation valve assembly, and changes to pulse air cycle time and pulse duration.

**Wet Scrubber Retrofit – Plating Shop.** Project engineer on retrofit evaluation of plating shop packed-bed wet scrubbers failing to meet performance guarantees during acceptance trials, due to excessive mist carryover. Recommendations included relocation of the mist eliminator (ME), substitution of the original chevron blade ME with a mesh pad ME, and use of higher density packing material to improve exhaust gas distribution. Wet scrubbers passed acceptance trials following completion of recommended modifications.

**Electrostatic Precipitator (ESP) Retrofit Evaluation – MSW Boiler.** Lead engineer for retrofit evaluation of single field ESP on a municipal solid waste (MSW) boiler. Recommendations included addition of automated power controller, inlet duct turning vanes, and improved collecting plate rapping system.

**ESP Electric Coil Rapper Vibration Analysis Testing - Coal-Fired Boiler.** Lead engineer for evaluation of ESP rapper effectiveness test program on three field ESP equipped with "magnetically induced gravity return" (MIGR) rappers. Accelerometers were placed in a grid pattern on ESP collecting plates to determine maximum instantaneous plate acceleration at a variety of rapper power setpoints. Testing showed that the rappers met performance specification requirements.

**Aluminum Remelt Furnace Particulate Emissions Testing.** Project manager and lead engineer for high temperature (1,600 °F) particulate sampling of a natural gas-fired remelt furnace at a major aluminum rolling mill. Objectives of test program were to: 1) determine if condensable particulate was present in stack gases, and 2) to validate the accuracy of the in-stack continuous opacity monitor (COM). Designed and constructed a customized high temperature (inconel) $PM_{10}$/Mtd 17 sampling assembly for test program. An onsite natural gas-fired boiler was also tested to provide comparative data for the condensable particulate portion of the test program. Test results showed that no significant levels of condensable particulate in the remelt furnace exhaust gas, and indicated that the remelt furnace and boiler had similar particulate emission rates. Test results also showed that the COM was accurate.

**Aluminum Remelt Furnace CO and $NO_x$ Testing.** Project manager and lead engineer for continuous week-long testing of CO and $NO_x$ emissions from aluminum remelt furnace. Objective of test program was to characterize CO and $NO_x$ emissions from representative remelt furnace for use in the facility's criteria pollution emissions inventory. A TECO Model 48 CO analyzer and a TECO Model 10 $NO_x$ analyzer were utilized during the test program to provide $\pm$1 ppm measurement accuracy, and all test data was recorded by an automated data acquisition system.

## PETROLEUM REFINERY AIR ENGINEERING/TESTING EXPERIENCE

**Big West Refinery Expansion EIS.** Lead engineer on comparative cost analysis of proposed wet cooling tower and fin-fan air cooler for process cooling water for the proposed clean fuels expansion project at the Big West Refinery in Bakersfield, California. Selection of the fin-fin air-cooler would eliminate all consumptive water use and wastewater disposal associated with the cooling tower. Air emissions of VOC and $PM_{10}$ would be reduced with the fin-fan air-cooler even though power demand of the air-cooler is incrementally higher than that of the cooling tower. Fin-fan air-coolers with approach temperatures of 10 °F and 20 °F were evaluated. The annualized cost of the fin-fin air-cooler with a 20 °F approach temperature is essentially the same as that of the cooling tower when the cost of all ancillary cooling tower systems are considered.

**Criteria and Air Toxic Pollutant Emissions Inventory for Proposed Refinery Modifications.** Project manager and technical lead for development of baseline and future refinery air emissions inventories for process modifications required to produce oxygenated gasoline and desulfurized diesel fuel at a California refinery. State of the art criteria and air toxic pollutant emissions inventories for refinery point, fugitive and mobile sources were developed. Point source emissions estimates were generated using onsite criteria pollutant test data, onsite air toxics test data, and the latest air toxics emission factors from the statewide refinery air toxics inventory database. The fugitive volatile organic compound (VOC) emissions inventories were developed using the refinery's most recent inspection and maintenance (I&M) monitoring program test data to develop site-specific component VOC emission rates. These VOC emission rates were combined with speciated air toxics test results for the principal refinery process streams to produce fugitive VOC air toxics emission rates. The environmental impact report (EIR) that utilized this emission inventory data was the first refinery "Clean Fuels" EIR approved in California.

**Development of Air Emission Standards for Petroleum Refinery Equipment - Peru.** Served as principal technical consultant to the Peruvian Ministry of Energy in Mines (MEM) for the development of air emission

standards for Peruvian petroleum refineries. The sources included in the scope of this project included: 1) $SO_2$ and $NO_x$ refinery heaters and boilers, 2) desulfurization of crude oil, particulate and $SO_2$ controls for fluid catalytic cracking units (FCCU), 3) VOC and CO emissions from flares, 4) vapor recovery systems for marine unloading, truck loading, and crude oil/refined products storage tanks, and 5) VOC emissions from process fugitive sources such as pressure relief valves, pumps, compressors and flanges. Proposed emission limits were developed for new and existing refineries based on a thorough evaluation of the available air emission control technologies for the affected refinery sources. Leading vendors of refinery control technology, such as John Zink and Exxon Research, provided estimates of retrofit costs for the largest Peruvian refinery, La Pampilla, located in Lima. Meetings were held in Lima with refinery operators and MEM staff to discuss the proposed emission limits and incorporate mutually agreed upon revisions to the proposed limits for existing Peruvian refineries.

**Air Toxic Pollutant Emissions Inventory for Existing Refinery.** Project manager and technical lead for air toxic pollutant emissions inventory at major California refinery. Emission factors were developed for refinery heaters, boilers, flares, sulfur recovery units, coker deheading, IC engines, storage tanks, process fugitives, and catalyst regeneration units. Onsite source test results were utilized to characterize emissions from refinery combustion devices. Where representative source test results were not available, AP-42 VOC emission factors were combined with available VOC air toxics speciation profiles to estimate VOC air toxic emission rates. A risk assessment based on this emissions inventory indicated a relatively low health risk associated with refinery operations. Benzene, 1,3-butadiene and PAHs were the principal health risk related pollutants emitted.

**Air Toxics Testing of Refinery Combustion Sources.** Project manager for comprehensive air toxics testing program at a major California refinery. Metals, $Cr^{+6}$, PAHs, $H_2S$ and speciated VOC emissions were measured from refinery combustion sources. High temperature $Cr^{+6}$ stack testing using the EPA $Cr^{+6}$ test method was performed for the first time in California during this test program. Representatives from the California Air Resources Board source test team performed simultaneous testing using ARB Method 425 ($Cr^{+6}$) to compare the results of EPA and ARB $Cr^{+6}$ test methodologies. The ARB approved the test results generated using the high temperature EPA $Cr^{+6}$ test method.

**Air Toxics Testing of Refinery Fugitive Sources.** Project manager for test program to characterize air toxic fugitive VOC emissions from fifteen distinct process units at major California refinery. Gas, light liquid, and heavy liquid process streams were sampled. BTXE, 1,3-butadiene and propylene concentrations were quantified in gas samples, while BTXE, cresol and phenol concentrations were measured in liquid samples. Test results were combined with AP-42 fugitive VOC emission factors for valves, fittings, compressors, pumps and PRVs to calculate fugitive air toxics VOC emission rates.

## Oil and Gas Production Air Engineering/Testing Experience

**Air Toxics Testing of Oil and Gas Production Sources.** Project manager and lead engineer for test plan/test program to determine VOC removal efficiency of packed tower scrubber controlling sulfur dioxide emissions from a crude oil-fired steam generator. Ratfisch 55 VOC analyzers were used to measure the packed tower scrubber VOC removal efficiency. Tedlar bag samples were collected simultaneously to correlate BTX removal efficiency to VOC removal efficiency. This test was one of hundreds of air toxics tests performed during this test program for oil and gas production facilities from 1990 to 1992. The majority of the volatile air toxics analyses were performed at in-house laboratory. Project staff developed thorough familiarity with the applications and limitations of GC/MS, GC/PID, GC/FID, GC/ECD and GC/FPD. Tedlar bags, canisters, sorbent tubes and impingers were used during sampling, along with isokinetic tests methods for multiple metals and PAHs.

**Air Toxics Testing of Glycol Reboiler – Gas Processing Plant.** Project manager for test program to determine emissions of BTXE from glycol reboiler vent at gas processing facility handling 12 MM/cfd of produced gas. Developed innovative test methods to accurately quantify BTXE emissions in reboiler vent gas.

**Air Toxics Emissions Inventory Plan.** Lead engineer for the development of generic air toxics emission estimating techniques (EETs) for oil and gas production equipment. This project was performed for the Western States Petroleum Association in response to the requirements of the California Air Toxics "Hot Spots" Act. EETs were developed for all point and fugitive oil and gas production sources of air toxics, and the specific air toxics associated with each source were identified. A pooled source emission test methodology was also developed to moderate the cost of source testing required by the Act.

**Fugitive NMHC Emissions from TEOR Production Field.** Project manager for the quantification of fugitive Nonmethane hydrocarbon (NMHC) emissions from a thermally enhanced oil recovery (TEOR) oil production field in Kern County, CA. This program included direct measurement of NMHC concentrations in storage tank vapor headspace and the modification of available NMHC emission factors for NMHC-emitting devices in TEOR produced gas service, such as wellheads, vapor trunklines, heat exchangers, and compressors. Modification of the existing NMHC emission factors was necessary due to the high concentration of $CO_2$ and water vapor in TEOR produced gases.

**Fugitive Air Emissions Testing of Oil and Gas Production Fields.** Project manager for test plan/test program to determine VOC and air toxics emissions from oil storage tanks, wastewater storage tanks and produced gas lines. Test results were utilized to develop comprehensive air toxics emissions inventories for oil and gas production companies participating in the test program.

**Oil and Gas Production Field – Air Emissions Inventory and Air Modeling.** Project manager for oil and gas production field risk assessment. Project included review and revision of the existing air toxics emission inventory, air dispersion modeling, and calculation of the acute health risk, chronic non-carcinogenic risk and carcinogenic risk of facility operations. Results indicated that fugitive $H_2S$ emissions from facility operations posed a potential health risk at the facility fenceline.

## TITLE V PERMIT APPLICATION/MONITORING PLAN EXPERIENCE

**Title V Permit Application – San Diego County Industrial Facility.** Project engineer tasked with preparing streamlined Title V operating permit for U.S. Navy facilities in San Diego. Principal emission units included chrome plating, lead furnaces, IC engines, solvent usage, aerospace coating and marine coating operations. For each device category in use at the facility, federal MACT requirements were integrated with District requirements in user friendly tables that summarized permit conditions and compliance status.

**Title V Permit Application Device Templates - Oil and Gas Production Industry.** Project manager and lead engineer to prepare Title V permit application "templates" for the Western States Petroleum Association (WSPA). The template approach was chosen by WSPA to minimize the administrative burden associated with listing permit conditions for a large number of similar devices located at the same oil and gas production facility. Templates are being developed for device types common to oil and gas production operations. Device types include: boilers, steam generators, process heaters, gas turbines, IC engines, fixed-roof storage tanks, fugitive components, flares, and cooling towers. These templates will serve as the core of Title V permit applications prepared for oil and gas production operations in California.

**Title V Permit Application - Aluminum Rolling Mill.** Project manager and lead engineer for Title V permit application prepared for largest aluminum rolling mill in the western U.S. Responsible for the overall direction of the permit application project, development of a monitoring plan for significant emission units, and development of a hazardous air pollutant (HAP) emissions inventory. The project involved extensive onsite data gathering, frequent interaction with the plant's technical and operating staff, and coordination with legal counsel and subcontractors. The permit application was completed on time and in budget.

**Title V Model Permit - Oil and Gas Production Industry.** Project manager and lead engineer for the comparative analysis of regional and federal requirements affecting oil and gas production industry sources located in the San Joaquin Valley. Sources included gas turbines, IC engines, steam generators, storage tanks, and process fugitives. From this analysis, a model applicable requirements table was developed for a sample device type (storage tanks) that covered the entire population of storage tanks operated by the industry. The U.S. EPA has tentatively approved this model permit approach, and work is ongoing to develop comprehensive applicable requirements tables for each major category of sources operated by the oil and gas industry in the San Joaquin Valley.

**Title V Enhanced Monitoring Evaluation of Oil and Gas Production Sources.** Lead engineer to identify differences in proposed EPA Title V enhanced monitoring protocols and the current monitoring requirements for oil and gas production sources in the San Joaquin Valley. The device types evaluated included: steam generators, stationary ICEs, gas turbines, fugitives, fixed roof storage tanks, and thermally enhanced oil recovery (TEOR) well vents. Principal areas of difference included: more stringent Title V O&M requirements for parameter monitors (such as temperature, fuel flow, and $O_2$), and more extensive Title V recordkeeping requirements.

## RACT/BARCT/BACT EVALUATIONS

**RACT/BARCT Reverse Jet Scrubber/Fiberbed Mist Eliminator Retrofit Evaluation.** Project manager and lead engineer on project to address the inability of existing wet electrostatic precipitators (ESPs) and atomized mist scrubbers to adequately remove low concentration submicron particulate from high volume recovery boiler exhaust gas at the Alaska Pulp Corporation mill in Sitka, AK. The project involved thorough on-site inspections of existing control equipment, detailed review of maintenance and performance records, and a detailed evaluation of potential replacement technologies. These technologies included a wide variety of scrubbing technologies where manufacturers claimed high removal efficiencies on submicron particulate in high humidity exhaust gas. Packed tower scrubbers, venturi scrubbers, reverse jet scrubbers, fiberbed mist eliminators and wet ESPs were evaluated. Final recommendations included replacement of atomized mist scrubber with reverse jet scrubber and upgrading of the existing wet ESPs. The paper describing this project was published in the May 1992 TAPPI Journal.

**Aluminum Smelter RACT Evaluation - Prebake.** Project manager and technical lead for CO and $PM_{10}$ RACT evaluation for prebake facility. Retrofit control options for CO emissions from the anode bake furnace, potline dry scrubbers and the potroom roof vents were evaluated. $PM_{10}$ emissions from the coke kiln, potline dry scrubbers, potroom roof vents, and miscellaneous potroom fugitive sources were addressed. Four CO control technologies were identified as technologically feasible for potline CO emissions: potline current efficiency improvement through the addition of underhung busswork and automated puncher/feeders, catalytic incineration, recuperative incineration and regenerative incineration. Current efficiency improvement was identified as probable CO RACT if onsite test program demonstrated the effectiveness of this approach. Five $PM_{10}$ control technologies were identified as technologically feasible: increased potline hooding efficiency through redesign of shields, the addition of a dense-phase conveying system, increased potline air evacuation rate, wet scrubbing of roof vent emissions, and fabric filter control of roof vent emissions.

**RACT/BACT Testing/Evaluation of $PM_{10}$ Mist Eliminators on Five-Stand Cold Mill.** Project manager and lead engineer for fiberbed mist eliminator and mesh pad mist eliminator comparative pilot test program on mixed phase aerosol ($PM_{10}$)/gaseous hydrocarbon emissions from aluminum high speed cold rolling mill. Utilized modified EPA Method 5 sampling train with portion of sample gas diverted (after particulate filter) to Ratfisch 55 VOC analyzer. This was done to permit simultaneous quantification of aerosol and gaseous hydrocarbon emissions in the exhaust gas. The mesh pad mist eliminator demonstrated good control of $PM_{10}$ emissions, though test results indicated that the majority of captured $PM_{10}$ evaporated in the mesh pad and was emitted as VOC.

**Aluminum Remelt Furnace/Rolling Mill RACT Evaluations.** Lead engineer for comprehensive CO and $PM_{10}$ RACT evaluation for the largest aluminum sheet and plate rolling mill in western U.S. Significant sources of CO emissions from the facility included the remelt furnaces and the coater line. The potential CO RACT options for the remelt furnaces included: enhanced maintenance practices, preheating combustion air, installation of fully automated combustion controls, and energy efficiency modifications.

**BARCT Low $NO_x$ Burner Conversion – Industrial Boilers.** Lead engineer for evaluation of low $NO_x$ burner options for natural gas-fired industrial boilers. Also evaluated methanol and propane as stand-by fuels to replace existing diesel stand-by fuel system. Evaluated replacement of steam boilers with gas turbine co-generation system.

**BACT Packed Tower Scrubber/Mist Eliminator Performance Evaluations.** Project manager and lead engineer for Navy-wide plating shop air pollution control technology evaluation and emissions testing program. Mist eliminators and packed tower scrubbers controlling metal plating processes, which included hard chrome, nickel, copper, cadmium and precious metals plating, were extensively tested at three Navy plating shops. Chemical cleaning and stripping tanks, including hydrochloric acid, sulfuric acid, chromic acid and caustic, were also tested. The final product of this program was a military design specification for plating and chemical cleaning shop air pollution control systems. The hydrochloric acid mist sampling procedure developed during this program received a protected patent.

**BACT Packed Tower Scrubber/UV Oxidation System Pilot Test Program.** Technical advisor for pilot test program of packed tower scrubber/ultraviolet (UV) light VOC oxidation system controlling VOC emissions from microchip manufacturing facility in Los Angeles. The testing was sponsored in part by the SCAQMD's Innovative Technology Demonstration Program, to demonstrate this innovative control technology as BACT for microchip manufacturing operations. The target compounds were acetone, methylethylketone (MEK) and 1,1,1-trichloroethane, and compound concentrations ranged from 10-100 ppmv. The single stage packed tower scrubber consistently achieved greater than 90% removal efficiency on the target compounds. The residence time required in the UV oxidation system for effective oxidation of the target compounds proved significantly longer than the residence time predicted by the manufacturer.

**BACT Pilot Testing of Venturi Scrubber on Gas/Aerosol VOC Emission Source.** Technical advisor for project to evaluate venturi scrubber as BACT for mixed phase aerosol/gaseous hydrocarbon emissions from deep fat fryer. Venturi scrubber demonstrated high removal efficiency on aerosol, low efficiency on VOC emissions. A number of VOC tests indicated negative removal efficiency. This anomaly was traced to a high hydrocarbon concentration in the scrubber water. The pilot unit had been shipped directly to the jobsite from another test location by the manufacturer without any cleaning or inspection of the pilot unit.

**Pulp Mill Recovery Boiler BACT Evaluation.** Lead engineer for BACT analysis for control of $SO_2$, $NO_x$, CO, TNMHC, TRS and particulate emissions from the proposed addition of a new recovery furnace at a kraft pulp mill in Washington. A "top down" approach was used to evaluate potential control technologies for each of the pollutants considered in the evaluation.

**Air Pollution Control Equipment Design Specification Development.** Lead engineer for the development of detailed Navy design specifications for wet scrubbers and mist eliminators. Design specifications were based on field performance evaluations conducted at the Long Beach Naval Shipyard, Norfolk Naval Shipyard, and Jacksonville Naval Air Station. This work was performed for the U.S. Navy to provide generic design specifications to assist naval facility engineering divisions with air pollution control equipment selection. Also served as project engineer for the development of Navy design specifications for ESPs and fabric filters.

## CONTINUOUS EMISSION MONITOR (CEM) PROJECT EXPERIENCE

**Process Heater CO and $NO_x$ CEM Relative Accuracy Testing.** Project manager and lead engineer for process heater CO and $NO_x$ analyzer relative accuracy test program at petrochemical manufacturing facility.

Objective of test program was to demonstrate that performance of onsite CO and $NO_x$ CEMs was in compliance with U.S. EPA "Boiler and Industrial Furnace" hazardous waste co-firing regulations. A TECO Model 48 CO analyzer and a TECO Model 10 $NO_x$ analyzer were utilized during the test program to provide ±1 ppm measurement accuracy, and all test data was recorded by an automated data acquisition system. One of the two process heater CEM systems tested failed the initial test due to leaks in the gas conditioning system. Troubleshooting was performed using $O_2$ analyzers, and the leaking component was identified and replaced. This CEM system met all CEM relative accuracy requirements during the subsequent retest.

**Performance Audit of $NO_x$ and $SO_2$ CEMs at Coal-Fired Power Plant.** Lead engineer on system audit and challenge gas performance audit of $NO_x$ and $SO_2$ CEMs at a coal-fired power plant in southern Nevada. Dynamic and instrument calibration checks were performed on the CEMs. A detailed visual inspection of the CEM system, from the gas sampling probes at the stack to the CEM sample gas outlet tubing in the CEM trailer, was also conducted. The CEMs passed the dynamic and instrument calibration requirements specified in EPA's Performance Specification Test - 2 ($NO_x$ and $SO_2$) alternative relative accuracy requirements.

## LATIN AMERICA ENVIRONMENTAL PROJECT EXPERIENCE

**Assessment of operational deficiencies of Camisa pipeline – Peru.** Project leader of multi-year assessment of root causes of ruptures on Camisea 14-inch natural gas liquids pipeline for non-profit client. Determined that primary causes of hurried construction in difficult and unstable terrain, unstable right-of-way in the jungle sector due to inadequate erosion control practices, and inadequate pipe wall thickness to withstand external lateral forces. Two assessments were developed during the course of the project documenting deficiencies and recommending remedial actions.

**Evaluation of U.S.-Mexico Border Region Copper Smelter Compliance with Treaty Obligations – Mexico.** Project manager and lead engineer to evaluate compliance of U.S. and Mexican border region copper smelters with the $SO_2$ monitoring, recordkeeping and reporting requirements in Annex IV [Copper Smelters] of the La Paz Environmental Treaty. Identified potential problems with current ambient and stack monitoring practices that could result in underestimating the impact of $SO_2$ emissions from some of these copper smelters. Identified additional source types, including hazardous waste incinerators and power plants, that should be considered for inclusion in the La Paz Treaty process.

**Development of Air Emission Limits for ICE Cogeneration Plant - Panamá.** Lead engineer assisting U.S. cogeneration plant developer to permit an ICE cogeneration plant at a hotel/casino complex in Panama. Recommended the use of modified draft World Bank $NO_x$ and PM limits for ICE power plants. The modification consisted of adding a thermal efficiency factor adjustment to the draft World Bank $NO_x$ and PM limits. These proposed ICE emission limits are currently being reviewed by Panamanian environmental authorities.

**Mercury Emissions Inventory for Stationary Sources in Northern Mexico.** Project manager and lead engineer to estimate mercury emissions from stationary sources in Northern Mexico. Major potential sources of mercury emissions include solid- and liquid-fueled power plants, cement kilns co-firing hazardous waste, and non-ferrous metal smelters. Emission estimates were provided for approximately eighty of these sources located in Northern Mexico. Coordinated efforts of two Mexican subcontractors, located in Mexico City and Hermosillo, to obtain process throughput data for each source included in the inventory.

**Translation of U.S. EPA Scrap Tire Combustion Emissions Estimation Document – Mexico.** Evaluated the Translated a U.S. EPA scrap tire combustion emissions estimation document from English to Spanish for use by Latin American environmental professionals.

**Environmental Audit of Aluminum Production Facilities – Venezuela.** Evaluated the capabilities of existing air, wastewater and solid/hazardous waste control systems used by the aluminum industry in eastern

Venezuela. This industry will be privatized in the near future. Estimated the cost to bring these control systems into compliance with air, wastewater and solid/hazardous waste standards recently promulgated in Venezuela. Also served as technical translator for team of U.S. environmental engineers involved in the due diligence assessment.

**Assessment of Environmental Improvement Projects – Chile and Peru.** Evaluated potential air, water, soil remediation and waste recycling projects in Lima, Peru and Santiago, Chile for feasibility study funding by the U.S. Trade and Development Agency. Project required onsite interaction with in-country decisionmakers (in Spanish). Projects recommended for feasibility study funding included: 1) an air quality technical support project for the Santiago, Chile region, and 2) soil remediation/metals recovery projects at two copper mine/smelter sites in Peru.

**Air Pollution Control Training Course – Mexico.** Conducted two-day Spanish language air quality training course for environmental managers of assembly plants in Mexicali, Mexico. Spanish-language course manual prepared by Powers Engineering. Practical laboratory included training in use of combustion gas analyzer, flame ionization detector (FID), photoionization detector (PID), and occupational sampling.

**Stationary Source Emissions Inventory – Mexico.** Developed a comprehensive air emissions inventory for stationary sources in Nogales, Sonora. This project requires frequent interaction with Mexican state and federal environmental authorities. The principal Powers Engineering subcontractor on this project is a Mexican firm located in Hermosillo, Sonora.

**VOC Measurement Program – Mexico.** Performed a comprehensive volatile organic compound (VOC) measurements program at a health products fabrication plant in Mexicali, Mexico. An FID and PID were used to quantify VOCs from five processes at the facility. Occupational exposures were also measured. Worker exposure levels were above allowable levels at several points in the main assembly area.

**Fluent in Spanish.** Studied at the Universidad de Michoacán in Morelia, Mexico, 1993, and at the Colegio de España in Salamanca, Spain, 1987-88. Have lectured (in Spanish) on air monitoring and control equipment at the Instituto Tecnológico de Tijuana. Maintain contact with Comisión Federal de Electricidad engineers responsible for operation of wind and geothermal power plants in Mexico, and am comfortable operating in the Mexican business environment.

## PUBLICATIONS

Bill Powers, "*More Distributed Solar Means Fewer New Combustion Turbines*," Natural Gas & Electricity Journal, Vol. 29, Number 2, September 2012, pp. 17-20.

Bill Powers, "*Federal Government Betting on Wrong Solar Horse*," Natural Gas & Electricity Journal, Vol. 27, Number 5, December 2010,

Bill Powers, "*Today's California Renewable Energy Strategy—Maximize Complexity and Expense*," Natural Gas & Electricity Journal, Vol. 27, Number 2, September 2010, pp. 19-26.

Bill Powers, "*Environmental Problem Solving Itself Rapidly Through Lower Gas Costs*," Natural Gas & Electricity Journal, Vol. 26, Number 4, November 2009, pp. 9-14.

Bill Powers, "*PV Pulling Ahead, but Why Pay Transmission Costs?*" Natural Gas & Electricity Journal, Vol. 26, Number 3, October 2009, pp. 19-22.

Bill Powers, "*Unused Turbines, Ample Gas Supply, and PV to Solve RPS Issues*," Natural Gas & Electricity Journal, Vol. 26, Number 2, September 2009, pp. 1-7.

Bill Powers, "*CEC Cancels Gas-Fed Peaker, Suggesting Rooftop Photovoltaic Equally Cost-Effective*," Natural Gas & Electricity Journal, Vol. 26, Number 1, August 2009, pp. 8-13.

Bill Powers, "*San Diego Smart Energy 2020 – The 21st Century Alternative*," San Diego, October 2007.

Bill Powers, "*Energy, the Environment, and the California – Baja California Border Region*," Electricity Journal, Vol. 18, Issue 6, July 2005, pp. 77-84.

W.E. Powers, *"Peak and Annual Average Energy Efficiency Penalty of Optimized Air-Cooled Condenser on 515 MW Fossil Fuel-Fired Utility Boiler,"* presented at California Energy Commission/Electric Power Research Institute Advanced Cooling Technologies Symposium, Sacramento, California, June 2005.

W.E. Powers, R. Wydrum, P. Morris, *"Design and Performance of Optimized Air-Cooled Condenser at Crockett Cogeneration Plant,"* presented at EPA Symposium on Technologies for Protecting Aquatic Organisms from Cooling Water Intake Structures, Washington, DC, May 2003.

P. Pai, D. Niemi, W.E. Powers, *"A North American Anthropogenic Inventory of Mercury Emissions,"* presented at Air & Waste Management Association Annual Conference in Salt Lake City, UT, June 2000.

P.J. Blau and W.E. Powers, *"Control of Hazardous Air Emissions from Secondary Aluminum Casting Furnace Operations Through a Combination of: Upstream Pollution Prevention Measures, Process Modifications and End-of-Pipe Controls,"* presented at 1997 AWMA/EPA Emerging Solutions to VOC & Air Toxics Control Conference, San Diego, CA, February 1997.

W.E. Powers, et. al., *"Hazardous Air Pollutant Emission Inventory for Stationary Sources in Nogales, Sonora, Mexico ,"* presented at 1995 AWMA/EPA Emissions Inventory Specialty Conference, RTP, NC, October 1995.

W.E. Powers, *"Develop of a Parametric Emissions Monitoring System to Predict $NO_x$ Emissions from Industrial Gas Turbines,"* presented at 1995 AWMA Golden West Chapter Air Pollution Control Specialty Conference, Ventura, California, March 1995.

W. E. Powers, et. al., *"Retrofit Control Options for Particulate Emissions from Magnesium Sulfite Recovery Boilers,"* presented at 1992 TAPPI Envr. Conference, April 1992. Published in *TAPPI Journal*, July 1992.

S. S. Parmar, M. Short, W. E. Powers, *"Determination of Total Gaseous Hydrocarbon Emissions from an Aluminum Rolling Mill Using Methods 25, 25A, and an Oxidation Technique,"* presented at U.S. EPA Measurement of Toxic and Related Air Pollutants Conference, May 1992.

N. Meeks, W. E. Powers, *"Air Toxics Emissions from Gas-Fired Internal Combustion Engines,"* presented at AIChE Summer Meeting, August 1990.

W. E. Powers, *"Air Pollution Control of Plating Shop Processes,"* presented at 7th AES/EPA Conference on Pollution Control in the Electroplating Industry, January 1986. Published in *Plating and Surface Finishing* magazine, July 1986.

H. M. Davenport, W. E. Powers, *"Affect of Low Cost Modifications on the Performance of an Undersized Electrostatic Precipitator,"* presented at 79th Air Pollution Control Association Conference, June 1986.

## AWARDS

Engineer of the Year, 1991 – ENSR Consulting and Engineering, Camarillo
Engineer of the Year, 1986 – Naval Energy and Environmental Support Activity, Port Hueneme
Productivity Excellence Award, 1985 – U. S. Department of Defense

## PATENTS

Sedimentation Chamber for Sizing Acid Mist, Navy Case Number 70094