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October 29, 2004

Mr. David Lloyd,
Environmental Scientist
Air Enforcement Section
U.S. Environmental Protection Agency, Region IV
61 Forsyth Street, S.E.
Atlanta, Georgia 30303

Via FedEx
Airbill No. 7913 7471 2030

Re: **Tampa Electric Company**
Big Bend Station
Consent Decree
Civil Action No. 99-2524 CIV-T-23F
Electrostatic Precipitators
Revised Particulate Matter (PM) Best Operational Practices (BOP) Report

Dear Mr. Lloyd:

Pursuant to Paragraphs 32.C and 32.D of the above referenced Consent Decree, Tampa Electric Company (TEC) hereby submits the revised PM BOP report for the electrostatic precipitators (ESP) at Big Bend Station.

This PM BOP report was originally developed with the help of the Electric Power Research Institute (EPRI), Southern Research Institute (SRI), and Grady Nichols Enterprises (GNE) and has been revised by TEC to include the recommendations from the modified PM BACT Analysis. In addition, these three contractors provided TEC with a number of ESP modification options in support of the modified PM BACT Analysis, which was ultimately performed by Environmental Consulting & Technology (ECT), Inc. The original study was conducted over a period of 18 months and was implemented on August 19, 2003 providing a reduction in emissions of PM from Big Bend Station.

Revisions to the Original PM BOP

The following revisions have been made to the original PM BOP:

- The revised PM BOP includes the recommendations from the modified PM BACT Analysis.
- Additionally, the revised PM BOP includes the removal of the ESPert system. TEC evaluated ESPert which was state-of-the-art equipment at Big Bend Station and determined that it did not provide reliable data or value for operating the ESPs. TEC will no longer utilize the ESPert equipment.
- The revised PM BOP includes the removal of the SO_3 conditioning system. TEC does not anticipate firing fuels that will require an SO_3 conditioning system at Big Bend Station. TEC will not be refurbishing or maintaining the SO_3 system at Big Bend Station.

Additional details on the aforementioned revisions are in the revised PM BOP, which is enclosed. The revised PM BOP completely replaces the original September 2001 PM BOP which TEC submitted on September 28, 2001.

TEC understands that submission of this report satisfies the stipulations found in Paragraphs 32.C and 32.D of the Environmental Protection Agency (EPA) Consent Decree requiring the revision and submittal of this report. If you should have any further questions, please feel free to contact Shelly Castro or myself at (813) 228-4408.

Sincerely,

Shelly Castro for

Laura R. Crouch
Manager
Environmental, Health & Safety

EHS/bmr/SSC210

Enclosure

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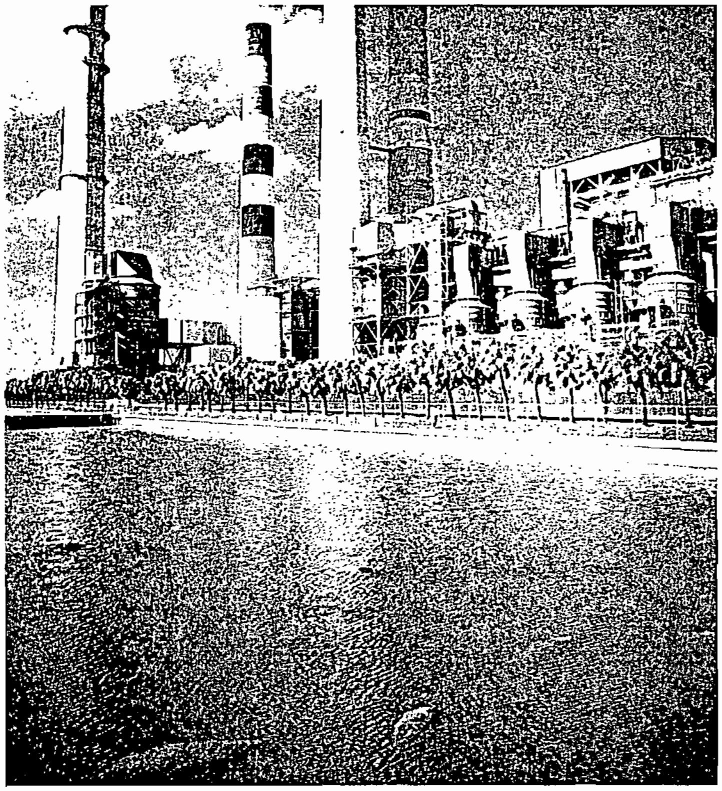
BIG BEND GENERATING STATION BEST OPERATING PRACTICES FOR PARTICULATE MATTER



Revised by:

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October 29, 2004

Executive Summary

Tampa Electric Company's (Tampa Electric) Big Bend Station (Big Bend) has four coal-fired units equipped with electrostatic precipitators (ESPs) for particulate matter control. As a result of the Consent Decree and Consent Final Judgment, a series of programs were undertaken to test and examine the performance of the Big Bend Station ESP's. This program helped to determine if changes to the equipment could be made to improve collection efficiency. In addition, the program helped to evaluate and revise, where necessary, current operating and maintenance procedures in an effort to further improve upon the reliability and performance of the ESP equipment. Tampa Electric initially issued contracts to numerous consulting firms inclusive to conduct these programs. The results of those studies indicated that, after implementation of various modifications recommended by the Best Available Control Technology (BACT) study and these Best Operating Practices (BOP) guidelines, the existing size and configuration of each ESP would yield particulate matter (PM) emissions substantially below current regulatory limits. This document focuses upon the results of the thorough investigation of Tampa Electric's existing operating and maintenance programs and methods. These guidelines define a set of operating procedures and maintenance practices that reflect Tampa Electric's current practices and the industries most up-to-date understanding of the technology. Proper implementation of these guidelines will result in particulate matter emissions that meet the expectations and intent of the United States Environmental Protection Agency (USEPA) Consent Decree and the Florida Department of Environmental Protection (FDEP) Consent Final Judgment.

Pursuant to Paragraph 32.C of the Consent Decree, these Best Operating Practices are revised to reflect the changes and modifications made as a result of the modified PM BACT Analysis recommendations as approved by the USEPA.

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1.0 Introduction

Tampa Electric Company (Tampa Electric), as a result of an agreement with federal and state regulators, embarked on numerous programs to minimize the environmental impact of the coal fired units at the Big Bend Station. These programs involve efforts to significantly reduce sulfur dioxide (SO_2) and nitrogen oxides (NO_x) emissions and to further reduce very low particulate matter (PM) emissions. The plant is currently equipped with flue gas desulfurization systems (FGD or scrubber) for SO_2 control, and low NO_x technologies will be added. The focus of this study is strictly concerned with the optimization of the PM equipment via changes to the equipment, including those described in the modified PM BACT Analysis and operational and maintenance practices. Since Big Bend Station already has electrostatic precipitators (ESPs) for PM control, studies were initiated to determine if the ESPs were capable of providing satisfactory levels of PM collection. The specific goals of this Optimization Study were to:

(1) Determine the existing condition of all of the ESPs,
(2) Examine the performance of the ESPs,
(3) Gather data needed to analyze and understand the measured performance, and
(4) Gather data needed to evaluate performance upgrade options.

This analysis was supplemented by an evaluation of current operating and maintenance practices. This understanding was needed to augment the existing operating and maintenance practices. Results from the extensive testing and the operation and maintenance study, as well as, the more recent modified PM BACT Analysis and PM BOP changes were used to develop the Best Operating and Maintenance Guidelines, which are contained in Sections 1.2, 4 and 5 of this manual.

1.1 Preliminary Supporting Studies

As noted in the foregoing, one of the primary objectives included determination of the condition of the existing ESP's. In support of this activity Tampa Electric solicited proposals from various testing and modeling firms who were noted as being leaders in the industry. The Southern Research Institute (SRI) was selected to develop a detailed test program to determine gas and mass flow characteristics to and within the ESP's at Big Bend Station and to evaluate the data once it was collected. The Airflow Sciences Corporation was selected to perform this testing and collect all of the data. In addition, they provided some analytical modeling services. These data were then used to develop unique computational fluid dynamic (CFD) computer models to determine where and what types of flow control devices would be necessary to achieve optimum two-phase transport conditions. The results of these tests and investigations led to the need to perform physical modifications to the units to obtain optimum flow conditions. In addition to these contracted services, Tampa Electric conducted various investigations of emerging technologies, which may have provided additional benefits beyond what was required in either the PM BOP or modified PM BACT Analysis. This information was supplied to Electric Power Research Institute (EPRI) and SRI for use in these studies.

1.2 Implementation Program

Tampa Electric sought out leaders in the field of ESP to develop the material in this report. Contracts were issued to the EPRI and SRI with a subcontract to Dr. Grady Nichols, to conduct both the performance analysis and to work with plant staff and utility engineers to establish enhanced operating and maintenance procedures. In addition, a contract was issued to ECT Incorporation to perform the modified PM BACT Analysis. These organizations were chosen because together they constitute a team with the knowledge and experience needed to conduct all of the required tests and analyses. EPRI conducted a PM control research and development program for over 20 years that has analyzed the performance of existing ESPs, evaluated and developed many ESP performance upgrade technologies and developed a series of operating and maintenance guidelines documents for the industry. Dr. Ralph Altman, the leader of EPRI's ESP research program, was selected as a lead member of the Tampa Electric team. SRI is the premier utility ESP research organization in this country. This organization has conducted more sophisticated utility ESP tests and evaluations than any other domestic organization. SRI developed a widely used computer model of ESP performance. Staff members have participated in many studies to help utilities solve ESP performance problems. Wim Marchant, Program Manager, and his staff members were also selected to be members of the Tampa Electric team. Dr. Grady Nichols, now working as a consultant, directed the SRI ESP research program for many years. He has a world-wide reputation as one of the most knowledgeable men in the field of ESPs. Dr. Nichols is also a member of the Tampa Electric team.

1.3 Guidelines Background

This team conducted two parallel efforts to meet the USEPA Consent Decree requirements. The first effort gathered the data needed to analyze the performance of the ESPs on each of the units at Big Bend Station. These data were used in a computer model study of the existing ESPs and a study of possible performance upgrade options. The second effort was a study of current operating and maintenance practices and an analysis to determine if changes in these practices were needed to produce ESP performance enhancements. This latter effort led to the development of a set of "Best Operating and Maintenance Practices", (BOP), which is the subject of this report. The Big Bend Station Units 1 through 4 ESPs were then modified in accordance with the EPA approved recommendations of the modified PM BACT Analysis and this PM BOP was updated to reflect these changes.

The development of the initial PM BOP included a number of steps to ensure a satisfactory result. These steps included: (1) interviews with plant personnel who operate and maintain the ESPs, (2) interviews with central office personnel, (3) the collection and examination of operating manuals and maintenance records for the ESPs and associated equipment, (4) the collection of EPRI reports related to ESP operating and maintenance procedures, and (5) site visits that included external inspections of all of the ESPs and internal inspections of the ESPs on Units 1 and 2.

In addition to these steps, the insights gained from the ESP data gathered during the particulate matter tests and computer analyses were factored into the development of the PM BOP guidelines. These tests included an analysis of the fly ash produced by the boilers at Big Bend Station (inlet particulate property measurements for the ESPs on Units 2 and 4) and measurements of the outlet emissions from Unit 2. The computer analyses included calibration of the computer model, and a calculation of the theoretical "optimum performance" that can be produced by the Big Bend Station ESPs, which incorporated various modifications identified herein.

1.4 Guidelines Structures

This effort resulted in a comprehensive set of guidelines that are found in Sections 4.0, Operations and Maintenance Guidelines, 5.0 Maintenance Practices and 6.0 Record Keeping, Data Acquisition & Trend Analysis. Activities in both the operating and maintenance sections are arranged in groups of actions that should occur at approximately the same frequency. The procedures for many of these activities are the same for the ESPs on all four units. There are, however, some design and equipment differences that necessitate the need for slightly different procedures for each unit. The design differences are identified in Section 2.0 Unit Descriptions. The resultant differences in operating or maintenance practices are identified at the appropriate locations within Sections 4.0, 5.0, & 6.0. Section 6.0 identifies the activities that must be conducted to collect and record a set of baseline operating parameters for the ESPs and associated systems, and to use these baseline parameters to conduct trend analyses. This database is used as a reference in many of the operating and maintenance activities to determine if an electrical parameter or mechanical condition falls within an acceptable range.

1.5 PM BACT Upgrade Activities

As required by the Consent Decree, Tampa Electric was to perform a modified PM BACT Analysis to determine cost-effective work to lower particulate emissions for all the Big Bend units and implement those work activities by May 1, 2004. Due to the design differences between the units, the work scope was not identical for all the Big Bend units. In addition to the work identified within the modified PM BACT Analysis, various other physical modifications were identified and included as part of the PM BOP program. Descriptions of the modified PM BACT Analysis items are delineated in Section 3.0 of this document. The modified PM BACT Analysis work activities included:

- Flyash gate valve replacements
- New ESP power controls
- Independent DCU for each of the units
- New/upgraded flyash controls
- Balancing of external flows and temperatures

Flyash Gate Valves - The flyash removal system for Big Bend Units 1 through 3 are positive pressure pneumatic transfer systems. These systems include a feeder isolated by two gate valve assemblies. Proper sealing of the gate valves is important to prevent re-entrainment.

ESP power controls - The new controls have been installed on each unit with the ability for increased programming to allow for increased power, monitoring of the equipment, and operation of the ESP.

Independent Digital Control Unit (DCU) - The former ESP control systems shared one DCU per pair of units. This was changed to improve overall ESP reliability. Dedicated DCU's have been supplied on a per unit basis.

New/upgraded flyash controls - The timing and sequencing of the flyash gate valves, hopper vibrators and other supporting systems were controlled via local computer control. New equipment specifically designed for the intended service will be utilized complete with diagnostic capabilities and enhanced local/remote alarming.

Balanced External Flows - Through examination of the results of thermal and mass flow testing upstream of the ESP's, it was determined improvements could be made to that balanced and uniformity of flows for all the units. In order to make these improvements CFD modeling was performed, flow correction and/or mixing devices were installed, where necessary.

2.0 Unit Descriptions

There are four coal fired units at Big Bend Station with a total generating capacity of 1,841 MW. The boilers for Units 1 through 3 are all Riley-Stoker, turbo-fired furnaces of similar designs. These units are rated at 445 MW for Units 1 and 2 and 465 MW for Unit 3. The boiler for Unit 4 is a Combustion Engineering, tangential fired furnace with a capacity of 486 MW. All four units are equipped with electrostatic precipitators for particulate matter control and wet limestone forced oxidized flue gas desulfurization (FGD) systems for SO_2 control. These units are further described in the following sections.

2.1 Big Bend Unit 1

2.1.1 Furnace

Unit No. 1 is a fossil fuel fired steam boiler generating unit rated at 4037 MMBtu/hour with an electrical generating capacity of 445 MW. It is a "wet" bottom utility boiler manufactured by Riley Stoker Corporation, and identified as a Riley-Stoker Turbo-Furnace. This unit may burn coal exclusively or a coal/petroleum coke blend with a maximum percentage of petroleum coke of 20% by weight or coal blended with coal residual generated from Polk Power Station, or a coal/petroleum coke blend further blended with coal residual generated from the Polk Power Station.. Unit No. 1 began commercial operation in 1970.

Unit No. 1 shares two common stacks (Stacks CS001 and CS0W1) with Unit 2. The flue gas is normally routed from the ESP outlet to an FGD system and then to stack CS0W1. When the flue gas cannot be sent to the FGD system, the flue gas is routed directly from the ESP to stack CS001.

2.1.2 ESP

The electrostatic precipitator originally installed with the boiler is referred to as the old or east ESP. This ESP was retained when a new ESP was added, with the total gas volume flow to be split with 40% flowing to the old (east) ESP and 60% to the new (west) one. This split was selected to provide approximately the same collecting efficiency in each of the parallel ESP units. The old ESP has four electrical fields in the direction of gas flow. The old ESP was rebuilt internally in 1992 with each electrical field now six-feet deep in direction of gas flow and 30-foot high collection plates, which have twelve-inch spacing. There are 100 gas passages in each electrical field. The discharge electrodes are of a "pipe & spike" design within a rigid pipe frames. The discharge and collecting electrodes are rapped with MIGI rappers.

The old ESP has two transformer rectifiers (TR's) per electrical field, each of which powers 50 gas passages or a total plate area of 18,000 ft^2/TR. There are a total of 16 hoppers arranged in a 2x8 pattern.

The new or west ESP has seven electrical fields in the direction of gas flow. The first four electrical fields are four and one-half feet in length in direction of gas flow while the fifth, sixth and seventh electrical fields are six-feet in length in direction of gas flow. The first five electrical fields were also rebuilt in 1992 and have 104 gas passages each 30-foot high and are on twelve-inch spacing. The sixth and seventh electrical fields have 140 gas passages on nine-inch spacing. The first five electrical fields have a rigid "pipe and spike" discharge electrode system connected to a rigid frame and are on twelve-inch spacing. The sixth and seventh electrical fields have the original weighted wire electrode assemblies with 0.109 inch wires, which are on nine-inch spacing.

The new ESP has two transformer rectifiers per electrical field, each of which powers 50% of the gas passages in its respective electrical fields (14,040 ft^2/TR for the first 4 fields, 18,720 ft^2/TR for the fifth electrical field, and 25,200 ft^2/TR for the last two electrical fields). The ESP also has sixteen hoppers and is a 2x8 pattern. The discharge and collecting electrodes are rapped with MIGI rappers.

Modified PM BACT Analysis work for this unit included, flyash gate valve replacements, new ESP power controls, an independent DCU, new/upgraded flyash controls and balancing of external flows and temperatures.

2.2 Big Bend Unit 2

2.2.1 Furnace

Unit No. 2 is a fossil fuel fired steam boiler generating unit rated at 3996 MMBtu/hour with an electrical generating capacity of 445 MW similar in design to that on Unit 1. It is a "wet" bottom utility boiler manufactured by Riley Stoker Corporation, and identified as a Riley-Stoker Turbo-Furnace. This unit may burn coal exclusively or a coal/petroleum coke blend with a maximum percentage of petroleum coke of 20% by weight or coal blended with coal residual generated from Polk Power Station, or a coal/petroleum coke blend further blended with coal residual generated from the Polk Power Station. Unit No. 2 began commercial operation in 1973.

Unit No. 2 shares two common stacks as mentioned above (Stacks CS001 and CS0W1) with Unit 1. The flue gas is normally routed from the ESP outlet to a flue gas desulfurization (FGD) system and then to stack CS0W1. When the flue gas cannot be sent to the FGD system, the flue gas is routed directly from the ESP to stack CS001.

2.2.2 ESP

The ESP installed on Unit No. 2 consists of two separate casings or boxes, an upper and a lower. The layout for each is identical and as such an even gas flow rate split between them is appropriate. Each box is divided into an "A" and "B" side or chamber. The following description is for one of the two boxes.

The upper or lower ESP each have seven electrical fields in the direction of gas flow. The first four electrical fields are four and one-half feet in length with gas flow while the last three fields are six feet in length. Each field has 81 gas passages that are 30-feet high and have twelve-inch spacing. All electrical fields have a rigid "pipe and spike" discharge electrode system connected to a rigid frame and are on twelve-inch spacing.

Each box has 14 transformer rectifiers. The first four electrical fields each have two TR's for a total plate area of 10,935 ft^2/TR. Fields 5, 6, & 7 have two TR's each, for a total plate area of 14,580 ft^2/TR each. There are three rows of hoppers under each box in the direction of gas flow. The first row of hoppers has 8 hoppers in it while the second and third rows have four hoppers each.

Modified PM BACT Analysis work for this unit included, flyash gate valve replacements, new ESP power controls, an independent DCU, new/upgraded flyash controls and balancing of external flows and temperatures.

2.3 Big Bend Unit 3

2.3.1 Furnace

Unit No. 3 is a fossil fuel fired steam boiler generating unit rated at 4115 MMBtu/hour with an electrical generating capacity of 465 MW. It is a "wet" bottom utility boiler manufactured by Riley Stoker Corporation similar in design to Units 1 and 2, known as a Riley-Stoker Turbo-Furnace. This unit may burn coal exclusively or a coal/petroleum coke blend with a maximum percentage of petroleum coke of 20% by weight or coal blended with coal residual generated from Polk Power Station, or a coal/petroleum coke blend further blended with coal residual generated from the Polk Power Station. Operation of this unit may include diverting all of the flue gas into the Unit 4 FGD system for sulfur dioxide removal. See Unit 4 furnace description for operation of the Unit 3 flue gas in the Unit 4 FGD system. Unit No. 3 began commercial operation in 1976.

2.3.2 ESP

The ESP installed on Unit 3 also consists of two separate casings or boxes, an upper and a lower. The layout for each is identical except for the plate spacing on the lower box. Each box if divided into an "A" and "B" side or chamber.

The upper ESP has eight electrical fields in the direction of gas flow. All electrical fields are four and one-half feet in length in the direction of gas flow and have 80 gas passages 30-feet high and have twelve-inch spacing. The discharge electrodes have a rigid "pipe and spike" discharge electrode system connected to a rigid frame. Each electrical field has one TR which powers 80 gas passages or a total plate area of 21,600 ft^2/TR.

The lower ESP also has eight electrical fields in the direction of gas flow. All electrical fields are four and one-half feet in length. The first six electrical sections have 106 gas passages each 30-feet high and nine-inches spacing. The last two electrical fields have 80 gas passages each 30-feet high and 12-inch spacing The discharge electrodes for the first six electrical fields are a weighted wire design with 0.109 inch diameter discharge electrodes. The last two electrical fields have a rigid "pipe and spike" discharge electrode systems connected to a rigid frame. Each electrical field has one TR. The first six TR's power 28,629 ft^2/TR while the last two power 21,600 ft^2/TR.

The hoppers for the upper and lower ESP boxes are arranged in two rows with four hoppers in each row.

Modified PM BACT Analysis work for this unit included, flyash gate valve replacements, new ESP power controls, an independent DCU, new/upgraded flyash controls and balancing of external flows and temperatures.

2.4 Big Bend Unit 4

2.4.1 Furnace

Unit 4 is a fossil fuel fired steam boiler generating unit rated at 4330 MMBtu/hour. It has a Combustion Engineering "dry" bottom tangentially fired pulverized coal boiler designed for 486 MW generation. This unit may burn coal exclusively or a coal/petroleum coke blend with a maximum percentage of petroleum coke of 20% by weight or coal blended with coal residual generated from Polk Power Station, or a coal/petroleum coke blend further blended with coal residual generated from the Polk Power Station. Unit 4 began operation in 1985.

The exit flue gas from Unit 4 is directed to an FGD system. As an option, the flue gas from Unit 3 ESP may be combined with those from Unit 4 in the FGD system. The flue gas stream from the Unit 4 FGD system is then split and exhausted through stacks CS002 and CS003. CS002 does not include a gas recirculation duct to return a portion of the scrubber flue gas to the FGD system inlet as CS003 does.

2.4.2 ESP

The Unit 4 ESP also consists of an upper and lower box with each box having an "A" and "B" side. The upper and lower boxes are identical and each consists of five electrical fields in the direction of gas flow. Each electrical field is 14.4-feet in length in direction of gas flow and has 90 gas passages. The collecting plates are 48 feet high and are spaced twelve-inch spacing. There are four TR's per electrical field/box for a total of 31,104 ft^2 /TR (1,244,160 ft^2 of collecting area for the entire Unit 4 ESP).

The discharge electrode system is a rigid frame design with ribbon cable type electrodes. Flail hammer rapping is used on the collecting and discharge systems. There are five rows of hoppers in the direction of gas flow, with four hoppers per row for the upper and lower boxes.

Modified PM BACT Analysis work for this unit included, flyash new ESP power controls and an independent DCU.

3.0 Summary Characterization of Big Bend Particulate Control Issues

This section discusses the performance of the precipitators as they were found at the beginning of the study, the actions that are being recommended to improve their operating potential and the theoretical performance for each unit after these improvements are completed. Although the ESP's currently operating at the Big Bend station are fully compliant with the required emissions limits, the recommendations made in this document may provide a means to reduce PM emissions below the established regulatory limits while using existing fuels.

3.1 Current Performance and Reliability

The existing ESPs for Big Bend Station Units 1, 2 and 3 are currently sized and operated such that the facility operates at or below a rate of 0.03 lb/mmBtu for PM emissions. The Big Bend Unit 4 ESP system is substantially over-sized based upon the fuels that it currently fires and operates such that PM emission rates are at or below 0.01 lb/mmBtu. Although these ESP's are fully compliant with the revised PM emissions limits, Tampa Electric shall pursuant to the requirements of the PM BOP perform additional physical work at the Big Bend facility as the need to replace obsolete or worn out equipment requires replacement.

To augment the monitoring of the ESP's performance, TEC installed a real-time monitoring system, ESPert, developed by the Electric Power Research Institute (EPRI). The system was installed on a personal computer and had automated inputs for various ESP operating parameters and from the station's data historian. Additionally, it required manual inputs for certain parameters such as fuels and blends. The automated inputs included the secondary electrical voltages and currents, as well as the gas volume flow rate and opacity. The intent of the ESPert system was for continuous calculation of the collection efficiency for each ESP and to estimate the outlet opacity. After a lengthy evaluation of this system at the Big Bend facility, Tampa Electric determined that it did not provided repeatable or reliable data. Accordingly, Tampa Electric has removed this equipment from service at the Big Bend facility and relies upon the balance of the monitoring, inspection and operation and maintenance practices identified herein to provide for enhanced operation of the ESP's.

3.2 Current Practices

Tampa Electric's Big Bend Station is staffed with various craft personnel who operate and maintain routine work activities on the ESP's. These practices were developed from both the manufacturer's recommendation and that learned from actual operation and industry good engineering practices. Various contractors usually perform large upgrade or repair projects. The station also collects and monitors operating data on a routine basis.

3.3 Recommended Physical Modifications

In addition to the modified PM BACT Analysis work activities identified in Section 1.5 of this document there were several other physical modifications recommended which are included as part of the PM BOP. As noted within the PM BOP there is no definitive time when this work must be completed, but rather should be completed when the existing equipment fails and is required to be replaced or for new work during scheduled outages at some point in the future. The work includes,

- Correct Internal Flows
- Increase T/R Sectionalization
- ESPert Implementation
- Wide Plate Spacing and Rigid Electrodes

- Flyash Hopper Level Controls
- Relocate Slag Vent Lines
- Rapper Optimization
- High Level Hopper Electrical Cut-Out
- New/Revise Hopper Baffles
- Enhance O&M Procedures
- O&M Training Requirements

Correct Internal Flows - In order to maximize collection efficiency, balanced and uniform flows are required within the collection chambers of the ESP's Tampa Electric contracted with testing firms to perform selected testing within some of the ESP's to discover if they meet industry standards. Based upon the data collected, computational fluid dynamic (CFD) modeling was performed to determine the correct sizing and placement of perforations in the inlet and outlet perforated plates. Physical work included the replacement of inlet and outlet perforated plates and modifications to various internal turning vanes to achieve proper flow distribution.

Increased T/R Sectionalization - Some of Tampa Electric's ESP's require the installation of additional T/R sets to provide the capability of increased sectionalization. The equipment was installed and the fields can now be isolated in the event of failure and effectively maintain high collection efficiencies and have a higher T/R to field ratio.

ESPert Implementation - ESPert is a leading edge technology being introduced into the industry. This real-time system was to provide for monitoring and prediction of ESP performance. Additionally, this system can be used by Tampa Electric as a diagnostic tool for troubleshooting performance-related issues. Due to technical difficulties it is not being utilized.

Wide Plate Spacing & Rigid Electrodes - Many of Tampa Electric's ESP's were originally designed with 9-inch plate spacing. The current industry standard uses 12-inch spacing. This current design allows for higher power levels to be introduced to the fields and increases reliability. The replacement of the plates and electrodes is an on-going major effort, which will require unit outages of 10-12 week duration.

Relocate Slag Vent lines - Wet bottom boilers require venting of furnace gases from the bottom ash collection system. These vents originally were vented to atmosphere however regulations required that they be treated along with the bulk furnace gas stream. These vent lines currently inject of moisture and carbon immediately upstream of the ESP's. Relocation of these lines requires major modifications, the introduction of booster fans capable of operating in a severe duty environment, and re-injection ports at strategic locations in the furnace.

Refurbished SO_3 Conditioning System - Due to the current fuels used at Big Bend, the SO_3 conditioning system may only be required during intermittent periods. Should this system be determined to be necessary when burning low sulfur fuels (unscrubbed days only), it will be refurbished or replaced with other equipment. Tampa Electric does not anticipate firing fuels that will require an SO_3 conditioning system at Big Bend Station. Therefore, Tampa Electric will not be refurbishing or maintaining the SO_3 system at Big Bend Station.

Rapper Optimization - Proper rapper sequencing and operation are critical to good collection efficiencies. Additionally, the rapper programming should be adjusted to optimize for varying fuel types. Tampa Electric monitors rapper programs/sequences to optimize operations as various fuels are combusted at the facility. This task includes the use of ESP consultants who are considered experts with this type of work.

High Level Hopper Cut-Outs - Tampa Electric is installing back-up high-high level detection devices that will trip out the associated electrical fields. This will provide an alarm that the hoppers are full, and allow for immediate corrective action before mechanical damage can occur to the frames.

Enhanced O&M Procedures - As described throughout the PM BOP document, Tampa Electric has committed to an extensive monitoring, corrective and maintenance programs, and testing of the ESP's to help improve their operation. The effect will be increased reliability and performance of the equipment to reduce PM emissions.

O&M Training - Tampa Electric operators have already received additional specific training in regard to the operation and maintenance of ESP's. Periodic training of existing and new staff members will be performed as required.

3.4 Factors Effecting ESP Optimization

3.4.1 Fuels

The characteristics of the fuel burned coupled with the furnace design and operation are determining factors for the operation of an ESP. The primary factors of concern are: ash content, particle size distribution and ash electrical resistivity. The ESP systems with the present fuel supply for the station produces emission levels, with a significant margin of safety with regard to meeting the allowable particle emission limits. The fuel and boiler conditions for Big Bend Units 1 through 3 are very similar. These units burn a medium high-sulfur, medium ash content coal, which is sometimes blended with a small portion of petroleum coke. The resultant fly ash exhibits a resistivity in the 10^{10} Ω-cm range with a particle size distribution as measured in September of 2000 having an mmd of about 15.4 μm. The fuel supply for Unit 4 is essentially the same as for the other units, but the furnace is a tangentially fired Combustion Engineering, (now Alstom) pulverized coal boiler.

3.4.2 Ash Content

The collection efficiency of an ESP is somewhat dependent on the inlet ash loading. If all other factors are equal, an increase in the inlet mass loading will generally result in a corresponding increase in the outlet emissions. Therefore, the emissions from an ESP are directly related to the ash content of the coal. Switching to a higher or lower ash coal should cause a corresponding change in the emissions, if ash content is the only change (which it usually is not).

3.4.3 Particle Size Distribution

The collection efficiency of an ESP changes drastically for different particle sizes. Very large particles, 20 micrometer (μm) and above, are collected with a much greater efficiency than particles in the 0.2 to 3.0 μm range, and finally, particles much smaller than 0.05 μm are again collected with a higher efficiency. The large particles (primarily charged by what is termed field charging) attain a greater electrical charge than the smaller ones, providing a greater electrical force to remove them from the gas stream. The larger surface area of the particles provides for retaining a greater amount of electrical charge. The collecting efficiency drops steadily as the size of the fly ash particle (and surface area) decrease, until another charging mechanism begins to dominate - diffusion charging. These particles are small enough that the drag force from the gas stream (described by the Cunningham Correction factor to Stokes Law) decreases, allowing the particles to be collected with a greater efficiency. Finally, as the particles become extremely small, the drag force from the gas stream is diminished further so that the finer particles are collected with a very high efficiency. Therefore, if the combination of the furnace and coal characteristics produces more particles in the fractional size range from 0.2 to 3.0 μm, the collecting efficiency of the ESP would be expected to decrease.

The particles present in the exit gas stream from a furnace are produced by at least two and sometimes three independent mechanisms. First, the ash contained in a particle of coal is left as a residue when the coal particle is burned. When the fuel burns away, the ash is left either as a molten droplet or solid particle. For a pulverized coal furnace, the mass median diameter (mmd) for this residue fraction is in the 8 to 20 μm range. A cyclone boiler actually produces about the same particle size distribution in the furnace, but the cyclonic action of the gas flowing in the combustion zone serves to remove some of the larger particles. The result is that the fly ash transported to the ESP has a smaller particle size distribution and a reduced mass loading. A greater percentage of the coal ash is retained in the cyclone furnace as bottom ash than one with wall burners. The mass median diameter for a cyclone boiler will usually be in the 6 to 12 μm range. The furnaces for Big Bend Station Units 1 through 3 are Riley Stoker Turbo Fired furnaces, and these furnaces tend to produce a particle size distribution similar to that produced by a cyclone furnace.

A second mechanism for producing particles results from the rapid heating of the coal particle that contains volatiles or entrapped gases. As the coal burns, particles of coal, (containing ash) "spalls" off from the primary coal particle, burning independently, resulting in a much smaller residual fly ash particle than would result from the combustion of the original coal particle. Some western coals have more of a tendency to produce fine particles from this mechanism. The mass medium diameter for this size fraction is usually in the 0.2 to 1 μm range.

Another potential mechanism for particle formation in the furnace flue gas is the evaporation and re-condensation of some materials contained in the coal. There is a potential for some alkali metals and acids to condense when the flue gas temperature falls below their respective dew points. If the concentration of these constituents is great enough, they can evaporate in the furnace or in the case of sulfur trioxide combine with water vapor and condense as the flue gas stream cools in the ductwork and heat exchangers. Typical particle size distributions for these condensation products are in the sub-micron range.

3.4.4 Fly Ash Resistivity

The electrical resistivity of fly ash particles is the most critical factor in establishing the collecting efficiency of ESPs. For the ESPs at Big Bend Station, which operate on the cold side of the air preheater, the resistivity is determined by the temperature, moisture and sulfur trioxide (sulfuric acid) content in the flue gas, and the chemical composition of the fly ash particle. The resistivity of the fly ash from the current fuel supply is in the 10^{10} Ω-cm range. This is the most favorable resistivity range for operating a conventional dry ESP. This favorable resistivity range is probably the reason that these Big Bend ESPs have as much performance margin as they do.

3.5 General Recommendations

Each ESP unit of the Big Bend Power Station consists of two or more independent ESP chambers. These chambers were designed to accommodate a specific volume flow rate of flue gas. The gas volumetric flow rate and gas velocity distribution should be balanced according to the original design values, and the flow within each casing should be made as uniform as practical. Model studies performed for these units either at the time of installation or more recently can provide guidelines for balancing and maintaining these desired flows. Maintaining the proper distribution of gases to and within the individual ESPs minimizes the total PM emissions from the power station.

3.5.1 Unit One

The ESP systems for Unit 1 consist of two individual ESP units: old (east) and new (west). The ESP systems for each unit are described in detail in Section 2.0 entitled "Unit Descriptions" previously in this report. The original ESP was retained when the new ESP was added with the total volume flow rate to be split with 40% flowing to the old ESP and 60% to the new one. This split was selected to provide approximately the same collecting efficiency in each of these parallel ESP units.

The sixth and seventh fields of the new ESP have weighted wire corona electrodes. The electrical readings for these fields should be checked regularly to identify whether there has been an electrode failure. Weighted wire corona electrodes are more prone to failure than other designs.

The gas volume flow rate split between the old and new units is set at the 40%/60% respectively range as closely as possible.

3.5.2 Unit Two

The Unit 2 ESP system consists of two identical ESPs, upper and lower. A balanced gas flow rate split is appropriate for these ESPs. This ESP is designed with 9 inch plate-to-plate spacing with weighted wire corona electrodes. Each corona wire is a twisted pair of individual wires. The electrical sectionalization of the first four fields is an area where some improvement is needed to achieve optimum performance.

Unit 2 served as the test ESP for the data-collecting program conducted in September of 2000 used for this optimization study. The results of this field study was that both the "A" and "B" sides of the upper and the "A" side of the lower ESP operated as expected.

The results of the model studies based on the measured and calibrated performance for the Unit 2 ESPs indicate that the existing ESP systems have the potential for attaining collecting efficiencies somewhat greater than they were producing at the beginning of this study. Careful attention to proper maintenance and operating procedures and the modifications made to the ESPs early in the study should assure that these units operate at or very near their potential. The specific guidelines included in this manual should provide the plant personnel with the information to maintain this performance level.

3.5.3 Unit Three

Unit 3 has upper and lower ESPs with somewhat different internal designs. The upper unit has 12 inch plate-to-plate spacing throughout, while the lower retains the first six electrical fields with 9 inch plate spacing and weighted wire corona electrodes, with the remaining two electrical fields at 12 inch plate-to-plate spacing. Again, the weighted wire corona electrodes should be monitored for wire failure, and the weighted wire fields should be replaced with new plates and rigid discharge electrodes to eliminate the wire breakage problem.

3.5.4 Unit Four

The Unit 4 ESP is designed with a greater safety margin than those on Units 1 through 3. This unit should provide very good collecting efficiency with several electrical fields OOS. However, the same good maintenance and operating practices established for the other units should be used for Unit 4.

The Unit 4 ESP exhibits a greater than expected corona electrode failure rate. The corona electrodes are supported in a frame, with tumbling hammers rappers in line with the gas flow. The increased corona electrode failure rate could be caused by over rapping. It is suggested that when tumbling hammer failures occur, replace those hammers with lighter ones.

3.5.5 Recommended Improvements in Maintenance and Operation

The general maintenance and operation practices for the Big Bend Station should follow those practices defined in Section 4 to establish and retain the potential collecting characteristics of all the ESPs operating at the station. The concern is to correct any mechanical deficiencies associated with each of the ESP installations. The corrective measures can best be determined by following the requirements for the inspection program defined in Section 4.0. The specific procedures to follow are presented in EPRI Document TR-113582-VI, *Guidelines for Upgrading Electrostatic Precipitator Performance, Volume 1: Optimizing an Existing Electrostatic Precipitator* and EPRI CS-5198-V3, *Electrostatic Precipitator Guidelines, Volume 3: Troubleshooting*. These documents are provided to Tampa Electric and are to become a part of this optimization program description.

3.5.6 Material and Equipment

The ESP maintenance personnel should develop and must maintain an adequate inventory of spare parts to be able to address the common ESP problems expected to develop. The instruction manuals provided with the original equipment also suggest appropriate spare parts to stock. However, experience will assist in developing a more appropriate set of spares using the items actually replaced and the frequency of their replacement during the following years with this maintenance program.

3.5.7 Training

The primary plant personnel assigned to the maintenance and operation of the ESP systems have developed a considerable amount of skill in the operation of electrostatic precipitators. Participation in workshops and symposia are also valuable sources of assistance in establishing the required level of training to effectively operate and maintain these fly ash collectors. Consultants are also available to assist in specific areas where needed. EPRI as well as the other contractors for this study are available as needed.

4.0 Operations and Maintenance Guidelines

The following portions of these guidelines are organized into separate Operating; Maintenance; and Record Keeping, Data Acquisition & Trend Analysis sections. As a general rule, activities that take place daily or, at the most, weekly intervals are considered operating practices. Activities that occur biweekly or at longer intervals are treated as maintenance practices. Troubleshooting efforts are sometimes required by the practices in this manual. The required troubleshooting procedures are described in the accompanying EPRI Troubleshooting Manual.

In addition to the troubleshooting efforts, the operating and maintenance practices in Sections 4.0 and 5.0 rely on the use of baseline data identified in Section 6.0, Record Keeping, Data Acquisition, and Trend Analysis.

Finally, the practices in this manual are not intended to rewrite or replace the procedures described in the operating manuals for the ESPs, ESP controls or the manuals for the ancillary ESP systems. Instead, the operating and maintenance practices describe an orderly and systematic set of procedures (unit specific, where needed) that identify when and how often these standard procedures need to be performed.

4.1 Operating Practices Organization

As indicated, the practices in this section, Section 4.0, include those activities that are expected to occur on a daily or weekly basis. The procedures to be followed during the start-up of a unit are included in this section because they lead directly into the daily operating routine of the ESPs. Likewise, shutdown procedures are included because they are largely an extension of the daily operating routine of the ESPs. Throughout this section, referral is made to "baseline values." These are nominal parameter values or parameter ranges established following the guidance in Section 6.0 of this manual.

Hence, the subsections following include:

- Pre-start-up Inspection
- Start-up Procedures
- Routine Operation
- Shut Down Procedures

The activities in each section include the routine inspections, monitoring and routine record keeping with the unit on line. It is assumed that plant personnel are properly trained and correctly follow all plant safety practices and procedures.

4.2 Pre-Start-up Inspections

4.2.1 Inspection Following Outage with ESP Repairs

Scheduled maintenance outages provide good opportunities to investigate ESP conditions. Review the ESP log where the electrical readings and inspection reports are stored to identify areas requiring detailed inspections or corrective actions. Pay particular attention to ash buildup on the electrodes and in the ductwork, plugging of flow control devices and turning vanes, electrode alignment and any problems with the ESP casing and closures. Record air load voltage vs. current curves for all transformer-rectifier (T/R sets) and correct discrepancies. All electrical sections of similar design should exhibit essentially identical secondary voltage vs. current density (current/area) characteristics. Conduct an internal inspection of work area. Inspect hoppers for proper function. Record and schedule for correction any deficiencies that would significantly impact ESP performance. Close and secure ESP following the manufacturers recommended procedures. Inspect the external part of the ESP to insure all access doors closed, all doors to hot and cold roof are closed and secured. Energize each TR set to maximum voltage. Record readings and compare to baseline. Correct problems.

4.2.2 Inspection Following Outage with No ESP Repairs

Inspections during outages are an important part of ESP maintenance and operating procedures. When the furnace is taken off line, any problems noted during the routine monitoring of the ESP systems should be investigated and corrected, if possible. Such items as: broken corona electrodes, ash hopper plugging, and ash buildup should be corrected, if sufficient outage time is available. If the corrective measures require more extensive outage time or parts must be ordered, inspections will determine what is needed, so that the deficiencies can be corrected during the next outage. Inspect hoppers and verify proper operation. Close and verify that the ESP is properly secured following manufacturer's recommendations. Energize all TR's to maximum voltage to ensure all fields are operating properly. Identify and correct problem if TR set voltage or current is limited to 80% of the established baseline value. Record readings and compare with baseline data set to look for trends.

4.3 Start-up Procedures

It is Tampa Electric's intent to bring the unit and precipitator into service in a manner that is safe and will optimize PM emissions. If the unit is past the startup mode, and the ESP field is operational, then the field will be running. The ESP startup procedure is not only intended to minimize total particulate emissions during startup, but also to preserve the operating integrity of the collecting plates during coal firing operations. During the initial stages of startup oil is fired exclusively to warm the boiler, after which coal is injected at low levels to further heat the boiler. After the boiler has reached a safe operating condition, oil can be removed as a support fuel.

It is frequently the case that the particulate produced during the early part of a startup has a high resistivity and tends to foul the precipitator plates resulting in low power levels in the sections where this ash is collected. To avoid precipitator plate fouling and maintain optimal performance of the ESP, only the minimum number of sections should be placed into service during this time. Additional fields should be put into service, as necessary, to minimize opacity. However, this is rarely required since emissions during this period are normally low due to low gas volumes at low boiler loads.

As load is increased and the injection of coal is increased additional fields are placed into service until all fields are in service. This procedure allows for maximum power to be available to the ESP during normal operating conditions and is recommended by the original equipment supplier and EPRI.

4.3.1 Pre-start-up Activities

Before start-up begins, activate insulator heaters where appropriate, activate ESP penthouse blowers, verify correct operation of all hoppers evacuation equipment and energize rappers, both plate and discharge electrode.

4.3.2 ESP Energization

For all units, Energize only as many precipitator sections as necessary to maintain compliance with opacity regulations:

Unit 1 The inlet high voltage sections of the east and west precipitators (east sets 4AB and 4CD and west set 7ABCD) should be the first sections energized.

Unit 2 The inlet high voltage sections of the upper and lower precipitators (upper and lower sets 7ABCD) should be first sections energized.

Unit 3 The inlet high voltage sections of the upper and lower precipitators (upper and lower set 1) should be first sections energized.

Unit 4 The inlet high voltage sections of the upper and lower precipitators (upper and lower sets 11, 12, 13, and 14) should be the first sections energized.

Maintain opacity below 20% with only the inlet high voltage sections energized as long as the boiler is on oil fire. Place a second high voltage section in service if opacity begins to approach 20%.

Unit 1 Energize east precipitator sets 3AB and 3CD and west set 6ABCD if opacity cannot be maintained below 20% with the boiler on oil fire.

Unit 2 Energize upper and lower east precipitator sets 6ABCD if opacity cannot be maintained below 20% with the boiler on oil fire.

Unit 3 Energize upper and lower east precipitator set 1 if opacity cannot be maintained below 20% with the boiler on oil fire.

Unit 4 Energize upper and lower east precipitator sets 21, 22, 23, and 24 if opacity cannot be maintained below 205 with the boiler on oil fire.

Place all high voltage sections in service just prior to establishing coal fire in boiler. Notify the Electric Shop if any problems are encountered with the precipitators during start-up.

4.3.3 ESP Normal Control Mode

Verify the ESP controls are set to their normal antomatic control mode of operation. Verify that power levels are within the expected range. Set the rapper controls to the established rapping sequence. Set the ash removal system control to the normal sequence.

4.3.4 Post Startup Systems Check

Verify that all rappers are functioning normally by observing the fault detection indicator on the rapper controls on Units 1-3. Verify that the ash removal system is functioning normally on Units 1-3, observe the operation of hopper valves and determine if the ash lines are getting hot during the ash removal sequence. On Unit 4, verify that the vacuum system is operating properly.

4.3.5 Systems Troubleshooting

If any problems with TR set power levels, rapping system, or ash removal system are detected, troubleshoot and correct the problem as soon as possible.

4.4 Routine Operation – Daily & Weekly

These procedures assume that the current configuration of the precipitator on all four units is such that normal operation produces outlet emissions that are in compliance with particulate and opacity limits and that the ESP operating parameters are in the normal range established following the recommendations in Section 6.0. The activities in this section are intended to allow the ESPs on all units to continue to function in a satisfactory manner with minimal outlet emissions.

4.4.1 TR Set Power Level Check

Power levels for each TR set should be checked and recorded daily. The levels should be compared with baseline readings for each TR set established during a period when the ESP is in optimum operating condition. These readings should be taken at the same generation rate, or as is practicable. The stack or duct opacity, flue gas temperature and generation rate should be recorded as well. Any significant deviation from the previous readings should be investigated. Of greatest importance is in investigating and correcting the cause(s) for electrical sections exhibiting short circuits or sets OOS.

4.4.2 Ash Removal System Check

The proper operation of the ash handling system should be frequently checked, but not less than once a day. Any evidence of ash handling problems should be investigated and corrected immediately. Ash buildup in hoppers can cause corona electrode failure, shorting of electrical sections or deformation of collecting and corona electrodes or support structure.

Verify on Units 1-3, proper operation of ash removal system valves. Verify a temperature rise of the ash lines has occurred when ash is flowing through the lines. Verify on Unit 4, proper operation of the vacuum system.

In addition, verify daily that the hopper vibrators are operable. Listen for unusual sounds to detect vibrator problems. Take corrective action as necessary.

Verify hopper levels once per shift. High hopper level indications should be dealt with immediately. Verify once per shift that the pressure equalization systems are continuously monitored and functioning properly, and that the time to empty hopper is in a reasonable range. Special care should be taken to look for signs of air in-leakage on Units 1 and 2 when these units are in the integrated mode of operation.

4.4.3 Rapper System Check

Verify proper rapper operation daily. On a daily basis, the proper operation of the MIGI rappers (Units 1-3) should be checked by observing the fault indicators on the rapper controls. The rapper controllers should be checked once per day to ensure proper program settings and detect rapper faults.

4.4.4 SO_3 Conditioning System Check

The SO_3 injection rate should be just high enough to produce power levels in the normal range. Excessive rapping spikes are an indication that the fly ash resistivity is too low, and this condition is indicative of an SO_3 injection rate that is too high. Tampa Electric does not anticipate firing fuels that will require an SO_3 conditioning system at Big Bend Station. Therefore, Tampa Electric will not be refurbishing or maintaining the SO_3 conditioning system at Big Bend Station.

4.4.5 Motor Checks

Inspect the blower motors in the pressurized ash removal systems and vacuum pump motors in the vacuum ash removal system for signs of vibration and overheating.

4.4.6 Inspect Feed Gates

Inspect feed gates daily to for signs of leakage, breakage, seal problems and proper operation. Be sure to lubricate the feed gates on a weekly basis.

4.4.7 Daily ESP Controls Check

Monitor the ESP controls to ensure they are operational, providing generally expected values and that local displays are consistent with remote monitoring. Input/output power ratings (voltage & current), spark rate, and gross power output (kW) should be monitored.

Table 4.1

Summary of Operating Practices for Each Unit

Daily Activities

1.	Check TR set power levels once per shift.	Section 4.4.1
2.	Check function of ash removal system.	Section 4.4.2
3.	Hopper Level Indication.	Section 4.4.2
4.	Verify proper MIGI rapper operating control fault indicator.	Section 4.4.3
5.	Inspect/service motors	Section 4.4.5
6.	Inspect feed gates	Section 4.4.6
7.	Daily ESP controls check	Section 4.4.7

4.5 Shut Down Procedures

4.5.1 Rapper System Shutdown

Continue rapping the ESP during shutdown unless a "dirty" inspection is planned immediately following shutdown. Otherwise, the rappers should be run as long as possible to remove as much ash from the plates as practicable.

4.5.2 Ash Removal System Shutdown

Continue to run the ash removal system to ensure all hoppers are operating properly.

4.5.3 Auxiliary Systems Shutdown

Other auxiliaries should remain in service for as long as necessary after there is no flame in the boiler to minimize the chance of condensation on metal surfaces and insulators. After this period, the auxiliaries should be shut down in an orderly manner. These auxiliaries include heaters, blowers, etc.

5.0 Maintenance Practices

Maintenance practices include inspection during outages, repair of all malfunctioning equipment and non-routine data gathering and record keeping. Regular inspections form the foundation of this maintenance program. These inspections, combined with observations identified in the operating practices section, should provide the operators with the information needed to detect incipient problems and keep the ESPs operating at optimum efficiencies. The maintenance activities are organized into groups that share a common activity frequency; monthly, fuel system outages, major outages, etc. Some of the activities are specified to take place during fuel system outages. These outages currently take place at intervals between approximately twelve and eighteen months. Likewise, some activities are scheduled to take place during major outages. Major outages occur at approximately four-year intervals. As indicated earlier, activities that take place at intervals greater than a week are treated as maintenance activities and are identified in the following sections.

5.1 Monthly Activities

5.1.1 Insulator Compartments

The ESP penthouse pressurization fans should be checked once a month for proper operation and repair as needed.

5.1.2 ESP Penthouse Ventilation System

Verify proper operation of all ESP penthouse ventilation systems. Replace air filters in the blowers once a month.

5.1.3 Rapping System Cycle Operation

The proper operation of the rapping system cycle should be verified on a monthly basis. Verify the complete cycling of the MIGI system rapping to verify sequence and cycling. Verify the operation of the external drive mechanisms for the tumbling hammer rappers monthly on Unit 4.

5.1.4 Ash Removal System

Service ash removal system by conducting the following tasks:

a. The ash removal system should be observed as it is operated through a complete cycle to assure that each hopper is cycled correctly and that the valve gates with associated equipment operate properly. Solenoids and hydraulic cylinders are to be inspected, serviced and lubricated according to the manufacturer's recommendations.

b. The ash transport lines are to be inspected to verify the absence of leaks at joints, bends and connecting points. ESP hopper access doors in the vicinity of the ash transport lines are to be inspected as part of this process. Joints, bends and connections should be checked for wear, corrosion or abrasion. Expansion joints should be inspected with discrepancies corrected.

5.1.5 Pressure Transducers

Inspect all pressure transducer lines and clean as necessary. The sensing elements should be checked and calibrated, as needed.

5.1.6 Transformer-Rectifiers/Linear Reactors

Check dielectric fluid level and temperature and listen for arcing. Dielectric fluid of the type specified on the T/R set nameplate should be added, if needed, as indicated by the liquid level gauge.

Table 5.1

Summary of Monthly Maintenance Activities

1.	Check insulator compartment fans.	Section 5.1.1
2.	Change air filters in air purge systems.	Section 5.1.2
3.	Verify operation of rapping system.	Section 5.1.3
4.	Inspect/repair ash removal system	Section 5.1.4
5.	Inspect, clean & calibrate pressure transducers	Section 5.1.5
6.	Service transformer-rectifiers/linear reactors	Section 5.1.6

5.2 Fuel System Outage Activities

5.2.1 Discharge Electrodes

Inspect discharge electrodes for proper alignment, tension, excessive dust buildup, and signs of arcing. Those sections that have exhibited poor electrical readings should be given first priority

5.2.2 Collecting Electrodes

Inspect collecting plates for structural integrity and identify areas of deterioration, corrosion or erosion. Plate alignment should be checked. Plates requiring corrective measures should be repaired or scheduled for next available outage.

5.2.3 Ductwork and Expansion Joints

Inspect precipitator ductwork and expansion joints for structural integrity, corrosion, erosion, and dust build-up. Fabric type expansion joints should be checked for tears or punctures and functionality. Identify, prioritize and schedule for repair or replacement all holes in the ductwork and expansion joints.

5.2.4 Casing and Hoppers

Inspect precipitator casings and hoppers internally and externally for structural integrity, as well as signs of corrosion, erosion, leaks, and dust build-up. All holes and structural problems should be identified, prioritized and scheduled for repair or replacement. Particular attention should be paid to the areas around access doors and expansion joints.

Inspect each ash hopper to determine if all hoppers are emptying completely. Operate the ash removal system through a complete cycle to observe that each hopper is cycled correctly and that the gate valves and associated equipment operate properly. Inspect and lubricate solenoids and hydraulic cylinders according to the manufacturer's recommendations. Inspect the gate valve surfaces and any gasketing material installed for wear and alignment. Worn gaskets are to be replaced and sealing surfaces smoothed as required. Pressurized systems are to be checked for leaks. Inspect rotary valves and vent lines.

Inspect and clean electric vibrators. If excessive wear occurs to the vibrator internals, the armature can strike the core and produce serious damage to the vibrator. If such striking occurs, de-energize the unit and repair it.

5.2.5 Motors

Inspect the blower motors in the pressurized ash removal systems and vacuum pump motors in the vacuum ash removal system for signs of vibration and overheating.

5.2.6 Rappers

Inspect rapper assemblies for binding or for misalignment. Each assembly must be plumb and level, and the plunger should fit full-faced on the rapper anvil rod (if the mismatch is more than ¼ the diameter of the rod, then corrective action should be taken.). Inspect and clean rappers and insulators. Check rapper rod penetration seals (rubber boots) for loose clamps, splits, or cracks and replace as needed. Check for the proper operation of the internal portion of the tumbling hammer rappers on Unit 4. Defective rappers should be repaired or replaced, as required.

5.2.7 High Voltage Components

Visually inspect all non-gas path insulators, switches, and insulators not in the high voltage bus duct for cleanliness, cracks, chips and signs of electrical tracking. Clean dirty insulators or replace damaged insulators. Faulty switches should be replaced or repaired.

5.2.8 Key Interlock System

Inspect and lubricate the key interlock system

5.2.9 Controls/Calibration

Inspect all cabinet interiors for cleanliness. Cabinet filters should be cleaned or replaced as necessary. Precipitator control settings should be checked to verify that all adjustable parameters are at their correct value.

Cabinets and all components should be inspected for signs of overheating. Relays should be checked for free movement, and contacts should be cleaned and dressed. The ventilation fan should be cleaned or replaced, as needed. A check should be made for loose electrical connections. Cabinet door gaskets should be inspected and replaced as needed. The main power supply breaker should be inspected and cleaned. Check and calibrate all instrumentation.

Calibrate the ESP control sensors. This process should be carried out for the primary current and voltage circuits and for the secondary current circuits. The primary readings should be checked with an accurate true RMS clamp-on ammeter and true RMS voltmeter and the secondary current should be checked with a low impedance ammeter. The secondary voltage reading should be checked by taking the data to generate a secondary current vs. voltage curve after all the other meters have been calibrated. These data should be compared with the baseline data for each transformer-rectifier set to verify that the secondary voltage readings are consistent with the baseline data.

5.2.10 Auxiliary Equipment Controls

Inspect all auxiliary equipment control and power supply cabinets and panels for cleanliness. All indicator lights should be checked and replaced, if needed

5.2.11 Insulator Compartment Ventilation Systems

Inspect and clean the entire heating and ventilating system. Fans, motors, dampers and switches should be cleaned and checked for proper operation. Dampers in the penthouse ventilation system should be checked for proper operation. Electrical connections should be checked for tightness. All air ducts should be checked for leaks, corrosion, or obstructions. Gaskets and seals should be inspected and replaced as necessary.

5.2.12 Sliding Bearings

Sliding bearings should be inspected for evidence of binding.

5.2.13 Inspect Feed Gates

Inspect the feed gates annually and look for signs of wear, sealing problems and breakage.

5.2.14 Inspect ESP Controls

Inspect the ESP controls for electric termination and vacuum.

5.2.15 Inspect Balanced Temperature/Flows

Inspect and clean the ducts and flow distribution devices.

Table 5.2

Summary of Fuel System Outage Requirements

1.	Inspect discharge electrodes	Section 5.2.1
2.	Inspect collecting electrodes	Section 5.2.2
3.	Inspect ductwork and expansion joints	Section 5.2.3
4.	Inspect casings and hoppers	Section 5.2.4
5.	Inspect/service motors	Section 5.2.5
6.	Inspect & service rappers & vibrators	Section 5.2.6
7.	Inspect/service high voltage components.	Section 5.2.7
8.	Service key interlock system	Section 5.2.8
9.	Service control equipment & verify calibration of control sensors	Section 5.2.9
10.	Inspect & service auxiliary equipment controls.	Section 5.2.10
11.	Inspect/service insulator compartment heating & ventilation system.	Section 5.2.11
12.	Inspect/repair sliding bearings	Section 5.2.12
13.	Inspect feed gates	Section 5.2.13
14.	Inspect ESP controls	Section 5.2.14
15.	Inspect balanced temperature/flows	Section 5.2.15

5.3 Major Outage Activities

5.3.1 Discharge Electrodes

Inspect discharge electrodes for proper alignment, tension, excessive dust buildup, and signs of arcing. Those sections that have exhibited poor electrical readings should be given first priority.

5.3.2 Collecting Electrodes

Inspect collecting plates for structural integrity and identify areas of deterioration, corrosion or erosion. Plate alignment should be checked. Plates requiring corrective measures should be repaired or scheduled for next available outage.

5.3.3 Ductwork and Expansion Joints

Inspect precipitator ductwork and expansion joints for structural integrity, corrosion, erosion, and dust build-up. Fabric type expansion joints should be checked for tears or punctures and functionality. Identify, prioritize and schedule for repair or replacement all holes in the ductwork and expansion joints.

5.3.4 Casing and Hoppers

Inspect precipitator casings and hoppers internally and externally for structural integrity, as well as signs of corrosion, erosion, leaks, and dust build-up. All holes and structural problems should be identified, prioritized and scheduled for repair or replacement. Particular attention should be paid to the areas around access doors and expansion joints.

Inspect each ash hopper to determine if all hoppers are emptying completely. Operate the ash removal system through a complete cycle to observe that each hopper is cycled correctly and that the gate valves and associated equipment operate properly. Inspect and lubricate solenoids and hydraulic cylinders according to the manufacturer's recommendations. Inspect the gate valve surfaces and any gasketing material installed for wear and alignment. Worn gaskets are to be replaced and sealing surfaces smoothed as required. Pressurized systems are to be checked for leaks. Inspect rotary valves and vent lines.

Inspect and clean electric vibrators.

5.3.5 Hopper Level Indicators

The hopper level indicators should be inspected, calibrated, and checked for proper operation in accordance with the manufacturer's procedures. For all detectors, verify hoppers are empty and calibrate.

5.3.6 Thermal Insulation

Inspect precipitator insulation and lagging. Any wet or damaged insulation should be scheduled for replacement at the earliest opportunity.

5.3.7 Ground System

The ground switch should be checked every time it is keyed open and all bus ducts should be opened and the ground switches should be inspected during each major outage.

5.3.8 Transformer-Rectifier Sets

If arcing has been detected, the dielectric strength of the insulating fluid should be sampled and tested in accordance with the American Society for Test and Materials Methods as outlined in American National Standards Institute Standard C59.131-1971, which is the Institute of Electrical and Electronics Engineers, Inc. Standard G4-1969, IEEE Guide for Acceptance and Maintenance of Insulating Oil in Equipment, or other currently approved method.

5.3.9 Transformer-Rectifier Linear Reactors

Inspect and clean as required linear reactors, high voltage conductors, insulators, bushings and terminals. Cracked or chipped bushings should be repaired or replaced. All electrical connections should be checked for tightness and for signs of corrosion. The surge arrestor spark gap should be checked. In addition to the inspection of all external insulators, insulators exposed to the gas stream should be inspected and cleaned.