TAMPA ELECTRIC

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BUREAU OF AIR REGULATION

September 28, 2001

Mr. David Lloyd
Environmental Engineer
U.S. Environmental Protection Agency, Region IV
61 Forsyth Street, S.E.
Atlanta, Georgia 30303

Via FedEx
Airbill No. 7901 6876 2390

Re: Tampa Electric Company
Consent Decree
Civil Action No. 99-2524 CIV-T-23F
Big Bend Station Electrostatic Precipitators Best Operational Practices (BOP) report and Best Available Control Technology (BACT) analysis

Dear Mr. Lloyd:

Pursuant to Specific Conditions 32.A and 32.B of the above referenced Consent Decree, Tampa Electric Company hereby submits the BOP report and the BACT analysis for the electrostatic precipitators at Big Bend Station.

The BOP report was developed with the help of the Electric Power Research Institute (EPRI), Southern Research Institute (SRI), and Grady Nichols Enterprises (GNE). These three contractors also provided Tampa Electric Company with a number of ESP modification options in support of the BACT analysis, which was ultimately performed by Environmental Consulting & Technology (ECT), inc. Both of these studies were conducted over a period of 18 months and, when implemented, will provide a reduction in emissions of particulate matter from Big Bend Station.

TEC understands that submission of these reports satisfies the stipulations found in Specific Conditions 32.A and 32.B of the EPA Consent Decree requiring the completion and submittal of these reports. If you have any questions, please feel free to telephone Shannon Todd or me at (813) 641-5215.

Sincerely,

Gregory M. Nelson, P.E.
Director
Environmental Affairs

EP\br\SKT288

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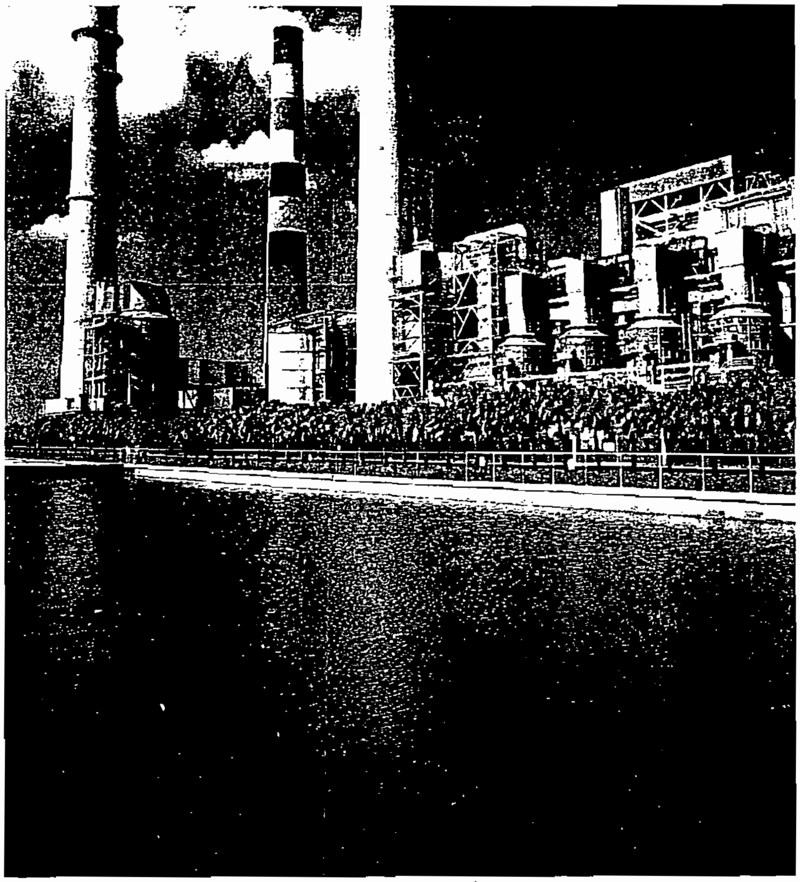
BIG BEND GENERATING STATION BEST AVAILABLE CONTROL TECHNOLOGY FOR PARTICULATE MATTER



Prepared for:

TAMPA ELECTRIC

Prepared by:

ECT
Environmental Consulting & Technology, Inc.
3701 Northwest 98th Street
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ECT No. 000883-0100

September 2001

1.0 INTRODUCTION AND SUMMARY

1.1 INTRODUCTION

Tampa Electric Company (TEC) recently entered into agreements with the Florida Department of Environmental Protection (FDEP) and the U.S. Environmental Protection Agency (EPA) to reduce emissions at its Big Bend Generating Station located in Hillsborough County, Florida. These agreements (FDEP's Consent Final Judgement and EPA's Consent Decree) call for minimization and monitoring of particulate matter (PM) emissions from Units 1 through 4 at the Big Bend Generating Station.

The Big Bend Generating Station's four steam boilers (i.e., Units 1 through 4) are primarily fired by coal and coal/petroleum coke blends. Units 1 and 2 are 445 megawatt (MW), Riley-Stoker, wet-bottom, opposed-fired boilers that began commercial operation in 1970 and 1973, respectively. Unit 3 is a 465 MW, Riley-Stoker, wet-bottom, opposed-fired boiler that began commercial operation in 1976. Unit 4 is a 486 MW, Combustion Engineering, tangentially-fired unit that commenced operation in 1985. Each boiler is equipped with two electrostatic precipitators (ESPs) to control PM emissions.

The above-mentioned EPA Consent Decree specifically requires the following:

- TEC must complete an optimization study for each ESP at the Big Bend Station. The study must also recommend best operational practices (BOPs) to minimize PM emissions. The study must be completed and reported to EPA for review and approval within 12 months after entry of the Consent Decree.
- TEC must also complete a Best Available Control Technology (BACT) analysis for upgrading each ESP. The BACT analysis must be submitted to EPA for review and approval within 12 months after entry of the Consent Decree.
- Upgrades and installation of equipment called for by the BACT analysis must be completed by May 1, 2004.

- Within 6 months after completion of the upgrades and installation of equipment called for by the BACT analysis, TEC must revise the optimization study and BOPs, as necessary. These revisions must be submitted to EPA for review and approval. The ESPs must be operated in accordance with the approved study and its recommendations no later than 180 days after EPA approval.

The purpose of this report is to present a BACT analysis for PM based on the results of the optimization study conducted by Electric Power Research Institute (EPRI) and Southern Research Institute (SRI) under contract with TEC.

1.2 SUMMARY

As presented in this report, the PM BACT analyses resulted in the following conclusions:

- The use of BOPs, installation of modern ESP controls, balanced exhaust flow rates, and upgrading the ash removal system is proposed as PM BACT for Units 1, 2, and 3. Implementation of these control technologies will result in PM emissions of not more than 0.045, 0.042, and 0.036 pound (lb) PM per Million British thermal units (MMBtu) heat input for Units 1, 2, and 3, respectively. These emission rates represent a 55, 58, and 64 percent decrease from the current permit limit of 0.1 lb PM per MMBtu for Units 1, 2, and 3, respectively.
- The use of BOPs and installation of modern ESP controls is proposed as PM BACT for Unit 4. Implementation of these control technologies will result in PM emissions of not more than 0.010 lb PM per MMBtu heat input. This emission rate represents the "top" case based on a review of BACT determinations for coal-fired power plants contained in EPA's Reasonably Available Control Technology (RACT)/BACT)/Lowest Achievable Emission Rate (LAER) Clearinghouse (RBLC) and a 67 percent decrease from the current limit of 0.03 lb PM per MMBtu.

Following this introduction and summary, a description of the BACT methodology is provided in Section 2.0. A review of applicable federal and state PM emission limitations applicable to the Big Bend Generating Station is provided in Section 3.0. A discussion of

ESP control technology and the PM BACT analysis is provided in Sections 4.0 and 5.0, respectively.

Appendix A contains the supporting documentation used in the preparation of this report. Summaries of RBLC BACT determinations for coal-fired power plants are provided in Appendix B.

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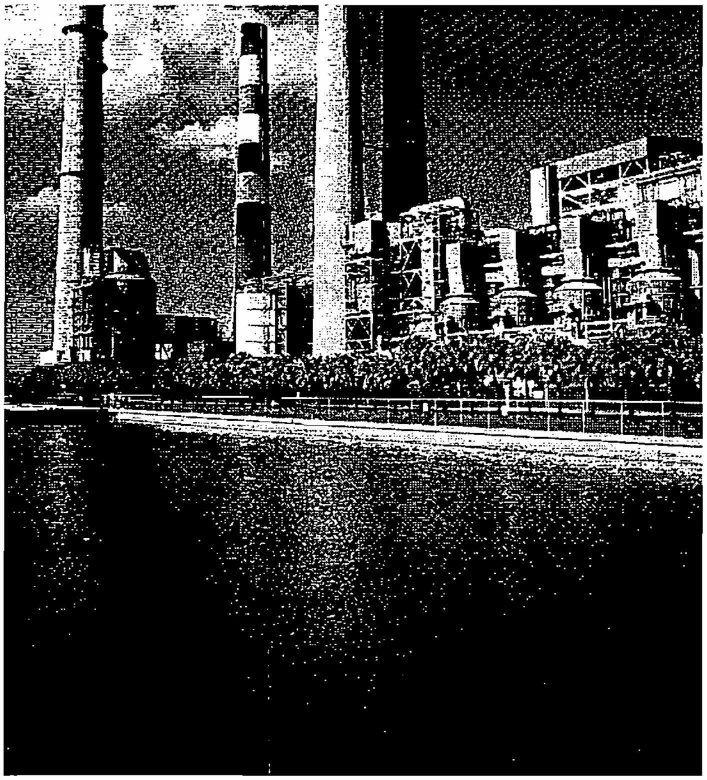
BIG BEND GENERATING STATION BEST OPERATING PRACTICES FOR PARTICULATE MATTER



Prepared for:

TECO

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September 2001

Executive Summary

Tampa Electric's Big Bend Station has four coal-fired units equipped with electrostatic precipitators (ESPs) for particulate matter control. As a result of an agreement with federal and state regulators, a series of programs were undertaken to test and examine the performance of the Big Bend ESP's to determine if changes to the equipment could be made to improve collection efficiency and to evaluate and revise, where necessary, existing operating and maintenance procedures in an effort to further improve upon the reliability and performance of the ESP equipment. Tampa Electric Company issued contracts to numerous consulting firms inclusive, but not necessarily limited to the Air Flow Sciences Corporation, (ASC), the Electric Power Research Institute, (EPRI), and the Southern Research Institute, (SRI) to conduct these programs. The results of those studies indicated that, after implementation of various modifications recommended the Best Available Control Technology study and these Best Operating Practices guidelines, the existing size and configuration of each ESP would yield particulate emissions substantially below current regulatory limits. This document focuses upon the results of the EPRI, SRI, and Grady Nichols thorough investigation of TEC existing operating and maintenance programs and methods. These guidelines define a set of operating procedures and maintenance practices that reflect TEC's current practices and the industries most up-to-date understanding of the technology. Proper implementation of these guidelines can result in particulate matter emissions that meet the expectations and intent of the EPA Consent Decree and the FDEP Consent Final Judgment.

1.0 Introduction

Tampa Electric, as a result of an agreement with federal and state regulators, has embarked on numerous programs to minimize the environmental impact of the coal-fired units at the Big Bend Station. The programs involve efforts to significantly reduce SOx and NOx emissions and to further reduce very low particulate emissions. The plant is currently equipped with scrubbers for SO_2 control, and low NOx technologies will be added. The focus of this study is strictly concerned with the optimization of the PM equipment via changes to the equipment, and to operational and maintenance practices (which are not identified in the BACT). Since Big Bend already has electrostatic precipitators (ESPs) for particulate matter control, studies were initiated to determine if the ESPs were capable of providing satisfactory levels of particulate matter 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, described in Section 1.2, were used to develop the Best Operating and Maintenance Guidelines that's contained in Sections 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 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 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 BOP or BACT. This information was supplied to EPRI and SRI for use in the aforementioned studies.

1.2 Program Implementation

Tampa Electric Company sought out leaders in the field of electrostatic precipitation to develop the material in this report. Contracts were issued to the Electric Power Research Institute and the Southern Research Institute, 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. 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. The Electric Power Research Institute has conducted a particulate matter 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. The Southern Research Institute 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. The Southern Research Institute has 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 Southern Research Institute ESP research program for many years. He has a world-wide reputation as one of the most knowledgeable men in the electrostatic precipitation field. Dr. Nichols is also a member of the Tampa Electric team.

1.3 Guidelines Background

This team conducted two parallel efforts to meet the EPA 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. 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 development of the 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

BOP guidelines. These tests included an analysis of the fly ash produced by the boilers at Big Bend (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 ESPs, which incorporated various modifications identified herein.

1.4 Guidelines Structure

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 Preliminary Performance Upgrade Activities

During the preliminary study of the ESPs at Big Bend, certain areas of improvement were identified that are included as BOP recommendations and could further enhance the ESP performance on some of the units. These were:

(1) Unbalanced gas flow to the ESPs and non-uniform flow within these ESP's.
(2) Leaking valves in the ash removal systems on Units 1, 2 and 3, as described in the BACT.
(3) Wire breakage in the ESP on Unit 4.
(4) Potential of SO_3 formation.
(5) Electrical (T/R) Sectionalization of Unit #2.

To address some of these issues, a gas flow study was conducted for Unit 1 and new gas flow distribution devices were installed in the ducts and ESPs on Unit 1. In addition, modified fly ash gate valves were installed in the ash removal system. The new ESP monitoring program, ESPert, was also installed on all four units. This computer program is linked to the ESP controls and continuously predicts outlet opacity based on the electrical operating parameters within the ESP. A divergence of the predicted and measured opacity can now be used to initiate various actions. In fact, the installation of this state-of-the-art program will contribute to the plant personnel's ability to track and understand ESP performance and, hence, contribute to the program to support a goal of long-term optimum ESP performance.

2.0 Unit Descriptions

There are four coal-fired units at Big Bend with a total generating capacity of 1,841 MWe. The boilers for Units 1-3 are all Riley-Stoker, turbo-fired furnaces with very similar designs. These units are rated at 445 MWe for Units 1 and 2 and 465 MWe for Unit 3. The boiler for Unit 4 is a Combustion Engineering, (now Alstom), tangential-fired furnace with a capacity of 486 MWe. 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 MWe. It is a "wet" bottom utility boiler manufactured by Riley Stoker Corporation, and identified as a Riley-Stoker Turbo-Furnace. This unit may be fired on coal or a coal/petroleum coke blend consisting of a maximum of 20 percent petroleum coke, by weight. 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 can be 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 the 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 in length with 30-foot high collection plates, which are twelve inches apart. There are 100 gas passages in each electrical field. The discharge electrodes are of a "pipe & spike" design within a rigid pipe frame with an equivalent discharge wire diameter of 0.095 inches on nine-inch centers. The discharge and collecting electrodes are rapped with magnetic impulse 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. The old ESP has two rows of hoppers in the direction of gas flow with 8 hoppers in each row for collecting the fly ash.

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 while the fifth, sixth and seventh electrical fields are six feet in length. The first five electrical fields were also rebuilt in 1992 and have 104 gas passages each 30-foot high and 12 inch wide. The sixth and seventh electrical fields have 140 gas passages, which are 9-inches wide. The first five electrical fields have a rigid "pipe and spike" discharge electrode system with an equivalent discharge wire diameter of 0.095 inches on nine-inch centers. The sixth and seventh electrical fields have the original weighted wire electrode assemblies with 0.109 inch wires, which are on 8 inch centers.

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 New ESP has two rows of hoppers in the direction of gas flow with 8 hoppers in each row for collecting the fly ash.

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 MWe 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 be fired on coal or a coal/petroleum coke blend consisting of a maximum of 20 per cent petroleum coke, by weight. 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 has seven electrical fields in the direction of gas flow. The first four electrical fields are four and one-half feet in length while the last three fields are six feet in length. Each field has 108 gas passages each 30-foot high and 9 inches wide. The weighted wire discharge electrodes are twisted paired 0.109 inch diameter wires on nine-inch centers.

Each box has ten transformer rectifiers. The first four electrical fields have only one TR that powers all 108 gas passages or a total plate area of 29,160 ft^2/TR. Fields 5, 6, & 7 have two TR's each, and they power 54 gas passages or a total plate area of 19,440 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.

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 MWe. 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 also be fired on coal or coal/petroleum coke blend with a maximum percentage of petroleum coke of 20% by weight. 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 and have 80 gas passages each 30-foot high and 12-inches wide. The discharge electrodes have a rigid "pipe and spike" discharge electrode system with an equivalent discharge wire diameter of 0.095 inches on eight-inch centers. 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 9-inches wide. The last two electrical fields have 80 gas passages each 30-feet high and 12-inches wide. 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 system with an equivalent discharge wire diameter of 0.095 inches on eight-inch centers. 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.

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 MWe generation. 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 deep and has 90 gas passages. The collecting plates are 48 feet high and are spaced 12 inches apart. 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.

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. Albeit that the ESP's currently operating at the Big Bend station are fully compliant with the required emissions limits, the recommendations made herein 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 the current regulated PM emission limits. Big Bend Unit 4 ESP system was substantially over-sized based upon current fuels and provides for even greater levels of PM reduction as compared to other comparable units of this vintage and size. Accordingly, Big Bend Unit 4 traditionally is operated well below current regulated PM emission limits. Although these ESP's are fully compliant with existing PM emissions limits, there is a potential that greater reductions in PM emissions are possible through the implementation of certain physical, operational, and maintenance activities, which would supplement existing practices.

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.

To augment the current ESP operation, TEC has recently installed a new real time monitoring system, ESPert, developed and provided by the Electric Power Research Institute (EPRI). This system is installed on a small computer and connected to a number of ESP operating parameters and conditions. These inputs include the secondary electrical voltages and currents, as well as the gas volume flow rate and opacity. The ESPert system continuously calculates the collection efficiency for each ESP and estimates the outlet opacity.

3.3 Recommended Physical Modifications

Physical modifications, which are expected to improve the performance of the ESP's, are described and analyzed within the BACT study. However, there are other discrete physical modifications which can be made to the existing ESP's, but indirectly have the potential to increase the performance via increases in reliability. These reliability modifications can be either improvements to specific equipment or an improved design of the systems. The specific recommendations of this study include:

- Wide plate spacing for Units 1 through 3, which involves replacing the plates and wire discharge electrodes with new plates and rigid discharge electrodes, thereby eliminating wire breakage problems.

- Increased electrical sectionalization for Unit 2 through the addition of eight new T/R sets and controls to improve the power levels in the ESP's on this unit.

- Flow Corrections to and within the ESP's which includes new or modified turning vanes to balance the gross flow to each ESP and new or modified inlet and outlet distribution plates to achieve uniform flow within the ESP's to achieve the uniform gas flow distribution needed to optimize ESP performance.

- Upgraded fly ash level controls to aid in the prevention of high hopper levels that are detrimental to ESP operation.

These recommendations are further discussed in section 3.5.

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 should be maintained at the 40%/60% respectively range as closely as possible. If the actual opacity changes significantly from that predicted from ESPert, ash dropout in the ductwork might be causing a change in the gas split. This discrepancy should be checked and corrected, as necessary, at the first opportunity.

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.

ments in Maintenance and Operation

peration practices for the Big Bend Station should
in Section 4 to establish and retain the potential
the ESPs operating at the station. The concern is
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measures can best be determined by following the
n program defined in Section 4.0. The specific
nted in EPRI Document TR-113582-VI, *Guidelines*
recipitator Performance, Volume 1: Optimizing an
pitator and EPRI CS-5198-V3, *Electrostatic*
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a considerable amount of skill in the operation of
addition, the installation of the EPRI ESPert system
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vel of training to effectively operate and maintain
sultants are also available to assist in specific areas
s the other contractors for this study are available as

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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. In addition, the installation of the EPRI ESPert system to monitor the day-to-day operation of the units will augment their experience. 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.