BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

RECEIVED
CLERK'S OFFICE
FEB 0 1 2011
STATE OF ILLINOIS
Pollution Control Board

IN THE MATTER OF:	)	
	)	
WATER QUALITY STANDARDS AND	)	
EFFLUENT LIMITATIONS FOR THE	)	R08-9 Subdocket C
CHICAGO AREA WATERWAY SYSTEM	)	(Rulemaking – Water)
AND THE LOWER DES PLAINES RIVER:	)	
PROPOSED AMENDMENTS TO 35 Ill.	)	
Adm. Code Parts 301, 302, 303 and 304	)	

NOTICE OF FILING

ORIGINAL

TO: John Therriault, Assistant Clerk
Illinois Pollution Control Board
James R. Thompson Center
100 West Randolph Street, Suite 11-500
Chicago, IL 60601

Attached Service List

PLEASE TAKE NOTICE that I have today filed with the Illinois Pollution Control Board Midwest Generation's Pre-Filed Testimony of Ray E. Henry, a copy of which is herewith served upon you.

Dated: February 1, 2011

MIDWEST GENERATION, L.L.C.

By: /s/ Susan M. Franzetti
One of Its Attorneys

Susan M. Franzetti
NIJMAN FRANZETTI LLP
10 South LaSalle Street, Suite 3600
Chicago, IL 60603
(312) 251-5590

SERVICE LIST R08-09

Marie Tipsord, Hearing Officer
Illinois Pollution Control Board
100 West Randolph St
Suite 11-500
Chicago, IL 60601

Frederick Feldman
Ronald Hill
Louis Kollias
Margaret Conway
Metropolitan Water Reclamation District
100 East Erie St
Chicago, IL 60611

Katherine Hodge
Monica Rios
Hodge Dwyer Zeman
3150 Roland Avenue
Springfield, IL 62705-5776

Fredric Andes
Erika Powers
Barnes & Thornburg LLP
1 North Wacker Dr
Suite 4400
Chicago, IL 60606

Lisa Frede
Chemical Industry Council of Illinois
1400 E. Touhy Avenue, Suite 110
Des Plaines, IL 60018

Jeffrey C. Fort
Ariel J. Tesher
SNR Denton US LLP
233 S. Wacker Drive, Suite 7800
Chicago, IL 60606-6404

Stacy Meyers-Glen
Openlands
25 E. Washington, Suite 1650
Chicago, IL 60602

Deborah J. Williams
Stefanie N. Diers
Illinois EPA
1021 North Grand Avenue
Springfield, IL 62794-9276

Keith Harley
Elizabeth Schenkier
Chicago Legal Clinic, Inc.
211 West Wacker Drive
Suite 750
Chicago, IL 60606

Ann Alexander
Natural Resources Defense Council
Two North Riverside Plaza
Suite 2250
Chicago, IL 60606

Andrew Armstrong
Elizabeth Wallace
Office of Illinois Attorney General
Environmental Bureau
69 West Washington St. Ste 1800
Chicago, IL 60602

Jack Darin
Cindy Skrukrud
Sierra Club, Illinois Chapter
70 E. Lake St., Suite 1500
Chicago, IL 60601-7447

Albert Ettinger
Jessica Dexter
Environmental Law & Policy Center
35 E. Wacker
Suite 1300
Chicago, IL 60601

Thomas W. Dimond
Susan Charles
Ice Miller LLP
200 West Madison Street, Suite 3500
Chicago, IL 60606-3417

Lyman C. Welch
Alliance for the Great Lakes
17 N. State St., Suite 1390
Chicago, IL 60602

Cathy Hudzik
City of Chicago
Mayor's Office of Intergovernmental Affairs
121 North LaSalle Street, Room 406
Chicago, IL 60602

Mitchell Cohen
Illinois DNR, Legal
Illinois Department of Natural Resources
One Natural Resources Way
Springfield, IL 62705-5776

CERTIFICATE OF SERVICE

The undersigned, an attorney, certifies that a true copy of the foregoing Notice of Filing and Pre-Filed Testimony of Ray Henry were filed electronically on February 1, 2011 with the following:

John Therriault, Assistant Clerk
Illinois Pollution Control Board
James R. Thompson Center
100 West Randolph Street, Suite 11-500
Chicago, IL 60601

and that true copies were mailed by First Class Mail, postage prepaid, on February 1, 2011 to the parties listed on the foregoing Service List.

/s/ Susan M. Franzetti

BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

IN THE MATTER OF:	)	
	)	
WATER QUALITY STANDARDS AND	)	
EFFLUENT LIMITATIONS FOR THE	)	R08-9
CHICAGO AREA WATERWAY SYSTEM	)	Subdocket C
AND THE LOWER DES PLAINES RIVER:	)	(Rulemaking - Water)
PROPOSED AMENDMENTS TO 35 Ill.	)	
Adm. Code Parts 301, 302, 303 and 304	)	

PRE-FILED TESTIMONY OF RAY E. HENRY

I. Introduction and Witness Background

My name is Ray E. Henry. I am employed as a Principal Consultant with Sargent & Lundy LLC. I have been employed with Sargent & Lundy since 1971 and have over 39 years of experience in the areas of pow er plant design, performance, testing and evaluation. I am testifying today on behalf of Midwest Generation EME, LLC ("MWGen").

Sargent & Lundy LLC (S&L) is a full-service architect-engineering firm dedicated to the electric power industry. S&L has been serving electric power clients exclusively since its founding in 1891. S&L is one of the oldest, largest and most experienced engineering companies in the United States. S&L has been authorized to design more than 885 electric generating units representing more than 129,500 megawatts of generating capacity. S&L designed approximately 80% of the large generating units in the State of Illinois, including most of the units currently owned and operated by MWGen, when they were first built. S&L has designed over 60 cooling systems with cooling towers, in several countries over the past 40 years. S&L's experience also includes the preparation of studies and designs for power plant modifications, including the addition of air pollution control equipment, such as flue gas desulfurization systems, mercury removal systems and NOx reduction systems.

I personally have worked on studies and evaluations of cooling towers for new units and the conversion of existing once-through cooling systems to cooling towers. These studies included sizing, performance and cost estimates. S&L has conducted at least 15 studies for the addition of cooling towers at existing plants in the past 30 years. Most of these studies involved the preparation of a conceptual design and accompanying cost estimates to convert an existing power plant's open-cycle cooling system to a closed-cycle cooling system. In all cases, the primary reason that a potential conversion to closed-cycle cooling was under consideration by the power plant operator was to evaluate what options were available for reducing thermal discharges to proposed or actual regulatory thermal standards. Based on both my personal knowledge and information obtained from other S&L personnel, only two of these projects actually were implemented. One project was the Quad Cites, Illinois Nuclear Plant, which was converted to closed-cycle cooling (using a spray canal instead of cooling towers) but was later converted back to once-through cooling. Th e other project was the Noblesville repowering project in Indiana, where as part of the conversion to a combined cycle plant the cooling system was converted to closed-cycle cooling using mechanical draft cooling towers. The Noblesville plant has two small steam turbines (approximately 50 MW each), which is much smaller than any of the MWGen units in this study. Also, the Noblesville site had more open space available for cooling tower installation than do any of the five MWGen station sites that are the subject of my testimony.

I have a Bachelor of Science in Mechanical Engineering from Purdue University. I am a member of the American Society of Mechanical Engineers (ASME) and a member of the ASME committees for codes and standards and the committee for performance test code for fans. I am a registered Professional Engineer in the states of Illinois and Indiana. A copy of my *curriculum vitae* is attached as Exhibit A.

My testimony will focus on describing and explaining the study performed by Sargent & Lundy (S&L) for MWGen which includes the following: (1) the review of potential options for the subject MWGen electric generating stations to achieve and maintain compliance with the thermal water quality standards proposed in this rule-making proceeding; (2) the design criteria for each of the MWGen stations developed by Sargent & Lundy for use as a basis for estimating the costs of achieving and maintaining such compliance; and (3) the estimated capital and operation and maintenance costs and estimated power loss revenues associated with the additional power demands associated with achieving and maintaining such compliance. A copy of the detailed study report prepared by S&L is attached as Exhibit B.

II. Retention by MWGen and Project Scope

The Illinois Environmental Protection Agency ("IEPA") has proposed a re-designation of the aquatic life use of the areas identified in its rule-making petition as the "Upper Dresden Island Pool" in the Lower Des Plaines River (the "UDIP") and the Chicago Area Waterways ("CAWS"). and the IEPA also has proposed revisions to the current thermal water quality standards to seasonal period average and daily maximum standards for both the UDIP and the CAWS (the "Proposed UAA Thermal Standards"). The Proposed UAA Thermal Standards would apply to receiving waters into which the following five MWGen stations discharge wastewater: Fisk, Crawford, Will County, Joliet 6 (also known as "Joliet Station 9") and Joliet 7&8 (also known as "Joliet Station 29"). MWGen requested that S&L evaluate the technologies that could be installed at these stations to comply with the Proposed UAA Thermal Standards and the estimated costs to do so.

Under the Proposed UAA Rules, the CAWS Aquatic Life Use B ("ALU B") standards would apply to the wastewater discharges from the Fisk, Crawford, and Will County stations, while the Upper Dresden Island Pool ("UDIP") standards would apply to the wastewater discharges from the two Joliet stations. Table 1 below lists the Proposed UAA Thermal Standards for ALU B and the UDIP. Currently, for both the UDIP and the CAWS, the applicable thermal water quality standard is a daily maximum temperature of 93°F which is not to be exceeded more than 5 percent of the time and an absolute maximum of 100°F. (IEPA Statement of Reasons, pps. 11-12). The proposed thermal standards for the UDIP would reduce the daily maximum temperature to 88.7°F which is not to be exceeded more than 2 percent of the time and would establish period averages ranging from 85.1°F during most summer periods down to 53.6°F during the month of February. (IEPA Statement of Reasons, p. 85) The proposed thermal standards for the ALU B waters would reduce the daily maximum to 90.3°F which is not to be exceeded more than 2 percent of the time and would establish period averages ranging from 86.7°F during most summer periods down to 53.6°F period average during the month of February. (IEPA Statement of Reasons, pp. 84-5) The only difference in the proposed period average standards between the UDIP and ALU B waters is during the summer months of July and August when the ALU B waters allowed maximum monthly average is 86.7°F versus 85.1°F for the UDIP. For both the UDIP and ALU B waters, the IEPA is proposing to allow excursions up to 3.6°F. (IEPA Statement of Reasons, p. 86) As the IEPA has explained, "[t]he proposed thermal water quality standards are more stringent than the General Use standards for the months April through November, especially when considering the period average" and they "are more stringent than the current Adjusted Water Quality Standards at Interstate-55 for all of the months, especially when considering the period average." (*Id.*)

Table 1
Proposed IEPA Water Temperature Limits

Month	Proposed UAA Period Average CAWs Aquatic Life Use B Thermal WQS	Proposed UAA Maximum CAWs Aquatic Life Use B Thermal WQS	Proposed UAA Period Average Upper Dresden Island Pool Thermal WQS	Proposed UAA Maximum Upper Dresden Island Pool Thermal WQS
Jan 1-31	54.3	90.3	54.3	88.7
Fab 1-29	53.6	90.3	53.6	88.7
Mar 1-15	57.2	90.3	57.2	88.7
Mar 16-31	57.2	90.3	57.2	88.7
Apr 1-15	60.8	90.3	60.8	88.7
Apr 16-30	62.1	90.3	62.1	88.7
May 1-15	69.2	90.3	69.2	88.7
May 16-31	71.4	90.3	71.4	88.7
Jun 1-15	74.2	90.3	74.2	88.7
Jun 16-30	86.7	90.3	85.1	88.7
Jul 1-15	86.7	90.3	85.1	88.7
Jul 16-31	86.7	90.3	85.1	88.7
Aug 1-15	86.7	90.3	85.1	88.7
Aug 16-31	86.7	90.3	85.1	88.7
Sep 1-15	86.7	90.3	85.1	88.7
Sep 16-30	77	90.3	77	88.7
Oct 1-15	73.2	90.3	73.2	88.7
Oct 16-31	69.6	90.3	69.6	88.7
Nov 1-30	66.2	90.3	66.2	88.7
Dec 1-31	59.9	90.3	59.9	88.7

All five MWGen stations are currently subject to an adjusted thermal standard granted by the Illinois Pollution Control Board (Docket AS 96-10, October 3, 1996), referred to as the "I-55 Adjusted Standards," whose limits must be achieved further downstream in the Lower Des Plaines River at the I-55 Bridge. The I-55 Bridge is approximately seven miles downstream of the Joliet Stations. The National Pollution Discharge Elimination System ("NPDES") permits for the five MWGen stations incorporate the I-55 Adjusted Thermal Standards. The S&L Study assumed that the I-55 Adjusted Standards will remain in effect.

III. Description of Sargent & Lundy (S&L) Cost Estimates Study

A. Background Regarding Steam Electric Generating Stations

In most power plants, heat from coal, natural gas, oil, nuclear, biomass or solar energy is used to generate steam that turns a steam turbine and generator to generate electricity. Steam electric generating stations, like the five MWGen stations here, all operate on the same principle: water is boiled to make steam, which drives a turbine, which powers an electric generator. All of the units at the five MWGen stations are "Rankine cycles." A Rankine cycle converts heat into "work", a form of energy. A Rankine cycle is the most common method of generating electricity. . The exhaust steam from the steam turbine must be condensed so that the water can be returned to the steam generator. Condensing the exhaust steam requires a cooling source, which is usually water.

The amount of heat generated from condensing the turbine exhaust steam is greater than the amount of electricity generated. For example, each unit at Joliet 7&8 has a rating of 569 Megawatt (MW) gross electrical output, and the design cooling system heat duty for each unit is greater, at approximately 830 MW (thermal). Thus, large cooling systems are required for these types of units. The five MWGen stations were not designed nor were the station sites selected or arranged to attain thermal water quality standards as strict as those proposed in this rule-making. All of the electrical generating units at all five stations were placed in service in 1966 or earlier.

The amount of cooling water withdrawn from a waterbody by a steam electric generating station depends on several factors, one of which is the type of condenser cooling system. There are two basic types of "wet" condenser cooling systems: open-cycle and closed-cycle. Open-cycle systems pass water through the condenser only once before returning virtually all the water to its source, albeit at a higher temperature. Closed-cycle systems recirculate the heated water from the condenser through an evaporative cooling structure (typically a cooling tower, pond, or lake), Evaporation of some of the water results in the build-up of salts in the water requires the system to "blow down" (*i.e.,* discharge). Closed-cycle cooling systems withdraw much less water than open-cycle systems, but they evaporate (*i.e.,* consume) most of the water withdrawn, returning very little to its source.

Joliet 7&8 is the only station that currently has any cooling towers. These supplemental "helper" cooling towers were not part of the original design of the station. They were installed in 1999, subsequent to the issuance of the I-55 Bridge Adjusted Standards. As previously explained in this proceeding in the testimony of Julia Wozniak of MWGen, the Joliet 7&8 towers are used primarily to maintain compliance with the I-55 Bridge Adjusted Thermal Standards. The towers are also used to meet the existing Secondary Contact thermal water quality standards during critical low flow periods that occur in the Dresden Pool. The use of the towers is necessary during the summer months and also at times of unseasonably warm spring and fall periods to meet the existing thermal water quality standards. The existing cooling towers are wholly insufficient to attain and maintain compliance with the Proposed UAA Thermal Standards for the Upper Dresden Island Pool. They also are not adequate for use as part of a design to convert Joliet 7&8 to a closed-cycle cooling system. The existing cooling towers do not have plume abatement and hence, plumes from these towers would cause fogging and icing if used during cold periods. Also, because the existing cooling towers are not "low drift" towers, they would probably exceed particulate matter emission standards if used in a closed-cycle operation. For all of these reasons, the conceptual design and cost estimate S&L prepared is not based on reusing the existing cooling towers.

B. Description of Technologies Considered by S&L

S&L applied the following criteria to evaluate candidate cooling technologies for the MWGen stations:

- A proven technology for large cooling systems (proven performance and reliability);
- A design that would fit within existing site boundaries;
- A system capable of operating during the range of expected weather conditions;
- A technology that would produce minimal ground level fog or icing;
- A cooling system that would have minimal impact on the efficiency and the net electrical output;
- A design that would minimize construction and station outage time; and
- A technology that would minimize capital and operating cost.

When the above criteria were applied to available cooling technologies, it became apparent that several technologies were not feasible for the MWGen stations due to the lack of sufficient land area at the stations on which to construct the necessary structures or equipment associated with a given technology. For example, two established cooling technologies are man-made cooling lakes and cooling ponds with sprays. However, both of these technologies require a significant amount of land area to construct. These technologies are not technically feasible for the MWGen stations because of their site area limitations.

An open-cycle cooling system with "helper" towers would not be able to meet the proposed temperature limits during all weather conditions. There are times, especially during the months of April, May and June, when the difference between the Proposed UAA Thermal Standards and the wet bulb temperature is too small to allow any practical size of cooling tower to meet these proposed standards. During these periods, the towers sized for closed-cycle operation would not be large enough to cool the effluent discharge to temperatures that comply with the Proposed UAA Thermal Standards if they were operated as "helper" towers. Because open-cycle cooling is more efficient than closed-cycle cooling, the conceptual design for each MWGen station includes provisions to operate open-cycle when the actual river water temperature is low enough to allow open-cycle operation and still meet the Proposed UAA Thermal Standards.

As part of its study, S&L also considered several alternative types of closed loop cooling technologies, including wet and wet/dry mechanical draft cooling towers, radiator type towers (external water required), air cooled condensers (new condenser is located external to the turbine room), and hyperbolic cooling. With the exception of the wet and wet/dry mechanical draft cooling towers, the remaining closed loop cooling technologies considered have either not been proven on such large scale installations as the MWGen stations or are considerably more expensive than the wet and wet/dry mechanical cooling tower technologies. Accordingly, these technologies were eliminated from further consideration.

Mechanical draft cooling towers (either wet or dry) are the most common type of cooling system for use in a closed-cycle system for a large heat load. Mechanical draft cooling towers have the advantages of being a proven design, are usually the lowest cost cooling option and require the smallest land area to construct. A mechanical draft tower is typically 40 to 60 feet tall and anywhere from 40 to several hundred feet long, depending on how much circulating water flow the tower is designed to process.

A cooling tower is actually comprised of several semi-independent modules referred to as "cells". Each cell consists of: 1) a structural steel, concrete or fiberglass frame; 2) walls (to confine the air and water flow); 3) piping near the top of the framework to distribute the water evenly; 4) a section of "fill" that enhances the contact between the air and water; 5) a large-diameter fan to pull air upward through the tower; and 6) an exhaust stack to help direct warm air upward and away from the sides of the tower. A group of cells is typically linked end-to-end to form a single cooling tower assembly. The group of cells is constructed inside a concrete basin which collects the cool water. The pumps which return the cool water to the condenser are installed on one end of the basin. A more detailed description of mechanical draft cooling towers is provided in Section 2.B of the attached S&L report (Exhibit B).

Wet cooling towers dissipate heat to the atmosphere primarily by evaporating some of the cooling water. The temperature of the cooling water that is not evaporated is reduced. The extent of the reduction in the temperature of the cooling water is limited by what is called the "inlet air wet bulb temperature." The amount of humidity in the atmosphere air determines the wet bulb temperature, which, in turn influences the effectiveness of a cooling tower in removing heat from the circulating water. The wet bulb temperature changes continually (*i.e.*, hour to hour and day to day) as the weather changes. Higher humidity levels result in higher wet bulb temperatures, and lower humidity levels result in lower wet bulb temperatures. In general, the lower the wet bulb temperature, the lower the cold water temperature – the temperature of the circulating cooling water after it has passed through the cooling tower. Thus cooling towers are more effective on cool, dry days and less effective on warm, humid days. Therefore, tower design for cooling performance and the ability to meet thermal discharge limits involves consideration of meteorology probabilities.

The difference between the cold water temperature leaving the cooling tower and the inlet air wet bulb temperature is called the "approach." The approach is a measure of the effectiveness of the cooling tower. A lower approach results in a lower water temperature but requires a larger and more expensive cooling tower. A larger tower will provide greater contact time between the circulating water and the airflow, which increases heat removal and lowers the circulating water temperature prior to its discharge. A larger tower is more expensive for a given circulating water flow rate, but it will increase the likelihood that the generating station can remain running at its capacity during hot and humid days, when cooling tower efficiency is reduced.

Although not nearly as widely used as wet cooling towers, another alternative means of cooling the steam generated at power plants is to use "dry cooling" towers. Unlike a wet cooling tower, a dry cooling tower has no direct contact between the circulating water and air and no evaporation. The heat transfer is all "sensible heat" (*i.e.*, the water temperature decreases and the air dry bulb temperature increases). A dry cooling tower uses natural or mechanical air drafts to remove heat and requires little or no water. However, dry cooling is less effective than wet cooling. Also, a dry cooling tower is much larger and results in higher discharge water temperatures than does a wet tower. Dry cooling towers are costly, reduce water intake only minimally compared to closed-cycle wet tower cooling and have other disadvantages. One advantage of a dry tower is that it does not produce a vapor plume (as does a wet tower) because it does not evaporate the cooling water.

A wet/dry tower is, as it sounds, a combination of both wet and dry cooling tower technology. As its name implies, a wet/dry tower has both a wet section and a dry section. The wet section achieves a low cooling water temperature and effective cooling through evaporation. The dry section in turn reheats the air leaving the wet section and thereby reduces the water vapor plume exiting the tower. The S&L study concluded that mechanical draft wet/dry cooling towers were the most cost effective type of cooling for all five MWGen stations.

The use of "helper" cooling towers also was considered for the MWGen stations. "Helper" cooling towers are used to reduce the temperature of the cooling water from the station before it is discharged back to the river. However, applying the Proposed UAA Thermal Standards, under certain reasonably expected weather conditions, such as when the wet bulb temperature is close to the applicable thermal standard, it would not be possible to achieve and maintain compliance, regardless of cooling tower size. For this reason, the cooling towers have to be sized for the full circulating water flow rate and heat load and must be operated in a closed-cycle mode during certain weather conditions.

C. Description of Closed-Cycle Cooling Options for MWGen Stations

The mechanical draft wet/dry cooling towers systems selected for the MWGen stations were sized for closed-cycle operation for the expected range of weather conditions throughout the year. The condition that determines the size of the cooling tower is the maximum wet bulb temperature. The specified design point is a 78°F wet bulb, which corresponds to the 1% occurrence in the summer. (, *Facility Design and Planning Engineering Weather Data*, Departments of the Air Force (USAF), the Army, and the Navy, A FM 88-29, TM 5-785, NAVFAC P-89, Washington D.C., 1978). This ensures that the cold water temperature from the cooling tower to the plant will be equal to or less than the design temperature of 85°F (7°F approach), except for 1% of the time in the summer. The use of the 1% summer wet bulb temperature is the standard industry practice for specifying the cooling tower design point. During periods when the wet bulb temperature is greater than 78°F, the generating units will be able to operate but some load reduction may be required.

Gates, piping and pumps to maintain the flexibility to operate in an open-cycle mode and to operate in a closed-cycle mode were included in the design. This allows the stations both to achieve compliance with the Proposed UAA Thermal Standards and to achieve higher operating efficiency (and hence, lower O&M costs for tower operation) by using once-through cooling when the river and ambient air temperatures are favorable.

Converting a once-through cooling system at a power plant into a closed-cycle system, as would be necessary for each of the five MWGen stations, is a major undertaking for many reasons. First, it is difficult because of the size of the cooling system that is needed. For example, the design cooling water flow rate at Joliet 7&8 is 920,000 gallons per minute. For this cooling water flow rate, three cooling tower sections, two 21-cell, 1008 feet long and one 22-cell, 1056 feet long, 48 feet wide and 58 feet high, would be required. The cooling towers have 64 fans that are 250 horsepower each. The length of these cooling tower sections is approximately the equivalent of slightly over 3.5 football fields laid end to end and reaching approximately 6 stories high across the length of that expanse. The circulating water pipes would be up to 14 feet in diameter, over twice the height of the average person. Also, for a power plant such as the MWGen Joliet 7&8, the cooling system would require at least two new sets of large circulating water pumps in addition to the existing set of pumps in place at the station. Operating the new pumps will require over 18MW of power.

The installation of the closed-cycle cooling system at an existing station requires that a major construction project be completed. The construction of the closed-cycle cooling system requires not only large excavations and foundation work which may need to be conducted in a relatively confined area but also requires work to interface the new cooling system with other existing plant systems, including the auxiliary power system, fire protection system, auxiliary cooling system and controls, in addition to the main cooling system.

As noted above, although there have been several studies of existing plants with once-through cooling systems to evaluate retrofitting them to once-through cooling, few have actually converted to once-through cooling because of the high capital cost, impact on plant performance and the complexity of converting an operating station from once-through to closed-cycle cooling. Plants that have closed-cycle cooling systems were typically designed as closed-cycle stations. When a new plant is designed, the cooling system is a major factor in both the site selection and the overall site arrangement.

D. Key Design Parameters for Estimating Closed-Cycle Cooling System Costs

In order to calculate the estimated costs for installing closed-cycle cooling systems at the five MWGen stations, the key elements of the system conceptual design needed to be identified. For closed-cycle cooling systems, the key design elements include: circulating water design flow rate; design wet bulb temperature and circulating water pump size. However, a complete, detailed design of the cooling system was beyond the scope of the S&L Study. Accordingly, there are likely items that are not included in the S&L design concept that would become necessary to include in an actual design of a closed-cycle cooling system for each of the stations. The costs of such additional items are not included in the cost estimates prepared by S&L for this study.

The closed-cycle cooling system conceptual design includes redundancy that is consistent with normal industry practice. The cooling towers have multiple cells, each with a fan, and the failure of one fan or cell will only slightly reduce cooling that should not require a generating unit shutdown or derating. The cooling system will have multiple pumps, but the design is based on all pumps operating (*i.e.*, there is no spare pump). If a pump fails, the load may need to be reduced through derating at the station, depending on the weather conditions, but it should not require a generating unit to be shut down. Multiple pump losses and/or fan failures can put the affected station at greater risk of having to derate to maintain thermal compliance.

As noted above, the closed-cycle-cooling system for each MWGen station was sized for 100% of the circulating water design flow rate. The cooling tower size is determined by the 1% summer wet bulb temperature.

In addition to cooling towers, a closed-cycle cooling system requires large pumps and piping to supply the circulating water to the cooling towers and to return the water to the existing circulating water pumps. Preliminary sizes were determined for the pumps and piping to use in the S&L cost estimates. The quantities of concrete and steel required for the cooling tower basin and pump and cooling tower supports were estimated along with other commodities, such as a rack system for supporting pipe and conduit.

The preliminary cooling tower design used to estimate costs is based on towers with a low drift design to minimize emissions of particulate matter. Based on a preliminary review of applicable air regulations, the installation of cooling towers at the MWGen stations may trigger New Source Review under the Clean Air Act that would require modeling work to be performed and permitting issues to be addressed. The estimated costs included in the S&L Study did not include the additional costs that would be associated with New Source Review requirements.

Based on a review of receiving waters temperature data for the past several years, and due to the wide variability and uncertainties of flow and temperature in the CSSC and Lower Des Plaines River, a credit for a mixing zone was not utilized in the cooling tower sizing for once-through operation. For each of the MWGen stations, there are many days (over 100 days per year in recent years for some of the stations) where the upstream river temperature exceeds the Proposed UAA Thermal Standards. During these periods, mixing of the stations' respective discharges with the receiving water would not reduce the outlet water temperature to below the proposed standards. However, it was beyond the scope of the S&L Study to try to identify a way to predict the various receiving water conditions and any resulting, available mixing zone based on those conditions, that might allow the stations to operate at limited times during the year in a once-through mode bef ore switching back to closed-cycle operation. Further, even with a closed-cycle cooling system, there is a small (~650 to ~3000 gpm) cooling tower blowdown flow generated. Although this cooling tower blowdown flow will not contribute to any significant water temperature rise within the receiving stream, based on existing receiving stream data, it is expected that there may be times when no mixing is available due to low river flow and/or ambient river temperatures which are higher than the Proposed UAA Thermal Standards. If a small mixing zone is needed but not available, an additional cooling mechanism (likely a chiller at an approximate cost of $3 million per station) may be required to ensure compliance under all operating and receiving water scenarios. However, for purposes of S&L's study, supplemental cooling of the condenser blowdown discharge for the MWGen stations was not included in the study cost estimates.

E. General Description of Design Concept for Each MWGen Station

After identifying the basic design elements common to each of the MWGen stations, S&L then proceeded to evaluate the preliminary design criteria further based on relevant site-specific conditions for each of the stations. During this "station-specific" phase of the preliminary design development for cost estimating purposes, the design criteria were refined as appropriate to address the relevant conditions and issues presented by each of the MWGen stations. To a significant extent, the relevant characteristics of the MWGen stations were similar enough that the preliminary design criteria remained relatively the same for most of the stations. Exhibits A and B in the attached S&L Report include arrangement drawings and flow diagrams that illustrate how the cooling systems would be modified for each station. The results of this phase of the S&L costs study are further explained below.

1. Fisk, Crawford and Joliet 6 Stations

For closed-cycle cooling system design purposes, the Fisk, Crawford and Joliet 6 Stations presented similar conditions. Hence, the preliminary design criteria was substantially the same for these stations. Two cooling tower sections were included in the preliminary design to provide adequate cooling and to fit within the site boundaries. The existing intake and discharge canals would be blocked with diversion walls and gates. The diversion gates could be opened during favorable weather and receiving stream conditions to allow once-through cooling water operation. The existing circulating water pumps would pump water from the intake through the condenser to the discharge, similar to current operation. A new pump house and pumps would be installed in the discharge bay to pump the water to the new cooling towers. Water from the cooling towers would be pumped by new pumps, located in the cooling tower basin, to the existing intake area.

Makeup water for the cooling system will come from the existing intake bay. The existing circulating water inlet channel would be partially left open to the river in closed-cycle operation so that makeup water to the cycle can be drawn in as needed. No separate makeup pumps or piping were included in the design or cost estimate. Blowdown from the system will be taken from the discharge of the pumps located in the cooling tower basin, which will be the coldest water in the cooling system.

2. Will County Units 3 and 4

The design of the closed-cycle cooling system at Will County Station for Units 3 and 4 generally would be similar to the arrangement at Fisk and Crawford. However, due to the larger capacity of the Will County Station as compared to either Fisk or Crawford, the size of the cooling tower would need to be larger to provide the cooling necessary for compliant operations. For Will County, the design criteria include three cooling tower sections instead of the two sections specified for the Fisk and Crawford cooling towers.

3. Joliet 7&8

As is the case for Will County Units 3 and 4, three cooling tower sections would be necessary at Joliet 7&8 to supply adequate cooling. The existing intake and discharge canals would be blocked with diversion gates. The existing circulating water pumps would pump water from the intake through the condenser to the discharge, similar to current operation. A division wall would be installed in the discharge bay to divide the bay into two sections. A new pump house and pumps would be installed in one section of the discharge bay and would be isolated from the other section by a movable gate. Pumps in the new pump house would pump the water to the new cooling towers. Water from the cooling towers would be pumped by new pumps, located in the cooling tower basin, to the existing intake area.

While the preliminary design for all of the MWGen stations includes the ability to operate in two possible modes of operation, closed and open-cycle, Joliet 7&8 would have three possible modes of operation. Joliet 7&8 could operate in closed-cycle or open-cycle mode similar to the other stations but could also operate in open-cycle mode using the new cooling towers as helper towers. This would provide more operating time in open-cycle mode, which would reduce operating costs. Because of the site layout and existing intake and discharge arrangement, this is only practical for Joliet 7&8.

F. Cooling System Design Challenges and Constraints

The new cooling system at all five MWGen stations requires installing large equipment in relatively small areas. The space constraints presented by each of the MWGen station properties affected the design of the cooling tower arrangements, making it less than an optimal design if space were not limited. More specifically, the cooling tower arrangements included in the preliminary design are less than ideal with respect to preventing recirculation of air between cooling towers. Recirculation of air between cooling towers is typically something that is prevented or minimized in designing cooling towers because any such recirculation will reduce tower performance. Reduced tower performance results in higher operating costs.

In addition to space limitations at the MWGen stations, additional design issues arise from existing structures and equipment at the stations that interfere with retrofitting them to closed-cycle operations. At Fisk, Crawford and Will County Stations, the available area for locating the cooling towers is also the location of existing high voltage transmission lines owned by Commonwealth Edison ("ComEd"). Therefore, the preliminary design for each of these stations includes having to move and relocate these high voltage transmission lines. However, S&L does not know whether an evaluation by ComEd would determine that the relocation of its transmission lines is feasible or, if feasible, what conditions or costs ComEd would require in return for its agreement to move and relocate these lines.

Another design consideration was the noise that is generated from the operation of cooling towers. S&L's review concluded that noise emissions from the cooling towers are expected to be below the regulatory limits for all of the units except for Joliet 7&8 due to the proximity of an existing office building west of the proposed Joliet 7&8 cooling tower location. However, because of the preliminary scope of the design work completed for this study, the cost of noise abatement was not included in the Joliet 7&8 capital cost estimates prepared by S&L.

Due to the nature of the preliminary design concept work conducted by S&L, certain assumptions needed to be made to complete the cost estimates. This was primarily the case in the area of permitting. The design concept and cost estimates are based on the assumption that state and federal permitting authorities, *e.g.*, Illinois EPA and the U.S. Army Corps of Engineers, will grant all of the necessary permits for the construction and operation of the cooling tower system at each of the MWGen stations. Such permits would include the required construction permit(s) for the towers and the modifications to intake and discharge canals as included in the design concept, as well as any related environmental operating permits, such as for particulate matter emissions from the towers. Due to the relatively high level of uncertainty associated with the extent of the effort necessary to complete the permitting process for each of the stations, S&L did not include a cost estimate line item for permitting in the capital and O&M estimated costs presented in its study. S&L also assumed that the permits could be obtained within the estimated project schedule it prepared as part of its report.

IV. Estimated Economic Costs of Compliance with Proposed UAA Thermal Standards

Based on the preliminary design criteria S&L identified for each of the five MWGen stations, S&L then developed estimates for the costs that are involved in implementing the retrofitting of each of the five MWGen stations to closed-cycle cooling. These estimated costs included capital and O&M cost estimates and estimated power loss revenues associated with the additional power required to operate the cooling towers. The cost estimates for each of the MWGen stations, and how they were prepared for each of the cost categories, is explained further below.

A. Capital Cost Estimates

The estimated capital costs for each MWGen station to convert to closed-cycle cooling systems are listed in Table 2 below, and are explained in more detail in Section 5 of the S&L report (Exhibit B). The estimated capital costs range from $115 million for Joliet 6 to $300 million for Joliet 7&8, for a total capital cost of nearly $1 billion for all five of the MWGen stations.

Table 2

Capital Cost Estimates for Conversion of MWGen Stations to Closed-Cycle Cooling

UNIT	STATION TOTAL GROSS MW	CAPITAL COST WET/DRY TOWER ($)	WET/DRY CAPITAL COST ($) PER KW
FISK 19	348	$137,100,000	$394
CRAWFORD 7&8	585	$165,200,000	$282
WILL COUNTY 3&4	832	$257,100,000	$309
JOLIET 6	341	$115,700,000	$339
JOLIET 7&8	1,138	$300,900,000	$264
TOTALS	3,244	$976,000,000	$301 (AVERAGE)

S&L generated the capital cost estimates based on a combination of budgetary equipment quotes, engineering material quantity estimates and the use of S&L's cost estimating database. The largest cost component is the physical cooling tower itself, which is approximately 15% to 25% of the total capital cost, depending on the station. Budgetary quotes were obtained from SPX/Marley, a major cooling tower supplier. The cost for pumps, piping, electrical equipment and labor were obtained both from S&L's estimating database, which includes data from budget quotes and contracts from past S&L projects, and from published rates for labor and productivity.

The cost estimates provided are "order of magnitude" – meaning that the accuracy is limited to -30%/+50%. These are reasonable cost estimates in the context that they are based on conceptual designs, physical layouts and contain a fair level of detail in all the major account categories.

However, detailed engineering and detailed design have not been performed. During the detailed design and engineering phase of installing a new system into an existing plant, it is common to encounter unforeseen problems that increase the cost. Thus, the +50% is more likely than the -30%. The design parameters used for the cost estimates are based on assumption of the scope and design basis. There are several unknowns that could, and likely will, lead to changes in the cost estimates. Generally, these unknowns are items that would increase the estimated costs, as further explained below.

B. Closed-Cycle Cooling Systems Estimated O&M Costs for MWGen Stations

In addition to the capital costs, the closed-cycle cooling systems will also require annual expenditures to operate and maintain the system (the "O&M costs"). The principal elements of O&M costs for closed-cycle cooling systems are a) cooling tower fan and circulating water system pump power costs, b) preventative maintenance and repair of cooling tower fan and circulating water pump systems, and 3) chemicals for control of corrosion and biological growth. The estimated annual O&M costs, including the costs for the auxiliary power consumptions are listed in Table 3.

Table 3

Estimated Annual Operating and Maintenance Costs for Conversion of MWGen Stations to Closed-Cycle Cooling

Unit	Station Total Gross MW	Wet/Dry Towers
Fisk 19	348	$2,127,000
Crawford 7&8	585	$3,960,000
Will County 3&4	832	$5,750,000
Joliet 6	341	$2,660,000
Joliet 7&8	1,138	$9,080,000
Totals	**3,244**	**$23,577,000**

In addition to the auxiliary power consumption (as discussed further below) and the O&M costs associated with closed-cycle cooling, the cooling water temperature to the condensers will be higher than with once-through cooling. This will result in a loss in gross electrical output and plant efficiency. The loss will vary with ambient temperature, but is expected to be approximately 1%.

C. Auxiliary Power Use Associated with Conversion to Closed-Cycle Cooling

The operation of cooling towers requires a power supply. The power demand of the cooling towers results in additional power that would have to be supplied by each MWGen station on an ongoing basis. This additional power would be supplied by the electricity generated by each of the stations. This additional power demand, referred to here as the "auxiliary power use," results in a loss of revenue to MWGen because it can no longer be sold on the open market. It instead must be used to operate the new cooling towers. It also means that other electrical generating station units must produce more power to supply to the electric grid to make up for the power consumed by the cooling towers. The cooling tower fans and new pumps will consume 2 to 3% of the gross electrical output of the stations. For Joliet 7&8, the cooling system will require over 35MW of power. The auxiliary power consumption for the closed-cycle cooling system for each MWGen station is listed below in Table 4.

Table 4

Cooling Tower Annual Auxiliary Power Use (MW) for MWGen Stations

	Fisk 348 MW	Crawford 585 MW	Will County 3&4 832 MW	Joliet 6 341 MW	Joliet 7&8 1,138 MW
Cooling Tower Fan Power	3.24	6.08	9.32	4.28	16.20
Supply Pump Power	3.89	6.48	9.72	4.78	17.01
Discharge Pump Power	0.65	0.97	0.81	0.81	1.94
Average Aux Power Use	**7.78**	**13.53**	**19.85**	**9.87**	**35.15**
Percentage of MW Output	**2.2**	**2.3**	**2.4**	**2.9**	**3.1**

D. Loss of Plant Generating Capacity

The circulating water inlet temperature to the condenser is higher in closed-cycle mode than in open-cycle mode, because it is not possible to reduce (with cooling towers) the cold-water temperature of the circulating water system to the temperature of the body of water previously used for open-cycle cooling. This higher condenser inlet temperature reduces turbine-generator efficiency and results in a loss of plant generating capacity, and a corresponding loss of revenue from electricity sales. The estimated annual loss in revenue for all five stations is approximately $3,800,000.

E. Potential Additional Costs

Although the work required in preparing the above cost estimates involved an extensive effort, there are still several unknowns in the design basis that could lead to changes in the cost estimates, primarily changes which would increase the cost estimates provided here. These items including the following:

- Noise abatement for the cooling towers is not included in the cost estimates. Noise abatement could cost up to $12.6 million at Joliet 7&8. Although noise abatement is not expected to be required at the other stations, if it does become an issue during permitting, it would increase the S&L estimated costs.

- Blowdown from the cooling towers will be higher than the allowable discharge temperature during some weather conditions. Since the blowdown flow rate will be small compared to the total flow rate, S&L assumed additional cooling of the blowdown will not be required based on the assumption that a mixing zone may be available to allow for compliance at the edge of the mixing zone and not at the end-of-pipe outfall. If however sufficient mixing is not available for one or more of the stations' discharges of cooling tower blowdown, then additional cooling of the blowdown will be required. The capital cost per station for this additional cooling, through the add-on installation and operation of a chiller, will be approximately an additional $3 million per station.

- Changes in the cooling tower location due to transmission line issues would increase the cost. S&L assumed that any interference with the siting of the cooling towers caused by third-party owned, existing transmission lines could be addressed through relocating of the transmission lines. It is not known whether this is a correct assumption.

- A change in cooling tower type, such as dry cooling, would increase cost.

- Additional work resulting from requirements imposed by the Illinois EPA, U.S. EPA Army Corp of Engineers or city or county governments during permitting reviews could increase costs. As an example, if the cooling towers are required to be relocated, the cost would increase.

- Interference from underground utilities could require design changes and impact cost. All of these generating units are on old sites and there may be abandoned, below-ground utilities discovered during the construction phase of the work that have to be removed. No costs for such unknown conditions were included in the S&L cost estimates.

- A constructability review by a general contractor could either identify cost savings or extra costs not included in the estimates. For example, a construction contractor may find that the lack of on-site construction storage area may increase the construction costs.

V. Conclusion

S&L's study of the applicable technology and estimated compliance costs relating to the Proposed UAA Thermal Standards involved an extensive amount of effort by several of its experienced and qualified personnel, as well as cost information generated by an outside cooling tower manufacturer. Based on the significant level of effort devoted to this study, it is clear that the IEPA's proposed re-designation of the aquatic life use of the Upper Dresden Island Pool and the CAWS and the accompanying Proposed UAA Thermal Standards would require new closed-cycle cooling systems for all five MWGen stations that have used these waterways for once-through cooling since they began operating. When the MWGen stations were designed several decades ago, they were not designed nor were their respective sites selected or arranged to attain thermal water quality standards as strict as those proposed in this rule-making. Due to the lack of sufficient land area at the MWGen stations on which to construct the necessary structures or equipment associated with cooling lakes and cooling ponds with sprays, these technologies are not technically feasible for the MWGen stations. Further, there are reasonably expected weather conditions in the vicinity of the MWGen stations which make the use of "helper" towers another option which is not technically feasible for these stations to employ to achieve compliance with the Proposed UAA Thermal Standards. Thus, the new cooling system required for each of the MWGen stations must be designed for closed-cycle operation.

Based on the results of S&L's study, plume abated (wet/dry) mechanical draft cooling towers are the lowest cost alternative for closed-cycle cooling that will achieve and maintain compliance with the Proposed UAA Thermal Standards. For all five MWGen stations, converting them to closed-cycle cooling systems would require an estimated total capital investment of nearly $1 billion, and would result in over $23,000,000 per year in operating and maintenance costs. In addition, the net electrical output and efficiency of all five stations would be reduced. However, as discussed above, because certain assumptions were made in the course of the S&L Study that may not be achieved in an actual implementation of the conceptual design, such as the relocation of high voltage transmission lines, as well as the existence of very few actual cases of converting open-cycle generating stations to closed-cycle operation with which to compare these estimated costs, the implementation of the conceptual design on which these cost estimates are based at each of the MWGen stations is not a technical certainty and is likely to result in actual costs that exceed these estimates.

Respectfully submitted,

Ray E. Henry

Ray E. Henry

EXHIBIT A

TO THE WRITTEN TESTIMONY OF RAY E. HENRY

Curriculum Vitae of Ray E. Henry

RAY E. HENRY
Principal Consultant
Sargent & Lundy Consulting

Sargent & Lundy

EDUCATION

Purdue University - B.S. Mechanical Engineering - 1971

REGISTRATIONS

Professional Engineer – Illinois, Indiana

PROFICIENCIES

Mechanical engineering

Project Management

Power plant design

Steam turbine design review

Boiler design review

Cycle optimization

Fan specialist

Plant betterment

Condition assessment and rehabilitation studies

Reliability and availability

Plant performance

Cooling Systems

Cycling conversion

Training and technology transfer

RESPONSIBILITIES

Mr. Henry is a principal consultant.

As a technical consultant, Mr. Henry provides technical support to the various project teams within Sargent & Lundy. His specialties include, system design, plant condition assessment, performance testing, heat balance studies, plant optimization studies, plant configuration, alternate technology assessment, cycling conversion, fuel switching, cooling system optimization, etc.

Mr. Henry also serves as a project manager for owner's engineer/consultant projects. The scope of these projects usually consists of conceptual design studies, feasibility studies and economic evaluations, preparation of engineering, procurement, and construction (EPC) specifications, evaluation of EPC bids, design review and construction technical support.

Mr. Henry is also Sargent & Lundy's specialist for power plant fans, condensers, and cooling towers.

EXPERIENCE

Mr. Henry has more than 35 years of experience in the mechanical engineering, design, and analysis of major steam-electric generating stations. Mr. Henry has participated in construction overviews, serving as the project lender's engineer.

Mr. Henry serves as a technical consultant on many of the combined cycle plants designed by S&L.

Mr. Henry is a member of the American Society of Mechanical Engineers (ASME) Performance Test Code Committee for fans, PTC II. He has participated in field tests and has provided performance evaluations of boilers, turbines, condensers, pumps, fans, steam generators, and feedwater heaters. He has participated in performance test for conventional and combined cycle plants, including preparation of test procedures, field testing, evaluation of test results and due diligence review of tests and test reports.

Mr. Henry is a member of the American Society of Mechanical Engineers (ASME) Performance Test Codes Standards Committee.

Mr. Henry currently serves as Sargent & Lundy's and fan specialist and one of several boiler and turbine specialists. He has been involved in fan evaluations and the development of specifications for replacement of fans.

Mr. Henry has also been involved in the preparation of and review of EPC and equipment specifications for unit sizes of 12 MW to 1000 MW. He has participated in EPC and equipment bid evaluations, design reviews, performance tests, unit assessments, and performance improvements.

Mr. Henry recently served as a technical consultant to the International Finance Corporation unit of the World Bank regarding its update, published in December 2008, of Environmental, Health, and Safety Guidelines for Thermal Power Plants. That is a key reference document for environmental evaluations of thermal power facilities worldwide.

Mr. Henry developed Sargent & Lundy's HTBAL program to model various steam turbine cycles.

Before assuming his position as consultant and project manger, Mr. Henry was the manager of Sargent & Lundy's Power System Engineering Division, consisting of consultants, technical specialists, senior engineers, and engineers who analyze units in design as well as units that are operating.

Prior to his position as a division manager, Mr. Henry was a senior mechanical project engineer. He performed preliminary design studies to determine general plant layout; sized and specified equipment; analyzed economic factors; prepared flow diagrams; and sized piping, which included analyzing flexibility and support systems. He maintained client contact and incorporated operating philosophies within design parameters. He also interfaced with suppliers in selecting equipment, materials, and labor packages; evaluated proposals; and recommended purchases.

Mr. Henry's specific experience includes the following:

INDEPENDENT ENGINEER / OWNER'S ENGINEER / CONSULTANT

- **Banco Itaú BBA S.A. MPX Energia (Brazil)**
  - Pecém II, 1x365 MW coal-fired. (2009 to present)

- **Fujian Electric Power Survey & Design Institute/Hebei Electric Power Design & Research Institute/Inner-Mongolia Power Exploration & Design Institute (China)**
  - Consulting services for design of 1000MW supercritical coal units (2008 to present)

- **Office National de l'Électricité (Morocco)**
  - Safi 2x660 MW coal fired plant (2008 to present)

- **Phu My 3 BOT Company (Vietnam)**
  - Phu My 3 2x2x1 natural gas combined cycle, 700 MW (2007-2008)

- **AES (Chile)**
  - Nueva Ventanas, 260 MW coal-fired.
    (2006 to 2007)

  - Guacolda, 150 MW coal-fired.
    (2006 to 2007)

- **Inter-American Development Bank/MPX Energia/Energias do Brasil (Brazil)**
  - Pecém I, 2x360 MW coal-fired. (2008 to present)
  - Itaqui, 1x360 MW coal-fired (2008 to 2009)

- **P.T. Tanjung Jati Power Company (Indonesia)**
  - Tanjung Jati "A", 2x600 MW coal-fired.
    (2005 to 2007)

- **Singapore Power International (Korea)**
  - Anyang and Buchon CHP, 2x475 MW LNG. (2000)
  - Bugok CC, 1x538 MW LNG-fired. (2000)

- **TotalFina/Tractebel (Abu Dhabi)**
  - 800 MW gas fired combined cycle
    Project Manager (1999-2000)

- **Shanghai Municipal Electric Power Company (China)**
  - Waigaoqiao Phase II, supercritical coal, 900 MW to 1000 MW.
    Project Manager. (1996-2002)

- **Wing Group (China)**
  - Dengfeng, 2x300 MW coal-fired.
    (1995 to 1998)

- **Sithe China Limited (China)**
  - Puqi, 2 x300 MW coal fired, IPP.
    (1997 to 1998)

- **Yellow Sea Company (China)**
  - Jinhua, 2x30 MW coal-fired cogeneration.
    (1995 to 1998)

- **Illinova (China)**
  - Zhuzhou, 2x12 MW coal-fired cogeneration.
    (1996 to 1997)

- **Electric Power of Henan (China)**
  - Qinbei, 2x600 MW coal-fired.
    (1995 to 1997)

CONCEPTUAL DESIGN STUDIES

- **Office National de l'Électricité (Morocco)**
  - Jorf Lasfer, Conceptual study for new coal fired generation, including site layout, evaluation of unit size and design, performance estimates and capital and O&M cost estimates. (2005 to 2007)

- **Shanghai Municipal Electric Power Company (China)**
  - Waigaoqiao, supercritical coal, 900 MW to 1000 MW.
    Project Manager. Phase II site evaluation for the potential addition of four supercritical coal-fired units. Stage 1 of the project, consists of conceptual design and bid document review and Stage 2 consists of interface. (1996 to 2002)

    Site study for extension units. (1993)

- **Central & South West Services, Inc.**
  - Technology assessment of new generation. (1993 to 1994)

PLANT DESIGN

- **Huaneng International Power Development Corporation**
  - Shidongkou 1 and 2, coal, 600 MW, supercritical.
    Performed pipe sizing and prepared heat balances. (1988)

- **PSI Energy**
  - Gibson 5, coal, 618 MW, supercritical.
    Performed preliminary design studies for plant layout; optimized cycle configuration; sized and specified equipment, including auxiliary boiler; analyzed economic factors; prepared flow diagrams; procured equipment and materials; and prepared labor packages, provided technical support for construction. (1979 to 1983)

For the following projects, Mr. Henry supervised equipment sizing, optimization of systems and components, performance evaluation of equipment from various manufacturers, and feasibility studies.

- **Central Power & Light Company**
  - Coleto Creek 1, coal, 570 MW.
    (1974 to 1977)

- **Commonwealth Edison Company**
  - Byron 1 and 2/Braidwood 1 and 2, nuclear, 1175 MW each.
    (1974 to 1977)

- **Northern Indiana Public Service Company**
  - Schahfer 14 and 15, coal, 550 MW each.
    (1971 to 1973, 1974 to 1977)

- **Illinois Power**
  - Clinton 1, nuclear, 985 MW;
  - Havana 6, coal, 439 MW.
    (1973 to 1977)

- **American Electric Power Service Corporation/Buckeye Power, Inc.**
  - Cardinal 3, coal, 615 MW, supercritical.
    (1973 to 1974)

BOILERS

- **Mitsui**
  - Point Aconi, 185 MW CFB.
    Boiler efficiency and plant heat rate tests. (1994 to 1995)

- **National Power**
  - Jiaxing 660 MW coal.
    Design review of boiler proposal. (1995)

- **PSI Energy**
  - Gibson 3, 668 MW, coal.
    Technical support for test burn of PRB coal. (1993 to 1995)

- **Carolina Power & Light Company**
  - Asheville Unit 2, coal 200 MW.
    Boiler capacity and HUT tests. (1995)

- **Carolina Power & Light Company**
  - Roxboro Unit 2, 600 MW coal.
    Retrofit of new pulverizers and coal pipe. (1995)

COOLING SYSTEM

- **PSI Energy**
  - Cayuga 1 and 2, coal, 531 MW each.
    Study to convert to closed cycle cooling. (1993)

- **PSEG Nuclear**
  - Salem 1 and 2, nuclear
    Evaluation of cooling tower retrofit (1994)

- **Genesis Energy**
  - Huntly Power Station Units 1 to 4
    Specification and evaluation of helper cooling tower (2004)
    Evaluation of alternative cooling systems (2010)

- **Enviro Power**
  - Various sites
    Cooling tower evaporation rates (2001)

- **Vattenfall**
  - Moorburg Units 1 and 2, coal, 840 MW each.
    Study of cooling system (2009)

PRECIPITATOR UPGRADES

- **Indianapolis Power & Light Company**

- Pritchard 6, coal, 69 MW.
  Fan testing, model flow testing, and precipitator procurement. (1992 to 1993)

CONDITION ASSESSMENT

- **ATCO Power**
  - Battle River Units 3 and 4
    Evaluated condition of steam turbine, boiler and other major equipment. (2006)
- **AES**
  - Ekibastuz units 1-5
    Review of steam turbine, boiler and other major equipment (2007)
- **The Cincinnati Gas & Electric Company**
  - Miami Fort 5, coal, 80 MW.
    Evaluated condition of fans, fluid drives, and condenser. (1987)
- **PSI Energy**
  - Gallagher 4, coal, 150 MW.
    Evaluated condition of fans, condenser, and feedwater heater. (1986)
- **Northern Indiana Public Service Company**
  - Mitchell 4, coal, 138 MW.
    Evaluated condition of fans, condenser boiler feed pumps, fluid drives, and feedwater heaters. (1985)
- **Boston Edison Company/Electric Power Research Institute**
  - Mystic, oil, 565 MW.
    Developed guidelines for fans and heat rate. (1984)

MISCELLANEOUS

- **Arizona Public Service Company**
  - Various stations.
    Developed turbine cycle and heat rate seminar for presentation to client's personnel. (1987)
- **Northern Indiana Public Service Company**
  - Provided engineering services to increase unit capacity. (1984)

- **Mitsui/Toshiba**
  - Performed survey of moisture separator reheaters. (1983 to 1984)

- **University of Wisconsin**
  - Performed balance-of-plant conceptual design for a fusion reactor. (1973 to 1974)

PLANT PERFORMANCE

- **TU Electric**
  - Mechanical Project Engineer. Subcontractor on EPRI heat rate improvement guideline project (RP2181). (1987 to 1989)

- **SEGS VIII and IX**
  - Plant performance improvement study. (1994)

- **Wisconsin Electric**
  - Pleasant Prairie, coal, 570 MW.
    Determined sources from plant to supply energy to industrial park. Identified sources and determined heat rate and power generation degradation caused by source. Also evaluated advantages and disadvantages and balance-of-plant impact. (1987)

- **Wisconsin Power & Light Company**
  - Rock River 2, coal, 75 MW.
    Conducted unit performance evaluation and developed a performance evaluation manual. (1987)

- **Boston Edison Company**
  - Mystic 4-7, oil, 1086 MW total;
  - New Boston 1 and 2, oil, 738 MW total.
    Performed unit availability study. (1985)

- **Interstate Power Company**
  - Lansing 4, coal, 252 MW.
    Performed unit performance evaluation. (1984)

- **Central Illinois Public Service Company**
  - Grand Tower 4, coal, 100 MW;
  - Newton 2, coal, 567 MW.
    Performed unit performance evaluation. (1983)

CYCLING CONVERSION

- **Houston Lighting & Power Company**
  - Sam Bertron 1 and 2/Deepwater 7/W. A. Parish 1 and 2; gas; 156 MW each.
    Development of system design for cycling modifications and determination of startup times for warm starts. (1986)

CLEAN AIR ACT AMENDMENT

- **PSI Energy**
  - All stations.
    Program Manager. Design, procurement, and installation design of continuous emission monitors. (1991 to 1992)

    Program Manager. Phase I Clean Air Act Amendment compliance study. (1991)

TRAINING AND TECHNOLOGY TRANSFER

- **Korea Electric Power Corporation/Korea Power Engineering Company**
  - Yonggwang 3 and 4, nuclear, 950 MW each.
    Conducted six-month transfer of technology course on heat exchangers. (1987 to 1988)

- **Arizona Public Service Company**
  - Conducted two-day course on heat balances. (1986)

- **Sargent & Lundy**
  - Instructor of a course in fans for Sargent & Lundy's Power Plant Fundamentals program.

FANS

- **Commonwealth Edison Company**
  - Kincaid 1 and 2, coal, 1160 MW total.
    Study for upgrading induced draft (ID) fans for the addition of an FGD system. (1991 to 1992)

    Provided engineering services for replacement of gas recirculation fan wheels. (1988)

  - Waukegan 8, coal and gas, 355 MW.
    Provided engineering services for replacement of ID fan wheel. (1988)

  - Joliet 7 and 8, coal and gas, 580 MW each.
    Performed engineering services in connection with ID fan wheel and fan rotor replacement. (1987)

- Powerton 5 and 6, coal, 828 MW each.
  Provided engineering services for replacement of forced draft (FD) fan wheel. (1987)

- Will County 1 and 2, coal, 280 MW total.
  Provided engineering services for ID fan hub replacement and prepared specifications for replacement of FD fan wheel. (1987)

- **Electric Power Research Institute**
  - Study manager for developing operating and maintenance guidelines (RP 2504-7) for draft fans. (1988 to 1992)

- **PSI Energy**
  - Gibson 4, coal, 668 MW.
    Study for upgrading ID fans for the addition of a flue gas desulfurization system. (1991)

  - Cayuga 1 and 2, coal, 1062 MW total.
    Provided engineering service for replacement of FD and ID fan wheels. (1988)

  - Wabash River 6, coal, 365 MW.
    Provided engineering services for replacement of ID fan wheels. (1988)

- **Florida Power & Light Company**
  - Various stations.
    Prepared generic FD fan specifications for several 400 MW units. (1987)

MEMBERSHIPS

American Society of Mechanical Engineers
- Performance Test Codes Standards Committee
- Committee PTC-11, Fans

PUBLICATIONS

"Emission Limits and Controls for Coal Fired Plants in the United States" (coauthor), Presented at the International Seminar on Energy Savings and Environmental Protection in Large Scale Thermal Power Companies, Shanghai, 2007

"Uncertainty Analysis in Fan Testing" (coauthor), ASME POWER2007, San Antonio, Texas, July 2007.

"Using Technology to Resolve Power Plant Design and Construction Disputes" (coauthor), ASME Joint International Power Generation Conference, Phoenix, Arizona, October 1994

"Economic and Operational Benefits from Retrofitting Variable-Speed Drives" (coauthor), American Power Conference, Chicago, Illinois, April 1994

"Fan Instability Associated with Variable-Frequency Drives" (coauthor), American Power Conference, Chicago, Illinois, April 1994

"Meeting CAA Demands on CEM Systems" (coauthor), Power Engineering, December 1992

"Heat Rate Study for the Base Case PC State-of-the-Art Power Plant Conceptual Design" (coauthor), EPRI Conference on Heat Rate Improvement, Birmingham, Alabama, October 1992

"Helping Operators Improve Plant Performance HEATXPRT: An On-Line Expert System" (coauthor), EPRI's Heat Rate Improvement Conference, Scottsdale, Arizona, May 1991

"Benefit from Lessons Learned in Replacing Centrifugal Fans," Power, January 1991

"Fan Replacement - Lessons Learned," American Power Conference, Chicago, Illinois, April 1990

"Development of an On-Line Expert System," HEATXPRT" (coauthor), EPRI Conference on Advanced Computer Technology for the Power Industry, Scottsdale, Arizona, December 1989

"Operating and Maintenance Guidelines for Draft Fans," EPRI Plant Maintenance Technology Conference, Houston, Texas, November 1989

"Heat Rate Improvement at TU Electric's North Lake Unit 2," EPRI Heat Rate Improvement Conference, Knoxville, Tennessee, September 1989

"Development of an On-Line Expert System: Heat Rate Degradation Expert System Advisor" (coauthor), EPRI Conference on Expert Systems Applications for the Electric Power Industry, Orlando, Florida, June 1989

"Performance Monitoring Systems" (coauthor), Instrument Society of America's Power Industry Division Conference, Phoenix, Arizona, May 1989

"Effective Use of Availability Data," (coauthor), Sargent & Lundy General Engineering Conference, Chicago, Illinois, Spring 1988

"Fossil-Fired Station Heat Rate Improvement," Sargent & Lundy General Engineering Conference, Chicago, Illinois, Spring 1987

"Performance-Related Monitoring and Diagnostics," Sargent & Lundy General Engineering Conference, Chicago, Illinois, Spring 1986, and JPGC 1987

"Integrated Power Plant Diagnostics" (coauthor), Pacific Coast Electrical Association's Engineering and Operating Conference, San Francisco, California, March 1986

"Heat Rate Improvement" (coauthor), Joint Power Conference, Toronto, Canada, September-October 1984

"Availability and Plant Betterment," 11th Annual Inter-RAM, Las Vegas, Nevada, April 1984