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REPORT

Summary of the

International Paper PEMS XL Project,

Final Project Agreement Dated April 20, 2000

September 15, 2002

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EXECUTIVE SUMMARY

From 1998 to the present, the International Paper Company (IP) Androscoggin Mill, the Maine Department of Environmental Protection, EPA New England (Region 1), the Town of Jay, Maine and other stakeholders collaborated as partners in a project to develop a computerized system to predict emissions from one of IP's stacks and thus reduce air emissions from IP's mill. With IP at the lead, the partners planned, developed and tested a state-of-the-art real-time computer model called a "Predictive Emissions Monitoring System" (PEMS), designed to predict air emissions from IP's waste fuel incinerator and use those predictions to manage and reduce pollution.

IP developed the PEMS in the spring and early summer of 2000. IP conducted validation testing of the PEMS in the fall of 2000 with results reported in early 2001. IP then conducted a follow-up relative accuracy test audit (RATA) of the PEMS in March 2001. The PEMS failed the EPA Specification 11 acceptability criteria in both the fall 2000 and March 2001 testing. After retraining the model to incorporate additional data, IP conducted follow-up testing in the summer of 2001. This time, the PEMS passed the correlation criterion of Specification 11, but failed the relative accuracy criteria set forth in the Specification.

Based on the testing, the project did not pass all of EPA's Specification 11 criteria. However, the project did produce beneficial aspects beyond its model development, including some environmentally positive results. The PEMS development led to a better understanding of how to effectively operate the Waste Fuel Incinerator (WFI) to assure emissions compliance, which in turn has led to an overall reduction in emissions and fossil fuel consumption by the facility. Although the principal goal of making a workable and legally enforceable PEMS turned out beyond IP's reach for that emission source at this time, other outcomes were real and positive, and in some cases transferable. Overall, the results confirm that IP's project was an appropriate undertaking for EPA's XL program.

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INTRODUCTION

The purpose of this report is to summarize and document the background, the activities undertaken, and the results stemming from the "International Paper PEMS XL Project Final Project Agreement", dated April 20, 2000.

EPA Project XL guidelines for reporting successful XL projects recommend that reports should:

- Track project commitments;
- Account for measurement of superior environmental performance;
- Report on stakeholder involvement;
- Account for costs and cost savings resulting from the project; and
- Be transferable to other facilities

This report speaks to each of these.

Because of its size and nature, the WFI PEMS project had diverse and interesting aspects, which are captured by this summary. Since many of these sections could merit their own reports, they are presented as stand alone pieces that do not necessarily flow from one to another. Sections I through IV present background information pertinent to the project, including introductions to PEMS, EPA Project XL, IP's Androscoggin Mill operations and the company's environmental approach. Section V describes IP's successful "A" Lime Kiln PEMS project, which was a precursor to this project. Sections VI and VII describe IP's WFI and explain why it was chosen as the subject of this study. Sections VIII through XI describe the actual WFI PEMS validation study, its participants, and how the experimental process unfolded. Finally, sections XII and XIII present project results and conclusions.

Appendix A to the report contains additional tables that detail the testing runs that were taken for this experiment.

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I. WHAT IS A PREDICTIVE EMISSIONS MONITORING SYSTEM (PEMS)?

Predictive emissions monitoring systems (PEMS) technology has evolved only in the past 10 to 15 years from the "black-box" model concepts of earlier systems modeling, which generally used multi-variant, nonlinear regression analyses. A PEMS is a computer black box model in the sense that all the process relationships are not clearly defined – input goes into the computer model and the model somehow measures an output (a prediction). Traditional black box models were built by measuring as many outcomes as possible (the more the better) that were associated with changes in just a few "key" variables (the less the better). But PEMS are created from a generally more organized and sophisticated process. The model builders and users better understand the variables that populate a PEMS and how the modeled processes function within it. While some of the relationships and functions remain ambiguous, model designers know much more about what is inside a PEMS "black box" and how it works internally.

A PEMS features what is called "inferential sensor technology" that is based on a high order non-linear mathematical model using an advanced artificial neural network to predict emissions from process operating data. Also referred to as "adaptive modeling", the PEMS is designed to integrate contemporary technologies such as neural networks, fuzzy logic and chaos systems theory into a software package that has the ability to model nonlinear processes. As such, it is well suited to modeling the typical processes that generate air pollution.

> <u>Neural networks</u> are computer systems composed of a number of simple, highly interconnected processing elements, somewhat similar to neurons in the brain. Neural networks are a powerful set of mathematical techniques that can "learn" from data and are more capable of analyzing complex situations than traditional programs that simply execute commands. Neural networks "learn" complex, non-linear processes directly from historical data and so they are adaptable to non-linear problems, with data that cannot be adapted to smooth regression models. Once

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trained, the neural networks can model the process and predict outputs based on process behavior.

Fuzzy logic is a branch of math based on the idea that traditional “true/false” logic cannot always deal with exceptions. Essentially “fuzzy rules” replace deterministic precision with intuitive logic. Fuzzy logic is very useful in tracking and characterizing relationships among variables and outcomes and expressing the outcomes of exceptional, irregular or even random occurrences in relative quantities.

Chaos Theory addresses how irregularities, e.g., in process behavior, evolve over time. In the real world many chemical and thermodynamic processes simply defy predictions that are arranged using traditional math. Modelers can use chaos theory to model and predict process operations and outcomes where there can be random process behavior[1].

In a PEMS, then, advanced computer programming with the above components is used to: model the emissions processes; apply intuitive operating constraints; and keep the modeling process on track in the face of unpredictable process behavior.

During the preparation stages the software PEMS must be “trained” using historic operating and emissions data from continuous emission monitors (CEMS) or other testing results under an appropriate range of operating conditions. Once trained to model the operation, the system is able to use real time operating data from plant instruments and the system to predict outcomes that would otherwise have to be measured directly.

The obvious primary value of the PEMS is that it can predict values for process outcomes where no physical sensors exist. It may be used, for example, to continuously predict air emissions on a, real-time basis where emissions cannot practically be measured continuously.

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Development of the PEMS also can lead to creation of a "sensor validation model" that can detect the failure of critical process sensors and maintain the accuracy of PEMS predictions by using the data from the remaining array of sensors. This allows for continuous predictions even when some sensors may malfunction. When a given sensor malfunctions, inferential sensors can predict the measurement anyway, based on the input from other sensors to the system.

Because the model is derived from targeted testing of the relationships among the important process variables, the act of model building itself can lead to a better understanding of the system and the basis for predicted values. The PEMS technology also enables subroutines in modeling air emission processes that identify optimal operational parameter settings to achieve lowest emissions rates. They also lend insight into which process variables have the largest impact (sensitivity analysis). Eventually experimenters can determine which sensors are the most critical to correct emissions predictions. A PEM system can identify the most important operating parameters as well as more accurately determine the ranges that affect emission rates.

Although not "hard-wired" to emission output measurements like a CEMS or a stack test, a PEMS uses the process inputs (from "hard-wired" process/parameter monitors) to predict excess emission events. The PEMS enables operators to avoid or mitigate some excess emission events before they even happen. Through a sensitivity analysis, the PEMS can identify the key parameters. The PEMS specifically predicts emission rates and the mathematical relationships between the operational parameters and emission rates so that quantitative relationships are developed in the model and priorities for action can be established. Because a PEMS models the range of process variables and establishes mathematical relationships among them, it can generate feedback about which variables may be manipulated to avoid or mitigate particular predicted excess emission events.

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[1] Collins and Terhune "A Model Solution for Tracking Pollution" Chemical Engineering, June, 1994

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In summary a PEMS can be used to:

- Identify the most significant operating variables that impact emissions.
- Accurately predict emission rates on a continuous basis.
- Provide immediate notification of potential exceedances.
- Numerically correlate operating parameters to emission rates.
- Identify optimal operating conditions to achieve lowest possible emission rates while maintaining efficient production.
- Identify remedial actions to mitigate real or potential excess emission events.

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II. EPA's PROJECT XL

Project XL, which stands for "e**X**cellence and **L**eadership," is a national EPA program. EPA designed the program to encourage state and local governments, businesses and federal facilities to develop with the EPA, innovative strategies that search for and test better or more cost-effective ways to protect or improve the environment and safeguard public health. The EPA initiated Project XL in March 1995 to promote innovative initiatives that improve environmental performance at reduced cost.

EPA's Office of Policy, Economics and Innovation coordinates Project XL. Any environmental project that requires some flexibility in environmental regulations or procedures can be designed and initiated as an XL application by project sponsors. EPA personnel in conjunction with state agencies review each proposed project for inclusion into Project XL. If EPA approves the project, the project sponsor is afforded the appropriate regulatory flexibility on an experimental basis, conditional on demonstration of expected greater environmental benefits. For example, EPA may issue regulatory, program, policy, or procedural flexibilities to conduct an experiment that would likely lead to superior environmental results. EPA applies eight Project XL selection criteria:

1. Does the proposal produce superior environmental results beyond those that would have been achieved under current and reasonably anticipated regulations or policies;
2. Does the proposal produce benefits such as cost savings, paperwork reduction, regulatory flexibility or other types of flexibility that serve as an incentive to both project sponsors and regulators;
3. Is the proposal supported by stakeholders;
4. Does the proposal achieve innovation/pollution prevention;
5. Does the proposal produce lessons or data that are transferable to other facilities;

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6. Has the sponsor demonstrated that the proposal is feasible;
7. Does the proposal establish accountability through agreed upon methods of monitoring, reporting, and evaluations; and
8. Does the proposal avoid shifting the risk burden, i.e., it should not create environmental problems in other media, or shift the problems to other segments of the population.

XL projects are real world tests of innovative strategies designed to achieve cleaner and cheaper environmental results than conventional regulations, programs, policies, and procedures would achieve. EPA’s XL goal is to engage those parties affected by environmental regulations and policies in an unprecedented effort to find solutions that work better than those currently mandated, and to apply what is learned more broadly to public health and environmental protection fields.

While XL is a federal program, most projects rely upon the participation (and in some cases joint management) of other government agencies. Individual projects may be jointly managed by the units of government best suited to address the issues of the project.

EPA also requires stakeholder involvement in all XL projects. EPA’s guidelines encourage sponsors to develop project proposals with full and meaningful participation of local governments, environmental groups, and citizens’ organizations.

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III. THE INTERNATIONAL PAPER COMPANY ANDROSCOGGIN MILL

The Androscoggin Mill is located in Jay, Maine adjacent to the Androscoggin River. Jay is in west-central Maine, near the foothills of the Appalachian Range. It is approximately 40 miles west of Augusta, Maine and 35 miles north of Lewiston, Maine. The mill, built by IP in the early 1960's, is an integrated kraft pulp and paper mill that operates 24 hours a day, 365 days a year. The fully operating mill employs more than 1,000 workers and produces over 1,000 tons per day of specialty coated and uncoated papers.

The Androscoggin Mill consists of two kraft pulp mills operating side-by-side, termed "A" and "B" pulp mills. IP also operates a ground wood facility. The kraft process is an elaborate pulp-making process designed to maximize recycling of the chemicals that are used to produce pulp. In the pulp mills, hardwood or softwood chips are fed into two continuous digesters that cook the wood in a chemical solution of sodium and sulfur compounds called white liquor to dissolve lignin from the wood fibers. Washers separate the wood fibers from the spent (used) cooking liquor. The pulp is pumped from the brown stock washer and injected with oxygen, caustic and steam. After mixing, the pulp enters the reactor or vessel, gas separator, reaction tower, and then the washer system. From the washer, the pulp is sent back to the primary screen chest.

The separated pulp fibers are moved to the bleach plant where the pulp is treated by contact in a chlorine dioxide mixture to further aid in the removal of the lignin that colors and holds the fibers together. Washers then filter the fibers out of this solution, and the fibers pass on to a caustic and peroxide solution that extracts the remaining lignin. Washers then filter the fibers from this solution. The fibers are then further treated in a chlorine dioxide solution to whiten. Washers filter this solution and the fibers, called bleached stock, are then ready for use.

The pulp generated by this process is sent to the paper production area where there are five on-site paper machines. In the paper production area, the bleached pulp is dried on

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the paper machines or in the flash dryer. Additional pulp can be sent via pipeline to Otis Specialty Paper, Inc., also located in Jay approximately three miles south of the IP mill.

Chemicals in the spent cooking liquor (black liquor) are recovered first by evaporating much of its water content. This process concentrates the organic lignin cooked out of the wood chips as well as the inorganic chemicals. This concentrated black liquor is then burned in two recovery boilers where the organics provide the fuel to produce steam and the inorganic chemicals, primarily sodium and sulfur compounds, form smelt which flows out of the bottom of the boiler into the smelt dissolving tank to form green liquor, the beginnings of the new cooking liquor.

The green liquor is then sent to the causticizing/lime kiln area where reclaimed chemicals are further processed to form white liquor, which is the new cooking liquor used in the digesters. Lime (CaO) is used in the causticizing process to convert the recovered, but inactive sodium compounds, into active compounds. Almost all of the cooking liquors are recovered and reused in this process. The spent lime (lime mud) is washed to remove the remaining alkaline material and sent to the lime kilns where the $CaCO_3$ is reclaimed and the recovered lime (CaO) is recycled back into the process. Carbon dioxide, CO_2, is driven off as a byproduct of this process, but is reclaimed as a raw material by Specialty Minerals Inc. which uses the CO_2 to produce Precipitated Calcium Carbonate (which SMI sells back to IP and others as a paper additive),

The limekiln filtrate, called weak wash, is used as make-up flow to the system. Lime mud is regenerated to quicklime in the limekiln and then combining the regenerated quicklime with green liquor, weak wash, or water in the lime slaker makes the new lime solution. Lime that cannot be regenerated is either disposed in the landfill as slaker grit or becomes a component of IP’s “ashcrete” which is produced out of a beneficial reuse project to fill inactive portions of IP’s secondary treatment lagoon.

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In December 1999, Androscoggin Energy LLC (now Calpine) commenced operation of its combined cycle turbine generation facility. Heat recovery steam generators on the back end of their natural gas-fired turbines provide 900-pound and 160-pound steam to the Androscoggin Mill's power plant. In turn, IP's power plant provides demineralized water and condensate to the AEC plant for feed-water and boiler operations. The provision of AEC steam to IP's main steam header system allows IP to place its two oil-fired power boilers in a standby condition, thereby reducing emissions, especially sulfur dioxide (SO_2) and particulate matter (PM).

In addition to the recovery boilers, oil-fired power boilers, and lime kilns, IP operates a biomass/sludge boiler ("waste fuel incinerator" or "WFI"). The WFI provides heat energy (steam) for paper making processes. The WFI burns a variety of fuels, in various combinations to produce up to 317,000 lbs/hr of steam at 900 psig, which reflects a maximum heat input rate of 480 mmBtu/hr.

In 1996, IP installed a collector system and regenerative thermal oxidizer (RTO) to gather and thermally destroy volatile organic compounds (VOCs) and hazardous air pollutants (HAPS) from mill processes. The RTO operates with 99% destruction efficiency. This system collects and controls VOC emissions from the mill's Oxygen Delignification (OD) system and other high-volume low-concentration (HVLC) and non-combustible gas (NCG) sources. The RTO system is equipped with a packed tower-type wet scrubber system to remove SO_2 created as the NCG gases are destroyed.

In total, IP operates five major types of emission sources:

- Waste/Wood Fuel Incinerator
- Power Boilers 1 & 2 (which are generally on stand-by)
- Lime Kilns 1 & 2
- Recovery Boilers 1 & 2
- Smelt Tanks 1 & 2
- Regenerative Thermal Oxidizer

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Actual and currently licensed particulate and sulfur dioxide emissions from IP sources are as described in Table 1.

Table 1. International Paper Company Emissions

Source	Licensed Allowable SO_2 (lb/hr)	Actual SO_2 Emissions (lb/hr)	Licensed Allowable PM (lb/hr)	Actual PM Emissions (lb/hr)
Power Boilers*	2,185	2,020	267	145
Recovery Boilers #1 and #2	806	48.8	133	37.5
Lime Kiln #1	7	0.09	25.5	9.8
Lime Kiln #2	7	0.09	25	12
Smelt Tanks #1 and #2	6.6	----	25.4	----
RTO	2.02	----	1.0	----
Waste Fuel Incinerator	197	10.5	48.8	45.5
Total	3,210	2,080	526	250

*Power boilers are generally on standby since January 2000 when AELLC (now Calpine) gas-fired cogeneration project came on line. Actual Emissions data are from 1999.

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IV. IP'S ENVIRONMENTAL APPROACH

Over time, IP has developed an integrated approach to environmental compliance and improvement. IP's environmental management activities address all affected media and extend to all operations throughout the mill. IP's story of environmental stewardship is a very good one, but as is often the case, it is a difficult story to tell because of the range and diversity of factors and incentives that have led to success.

Over the years the IP Androscoggin Mill has responded to significant scrutiny relating to its environmental footprint from all levels (federal, state and local). In the late 1980's the residents of the Town of Jay enacted a local environmental ordinance, which regulated air emissions, wastewater discharges and solid waste disposal under home rule laws. In addition to meeting state and federal environmental permitting and reporting requirements, IP had to integrate those requirements with those of a similar local permitting, compliance and enforcement program, which is not the norm for most pulp and paper mills.

During the same time that IP adjusted to local environmental scrutiny, IP was also subject to significant enforcement action by the federal government (EPA) relating to toxics and hazardous waste handling and reporting irregularities. IP also had to meet the terms of a significant consent agreement with the State of Maine relating to the operation of its waste fuel incinerator and landfill operations.

IP responded to these compliance and enforcement challenges in a positive fashion. Over time, IP developed an effective environmental protection program and a mill-wide commitment to remain in compliance with all federal state and local environmental laws. It developed and still maintains a competent and responsive environmental department. Mill leaders approach environmental concerns cooperatively and directly, in a manner responsive to the regulatory agencies. IP's transactions with the state, federal and local environmental regulators have evolved from the predominant command and control

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scenarios to more cooperative endeavors. Collective problem solving, brainstorming, working together to research problems and assembling multi-level teams to address issues and tackle projects are now mainstream activities at IP. While the underlying regulations and permits remain and IP works hard to be a model of baseline compliance, IP and its environmental regulators have also learned how to move beyond the baselines and have carried out many beyond-compliance approaches.

For example, in the early 1990's IP and the local regulators developed a team approach in preparation for the upcoming EPA Maximum Available Control Technology (MACT) rules for the pulp and paper industry. By mid-1996 IP, working with the Town and Maine Department of Environmental Protection (ME DEP), had developed and installed the HVLC collection system and RTO to capture and treat its significant high-volume-low concentration (HVLC) gases. IP moved this project to completion even though there were delays in the development and final implementation deadlines of the EPA standards. This project was completed well ahead of the other Maine pulp and paper mills (and years ahead of what eventually became the regulatory deadline of 2006) because it stemmed from cooperation and a commitment by IP to take its environmental stewardship beyond the regulatory minimums.

IP continues to foster proactive and cooperative environmental approaches. It has twice participated in the EPA "Star Track" program and is currently participating in the "Performance Track" program. In these programs, IP has opened its doors to comprehensive environmental audits and self-audits observed by regulators. In the past eight years, IP has received numerous awards for environmental leadership. IP now possesses eight Governor's awards for pollution prevention projects.

Throughout the 1990s, IP and environmental regulators worked hard to develop a better way of keeping tabs on environmental performance. The Town of Jay, from early in its regulatory days, had expressed frustration with the reliance upon singular annual or semiannual stack tests to demonstrate compliance with important emissions limits,

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especially particulate matter (PM) limits. The town, through its environmental ordinance, challenged IP and the other local sources to find better ways to constantly assure that environmental compliance could be met, even for emissions and discharges that could not be monitored continuously. The Androscoggin Mill was the first Jay facility to implement an "assured compliance plan" for all its emission sources. IP's plan became the norm followed by all the regulated facilities in Jay. IP's assured compliance program sets requirements for plant operators to monitor and respond to routine process measurements of operational conditions in ways that help assure emission or discharge limits will not be exceeded.

Particulate emissions represent the largest remaining challenge to IP's ability (and the ability of many other sources in the nation) to monitor emissions continuously. Recent studies have found that increased concentrations of PM, a criteria pollutant, may lead to increased adverse health effects including cardio-pulmonary disorders. Because of these studies, EPA proposed more stringent ambient air quality standards for PM in 1997, and there has been increased public awareness of PM and its sources. Although particulates are generated in great quantities by IP and many other facilities, there are yet no proven Continuous Emission Monitors (CEMS) for particulates at a facility with saturated (high-moisture) stacks. The existing indirect monitors such as continuous opacity monitors (COMS) do not reliably correlate with PM emissions, especially under high moisture conditions. Regulators and the public are thus left to rely on singular stack tests conducted once every year or more as the sole demonstration of compliance with particulate emission limits, even by the major sources.

Since the early 1990's, the Town of Jay, as well as other regulators, urged IP and others to get a more reliable handle on particulate emissions and based on the meetings and projects that took place, all had sought earnestly for a means to do that. With the development of PEMS technologies in the early 1990s came a hopeful alternative for effective and continuous monitoring of particulate emissions. As the technology

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advanced, IP, DEP, EPA Region 1 and the Town of Jay collectively jumped at the opportunity. In 1997, they collaborated on IP's B Lime Kiln PEMS Project.

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V. THE LIME KILN PEMS PROJECT

In 1997 the State of Maine, EPA Region 1 and the Town of Jay participated in IP's project to develop a predictive emissions monitoring system for IP's B Lime Kiln. Lime kilns are a significant source of PM emissions and a PEMS that could be used to continuously "monitor" the creation of PM emissions would be valuable in helping control them.

From August 18 to September 13, 1997, IP conducted a designed experiment at the "B" Lime Kiln to assess operating variables and develop a PEMS with neural models that would predict kiln response variables. PM was the primary response variable in the Lime Kiln stack. PM levels throughout the experiment were measured using a new method called Modified Method 5, which was an abbreviation of the full EPA Method 5 calibrated to Full Method 5 measurements at this source. The Modified Method 5 tests allowed IP to run more tests to build the PEMS than it would have been able to afford using full method 5 tests.

IP used the data from these experiments to develop a PEMS for the prediction of PM emissions. After the designed experiment, the Town of Jay, with funding from EPA Region 1, conducted validation trials of the PEMS in December 1997. The Town compared results of the Method 5 stack tests it conducted to concurrent PEMS predictions from the neural models using a Relative Accuracy Testing Audit (RATA) procedure that measured the agreement of the uncorrected model predictions and Method 5 observations. EPA specifies the RATA criteria for predictive emissions monitoring systems, which is discussed in detail elsewhere in this report. The B Lime Kiln PEMS passed that round of RATA testing.

In a document dated April 8, 1998, IP reported its "CEM Calibration" results for PM at the B Lime Kiln. It identified three models that failed the RATA but had passed the corresponding CEM calibration, which implies they were relatively precise, but

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inaccurate (in this context, precision means the ability to match the values repeatedly and accuracy means the ability to match values exactly). During June and July 1998, the town performed a second round of data verification testing under several different process conditions in order to represent and bracket the normal operating ranges. This reference method program was successfully completed and the particulate models showed sufficient agreement with reference methods. Moreover, IP used data collected during the initial 1997 and 1998 tests to "train" the neural models to further improve accuracy and precision.

Since the B Lime Kiln PEMS system passed EPA specification criteria, IP incorporated it into the B Lime Kiln operations as a compliance monitoring system for the Town of Jay. It is now integrated into IP's mill-wide electronic collective information management infrastructure, known as the "PI System". The PI system acquires, processes and routes data from the various sources throughout the mill. With the PI System, the local kiln operators can access real-time information from the PEMS and determine corrective actions as needed when excess emission conditions may occur.

The B Lime Kiln PEMS was a success and is used by IP today. It offers continuous assurance that the conditions that cause excess particulate emissions from that source remain in check. Development of this PEMS and the associated testing have also allowed IP to optimize lime production, reduce PM emissions and reduce fuel consumption.

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VI. WHY IP INVESTIGATED A PEMS FOR ITS WASTE FUEL INCINERATOR

The Androscoggin Mill has operated within emission limits and permit conditions over the past decade with few exceptions. Nevertheless, air quality regulators and members of the affected community have continued to seek direct or indirect ways to be assured more regularly of acceptable particulate emissions than through annual stack tests. The local regulators wanted to have more continuous assurance that IP's emissions are below levels that could harm residents.

Probably more than anything else, the success of the Lime Kiln PEMS project affected IP's decision to propose a WFI PEMS. IP knew that the Town of , and perhaps others, were looking for continuing progress in regularly demonstrating compliance. The technological success of the B Lime Kiln PEMS offered a viable option to controlling other large particulate sources in the mill. Among the few sources at the mill that may have benefited from a similar PEMS process, the WFI, which creates approximately 10% of total PM emissions from the mill, was the most logical choice:

- One large source of particulates, the A lime kiln, had just undergone significant operational improvements to its pollution controls (mainly the A lime kiln scrubber). As a result, the unit was operating well below particulate emission limits and was not a needy candidate for a PEMS.

- IP's largest particulate source, the combined power boilers, were about to be supplanted and placed on standby with installation of the new Androscoggin Energy LLC gas-fired cogeneration plant.

- IP's recovery boilers, another large source of particulates, were not considered a good candidate for the next PEMS project because they presented different and more complex operational challenges. The

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processes, technology and operating constraints inherent to the recovery boilers would have made a PEMS project for those sources more complex, unwieldy and unpredictable than one for any other sources including the WFI.

- Currently approved emission monitoring methods do not include continuous monitoring for PM emissions in a wet (high-moisture) stack. Steam and the corrosive nature of the WFI stack emissions make other types of existing monitors, such as opacity monitors and continuous emission monitors (CEMs) generally prohibitive. While CEMS for SO_2 and nitrous oxides (NO_x) do operate at the WFI there are no federally approved continuous monitors for PM under such conditions. Consequently, IP's compliance demonstration of particulate emissions limits for the WFI relies solely on stack tests. The federal, state and local agencies require annual testing.

- The WFI is permitted at a maximum 317-klbs/hr steaming, but prior to 1998, the maximum steaming rate that could be achieved from bark was 250-klbs/hr. Based on past stack tests IP had experienced difficulty meeting PM limits from the WFI, even at 250-klbs/hr of steam load. In prior stack tests emissions were all near the limits.

- IP had determined that there are differences in amounts of bark that can be fed to the boiler depending on the species of wood. Hardwood bark has a higher heating value so it would take about 300 more tons of softwood bark to generate the same thermal output as a typical mixture of hardwood and softwood. IP needed a better handle on managing the mix of bark fuels for optimum boiler efficiency.

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- To date, PEMS had been developed and implemented elsewhere in the country for simple stack and emission conditions such as for gas-fired boilers, but had very limited application for complex, saturated stacks such as those for biomass incinerators with wet scrubbers. Although the WFI presented complexities that were not associated with the lime kiln PEMS, the mill operators had developed a substantial amount of information and expertise about the factors affecting WFI operations and emissions. IP had developed a compliance assurance action plan that identified important operational variables to monitor and manipulate in order to minimize potential excess emission events. IP's boiler operators had already identified many key operational parameters, such as temperature, oil firing rate and scrubber pressure drop. All of these could be better analyzed and managed through a more systematic approach as would happen with development of a WFI PEMS.

- For years IP had been investigating ways to use more mill waste products in the WFI, turning them into energy instead of disposing them in its landfill. Development of a better compliance assurance tool like the WFI PEMS would lead to greater use of non-petroleum fuels (i.e., bark, sludge and wood waste products) for boiler steam production and help reduce amounts of waste going into IP's landfill.

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VII. CHARACTERISTICS OF THE WFI

IP's waste fuel incinerator ("WFI") was manufactured by Babcock & Wilcox and constructed in 1975. The boiler has a design capacity of 480-mmBTU/hr-heat input and 317,000 lb steam per hour at 900 psig, firing a combination of fuels including biomass and oil. The boiler is limited to a capacity of 240-mmBTU/hr-heat input from the firing of oil. Biomass available for burning in the WFI may include sludge, wood waste (bark), knots and screenings, cotton roll residue, waste papers and other appropriate industrial waste products. Oil available for burning in the WFI includes No. 6 fuel oil, specification used oil, and off-specification used oil, each with a maximum sulfur content of 1.8% by weight.

When the WFI was built in 1976, it had only a dust collector (no scrubber). Over time the steam load demand on the WFI increased. EPA discovered that IP had increased its use of oil in the WFI in order to increase steam generation and had exceeded WFI emission limits. Consequently, EPA decreased the PM limits of the WFI, which made it even harder for IP to meet steaming needs. This was followed by a long legal battle that culminated in a consent order requiring IP to install a scrubber at the WFI and to abide by special operating, monitoring and reporting requirements.

Regulated pollutants emitted from the WFI are particulate matter (PM and PM_{10}), sulfur dioxide (SO_2), nitrous oxides (NOx), carbon monoxide (CO) and volatile organic compounds (VOCs) (See Table 2). WFI emissions are vented to a single stack. Before burning, dewatered sludge from the wastewater treatment plant is dried in a sludge dryer using waste heat from the WFI exhaust gases. The variable venturi scrubber and demister control all particulate emissions from the dryer and the WFI. They include a water spray in the demister. The venturi scrubber is operated at a pressure differential, across the throat, of at least 20 inches of water. IP controls scrubber media pH by adjusting levels of weak white liquor and/or a caustic solution. In addition to controlling particulate emissions, the wet scrubber absorbs some of the gaseous pollutants such as

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sulfur dioxide, nitrogen oxides and carbon monoxide. Also, the WFI is equipped with a combustion system designed to ensure the optimal balance between the control of NOx and the limitation of CO and VOCs.

Permitted WFI emission limits and current emission levels are presented in the table below:

Table 2. Androscoggin Mill WFI Emissions

Pollutant	**Emission Limits**			**Average Current Emissions (lb/hr)**	**Maximum Observed Emissions (lb/hr)**
	lb per mmBTU	**lb/hr**	**TPY**		
PM	0.1	48	210.2	41.7	46.5
SO_2	0.8	196.8	862	10.5	133
NOx	0.4	179.2	784.9	106	149
CO	n/a	1,200	5,256	116	116
VOC	n/a	140.2	614.1	n/a	n/a

Additional permit limits:

- No more than 40 percent opacity for more than 12 minutes in any 3-hour block period from the WFI stack.
- No more than a total heat input rate of 480 mmBTU/hr on a 24-hour block average basis demonstrated by a steam production limit of 317,000 lb/hr at 900 psig.
- A heat input rate of no more than 240 mmBTU/hr from the firing of No. 6 fuel oil or specification used oil.

The Town of Jay Air Emission Permit requires IP to perform annual stack tests for the WFI in accordance with the procedures in 40 CFR Part 60 for all limited pollutants except NOx, VOC and SO_2 (VOC emissions from this source are well below emission limits and NOx, and SO_2 emissions are monitored by CEMS).

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Process Variables that affect WFI emissions

Factors that affect combustion efficiency of the WFI also affect particulate matter generation and steaming rates. The combustion efficiency of the WFI is generally governed by heating values and moisture contents of fuels, fuel feed rates, fuel/air ratios and atmospheric conditions. Overall thermal efficiency also depends on temperature rise (delta T) of the cooling water available for steam production, the amount of solid accumulation in the tube banks and the pressure drop (delta P) that fans generate and must overcome in the furnace.

The outlet gas temperature and wet fuel moisture content determines the equilibrium moisture content of the fuel that can be achieved by the rotary dryer. It also determines the consistency of the dried fuel and amount of particulates that are carried by the dryer outlet gas. The separation efficiency of the cyclones, which remove solids and some particulates from the gas stream, is affected by the temperature, moisture content and particulate load of the dryer outlet gas, all of which combine to determine the particulate load entering the scrubber.

Scrubber (pollution control) efficiency is affected by the flow rate and solids load of the incoming flue gas, and relative feed rates of the recycled scrubber water to the gas conditioner and the venturi. It is also affected by the raw water make-up rate, the scrubber water pH and the scrubber water purge rate to the sewer.

WFI Normal Operating Conditions are described in the table below:

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Table 3. WFI Operating Conditions

Condition	**Description**	**Normal Range**
Scrubber dP	Differential pressure of inflow/exhaust gases through the scrubber	20-21 inches
Scrubber flow (venturi)	Flow of scrubber media	1000 gpm
Gas conditioner flow	Flow through the gas conditioner section immediately before the venturi scrubber.	500 gpm
Recycle drain	Flow of scrubbing media to recycle	250 gpm
Recycle pump pressure	Scrubbing media recycling	35 lbs
Recycle solids	Percentage of solids recycled through the scrubbing media	2%
Caustic	Added to adjust media pH	0 gpm
Scrubber pH	Scrubber media pH	5-7
Raw water	Make up water to scrubber media	400 gpm
Total steam flow	Total steam output from WFI	275,000 lbs
Bark steam	Steam attributed to bark burning	200-245 x 1000 lbs
Sludge presses	# of presses indirectly measure sludge to WFI	8
Paper pellets	Pellets to WFI from pelletizer operations	In
Oil flow	Flow of oil fuel to the WFI	4 gpm
Knots and screens	Amount of knots and screens burned in WFI	0
#1 Oil Burner	Use of the #1 oil burner	1
Sludge solids	Percent solids (vs. gas and moisture) in sludge	37%
Undergrate burner air	Air flow to undergrate burner	180 lb/hr
Burner tips	Size of burner tips used	Large
Furnace draft	Negative draft pressure	-3
Wind box pressure	Pressure of combustion air for all oil burners	TBD
Tempering air temperature	Air from the FD fan of the boiler that bypasses the air heater to cool the undergrate air to protect the grates from overheating.	450 °
Over fire air pressure	Air flowing to over-air system	Tbd
Oil burner air	Air to oil burners	Tbd
East grate speed	Moveable grates speed settings	2
West grate speed	Moveable grates speed settings	2
Super heater temperature	Temperature of steam heaters	800° F
Primary super heater temperature	Temperature of steam heaters	640° F
% valve open - super heater water	The amount of feed water injected in the superheater to control steam temperature out of the boiler.	15%
Super heater generator gas temp	Temperature of the boiler combustion gases exiting the superheater section	650° F
Boiler outlet temperature	Temperature of gases exiting the boiler	500° F
Primary temperature out	Temperature of steam exiting the primary superheater section.	300° F

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Table 3. WFI Operating Conditions

Condition	**Description**	**Normal Range**
Soot blowers	Periodically blowers are run to remove accumulated soot in the boiler	On/off
Bark surge bin level	Amount of bark cued for delivery to WFI	30%
Fluke O_2	Variations in oxygen levels to the boiler	TBD
Oil pressure	Fuel oil feed pressure	40-50 psi
Bark dryer • Damper • Temperature in • Cyclone differential • Temperature out	Conditions of the bark dryer operations affect fuel efficiency.	 Open 500° F 2.2 - 4” 225° F
Bark through dryer	How much of fuel load is utilizing the pre-dryer	80-100%
Boiler O_2	Percent oxygen to boiler affects burning efficiency and emissions	2-4%
Screw speed	Speed setting of fuel delivery system	4-6.5

Many of these characteristics are actually monitored and recorded for operational purposes by IP. Some are required to be monitored by permits while others are monitored voluntarily.

Table 4. Androscoggin Mill Parameter Monitoring Techniques

	Monitor			**Record**		
Parameter	**Required**	**Actual**	**Method**	**Required**	**Actual**	**Method**
WFI Flue Gas dp	continuous	continuous	Strip Chart	n/a	once/4-hours	operator logsheet
WFI scrubber fluid flow rate	continuous	continuous	Strip Chart Mill VAX	n/a	once/4-hours	operator logsheet
WFI scrubber fluid pressure	continuous	continuous	Strip Chart	n/a	once/4-hours	operator logsheet
WFI fuel flow rate	continuous	continuous	Strip Chart Mill VAX	n/a	once/4-hours	operator logsheet
WFI total biomass feed rate	continuous	continuous	Mill VAX	n/a	once/4-hours	operator logsheet
WFI total steam production	continuous	continuous	Diskette Mill VAX	n/a	once/4-hours	operator logsheet
WFI scrubber media solids	n/a	n/a		once/ 24-hours	once/4-hours	operator logsheet

These monitoring programs provide information that can be reviewed and compared over time to enhance emission predictions and the development and testing of PEMS.

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VIII. OBJECTIVES OF THE PEMS PROJECT

The primary objective of the WFI PEMS project was to provide assurance of acceptable levels of emissions on a continuous basis. Previous emissions testing had shown increased WFI emission levels and suggested that emission levels could exceed emission limits during the normal ranges of operations. While CEMS for SO_2 and NO_X, are currently in place at WFI, there are no federally approved methods for continuously monitoring particulate matter from saturated stacks. Thus, one of the primary objectives of this project was to determine whether the PEMS technology can be used to provide continuous information corresponding to PM emissions from a complex, saturated stack. Such a PEMS would allow operators to predict PM emission levels and stay within emission limits.

IP wanted to develop the PEMS to also predict NO_X and SO_2 emissions and, if possible, CO_2 and CO. If the WFI PEMS was successful in meeting the criteria set forth in the Final Project Agreement, IP hoped it would be able to use the PEMS, instead of its current CEMS for NO_X and SO_2 monitoring. That would have been both economically and operationally more effective for IP. As part of its XL application, IP proposed that if the project were successful, the ME DEP would submit, and the EPA would approve, a State Implementation Plan (SIP) amendment that would allow PEMS to become the approved continuous monitoring method for all of the modeled WFI emissions.

IP wanted to develop a PEMS that could also predict, and help optimize steaming rates. Steaming rate is a measure of the steam produced by the WFI and is important because it is the primary measure of production for the WFI. A PEMS that addressed the steaming rate could make it easier for IP to maintain a maximum stable steaming rate at optimum bark, sludge and oil consumption rates, thus maximizing production while minimizing emission rates.

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The PEMS technology would also allow IP to optimize stack emissions and production rates by developing a linkage between emission and production rates and the operating parameters that affect them. By identifying continuous emission levels and key operating parameters the PEMS would provide instant compliance information, allowing mill operators to proactively prevent potential non-compliance situations and stay within permitted limits. If the PEMS were effective, corrective actions could be triggered before an exceedance occurred and potential violations could be avoided. This type of proactive compliance is not possible using traditional CEMS systems and stack tests; CEMS measure emissions after the release and stack tests measure emissions only under the specific conditions that occur during the testing of the release.

As part of this project, IP also made a voluntary commitment to reduce overall emissions from the WFI. IP proposed to maintain all emissions from the WFI at or below 90% of its license limits, once the PEMS were operational and formal validation was completed.

Finally, IP and the project partners thought that, if successful, the PEMS technology might be transferable to other air emission sources in the IP mill and elsewhere, especially sources with high moisture stacks.

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IX. SPECIAL IMPLEMENTATION CONSTRAINTS

Project Complexity

Although the B Lime Kiln Project had proven successful, and had met the EPA specification for accuracy, the WFI PEMS partners were aware at the onset that the WFI posed unique challenges and that it's success would not be automatic. PEMS had been developed at IP and elsewhere for simple stacks with singular fuel sources such as gas fired boilers, but had only limited application at complex saturated stacks from sources with a variety of combustion fuels as in the WFI.

Dynamic Mill Operations

Operational conditions at an integrated pulp and paper mill change frequently. These facilities are constantly changing, tweaking and improving their processes as individual production units operate to maintain or improve profitability. In such an environment, even important research is adapted to ongoing operations and designed to hamper production as little as possible. Because of this, the company will implement production and efficiency improvements during the course of an ongoing study; including improvements that may have stemmed from that study.

IP made operational changes to the process during the WFI PEMS project. Some required experimental modification of the PEMS project and all had to be accounted for in evaluating the results of the PEMS testing.

1. WFI Sludge and Bark Burning Trial

Just prior to the PEMS project IP conducted a trial to burn sludge at controlled rates in the WFI in order to complete an energy and material balance at the boiler. IP's trial objectives were: to determine if the material handling system was

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capable of getting all the sludge to the boiler; to determine the ability of the WFI to burn all the WWTP sludge; and to determine the impacts of sludge burning on the bark burning process, on steaming capacity and on compliance with permit limits.

IP tested two burning conditions: a) all dewatered sludge combined from the primary and secondary clarifiers; and b) only dewatered primary sludge. These were done to hopefully improve fuel combinations and in so doing, to serve several mill-wide objectives, e.g., to lessen capital expenditures, to eliminate sludge going to the IP landfill and to maintain or improve performance of IP's wastewater treatment facility. Based on the successful conclusion of these trials, sludge fuel use became a variable that was incorporated into the PEMS as it developed.

2. Over-Fire Air

In 1998, just prior to the PEMS model development, IP began replacing the generating section tubes and modifying the air distribution system of the WFI to reduce system pluggage. This project included the "in-kind" replacement of approximately 620 generating tubes.

Then, in 2000, based largely on information gained during the PEMS development, IP installed a new over-fire air system in the WFI boiler. This system includes 8 new air nozzles, supplied by the boiler forced draft fan, that convert air pressure into a high velocity air stream that penetrates the boiler firebox. The air completes the burning of gasses formed by bark combustion on the grates, which decreases the amount of air needed under the grates to burn the bark, and completes combustion of particles that could become airborne. This new system did not increase the total amount of air introduced into the boiler, but instead redistributed the air for more efficient bark burning. As a result, the

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temperature in the lower part of the boiler increased so that it burns bark more efficiently.

While the project did not increase the capacity of the WFI, the modifications substantially improved the performance of the boiler by providing air flow over the grates, enhanced combustion in the boiler as well as the use of combustion controls and significantly enhanced steaming rates. This is an example of the facility making modifications to operations during the PEMS experiment. A further discussion of its impact is in the “Conclusions” section of this report.

Regulatory Flexibility

To adequately develop the PEMS model, IP had to be able to test conditions where variables would be set beyond values that could exceed license emission limits during model development, validation and calibration. This was necessary to ensure that the PEMS could, in fact, predict an exceedance because the PEMS technology is designed to interpolate within the tested range of conditions; the model does not make extrapolative predictions. If development of the PEMS did not include operating conditions associated with emission exceedances, the model would have no way of identifying such exceedances later during its operational application.

Since IP’s emissions are subject to state, federal and local regulations, IP requested flexibility from each of the three regulators to allow it to exceed WFI emission limits on a short-term basis so that it could fully develop, test and calibrate the PEMS technology. These scheduled short-term exceedances were critical so that IP could confirm the PEMS’ ability to identify license exceedances. After the ME DEP performed extensive air modeling to assure that the testing would not likely impact ambient air quality standards, the regulators agreed to allow regulatory flexibility for the purposes of this project under the following Testing Agreement conditions:

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- The regulatory flexibility applied only to WFI emissions;
- All testing would have to be conducted in accordance with IP's approved Test Plan;
- Any exceedances subject to regulatory flexibility may only occur during model development, validation and calibration;
- IP agreed to limit testing exceedances to periods when climactic conditions were favorable, and to reduce emissions from other sources during the tests;
- IP agreed for any testing to not violate National Ambient Air Quality Standards;
- The testing agreement would expire in thirty months unless extended by agreement of the parties; and
- Any signatory (IP, Town, DEP or EPA) may terminate the testing agreement at any time.

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X. THE WFI PEMS PARTNERSHIP

To follow EPA's XL guidelines, IP enlisted the participation of a wide variety of stakeholders for the project. But the key partnerships (IP, the Town of Jay, ME DEP and EPA Region 1) very much preceded the XL process. They were seasoned and familiar partners by the time the WFI PEMS project was conceived, having collaborated on the lime kiln PEMS project, two separate EPA Star Track audits and many other less visible environmental initiatives at the mill. IP's decision to prepare this XL proposal was made in consultation with these partners and the project moved forward with IP's confidence in their participation.

As with the lime kiln PEMS project, the supporting partners played an integral role in the WFI PEMS project development, review of data and model validation work. For example, the ME DEP, using ambient air modeling procedures, investigated IP's need to test WFI conditions that would represent emission exceedances and prepared a report entitled "Short Term SO_2 and PM_{10} Impact Assessments in the Jay, Maine Area". The DEP report presented dispersion modeling (ISCTS and RTDM) for sources in the Jay area in order to predict whether short-term emission exceedances necessary to develop the model would cause any violations of ambient air quality standards (AAQS). DEP's analysis showed that all 3-hour, 24-hour SO_2 and 24-hour PM impacts in all areas would remain below Maine AAQS (which is more stringent than National AAQS), even though the WFI would be among the larger contributors to any combined SO_2 impacts. They also showed how the WFI was a small contributor to PM impacts at critical local receptors and that, if necessary, other sources at the mill could be manipulated during the testing to make sure no AAQS violations would occur. That report opened the way to the regulatory flexibility agreement discussed in the previous section.

To complement the collaborative efforts by the project partners, and to carry out the EPA guidelines, IP also assembled a larger formal group of project stakeholders from a variety

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of affected groups and organizations. Stakeholders invited to participate in the project included the Commissioner of ME DEP, the ME DEP Air Bureau, members of the Town of Jay Planning Board, the Town of Jay Selectmen, the Town of Jay Code Enforcement Officer, the Penobscot Indian Nation, the Franklin County Soil and Water district, the Maine Lung Association, Environment Northeast, the Alliance for Environmental Innovation, the Western Mountain Alliance, the Jay High School Science Club, the Maine Pulp and Paper Association, the National Council on Air and Stream Improvement, various emission monitor manufacturers, and members of the American Forest and Paper Association.

The company, with EPA’s guidance, hosted facilitated stakeholder meetings to familiarize the stakeholders with the technical aspects of the project and to solicit input throughout the course of the project. A number of these stakeholders joined IP and the agency partners to form a project technical review team. That team became the direct participant stakeholder group available to review project plans, interim results and issues as they arose.

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XI. THE WFI PEMS EXPERIMENTAL PROCESS

The XL Application and Objectives

IP submitted a Project XL application for the WFI PEMS Project in 1998. The project Partners signed an accompanying XL project, dated April 20, 2000, to develop, test and implement a computer-generated PEMS for the Waste Fuel Incinerator (WFI) at IP. The main objective of the project was to develop an innovative technology and protocol (similar to a compliance assurance plan) using the real-time output of specially designed Predictive Emissions Monitoring System (PEMS) to assure continual compliance with emission limits. By achieving this project IP would be able to:

a. Correlate WFI operating parameters to emission rates and predict pollutant emissions on a continuous basis.
b. Monitor WFI emission-related operations at a frequency that would exceed the current compliance testing frequency.
c. Identify the operating parameters of the system, such as air flow rates, moisture content of feed-stocks, inlet temperatures, over-fire air temperatures, boiler temperature, feed rates and assess their importance in terms of affecting emissions.
d. Provide tangible compliance guidelines for WFI stack emissions and help optimize production within emissions constraints.

IP planned to design the WFI PEMS, which would employ a computer subroutine to integrate all relevant WFI operating data and emission data and calculate the optimal balance between emissions and steam production. IP saw this project as a possible way to improve operations and to find a more economical way to meet emissions limits.

For purposes of the XL project, IP indicated that it would also use the system and information gained from the project to work toward meeting a 10% reduction in emissions per unit of production based on license levels. IP made a commitment to

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maintain the source below 90% of the license limits and to accept the estimates of the installed PEMS as enforceable limits, if the project was found successful.

As previously stated, IP and the partners also thought the project would potentially reduce reliance on the CEMS, which are expensive to operate and have limited proactive application. As part of the project agreement process, IP requested that, if the necessary demonstrations were met, the State and EPA would amend the State Implementation Plan (SIP) to allow the PEMS to replace the existing SO_2 and NO_X CEMS.

Based on current monitoring requirements and methods, IP projected a number of improvements in its monitoring of emissions from the WFI as shown in Table 5.

Table 5. Monitoring Advantages of PEMS

Emissions	**Current Monitoring Methodology**	**Current Monitoring Frequency**	**Change in Frequency as a Result of PEMS**	**Additional Info Provided by PEMS System**
PM	Annual Stack Testing	4 one-hour tests	Increases to 480,000 data points from 4	Minute-by minute operational and emissions data
NO_x	CEM and RATA	Continuous - end of pipe	Continuous - predictive	Minute-by-minute operational data
SO_2	CEM and RATA	Continuous end of pipe	Continuous - predictive	Minute-by-minute operational data
CO	Stack Test	Annual	Increases from 4 data points to 480,000	Minute-by minute operational and emissions data
CO_2	None **	N/A	Increases from 4 data points to 480,000	Minute-by minute operational and emissions data

The project sponsors expected increased information on environmental emissions, particularly PM emissions, as a primary environmental benefit of this project. By developing a linkage between emission and production rates and the operating parameters that affect them, IP would be able to manage emissions rates and perhaps optimize the relationship between stack emissions and production rates. By identifying CEM levels and key operating parameters, the PEMS would provide instant compliance information, allowing mill operators to proactively prevent potential noncompliance events and to keep the source within limits via avoidance opportunities. A PEMS could prompt the

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operators to trigger corrective actions ahead of potential emission exceedances, thus avoiding violations. This is not possible with either CEMS or with stack tests.

Even if the WFI PEMS ended up failing the validation requirements, the knowledge gained about the system would still be usable by WFI operators and perhaps transferable to other system operations. The sponsors recognized that the project could serve to identify pollution reduction opportunities, even if the PEMS was not successful.

The sponsors also viewed the PEMS project as an opportunity for IP, the regulatory community and other stakeholders to continue to build upon positive working relationships towards even further pollution control and emissions reductions. It offered a possible way for all involved to keep tabs on particulate emissions with a manageable, reliable and more continuous process that would lead to greater assurance to the surrounding community of IP's compliance with emission limits.

In summary, then the proposed PEMS for the WFI would be developed to:

a. Numerically correlate operating parameters to emission rates;
b. Accurately predict emission rates on a continuous basis;
c. Identify optimal operating conditions to achieve decreased emission rates while maintaining efficient production;
d. Provide alarms to give immediate notification of potential exceedances; and
e. Provide continual assurance that emission limits are met by the WFI.

Experimental Considerations

As with most creative projects, building a statistically valid computer model requires a well-planned experimental process. Since a model is essentially a depiction of something in the real world, real-world information about relationships between input variables and outputs has to be placed in the model and the model has to be tested and fine-tuned until it yields a satisfactory result. One reaches a satisfactory result (in terms of the model's

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viability) by demonstrating that it is accurate and precise enough to reliably supplant other procedures or equipment currently used for that purpose.

IP’s experimental design appropriately called for a series of trials which:

- were directed toward a specific goal of building a viable PEMS;
- were planned by people knowledgeable of the process and alternative monitoring procedures;
- included all variables thought to be relevant;
- were sufficient in number so that important effects are detected and trivial variables are eliminated from further consideration; and
- were arranged in a pattern that would yield maximum information per amount of actual testing.

The “experiment” included two parts: experimentation to build the model; and experimentation (i.e., validation) to test whether or not the model works. IP performed the model-building task by building a series of neural nets based on information from the operation of the WFI. Initially, IP used information already known about the variables (and some initial “scouting” test runs) to make the model. Thereafter, IP conducted a rigorous statistical analysis to determine which of the variables actually impact emission rates and, thus, were essential in the final PEMS. Over time, IP intentionally refined (“trained”) the PEMS using the results of the validation testing as it occurred.

The validation phase was simply many sets of test runs representing the full range of operating conditions where emissions were measured using both the PEMS and the accepted contemporary methods. Each individual “experiment” represented simultaneous measurements taken under a single array of the operational variables. Collectively the “predicted” and “actual measurements” from all the experimental conditions were compared statistically to determine whether they were similar enough to assure that the PEMS predictions were really reliable enough to replace current methods.

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Because of the complexity of the WFI processes, the inputs and relationships among the variables, it would have been very expensive for IP to conduct a singular test for each variable while holding all others constant. There were hundreds of variables and literally thousands of permutations under normal operating ranges. Therefore, IP had to design its project in a way that would yield representative relationships for the model and yet not include a test for every conceivable permutation.

IP used a combination of experimental design techniques to manage the large number of variables and potential interrelationships. Some of IP's testing arrays were based on fractional factorial techniques, some were based on partial composites (not all of the variables used for a given test) and IP tested others by manipulating one factor at a time (the "on/off" or "bump" tests).

Fractional factorial design is a way to screen and distribute variables among the fewest possible number of experiments to yield the maximum information. This technique takes into account the interaction and relationships among variables and ends up testing the factor values that represent the range of the multiple factors. When planned carefully, it allows experimental runs to collectively account for multiple variables simultaneously. Metaphorically, it is a way to kill flocks of birds with just a few stones.

Many things can affect how a developmental project such as the WFI PEMS project is carried out. In addition to the kinds of things that generally might affect such a project, the IP PEMS project was necessarily undertaken in a working pulp and paper mill. As the project proceeded, so did steam, pulp and paper making at the mill, and important changes and improvements to the mills operations were carried out at the same time as this project. For example, during this PEMS project, IP implemented the over-fired air project. The over-fire air project was conceived, to a large extent, from the information gained during the design of the PEMS project. It was performed to improve the WFI operations; it may have affected the results of the PEMS validations; and it modified the

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ranges of some significant operating variables; and it probably assisted in reducing emission rates.

Modified Method 5B

Based on its experience with the B-Lime Kiln PEMS, IP chose to develop and use what it called “Modified Method 5B” (an abbreviated version of Modified Method 5) as a substitute for full Method 5 stack testing procedures. Modified Method 5B procedures allowed less costly and time consuming testing of model conditions; allowing IP the ability to test more conditions at a given cost. Major differences between the methods are:

- Modified Method 5B requires a minimum sampling time of 15 minutes rather than 60 minutes for Method 5;
- Each Modified Method 5B test run is done in a single stack traverse port using three representative traverse points, which means less ports are used for drawing the samples and more samples can be taken in the freed ports;
- Preliminary and final filter weights are done on-site for Modified Method 5B whereas with full Method 5, all final weights are done in an off-site facility. However, even with Modified Method 5B, final weights are verified off-site prior to reporting the results.
- Exhaust stream moisture (for the sample) is based on stack temperature for Modified Method 5B, which eliminates impinger recovery required by Modified Method 5 and full Method 5.

IP could not abbreviate all of the Method 5 procedures. IP still used normal Method 5B procedures to determine isokinesis and to do required leak tests before and after each run because no abbreviated procedures were deemed viable. Likewise, due to low sample size, Method 5B still required that the operator analyze the nozzle probe rinse as well as the filter samples, as normally done under Method 5.

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IP performed a series of tests to determine whether Method 5 and Modified Method 5B were comparable for the purpose of testing for PEM development by conducting Method 5B and Modified Method 5B sampling simultaneously from perpendicular ports. After the initial round of sampling, the Modified 5B probe would be removed and the Method 5B probe would be moved to the second port for sampling while a new Modified Method 5B probe would be put in the vacated port for sampling. IP repeated this testing sequence over a range of boiler operational conditions, resulting in over 11 Method 5B tests and over 22 Modified Method 5B tests as part of the study. The results demonstrated that the Modified Method 5B results were consistent enough with the Method 5B results to be an acceptable substitute (R= 0.92 based on reported data).

Experimental Design

IP divided the model development/verification project into four types of experiments:

1. *Dryer/Feed/Boiler experiments* to model the variables and interrelationships associated with the fuels and fuel feeding systems;
2. *Scrubber experiments* to model the variables of associated pollution control operations;
3. *Boiler Operational experiments* to model the physical operations of the boiler production unit; and
4. *Bump (on/off) tests* to model the "independent" operating conditions that either occur or do not occur under most operating and production conditions.

After applying experimental design techniques, the experimental tests were narrowed down as presented in Table 7.

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Table 7. WFI Key Variables

Run Set	**Key Control Variable (to be manipulated)**	**Lowest Range**	**Highest Range**	**Number of Runs**
1.0	**Dryer/Feed/Boiler Experiment**			**19**
	Sludge Feed Rate (# of sludge presses)	0	4 or 8	
	Bark Feed Rate (tph)	20	70	
	Bark Species Mix Hardwood/Softwood	0% H 100%S	40%H 60%S	
	Oil Flow (gpm)	4	15	
	Undergrate Damper (% open)	20	80	
	Oil Burner Damper (% open)	20	80	
	New “Lee” Damper (% open)	20	80	
2.0	**Scrubber Experiment**			**19**
	Gas Conditioner Flow (gpm)	50	150	
	Venturi flow (gpm)	500	1,500	
	Recycle Drain Flow (gpm)	150	350	
	Caustic Add Rate (gpm)	0.5	2	
	Scrubber Pressure Drop (inches)	15	25	
	Burner Tip Size	small	large	
	(Or Oil Flow) (gpm)	(4)	(16)	
3.0	**Boiler Operational Experiment**			**6**
	Small Oil Burner Tip, 275 mmBTU range			
	Bark Feed Rate	20	70	
	Oil Flow (gpm)	1.5	3	
	Large Oil Burner Tip, 300 mmBTU			
	Bark Feed Rate	20	70	
	Oil Flow	4	15	
4.0	**On/Off Tests**			
	Sludge Feed Rate	0	8	1
	ID Fan Speed	0.2	0.7	1
	Caustic Add Rate (if included in experimental design)	0.5	2	1
	Knots and Screenings	Include	None	1
	Soot Blowing (for each of 8 blowers)	On	Off	8
	Bark Dryer Dampers	Open	Shut	1
	Bark Flow Through Dampers	0	100	1
	Total Number of Runs			**64**

These run sets, as carried out, are each detailed in Appendix A. IP performed an additional 5 runs in the Dryer/Feed/Boiler set and, as shown in Table 8, below, a total of 38 (rather than 14) On/OFF (Bump) tests.

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Table 8. WFI* BUMP TESTS	
Test No.	**Action**
3-1	Sawdust OUT
3-2	Reclaim sawdust
3-3	Furnace draft @ .7"
3-4	Knots and screenings IN
3-5 to 3-12**	Soot blower (3.5, 3.6, 3.7, 3.8, 3.9, 3.10, 3.11, 3.12)
3-13	Caustic addition to scrubber - 2 gpm
3-14	Bark dryer OUT
3-15	1.8% S oil @ 4 gpm
3-16	1.8% S oil @ 8 gpm
3-17	Paper OUT
3-18	Maximum steaming @ 1 gpm oil
3-19	Maximum steaming @ 4 gpm oil
3-20	Overfire air 6" duct press
3-21	Overfire air 4" duct press
3-22	Waste oil only
3-23	Burner damper open
3-24	Total soot blow
3-25	Windbox pressure low
3-26	Knots & screenings redo
3-27	High S oil/no bark
3-28	Maximum steaming 1 gal redo
3-29	Caustic redo
3-30	High S oil (225)
3-31	High S oil (235)
3-32	High S fuel and caustic
3-33	8Y nozzles; 8 gpm (2 noz)
3-34	8Y nozzles; 15 gpm (2 noz)
3-35	5Y nozzles; 15 gpm (2 noz)
3-36	5Y nozzles; 8 gpm (2 noz)
3-37	5Y nozzles; 8 gpm (1 noz)
3-38	5Y nozzles; 4 gpm (1 noz)
*All other parameters at NOC. **A different soot blower each test.	

PEMS Test Plan

The complexity of the WFI boiler means that there were a large number of variables to be monitored, evaluated and, if appropriate, incorporated into the PEMS. Parameters that were measured and recorded for each stack test included: a) operational data for IP

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computers (such as fuel oil flow rate, boiler temperature, oxygen feed rate, etc.); b) fuel analysis (bark, fuel oil, wastewater sludge, etc.); and c) meteorological data for each stack test. Initially, IP anticipated that around 50 variables would be used in the development of the PEMS, but that number grew significantly as the project continued.

Model Validation

The first three sets of PEMS validation tests were called the formal validation phase; performed once IP determined that the PEMS was fully functioning. The project team used this formal validation phase to determine whether the PEMS was accurate and could remain accurate once it was running. During the testing, IP measured and recorded primary variables (PM, NOx, SO_2, and steaming rate) and secondary variables (CO and CO_2 among others), while at the same time it measured and recorded process variables. Emissions modeled by IP, and their respective contemporary measurement techniques were:

PM	Modified EPA Method 5B (Stationary Source Procedure)
SO_2	EPA Method 6C (Instrument Analyzer Procedure)
NO_x	EPA Method 7E (Instrument Analyzer Procedure)
CO_2	EPA Method 3A (Instrument Analyzer Procedure)
CO	EPA Method 10(Stationary Source Procedure)
O_2	EPA Method 3A (Instrument Analyzer Procedure)

IP performed the first test as specified in the model specifications (EPA Specification 11, discussed below) using EPA-approved reference methods to determine whether the PEMS accurately predicted emissions for PM, SO2, NOx, CO and CO2. Once IP conducted the sampling, it stored the data electronically and distributed it to databases and then assembled the key control variables in a single large data matrix.

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After IP completed the first test according to the model specifications and using reference methods, IP was able to use alternative monitoring methods in the ensuing testing (such as using Modified Method 5B, CEMS or other methods) to reduce costs while assuring accuracy.

The experimental sequence based on IP's initial plan followed the schedule below:

Table 6 Steps in PEMS Development

Step 1	Sampling and testing for PEMS development	IP runs the WFI under a number of different operating conditions. As an example, all parameters would be set at "normal" conditions and then one parameter would be adjusted to a new setting and, after reaching a steady state condition, emissions would be measured.
Step 2	Data work up	All data sources are collected, made compatible and entered into the computer.
Step 3	Site Specific PEMS model development	The neural network is run to develop the relationships among all operational parameters and emission rates. Once the model is developed, internal (computer) tests are run to assure the model is operating as anticipated.
Step 4	PEMS Installation	Once the model is completed, it is installed at the facility and many of the operating sensors may be "hard-wired" to the computer. The model, wiring, sensors and gauges will be tested by IP to assure all is working properly.
Step 5	PEMS Adjustment/Calibration	Based on internal QA/QCIP will further program and adjust the model. IP may perform an informal relative accuracy test to confirm operation of the "pieces" of the PEMS
Step 6	PEMS Formal Validation #1	Perform formal validation using OAQPS model specifications testing PEMS at high, medium and low emissions rates or high, medium and low operation rates. If the PEMS accurately predicts emissions it will continue to be evaluated. If it does not, IP may choose to do more PEMS development work or may exclude that pollutant from further evaluation.
Step 7	PEMS Formal Validation #2	A model specification test 3 months after validation test #1 using CEMS data to further evaluate PEMS performance.
Step 8	PEMS Formal Validation #3	A model specification test 6 months after validation test #1 using CEMS data to further evaluate PEMS performance.

IP conducted validation testing in three separate phases. In its first phase, IP carried out and analyzed the bulk of model testing runs in the first round in the fall of 2000. IP's second phase included RATA testing conducted in March of 2001. During the third phase, IP conducted a final round of targeted validation testing during the summer of 2001.

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EPA Specification 11.

IP evaluated the accuracy and precision of the PEMS through its three-phased formal validation test, using the Draft Model Specifications developed by the EPA Office of Air Quality, Planning and Standards (OAQPS) (see ***FR Vol. 66, No. 239, 12/12/2001***). Performance Specification 11 is part of a draft EPA document that sets forth the required testing procedures and performance specifications for PEMS and other such techniques that would serve in lieu of continuous emission monitors.

These specifications evaluate the variability between the measured and predicted emissions rates and would have to be applied to all five emission parameters (PM, SO2, NOx, CO2, CO) associated with the WFI and WFI PEMS for the PEMS to become the acceptable monitoring method for these emissions. Specification 11 sets the statistical/RATA validation criteria as follow:

- The correlation coefficient (predicted vs. actual for PEMS) must be greater than 0.85;
- The confidence interval (95%) at the emission limit shall be within ± 20 percent of the emission limit value; and
- The tolerance interval at the emission limit shall have 95% confidence that 75% of all possible values are within ± 35 percent of the emission limit value.

Under the specification, the relative accuracy of the PEMS measured against EPA-approved Method measurements, must be at least 80 percent of the mean value of the reference method test data in terms of units of the emission standard or 10 percent of the applicable emissions standard, whichever is greater. For emissions below ¼ of the applicable emission standard, the specification requires that 20 percent of the standard must be used.

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XII. PROJECT RESULTS

The PEMS project provided results in two important areas. First, it provided actual results of the statistical validation analysis of the model performance. Second, and perhaps as important as the first, it provided a number of collateral findings that will lead to long-term operational benefits. Both sets of findings are discussed below.

The Statistical Pass/Fail Results

IP performed validation tests in the fall 2000, March 2001 and July/August 2001, using the pass/fail criteria as set forth in EPA's Specification 11. The WFI PEMS did not pass the Specification 11 criteria in any of these testing phases even though the validation calculations were promising enough throughout to justify successive testing. The results described in detail below show that the PEMS failed the Specification 11 *correlation* criteria in the fall 2000 and March 2001 testing. IP retrained the PEMS to incorporate the fall 2000 and spring 2001 results prior to the July/August testing, (which because of the prior results was limited to only PM emissions testing). The July/August 2001 PEMS testing passed the correlation coefficient criterion but did not pass other statistical criteria of Specification 11.

Fall 2000 Testing

As shown in Chart 1 and its accompanying table, the fall 2000 experiments, based on full Method 5 tests, yielded particulate matter (PM) mass emission (lb/hr) predictions by the PEMS that had a positive correlation with reference method results. However, that correlation (R= 0.67) was not strong enough to meet the Specification 11 criterion (R=0.85).

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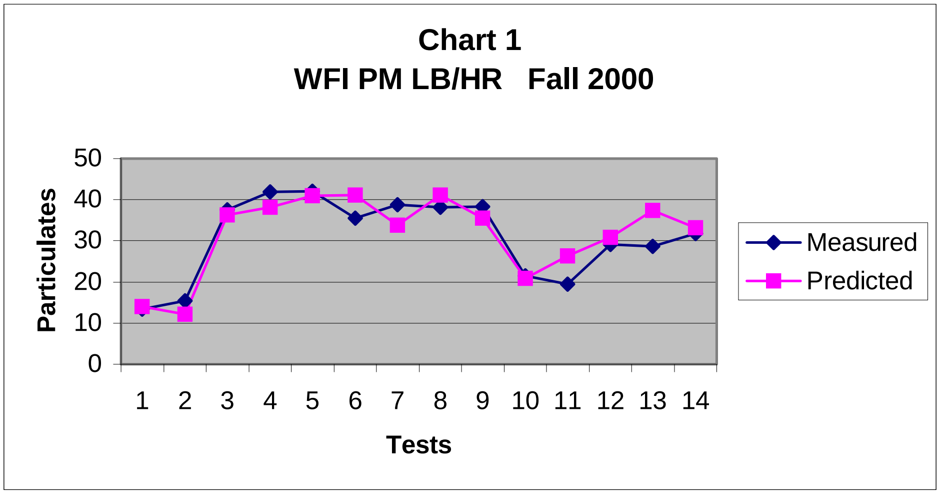
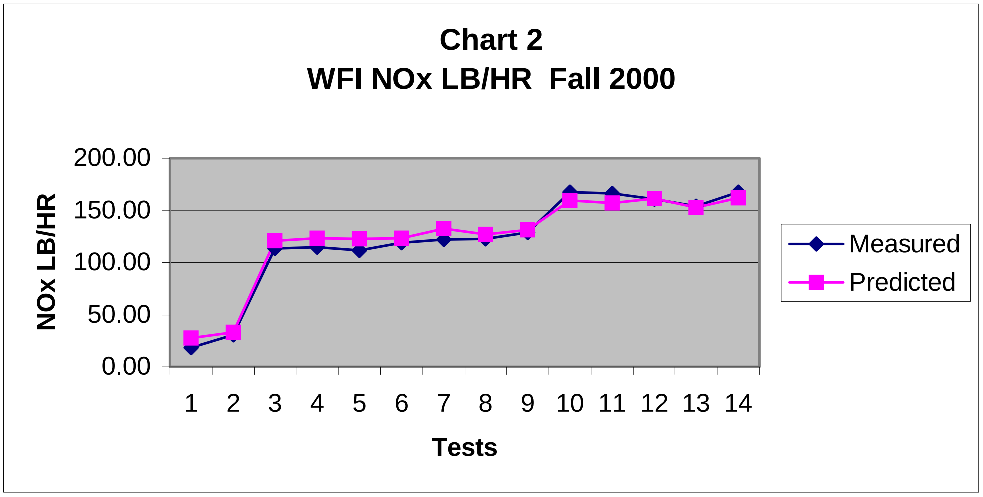


Performance Measure	Training Matrix	Testing Matrix	*Specification 11*	*Result*
Model R Square (PM)	0.67	0.67	*0.85*	*Fail*
95% Confidence Intervals for PM	± 16.9	± 17.2	*± 20%*	*Pass*

The fall 2000 experiments also yielded NO_x RATA comparisons, as shown in Chart 2 and its table that showed very promising results; nearly passing the Specification 11 criteria:



Performance Measure	Training Matrix	Testing Matrix	*Specification 11*	*Result*
Model R Square (NO_x)	0.86	0.83	*0.85*	*Fail*
95% Confidence Intervals for NO_x	± 17.9	± 18.7	*± 20%*	*Pass*

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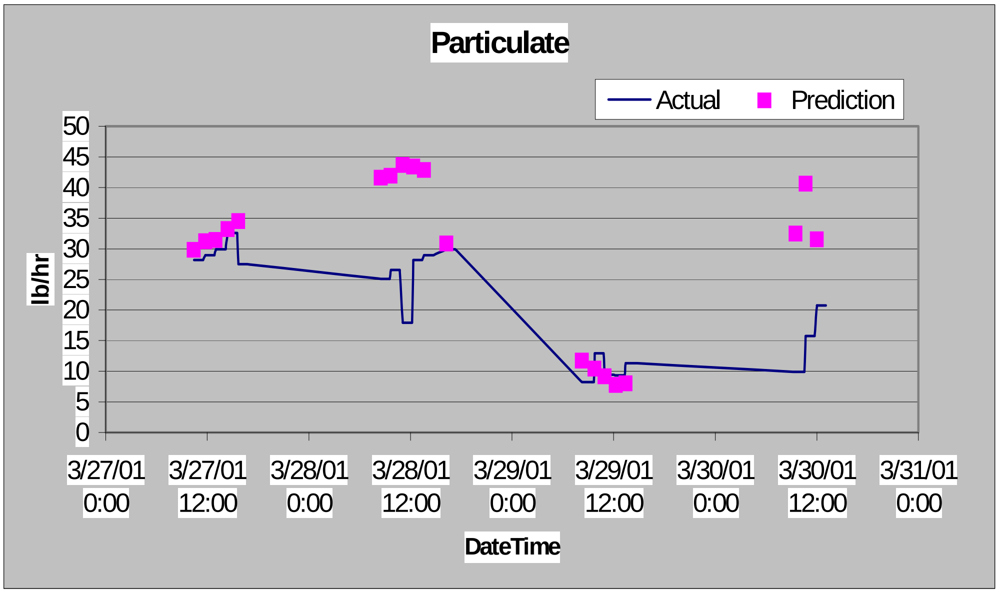
RATA analyses of CO and SO_2 results were not reported for the fall 2000 testing.

Spring 2001 Testing

The March 2001 RATA produced actual measurements and predicted PEMS measurements with weaker correlations for PM and very weak correlations for NO_x and CO. SO_2 was not initially analyzed and based on results of the NO_x and CO RATA, comparisons for SO_2 were not reported. The correlation coefficient PEMS predicted vs. actual particulate emissions in the March RATA was approximately 0.76. Particulate emissions results are shown in the Chart 3 below.

Chart 3: WFI Particulates; March 2001



Performance Measure	Training Matrix	*Specification 11*	*Result*
Model R Square (NO_x)	0.76	*0.85*	*Fail*

As shown in Chart 4 and Chart 5 below, actual and predicted NO_x and CO levels showed poor correlations in the March 2001 RATA. Specification 11 statistics were not provided for the NO_x , CO or SO_2 test results because the PM RATA did not pass and, as shown in the Charts 4 and 5, the actual and predicted data for NO_x and CO were clearly not well

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correlated. Again, SO_2 RATA were not reported for this testing although raw SO_2 data were recorded.

Chart 4. March 2001 Testing for NO_x

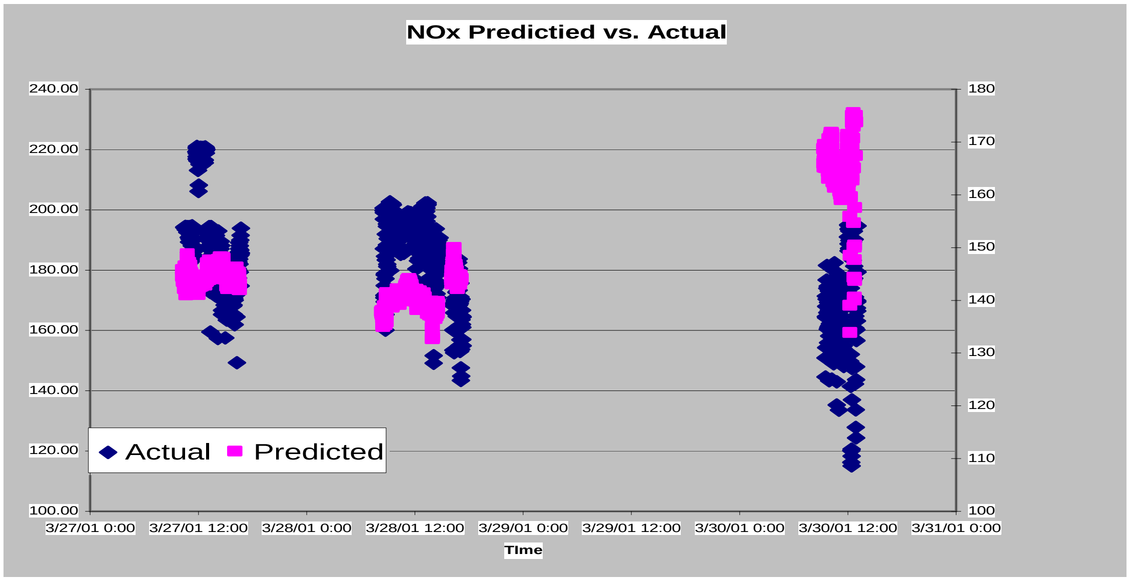
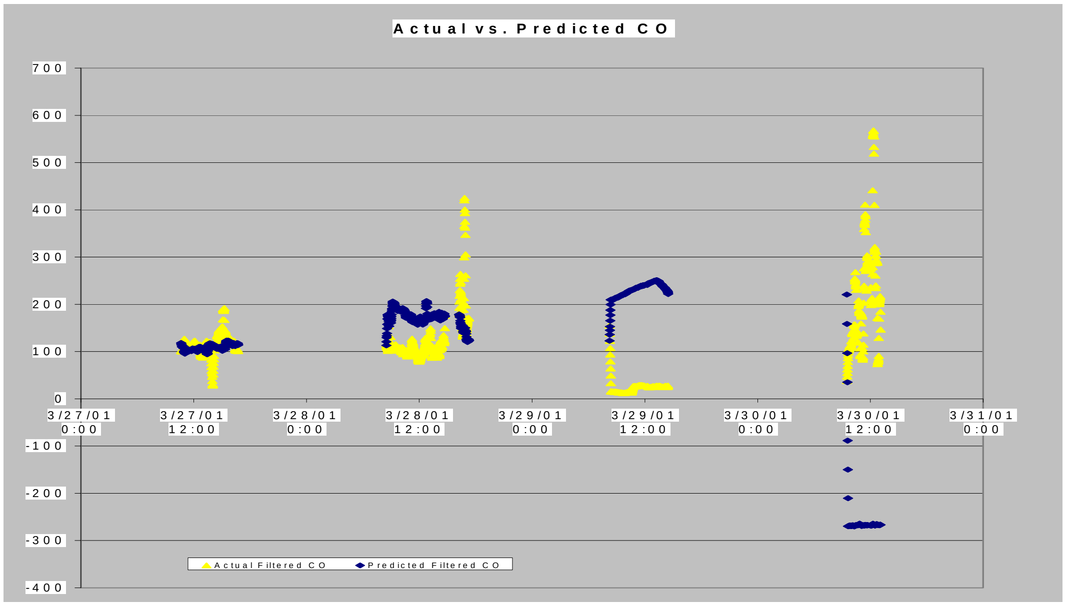


Chart 5. March 2001 Testing for CO.



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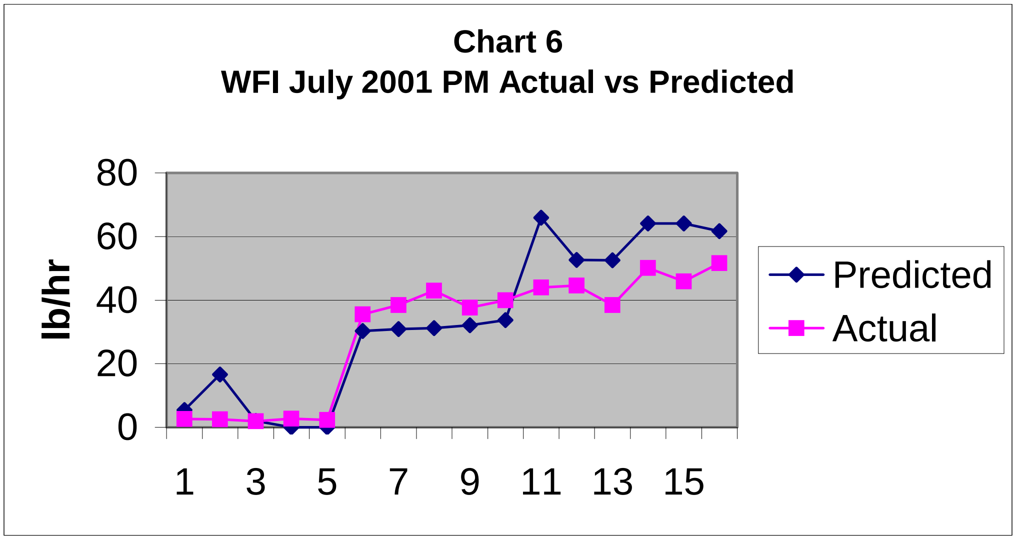
July/August 2001 Testing

The July and August 2001 experiment provided a test of the PEMS predictions for particulate matter as had been further trained from the previous data. As shown in the Chart 6 below and its corresponding table, the correlation between the actual vs. predicted PM emissions was itself strong enough to meet Specification 11. However, the PEMS again did not pass the Specification's relative accuracy requirements.



Performance Measure (PM July 01)	Test Result	*Specification 11*	*Result*
Model R Square	0.94	*0.85*	*Pass*
95% Confidence Intervals for NO_x	±11.43	*± 20%*	*Pass*
Relative Accuracy (% of Reference Method)	26.67	*≤ 20%*	*Fail*
Relative Accuracy (% of Standard)	16.97	*≤ 10%*	*Fail*

Sensitivity of Variables

From the data gained through the WFI PEMS experiments, IP was able to determine relative sensitivities among key WFI operational variables, which means that the variables could be compared according to their effects on emissions. IP boiler operators can use this information to focus upon the most effective variables when they must

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respond to emission increases and take actions to avoid excess emission events. Table 13 presents a quantification of the sensitivities in order from the highest to lowest average absolute sensitivity of the key variables. The three most important variables identified by the study are: *Scrubber differential*, which is a measure of the exhaust gas pressure coming into the scrubber minus the pressure leaving the scrubber (and indirectly measures scrubber effectiveness); *total steam production*, which is a measure of boiler output; and *excess* O_2 *in the boiler*, which is a measure of combustion efficiency.

Table 13. Sensitivity of WFI Variables

Variable	**Ave Absolute Sensitivity**	**Average Sensitivity**	**Peak Sensitivity**
Scrubber Differential	0.17182	+0.17182	+0.26012
Total Steam (mmpph)	0.09715	+0.09623	+0.12578
Excess O2 in boiler	0.09112	+0.07148	+0.15576
Windbox Pressure	0.09027	-0.09027	+0.15792
Surge Bin Level	0.06796	-0.06385	+0.14695
Gas Conditioner	0.06643	-0.06572	+0.10647
West Grate Speed	0.06597	-0.06597	+0.08864
O2 from Flue	0.06304	-0.05466	+0.10439
East Grate Speed	0.05938	-0.05938	+0.10783
Bark Flow (tph)	0.05745	-0.05275	+.0.11215
Venturi Feed Flow	0.05261	+0.01075	+0.08077
Oil Flow (gpm)	0.05206	+0.04383	+0.11755
Number of Burners	0.04155	-0.00507	+0.10081
Bark Steam (mmpph)	0.02319	+0.00712	+0.04236

Optimal Operating Ranges

From the results of the PEMS testing, IP was also able to refine its understanding of the ranges that reflect optimum operating conditions of key variables. Table 14 shows the ranges found for each parameter that will generate the least particulate matter at high steaming rates. These will be valuable to IP in optimizing their operations and minimizing emissions.

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Table 14. Optimum Parameter Ranges

Parameter	**Range**
Dryer IN/Out	In
Dryer Outlet Temperature	250 to 300
Burner Tip	S5 Type
pH control	< 6.5
SW	Out
Waste Oil	Out
Secondary Sludge	>9
Screw Control	High as Possible
Sludge Solids	High as Possible
Dog House	High as Possible
Bark Quality	45
Steam Temp	High as Possible
Total Air Flow	High as Possible
FD Fan Pressure	High as Possible
Recycle Air Flow	High as Possible
Total WFI Sludge	Low as Possible
Drum Level	High as Possible

As opposed to how the WFI was previously operated, based on these new ranges, IP has made several significant changes in operating conditions to improve efficiency and reduce emissions. These include changes that allow more wood bark to be used as a fuel source and thus decrease IP's fuel oil consumption. They also include revisions to IP's assured compliance approach as discussed in the next section.

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XIII. CONCLUSIONS

The IP WFI PEMS experiment did not pass the Specification 11 criteria for the PM predictions nor would it pass these criteria for the other pollutants (CO, NO_x and SO_2) based on the reported results. The experiment is now formally complete based on straight evaluation of the testing data. For the time being, IP will continue to rely on stack testing for PM and upon the existing NO_x and SO_2 CEMS to demonstrate compliance with emission limits.

There may be a number of reasons why the WFI PEMS was not as successful in meeting the Specification 11 criteria as the IP lime kiln PEMS. However, there is general agreement among the project partners that it probably had most to do with the complexity of the WFI operations and the large number of associated variables. There may simply have been too many variables affecting the experiment that were either not well known or were not properly placed in the experimental design.

For example, IP ended up with 38 separate “bump” tests, which suggests that quite a few variables might have appropriately been blended into a more elaborate factorial design. Then again, so many variables in the factorial design could have made the design too unwieldy. Having such a complicated system also suggests, and the test results seem to show, that there still may be a significant variable or variables that are not yet modeled. Even with the expertise and experimentation brought to bear on the development of this project, the sense of the review team now is that there still is a “lurking” undefined variable out there that directly affects emissions.

The fact that some of correlations for PM and NO_x were promising and that PM predictions did meet Specification 11 correlation criteria after the model had been trained would hold some promise for further development of a PEMS for PM, but much more work would be involved to make and further test a viable PEMS for NO_x, CO and SO_2

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emissions. The project technical review team estimates that significant additional time and money would have to be expended by IP to further isolate variables and even more would be needed to conduct a fresh set of tests with revised factorial design that would appropriately incorporate more of the bump test variables.

On the positive side, the PEMS project produced substantial insight and information about the management of the WFI. This knowledge has led to better overall management of the system. Although the PEMS did not pass Specification 11 criteria, its development produced a thorough and systematic study of the workings of the WFI that will be invaluable to boiler operators and environmental regulators for years to come.

IP and the partners now have a better understanding of how the WFI works and which variables affect emission levels. IP boiler operators now have greater ability to fine-tune the WFI operations and emission controls. They now know more about which variables to manipulate in order to correct or avoid adverse conditions. By knowing what the key variables are and which ones will have an effect on performance and emissions, IP's pollution prevention opportunities are enhanced. As a result of the PEMS project IP operators have assigned appropriate operational ranges to major parameters that affect particulate emissions.   IP will, no doubt, be able to approach future emission-related and other operational challenges with less conjecture and head scratching.

The WFI PEMS provided a clearer understanding into which variables are important and which are not and which could yield the best emissions when manipulated. IP has already used the PEMS insight to positively affect emissions. Based on the PEMS testing, IP determined more accurate ranges for certain operating parameters that were core components of its assured compliance plan. IP was able to update that plan so that better responses will be achieved to parameter ranges in the future. These improvements included changes to:

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- The compliance range for scrubber media flow rate (total of venturi and conditioner flow) was changed from > 1300 gpm to >1,400 gpm using combined fuels and >1,100 gpm with oil burning only and no bark.

- The compliance range for scrubber dP was changed from > 20 inches in all cases to > 20 inches for combined fuels and > 6 inches for fossil fuels only.

- The compliance range for Stack O_2 concentrations was changed from 1.5% to a range of 4 to 11% for combined fuels and 15% burning fossil fuels only.

- The response actions for out-of-range SO_2 emissions was changed to require maintenance of scrubber flows at > 1400 gpm and maintaining scrubber pH at >5.

- The response actions for out-of-range NO_x emissions were modified to adjust stack instead of boiler O_2 by changing air flow; these include maintenance of total steam flow at < 300 thousand pounds; maintenance of oil flow at < 17 gpm and maintaining boiler O_2 levels between 1.5% - 6.0% (combination fuels) or > 6% (oil only).

- IP created a new set of new compliance range and response actions using the ID fan amps and/or venturi damper conditions.

The insight and knowledge gained from the project has translated into direct emission reductions whether or not the PEMS will ever be operational. IP's operators have stated that CEMS read-outs have already demonstrated that 24-hour NO_x lb/hr emission rates have stabilized (less variations around the norm) under normal operations and that there

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have been reductions in both the 30-day and 24-hour /mmBTU levels since the PEMS project was completed. The knowledge gained about the system has allowed IP to further address the relatively high NO_x levels that occur when high levels of secondary sludge are used as fuel and currently IP is evaluating ways to modify system operations under those conditions to assure reduced NO_x emissions.

Prior to the PEMS project, particulate emissions were stack-tested at 45.5 lb/hr. After the project and the associated optimization work, particulates tested under the same production conditions at 35.5 lb/hr - a reduction of 16%. This is significant, since particulate levels used to always test very close to the limit.

The PEMS project was also a catalyst for IP's over-fire air project, which has led to significant economic and environmental enhancements. Prior to development of the over-fire air, emission levels were above the limits under higher steaming rates, so IP could only use bark-generated steam within the range of 180 to 130 klbs/hr and even then it was close to the PM limits. IP is now able to generate 260 to 290 klbs/hr of bark-generated steam without even approaching emission limits. The company has increased its steam production capabilities by over 40 % with no discernable impacts on emissions (at the same time NO_x emissions have remained well below the 0.4 lb/mmBTU limit). This newfound ability to keep emission levels down at the higher steaming rates represents a substantial cost savings to IP (in the neighborhood of 15% fuel cost) over alternative sources of steam production. IP now uses less fossil fuel to make up its steaming needs.

PEMS use, testing and optimization allowed better utilization of waste residuals for fuel, thereby reducing the requirement for supplemental fuel. The ability to reach the higher steaming rates using bark and other residual fuels means less use of oil to make steam. An available waste product (wood bark) that would have been landfilled is used as a fuel in place of fuel oil. Thus the WFI fuel oil feed rate has been reduced by almost 75% through replacement with a cheaper and renewable fuel source.

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As part of this project, IP tested the use of its knots and screens, a pulp mill waste product, as a WFI fuel. The results show that burning the knots and screens yields more particulates (due to higher concentrations of sodium and calcium compared to other fuels, probably from the black liquor that permeates them). Nevertheless, IP still wants to find ways to further control emissions from knots and screens so they can use them as a WFI fuel rather than a landfill waste. IP may even consider an additional testing protocol supplemental to this project to evaluate ways to further modify the knots and screens to get more acceptable emissions. The insight already gained will help in that regard.

Partnership/Cooperative Benefits

From the knowledge gained through the PEMS project, IP has been able to supplement and improve its WFI compliance assurance activities. That gives environmental regulators and stakeholders a higher level of confidence that WFI emissions will be minimized by IP.

Also, although the WFI PEMS project turned out to be a “no-go” in meeting the model verification criteria, one important legacy of this project remains; an era of continued communication and cooperation among IP, environmental regulators and the stakeholders. Collaboration was not a new activity for some of the participants. But, others learned first hand, that a sincere manufacturing company with a huge environmental footprint is capable of garnering positive and productive collaborative projects with its neighbors that will protect and improve the environment.

Transferability

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As stated, the project led to some significant insights and benefits and although the PEMS itself did not meet the Specification 11 criteria, the experiment was in many ways successful. The WFI PEMS approach led to some successful and rewarding techniques/outcomes that may be transferable to similar facilities or projects:

- A study design based on a bottom-up approach that used intimate knowledge of the facility operators, engineers and others to design the PEMS and the validation tests. This not only lent more expertise to the model development and testing, but also encouraged the people who run the boiler equipment to participate as partners with managers and regulators in efforts to improve their operations;

- An analytical approach that went beyond the required statistical pass/fail tests to evaluate sensitivities of the variables, thus leading to better knowledge of the system and ways to affect its performance and emissions output;

- Use of the testing data to adjust in-line compliance assurance approaches so that operators and others are assured that the system parameters are kept within appropriate ranges to prevent excess emission events; and

- The cooperative participation model, which broadened understanding of the facility and the company’s operations as well as the application of PEMS and other pollution control techniques, among an array of stakeholders.

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APPENDIX A

Run sets for WFI Variables

Based on fractional factorial and other design considerations, IP implemented the following run sets in the fall 2000 validation tests and spring 2001 RATA tests.

Tables A-1 through A-4, ***identify the testing runs conducted in the fall 2000 testing:***

Table A-1. WFI EXPERIMENT 1: Fuel Feed Conditions

Run No.	**Sludge Presses**	**SWD Bark**	**HWD Bark**	**Oil (gpm)**
1	4	In	Out	8
2	0	In	Out	13
3	0	In	Out	3
4	8	In	Out	3
5	8	In	Out	13
6	4	In	Out	15
7	4	In	Out	1
8	4	In	Out	8
9	4	In	In	8
10	8	In	In	13
11	8	In	In	3
12	0	In	In	3
13	0	In	In	13
14	4	In	In	15
15	4	In	In	1
16	4	In	In	8
17	4	Out	In	8
18	0	Out	In	13
19	0	Out	In	3
20	8	Out	In	13
21	8	Out	In	3
22	4	Out	In	15
23	4	Out	In	1
24	4	Out	In	8

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Table A-2. WFI EXPERIMENT 2: Scrubber Conditions

Test No.	Gas Condition Flow (gpm)	Venturi Flow (gpm)	Recycle Flow (gpm)	Scrubber Dp (inches)	Oil Flow (gpm)
2-1	300	1,000	250	20	9.5
2-2	500	500	150	25	13.0
2-3	100	1,500	350	25	4.0
2-4	100	500	350	25	13.0
2-5	500	500	350	15	13.0
2-6	100	1,500	150	15	4.0
2-7	500	500	350	25	4.0
2-8	100	1,500	350	15	13.0
2-9	100	500	150	25	4.0
2-10	300	1,000	250	20	9.5
2-11	100	500	150	15	13.0
2-12	500	1,500	150	15	13.0
2-13	100	1,500	150	25	13.0
2-14	500	1,500	350	15	4.0
2-15	500	1,500	150	25	4.0
2-16	500	500	150	15	4.0
2-17	500	1,500	350	25	13.0
2-18	100	500	350	15	4.0
2-19	300	1,000	250	20	9.5

Table A-3. WFI* BUMP TESTS

Test No.	Action
3-1	Sawdust OUT
3-2	Reclaim sawdust
3-3	Furnace draft @ .7"
3-4	Knots and screenings IN
3-5 to 3-12**	Soot blower (3.5, 3.6, 3.7, 3.8, 3.9, 3.10, 3.11, 3.12)
3-13	Caustic addition to scrubber - 2 gpm
3-14	Bark dryer OUT
3-15	1.8% S oil @ 4 gpm
3-16	1.8% S oil @ 8 gpm
3-17	Paper OUT

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Table A-3. WFI* BUMP TESTS	
Test No.	**Action**
3-18	Maximum steaming @ 1 gpm oil
3-19	Maximum steaming @ 4 gpm oil
3-20	Over-fire air 6" duct press
3-21	Over-fire air 4" duct press
3-22	Waste oil only
3-23	Burner damper open
3-24	Total soot blow
3-25	Windbox pressure low
3-26	Knots & screenings redo
3-27	High S oil/no bark
3-28	Maximum steaming 1 gal redo
3-29	Caustic redo
3-30	High S oil (225)
3-31	High S oil (235)
3-32	High S fuel and caustic
3-33	8Y nozzles; 8 gpm (2 noz)
3-34	8Y nozzles; 15 gpm (2 noz)
3-35	5Y nozzles; 15 gpm (2 noz)
3-36	5Y nozzles; 8 gpm (2 noz)
3-37	5Y nozzles; 8 gpm (1 noz)
3-38	5Y nozzles; 4 gpm (1 noz)
*All other parameters at NOC. **A different soot blower each test.	

Table A-4. PEMS Normal Operating Condition Tests	
Test No.	**Action**
NOC-1 through NOC 12	Normal operating conditions

Table A-5, below, identifies the RATA testing runs conducted in the March 2001 testing

Table A-5. WFI PEMS RATA TESTS	
Test No.	**Action**
r-1	8Y nozzles waste oil only
r-2	5Y nozzles waste oil only
r-3 to r-6	Bark dryer out, NOC otherwise
r-7 to r-9	NOC
r-10 to 12	1gpm oil flow, max bark steaming
r-13	3 gpm oil, max steaming
r-14	8 gal oil, max steaming, reduced scrubber flow
r-15	8 gal , max steaming, normal scrubber flow

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