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DOE/PC 189652--T1

INNOVATIVE CLEAN COAL TECHNOLOGY (ICCT)

DEMONSTRATION OF SELECTIVE CATALYTIC REDUCTION (SCR)
TECHNOLOGY FOR THE CONTROL OF NITROGEN OXIDE (NO_x)
EMISSIONS FROM HIGH-SULFUR COAL-FIRED BOILERS

DOE/PC/89652--T1

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DOE Contract
DE-FC22-90PC89652

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195-88-027

Quarterly Report No. 1
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November, 1990

Prepared by:

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Section 1

SUMMARY

The objective of this project is to demonstrate and evaluate commercially available SCR catalysts from U. S., Japanese and European catalyst suppliers on a high-sulfur coal-fired boiler. SCR is a post-combustion nitrogen oxide (NOx) control technology that involves injecting ammonia into the flue gas generated from coal combustion in an electric utility boiler. The flue gas containing ammonia is then passed through a reactor that contains a specialized catalyst. In the presence of the catalyst, the ammonia reacts with NOx to convert it to nitrogen and water vapor.

Although SCR is widely practiced in Japan and Europe, there are numerous technical uncertainties associated with applying SCR to U. S. coals. These uncertainties include:

- (1) potential catalyst deactivation due to poisoning by trace metal species present in U.S. coals that are not present in other fuels.
- (2) performance of the technology and effects on the balance-of-plant equipment in the presence of high amounts of SO₂ and SO₃.
- (3) performance of a wide variety of SCR catalyst compositions, geometries and methods of manufacture under typical high-sulfur coal-fired utility operating conditions.

These uncertainties will be explored by constructing a series of small-scale SCR reactors and simultaneously exposing different SCR catalysts to flue gas derived from the combustion of high sulfur U. S. coal.

The demonstration will be performed at Gulf Power Company's Plant Crist Unit No. 5 (75 MW capacity) near Pensacola, Florida. The project will be funded by the U. S. Department of Energy (DOE), Southern Company Services, Inc. (SCS on behalf of the entire Southern electric system), and the Electric Power Research Institute (EPRI). SCS is the participant responsible for managing

all aspects of this project.

The project is being conducted in the following three phases:

- Phase I - Permitting, Environmental Monitoring Plan and Preliminary Engineering
- Phase II - Detailed Design Engineering and Construction
- Phase III - Operation, Testing, Disposition and Final Report

During this reporting period, a number of Phase I activities have been initiated and many have been completed. Initial discussions were held between Gulf Power Company and the State of Florida Department of Environmental Regulations (DER) regarding environmental permitting of the SCR pilot plant facility. Based upon Florida DER review, Gulf Power has been formally notified that the SCR pilot plant project at Plant Crist will be exempted from the permitting process. The project's environmental subcontractor, Radian Corporation, prepared a draft Environmental Monitoring Plan for internal review. Southern Research Institute completed extensive characterization of existing flue gas conditions in Unit 5 and 6 ducts. Data from these characterization analyses are being interpreted, but a preliminary conclusion is that the proposed high dust extraction location from Unit 5 is satisfactory. However, extraction from Unit 6 is questionable, and the use of Unit 6 may be dropped from the program since it is unlikely that a representative gas sample could be obtained.

During this reporting period, DynaGen, Inc., a fluid mechanics consulting subcontractor, initiated work on the pilot plant ductwork layout, flue gas distribution and flow control concepts and preliminary pilot plant reactor design concepts. Conceptual designs were produced for flue gas flow distribution and control philosophy that includes a variable speed fan, dampers, full-flow venturi and reactor bypass ducting to ensure proper control and distribution among all the reactors. Moreover, Dynagen reviewed SRI test data from Plant Crist to evaluate the suitability of possible flue gas extraction locations.

Preparation of the SCR process Design Data Book for use by SCS Design Engineering during detailed design was begun with substantial progress being

made on the conceptual design specifications. Utility requirement calculations and review of Plant Crist interface locations were initiated to define SCR utility needs from, and interface points with, Plant Crist. Revisions to the general arrangement drawings to accommodate the pilot plant were also addressed. Preliminary revisions of SCR process flow diagrams and piping and instrumentation diagrams were produced for internal review. A request for final catalyst specifications was issued to each catalyst supplier.

Project engineering management developed a project management information system to track schedule and budget for engineering and equipment procurement. Construction management interacted with engineering to develop the CPM schedule for engineering and construction. An overall management information system for the project was completed to monitor, schedule, and budget for the project and to fulfill DOE reporting requirements.

Also, contracts with all named subcontractors, including the Electric Power Research Institute, were completed. An Evaluation Agreement was signed with Engelhard Corporation. Evaluation Agreements with Siemens and Haldor Topsoe were initiated and continue to be negotiated.

Section 2

INTRODUCTION

The Innovative Clean Coal Technology (ICCT) Program is designed to demonstrate clean coal technologies that are capable of retrofitting or repowering existing facilities to achieve significant reduction in sulfur dioxide (SO_2) and/or nitrogen oxides (NO_x) emissions. The technologies selected for demonstration are capable of being commercialized in the 1990s and are expected to be more cost effective than current technologies.

This ICCT project is jointly funded by the U.S. Department of Energy, the Electric Power Research Institute (EPRI), and by Southern Company Services (SCS) on behalf of the entire Southern electric system. The project's objective is to demonstrate the selective catalytic reduction (SCR) process that removes nitrogen oxides (NO_x) from the flue gas of boilers that burn U.S. high-sulfur coal. The SCR technology involves the catalytic reduction of NH_3 , which is injected into the flue gas to react with NO_x contained in the flue gas to produce molecular nitrogen (N_2) and water vapor.

A simplified SCR process flow diagram with major equipment is shown in Figure 1. Specifically, hot flue gas leaving the economizer section of the boiler is ducted to the SCR reactor. Prior to entering the reactor, NH_3 is injected into the flue gas at a sufficient distance upstream of the reactor to provide for complete mixing of the NH_3 and flue gas. The quantity of NH_3 can be adjusted and it reacts with the NO_x from the flue gas. The flue gas leaving the catalytic reactor enters the air preheater where it transfers heat to the incoming combustion air. Provisions are made for ash removal from the bottom of the reactor since some fallout of fly ash is expected. Duct work is also provided to bypass some flue gas around the economizer during periods when the boiler is operating at reduced load. This is done to maintain the temperature of the flue gas entering the catalytic reactor at the proper reaction temperature of about 700°F . The flue gas leaving the air preheater goes to the electrostatic precipitator (ESP) where fly ash is removed. The ESP is part of the existing plant and is generally unaffected by the SCR system except as higher SO_2 content affects the electrical resistivity of the fly ash or if NH_4HSO_4 co-precipitates with the fly ash.

FIGURE 1. BLOCK FLOW DIAGRAM OF SCR INSTALLATION.

The SCR technology is in commercial use in Japan and western Europe on gas, oil, and on low-sulfur, coal-fired power plants. The first utility applications of SCR catalyst technology started in Japan in 1977 for oil- and gas-fired boilers and subsequently in 1979 for coal-fired boilers. As of 1986, ninety utility boilers in Japan had been equipped with SCR catalyst technology including twenty-two coal-fired boilers. These coal-fired boilers represent a combined capacity in excess of 6500 MWe and are typically fired with a low-ash, low-sulfur coal.

In addition to Japanese experience, several countries in western Europe (most notably West Germany and Austria) have passed stringent NO_x emission regulations that have all but mandated the installation of SCR. Prior to commercial SCR installations in West Germany, utility companies demonstrated several types of SCR facilities in prototype demonstration programs similar to this ICCT project. Over 50 SCR pilot plants were built and operated in western Europe. These pilot plants ranged from 19 to 6200 SCFM and provided the data base that led to commercialization of the SCR technology in western Europe.

Previously completed U.S. work with the SCR process on utility boilers consists of three projects which were carried out in the late 1970s and early 1980s. One of these was carried out on a natural gas fired boiler by Southern California Edison. Another project consisted of a pilot test conducted for the EPA at Georgia Power's Plant Mitchell. This pilot plant treated a 1000 ACFM (0.5 MWe) slip stream of flue gas resulting from the combustion of low- to medium-sulfur coal. A third pilot-scale project, carried out at the Public Service Company of Colorado's Arapaho Station treated a 5000 ACFM (2.5 MWe) slip stream of flue gas resulting from the combustion of U.S. low-sulfur coal.

Although SCR is widely practiced in Japan and Europe, there are numerous technical uncertainties associated with applying SCR to U.S. coals. These uncertainties include:

- (1) potential catalyst deactivation due to poisoning by trace metal species present in U.S. coals that are not present in other fuels.

- (2) performance of the technology and effects on the balance-of-plant equipment in the presence of high amounts of SO_2 and SO_3 .
- (3) performance of a wide variety of SCR catalyst compositions, geometries and methods of manufacture under typical high-sulfur coal-fired utility operating conditions.

These uncertainties will be explored by constructing a series of small-scale SCR reactors and simultaneously exposing different SCR catalysts to flue gas derived from the combustion of high sulfur U.S. coal.

The first uncertainty above will be handled by evaluating SCR catalyst performance for two years under realistic operating conditions found in U.S. pulverized coal utility boilers. The deactivation rates for the catalysts exposed to flue gas from high sulfur U.S. coal will be documented to determine accurate catalyst life, and thus, accurate process economics.

The second uncertainty above will be explored by performing parametric testing and through the installation/operation of air preheaters downstream of the larger reactors. During parametric testing, operating conditions will be adjusted above and below design values to observe deNO_x performance and ammonia slip as functions of the change in operating conditions. Air preheater performance will be observed to evaluate effects from SCR operation upon heat transfer, and therefore, upon boiler efficiency.

The third uncertainty is being handled by using honeycomb- and plate-type SCR catalysts from U.S., Japan and Europe of various commercial composition. Results from the tests with these catalysts will expand our knowledge of performance on a variety of SCR catalysts under U.S. operating conditions.

The intent of this project is to demonstrate commercial catalyst performance, proper operating conditions, and catalyst life for the SCR process. This project will also demonstrate the technical and economic viability of SCR while reducing NO_x emissions by at least 80%.

The project will be conducted at Gulf Power Company's Plant Crist Unit 5, a commercially operating 75 MW unit, located in Pensacola, Florida. The SCR

process to be used in this demonstration will be designed to treat a slip-stream of flue gas and will feature multiple reactors installed in parallel. With all reactors in operation, the maximum amount of combustion flue gas that can be treated is 17,400 standard cubic feet per minute (scfm) which is roughly equivalent to 8.7 MWe.

The proposed SCS facility is a slip-stream SCR test facility consisting of three 2.5 MWe (5000SCFM) SCR reactors and six 0.20 MWe (400SCFM) reactors that will operate in parallel for side-by-side comparisons of commercially available SCR catalyst technologies obtained from worldwide vendors. Figure 2 presents a simplified process flow diagram for the proposed facility. The large (2.5 MWe) SCR reactors will contain commercially available SCR catalysts as offered by SCR catalyst suppliers. These reactors will be coupled with small-scale air preheaters to evaluate the long-term effects of SCR reaction chemistry on air preheater deposit formation and the deposits' effects on air preheater. The small reactors will be used to test additional commercially available catalysts. This demonstration facility size will be adequate to develop performance data to evaluate SCR capabilities and costs that are applicable to boilers using high-sulfur U.S. coals.

The demonstration project will be conducted over a 52-month period with project activities including environmental monitoring, permitting, design, construction, operation, and process evaluation. The project is organized into three phases: (1) Phase I - Permitting, Environmental Monitoring Plan and Preliminary Engineering; (2) Phase II - Detail Design Engineering and Construction; and (3) Phase III - Operation, Testing, Disposition, and Final Report. Phase I is scheduled for 4 months, Phase II is scheduled for 20 months and Phase III is scheduled for 28 months. Operations are planned for 26 months. The cooperative agreement was signed June 14, 1990, and the project completion date is projected to be in the fourth quarter of 1994. The total estimated project costs are \$15,574,355. The co-funders are SCS (\$6,049,017), DOE (\$7,525,338), and EPRI (\$2,000,000).

FIGURE 2. PROTOTYPE SCR DEMONSTRATION FACILITY-PROCESS FLOW DIAGRAM.

Section 3
PROJECT DESCRIPTION

Within the three phases of the project, the following tasks will be conducted to effectively demonstrate the SCR process:

Phase I - Permitting, Environmental Monitoring Plan and Preliminary Engineering

Task 1.1.1 - Prototype Plant Permitting Activities

Task 1.1.2 - Develop Environmental Monitoring Program

Task 1.1.3 - Preliminary Engineering

Task 1.1.4 - Engineering and Construction Contracts Scope Development

Task 1.1.5 - Project Management and Reporting

Phase II - Detail Design Engineering and Construction

Task 1.2.1 - Detailed Design Engineering

Task 1.2.2 - Construction

Task 1.2.3 - Operation Staff Training

Task 1.2.4 - Planning for Detailed Testing

Task 1.2.5 - Start-Up/Shakedown

Task 1.2.6 - Project Management and Reporting

Phase III - Operations, Testing, Disposition and Final Report

Task 1.3.1 - SCR Demonstration Facility Operations and Maintenance

Task 1.3.2 - Process Evaluation

Task 1.3.3 - Environmental Data Management and Reporting

Task 1.3.4 - Economic Evaluation

Task 1.3.5 - Dismantling/Disposition

Task 1.3.6 - Project Management and Reporting

Section 4

PROJECT STATUS

Progress during July - September, 1990, is summarized below for each of the on-going tasks in the Scope of Work.

PHASE I - PERMITTING, ENVIRONMENTAL MONITORING PLAN AND PRELIMINARY ENGINEERING

Task 1.1.1 - Prototype Plant Permitting Activities

Initial discussions were held between Gulf Power Company and the State of Florida Department of Environmental Regulations (DER) regarding possible permits or permit modifications that may be required for the Plant Crist SCR pilot plant facility. Based upon Florida DER review, formal notification has been received by Gulf Power that the SCR pilot plant project at Plant Crist will be exempted from the permitting process.

Task 1.1.2 - Develop Environmental Monitoring Program

Radian Corporation, as the project's environmental subcontractor, prepared a draft Environmental Monitoring Plan for internal review. The document is currently being reviewed by SCS and Gulf Power. Other work to be performed by Radian upon satisfactory completion of the Environmental Monitoring Plan include: prepare a Sampling and Analyses Procedure Manual, to document the methods of sample acquisition and analysis; and develop a Quality Assurance/Quality Control Project Plan.

Task 1.1.3 - Preliminary Engineering

During this reporting period, Southern Research Institute completed extensive characterization of existing flue gas conditions in Unit 5 and 6 ducts. The analyses were performed near the location where the slipstream extraction is anticipated for the SCR facility and included velocity profiles; particulate mass loading and distribution profiles; NO_x, O₂, and temperature profiles. A copy of these data are provided in Appendix A. As of the end of the quarter,

data from these characterization analyses are being interpreted, but a preliminary conclusion is that the proposed high dust extraction locations from Unit 5 is satisfactory. However, extraction from Unit 6 is questionable because of unstable flow patterns and wide fluctuations in particulate distributions and mass loadings. The use of Unit 6 may be dropped from the program since it is unlikely that a representative gas sample could be obtained.

During this reporting period, work was initiated by DynaGen, Inc., a fluid mechanics consulting subcontractor, on the pilot plant ductwork layout, flue gas distribution and flow control concepts and preliminary pilot plant reactor design concepts. Conceptual designs were produced for flue gas flow distribution and control philosophy that include a variable speed fan, dampers, full-flow venturi, and reactor bypass ducting, to ensure proper control and distribution among all the reactors. Additional work to model the SCR reactor inlet is planned.

Preparation of the SCR process Design Data Book for use by SCS Design Engineering during detailed design was begun. Substantial progress was made on the conceptual design specifications, which included the following:

- o Mass balances
- o Heat loss calculations
- o Major equipment lists
- o Preliminary piping and instrumentation diagrams
- o Preliminary ammonia storage and distribution system
- o Preliminary extractive gas sampling system
- o Operation philosophy discussion
- o Preliminary discussion of parametric test plans as they might affect design

These items are still under review. A complete Design Data Book will be issued at the conclusion of Phase I.

Based on the preliminary mass balances utility requirement calculations were initiated to define utility needs from, and interface points with, Plant Crist. Revisions to the general arrangement drawings to accommodate the pilot

plant were also addressed. A request for final catalyst specifications was issued to each catalyst supplier.

A meeting was held with Asea Brown Boveri (formerly Combustion Engineering) to review proposed air preheater designs. Detailed drawings were received and technical issues concerning the air preheaters were identified.

A project management information system (MIS) for engineering and construction was developed. A project cost and manhour tracking program capable of providing periodic expenditure reports to project management for monitoring the cost of engineering was implemented. A CPM schedule was developed with input from engineering and construction personnel. A project commitment tracking program including a numbering scheme for controlling and tracking material cost was implemented. Procurement control reports for major inquiry items were developed and implemented.

Task 1.1.4 - Engineering and Construction Contracts Scope Development

No progress was made on this task during this reporting period. Work is planned for the fourth quarter of 1990.

Task 1.1.5 - Project Management and Reporting

The MIS was developed for tracking overall budget and schedule information. This system is in place and is being used to control budget and schedule and to help fulfill DOE reporting requirements. Monthly reports were submitted, as was the Project Evaluation Plan, for this first reporting period.

Also, contracts with all named subcontractors, including the Electric Power Research Institute, were completed. An Evaluation Agreement was signed with Engelhard Corporation. Evaluation Agreements with Siemens and Haldor Topsoe were initiated and continue to be negotiated.

A kickoff meeting with Gulf Power was held, and coordination meetings with Design Engineering were conducted on a weekly basis.

Section 5

PLANNED ACTIVITIES

During the October - December, 1990 quarter, the following activities are planned:

- o Complete the Environmental Monitoring Plan and issue to DOE.
- o Prepare Sampling and Analyses Procedure Manual and develop Quality Assurance/Quality Control Project Plan.
- o Complete the Design Data Book, to include: process design documentation, including piping and instrumentation diagrams, ammonia storage and distribution system, and ductwork and inlet ductwork design.
- o Initiate reactor flow modeling.
- o Obtain catalyst final specifications and complete reactor internal design and catalyst supplier scope of supply.
- o Complete construction contract scope development.
- o Travel to visit Haldor Topsoe and Siemens.

APPENDIX A

**Southern Research Institute
Plant Crist Units 5 and 6
Duct Flow Characterization
Detailed Test Data**

Southern Research Institute

October 5, 1990

Mr. Kerry W. Bowers
Southern Company Services, Inc.
P. O. Box 2625
Birmingham, AL 35202

Dear Kerry:

This letter report presents results from a test program performed by Southern Research Institute at Plant Crist under SCS Contract 195-89-046. The primary goal of the test program was to obtain a detailed characterization of the flue gas and fly ash at locations under consideration for obtaining slipstreams for the SCS-DOE SCR Technology Demonstration Project.

SAMPLING PROCEDURES AND SCHEDULE

The following measurements were performed at Plant Crist during the time period July 28 through August 7, 1990:

1. Particle mass concentrations using EPA Method 17 were obtained as a function of position in the duct at three sampling locations: the inlet of the Unit 5 ESP, the outlet of the Unit 5 ESP, and the air heater inlet of Unit 6. A 12 point sample matrix was used at Unit 5 ESP inlet, and a 9 point sample matrix was used at Unit 5 ESP outlet. For the Unit 6 air heater inlet, an 8 point sample matrix was employed which was limited to the two existing ports. Diagrams of the three sample locations and the positions of the mass measurements in the ducts are provided by Figures 1-3. A 47 mm Gelman filter was used instead of the usual thimble filter for the inlet measurements. This change in procedure was adopted to facilitate weighing of the relatively small mass increments which result from the single-point sampling measurements.
2. In-situ cascade impactors were used to obtain the average size distribution of suspended fly ash particles at each of the three sampling locations. The sampling matrix for the impactor measurements generally included more points and covered the duct more completely than did the mass measurements, but no effort was made to determine the variations in particle size distribution as a function of position in the duct.

Pre-conditioned glass fiber substrates were employed to minimize artifacts resulting from flue gas-substrate

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chemical reactions. Modified Brink impactors were used for the inlet sampling, and University of Washington Mark III impactors were used for the outlet sampling. The Brink impactors are relatively low-flow rate sampling devices which are suitable for sampling inlet locations. The sampling rate (about 0.03-0.04 acfm) allows an average size distribution to be obtained over approximately a 10-minute sampling period with a multi-point traverse. In contrast, the UW instruments are relatively high flow rate devices (about 0.40 acfm) suitable for sampling the often very low mass concentrations which are encountered at control device outlets.

Both types of impactors sample at a constant flow rate during a given sampling period, under conditions that are isokinetic with respect to the average velocity over the sampling plane. This procedure is necessary because changing the flow rate through an impactor changes the cut-point of the stages; thus, constant-rate sampling is necessary to preserve the size-resolution capability of the impactor.

3. Concentrations of NO, NO_x and O₂ were obtained as a function of position at the three sampling locations. A Thermo-Electron Model 10 Chemiluminescence Analyzer was used for the NO and NO_x, and a Teledyne Portable Oxygen Monitor was employed for the O₂ traverses.

The sampling schedule was performed approximately in accordance with Table 1 of my letter to you of July 23, 1990. Actual test conditions and locations for the mass train and impactor sampling are provided in Table 1 of this report.

RESULTS

Tabular presentations of traverse data are contained in Tables 2 through 15; Table 16 provides the duct static pressure for the dates, locations, and load conditions which encompass the test program.

Point-to-point and port-to-port variations in mass concentration, gas velocity, temperature, and key gas components are of particular interest to the pre-design test effort. An examination of the data in Tables 2 and 3 indicates relatively uniform gas velocities and temperatures across the Unit 5 ESP inlet sampling plane, with coefficients of variation of 1% or less (based on the Fahrenheit scale) for the temperatures, and of 8% or less for the gas velocities.

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The mass loadings exhibit a somewhat greater point-to-point variation with coefficients of variation ranging from 8% to 16%. However, the mass loadings are still considered to be relatively uniform. Relatively uniform NO and NO_x profiles are also indicated by the data in Tables 4 and 5.

In contrast to the relatively uniform profiles found for the Unit 5 ESP inlet, large mass concentration and velocity profile differences were found at the Unit 6 ESP sampling locations, as indicated by the data in Tables 6 & 7. These profile variations would complicate the task of obtaining a representative slipstream sample. Table 8 indicates that significant O₂ increases and NO_x decreases are apparent as the traverse proceeds from point 1 to point 4, but this pattern is not apparent in the low-load data contained in Table 9.

Since a flue gas stream with a low dust concentration is required for a portion of the demonstration project, the test program included sampling at the outlet of the Unit 5 hot-side ESP. Mass loadings obtained at this location under high load conditions are presented in Table 10. These mass concentrations are consistently low, and the average (0.0034 gr/acf at 4.65% O₂ and 613°F) would correspond to a particulate emission rate of only 0.0005 pounds per million BTU. The mass train results were confirmed by the impactors, which averaged a total mass loading of only 0.0024 gr/acf. In view of the low mass concentrations, the point-to-point variations and the differences between mass train and impactor data are not considered to be excessive.

Oxygen, NO_x, and NO profiles for the Unit 5 outlet location are presented in Tables 11, 12, and 13. The relatively small differences between NO and NO_x values appear anomalous, and may indicate a problem with the measuring system. Temperature and gas velocity distribution profiles for this location are presented in Tables 14 and 15.

Table 16 contains duct static pressures obtained at the various sampling locations during the test program. The largest negative pressure readings were obtained at the Unit 5 outlet sampling location under high load conditions.

Particle size distribution data obtained during the test program are presented in this report in a graphical format. A separate Appendix will be provided which includes tabular print-outs from the Cascade Impactor Data Reduction (CIDR) program.

Figures 4 through 23 present particle size graphs in four formats for each condition tested: 1) cumulative mass loading in gr/acf and mg/acm vs diameter, 2) cumulative percent vs diameter, 3) differential mass

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distribution ($dM/d\log D$) vs diameter, and 4) differential number distribution ($dN/d\log D$) vs diameter. The error bars shown on the graphs (many of which are smaller than the data symbols) represent 90% confidence intervals to the data. The locations and conditions tested are presented in the following order:

Figures 4-7	Unit 5 Inlet--High Load
Figures 8-11	Unit 5 Inlet--Low Load
Figures 12-15	Unit 6 Inlet--High Load
Figures 16-19	Unit 6 Inlet--Low Load
Figures 20-23	Unit 5 Outlet--High Load

Since the particle size distribution of the fly ash may be a significant factor in catalyst performance during the demonstration project, it is appropriate to compare the Unit 5 and Unit 6 size distribution data to similar data obtained at other plants burning a bituminous coal. The following tabulation compares data obtained under the current project at high load with a typical plant from the EPRI data base (J. L. DuBard, R. S. Dahlin. Precipitator Performance Estimation Procedure. Electric Power Research Institute. EPRI CS-5040. February 1987.).

Size Band (microns)	EPRI-SRI Data		SCS-SRI Data	
	Mean	50% Conf.	Unit 5 Mean	Unit 6 Mean
<1	1.28	1.02-1.54	1.2	1.3
<2	4.32	3.52-5.12	3.5	5.2
<5	17.6	13.9-21.3	15.5	21.0
<10	35.4	27.0-43.8	30.0	38.6

This comparison indicates that the Crist size distribution data are generally typical of those we have measured at other utility power boilers firing pulverized bituminous coal.

In conclusion, the data indicate that the inlet location tested at Plant Crist Unit 5 should be suitable for providing a representative

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fly ash sample for the SCR project. In contrast to this location, the Unit 6 inlet was characterized by unstable flow conditions and large particle concentration and gas velocity variations with position. The Unit 5 outlet profiles were relatively uniform, but the particle concentration was quite low and would be unrepresentative of the outlet from many hot-side ESP's.

We appreciate the opportunity to work with you on this project. Please let us know if you need any additional information.

Sincerely,

E. C. Landham, Jr.

Head, Control Device Technology Section

ECL/jp

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Figure 1. Crist Unit 5 ESP inlet duct sampling locations.

Table 1

TEST CONDITIONS AND SAMPLING LOCATIONS
FOR MASS TRAINS AND IMPACTORS

<u>DATE</u>	<u>LOCATION</u>	<u>UNIT LOAD</u>
7/28	Unit 5 inlet	Low
7/29	Unit 5 inlet	Low
7/30	Unit 5 inlet	High
7/31	Unit 5 inlet	High
8/01	No data--tube leak	
8/02	Unit 5 inlet	High
8/03	Unit 6 inlet	High
8/04	Unit 6 inlet	Low
8/05	Unit 5 outlet	High
8/06	Unit 5 outlet	High
8/07	Unit 6 inlet	High

Table 2

CRIST UNIT 5 ESP INLET
HIGH-LOAD MASS, VELOCITY, AND TEMPERATURE DISTRIBUTIONS

DATE	PORT	MASS LOADING gr/acf		GAS VELOCITY ft/sec		TEMPERATURE °F	
		Pt 1	Pt 2	Pt 1	Pt 2	Pt 1	Pt 2
7/30/90	1	1.32	1.33	45.4	52.8	657	657
	2	1.33	1.38	45.4	49.8	657	657
	3	1.40	1.58	44.0	48.5	652	650
	4	1.61	1.67	43.8	45.2	640	646
	5	2.15	1.62	41.7	43.8	642	642
	6	1.65	1.61	41.6	48.4	638	643
DUCT AVG		1.55		45.9		648	
STD DEVIATION		0.22		3.2		7	
COEFF OF VAR		0.14		0.07		0.01	
7/31/90	1	1.45	1.38	46.0	54.2	655	655
	2	1.50	1.41	44.7	51.8	654	656
	3	1.47	1.76	45.6	47.9	654	651
	4						
	5	----- NOT RUN DUE TO CONDENSER LEAK -----					
	6						
DUCT AVG		1.50		48.4		654	
STD DEVIATION		0.12		3.5		2	
COEFF OF VAR		0.08		0.07		0.00	
8/02/90	1	1.23	1.27	44.8	52.4	661	663
	2	1.33	1.41	45.4	49.9	660	661
	3	1.32	1.50	43.3	48.0	659	660
	4	1.59	1.70	44.5	45.9	650	649
	5	1.96	1.97	40.9	43.1	643	644
	6	1.71	1.74	40.1	46.4	638	641
DUCT AVG		1.56		45.4		652	
STD DEVIATION		0.25		3.4		9	
COEFF OF VAR		0.16		0.07		0.01	

NOTES: Port 1 is at top of duct.
Point 1 is closest to West duct wall.

Table 3

CRIST UNIT 5 ESP INLET
LOW-LOAD MASS, VELOCITY, AND TEMPERATURE DISTRIBUTIONS

<u>DATE</u>	<u>PORT</u>	<u>MASS LOADING</u> <u>gr/acf</u>		<u>GAS VELOCITY</u> <u>ft/sec</u>		<u>TEMPERATURE</u> <u>°F</u>	
		<u>Pt 1</u>	<u>Pt 2</u>	<u>Pt 1</u>	<u>Pt 2</u>	<u>Pt 1</u>	<u>Pt 2</u>
7/28/90	1	1.62	1.26	29.4	35.6	595	595
	2	1.51	1.43	29.4	33.0	594	591
	3	1.37	1.51	29.4	31.2	594	593
	4	1.55	1.53	28.3	29.3	590	589
	5	1.78	1.40	28.3	29.2	585	584
	6	1.88	1.52	28.1	32.0	577	580
DUCT AVG		1.53		30.3		589	
STD DEVIATION		0.16		2.2		6	
COEFF OF VAR		0.11		0.07		0.01	
7/29/90	1	1.27	1.22	32.3	37.3	598	598
	2	1.25	1.19	32.3	35.7	600	599
	3	1.35	1.36	30.4	36.3	599	598
	4	1.36	1.44	31.3	32.2	594	594
	5	1.49	1.43	29.2	31.2	584	590
	6	1.52	1.51	29.2	33.8	584	587
DUCT AVG		1.37		32.6		594	
STD DEVIATION		0.11		2.6		6	
COEFF OF VAR		0.08		0.08		0.01	

NOTES: Port 1 is at top of duct.
Point 1 is closest to West duct wall.

Table 4

CRIST UNIT 5 ESP INLET
HIGH-LOAD NO, NO_x, AND OXYGEN DISTRIBUTIONS

DATE	PORT	NO CONCENTRATION			NO _x CONCENTRATION			O ₂ CONCENTRATION		
		PPM			PPM			%		
		Pt 1	Pt 2	Pt 3	Pt 1	Pt 2	Pt 3	Pt 1	Pt 2	Pt 3
7/30/90	1	322	320	352	345	343	352	NA	NA	NA
	2	321	321	337	345	346	354	NA	NA	NA
	3	325	326	335	354	352	360	NA	NA	NA
	4	327	329	348	358	358	361	NA	NA	NA
	5	331	329	330	360	361	362	NA	NA	NA
	6	330	330	341	358	359	367	NA	NA	NA
	DUCT AVERAGE	331			355					
	STD DEV	9			7					
	COEFF OF VAR	0.026			0.019					
7/31/90	1	322	323	345	342	344	352	NA	NA	NA
	2	317	320	326	336	343	346	NA	NA	NA
	3	320	317	320	346	342	345	NA	NA	NA
	4	320	318	338	338	345	354	NA	NA	NA
	5	315	317	321	337	338	341	NA	NA	NA
	6	312	312	324	328	328	337	NA	NA	NA
	DUCT AVERAGE	321			341					
	STD DEV	8			6					
	COEFF OF VAR	0.025			0.019					
8/02/90	1	318	319	335	325	325	335	NA	NA	NA
	2	321	319	327	328	329	331	NA	NA	NA
	3	325	327	336	337	340	343	NA	NA	NA
	4	323	333	337	342	349	347	NA	NA	NA
	5	330	319	335	350	342	350	NA	NA	NA
	6	329	328	338	346	354	350	NA	NA	NA
	DUCT AVERAGE	328			340					
	STD DEV	7			9					
	COEFF OF VAR	0.021			0.026					
8/06/90	1	289	275	294	292	275	298	2.9	3.0	3.0
	2	277	259	317	277	285	317	2.5	2.1	2.9
	3	302	298	314	306	298	318	2.8	2.8	3.0
	4	298	290	314	298	301	321	3.0	3.2	3.4
	5	276	308	282	279	309	286	3.4	3.0	3.0
	6	289	284	296	289	284	299	3.2	3.3	2.8
	DUCT AVERAGE	292			296			3.0		
	STD DEV	15			14			0.3		
	COEFF OF VAR	0.051			0.046			0.103		

NOTES: Port 1 is at the top of the duct.
Point distance is from the West wall of the duct.
NO and NO_x are actual measured concentrations.

Table 5

CRIST UNIT 5 ESP INLET
LOW-LOAD NO, NO_x, AND OXYGEN DISTRIBUTIONS

DATE	PORT	NO CONCENTRATION			NO _x CONCENTRATION			O ₂ CONCENTRATION		
		PPM			PPM			%		
		Pt 1	Pt 2	Pt 3	Pt 1	Pt 2	Pt 3	Pt 1	Pt 2	Pt 3
7/28/90	1	390	390	380	400	390	380	NA	NA	NA
	2	380	390	380	400	400	390	NA	NA	NA
	3	380	390	380	390	400	400	NA	NA	NA
	4	380	380	380	380	400	390	NA	NA	NA
	5	380	380	380	400	390	400	NA	NA	NA
	6	380	380	390	400	400	400	NA	NA	NA
DUCT AVERAGE		383			395					
STD DEV		4			7					
COEFF OF VAR		0.012			0.017					
7/29/90	1	300	300	310	320	310	310	NA	NA	NA
	2	310	310	310	320	320	320	NA	NA	NA
	3	320	310	310	340	330	330	NA	NA	NA
	4	320	320	330	350	340	340	NA	NA	NA
	5	330	310	320	360	350	350	NA	NA	NA
	6	330	330	330	360	360	360	NA	NA	NA
DUCT AVERAGE		317			337					
STD DEV		10			17					
COEFF OF VAR		0.032			0.051					
8/07/90	1	245	227	224	248	227	224	7.6	7.9	7.2
	2	267	249	229	270	251	235	7.9	7.3	7.1
	3	271	264	260	279	269	261	7.6	7.7	7.5
	4	289	282	261	298	288	266	7.4	7.8	7.8
	5	283	281	275	295	288	284	7.4	7.7	7.6
	6	287	280	283	298	298	313	7.3	7.2	7.1
DUCT AVERAGE		264			272			7.5		
STD DEV		21			26			0.3		
COEFF OF VAR		0.078			0.094			0.035		

NOTES: Port 1 is at the top of the duct.
Point distance is from the West wall of the duct.
NO and NO_x are dry and not corrected for constant O₂.

Table 6

CRIST UNIT 6 ESP INLET
HIGH-LOAD MASS, VELOCITY, AND TEMPERATURE DISTRIBUTIONS

<u>DATE</u>	<u>POINT</u>	<u>MASS LOADING</u> <u>gr/acf</u>		<u>GAS VELOCITY</u> <u>ft/sec</u>		<u>TEMPERATURE</u> <u>°F</u>	
		<u>PORT 1</u>	<u>PORT 2</u>	<u>PORT 1</u>	<u>PORT 2</u>	<u>PORT 1</u>	<u>PORT 2</u>
8/03/90	1	0.93	1.01	52.0	48.9	724	730
	2	1.10	1.61	79.9	58.6	737	733
	3	1.30	3.11	88.1	70.1	731	728
	4	1.23	2.40	63.2	49.6	726	730
	DUCT AVG		1.59		63.8		730
	STD DEVIATION		0.72		13.6		4
	COEFF OF VAR		0.46		0.21		0.01

NOTES: Port 1 is West of port 2.
Point 1 is at the top of the duct.

Table 7

CRIST UNIT 6 ESP INLET
LOW-LOAD MASS, VELOCITY, AND TEMPERATURE DISTRIBUTIONS

DATE	POINT	MASS LOADING		GAS VELOCITY		TEMPERATURE	
		gr/scf		ft/sec		°F	
		PORT 1	PORT 2	PORT 1	PORT 2	PORT 1	PORT 2
8/04/90	1	0.92	0.80	27.8	26.7	630	635
	2	1.10	1.22	47.1	35.2	615	622
	3	1.77	0.95	50.2	42.8	593	591
	4	1.28	0.84	37.3	29.7	557	552
DUCT AVG			1.11		37.1		599
STD DEVIATION			0.30		8.3		30
COEFF OF VAR			0.27		0.22		0.05

NOTES: Port 1 is West of port 2.
Point 1 is at the top of the duct.

Table 8

CRIST UNIT 6 ESP INLET
HIGH-LOAD NO, NO_x, AND OXYGEN DISTRIBUTIONS

DATE	POINT	NO CONCENTRATION		NO _x CONCENTRATION		O ₂ CONCENTRATION	
		ppm		ppm		%	
		PORT 1	PORT 2	PORT 1	PORT 2	PORT 1	PORT 2
8/03/90	1	865	846	903	913	NA	NA
	2	860	824	895	881	NA	NA
	3	830	811	855	868	NA	NA
	4	<u>763</u>	<u>760</u>	<u>815</u>	<u>822</u>	<u>NA</u>	<u>NA</u>
	DUCT AVERAGE		820		869		
	STD DEV		38		34		
	COEFF OF VAR		0.046		0.039		
8/07/90	1	NA	NA	NA	NA	2.6	2.5
	2	NA	NA	NA	NA	2.9	2.8
	3	NA	NA	NA	NA	3.3	3.4
	4	<u>NA</u>	<u>NA</u>	<u>NA</u>	<u>NA</u>	<u>4.4</u>	<u>3.7</u>
	DUCT AVERAGE						3.2
	STD DEV						0.6
	COEFF OF VAR						0.186

NOTES: Point 1 is at the top of the duct.
 Port 1 is West of port 2.
 NO and NO_x are actual measured concentrations.

Table 9

CRIST UNIT 6 ESP INLET
LOW-LOAD NO, NO_x, AND OXYGEN DISTRIBUTIONS

DATE	POINT	NO CONCENTRATION		NO _x CONCENTRATION		O ₂ CONCENTRATION	
		ppm		ppm		%	
		PORT 1	PORT 2	PORT 1	PORT 2	PORT 1	PORT 2
8/04/90	1	363	385	414	457	9.6	10.0
	2	372	389	417	456	9.5	10.2
	3	370	377	426	418	9.7	10.0
	4	376	379	427	434	9.7	9.5
DUCT AVERAGE		376		431		9.8	
STD DEV		8		16		0.2	
COEFF OF VAR		0.020		0.037		0.0	

NOTES: Point 1 is at the top of the duct.
 Port 1 is West of port 2.
 NO and NO_x are actual measured concentrations.

Table 10

CRIST UNIT 5 ESP OUTLET
HIGH-LOAD PARTICLE MASS DISTRIBUTION

<u>DATE</u>	<u>POINT</u>	<u>MASS LOADING. gr/acf</u>					
		<u>PORT 2</u>	<u>PORT 3</u>	<u>PORT 4</u>	<u>PORT 5</u>	<u>PORT 6</u>	<u>PORT 7</u>
8/05/90	1	0.0037			0.0038		0.0018
	2		0.0033	0.0034		0.0028	
	3	0.0040			0.0020		0.0023
			DUCT AVG		0.0030		
			STD DEVIATION		0.0008		
			COEFF OF VAR		0.26		
8/06/90	1	0.0031			0.0051		0.0058
	2		0.0042	0.0018		0.0026	
	3	0.0039			0.0023		0.0048
			DUCT AVG		0.0037		
			STD DEVIATION		0.0013		
			COEFF OF VAR		0.35		

NOTES: Port 1 is on the East side of the duct.
Point 1 is at the top of the duct.

Table 11

CRIST UNIT 5 ESP OUTLET
HIGH-LOAD FLUE GAS OXYGEN DISTRIBUTIONS

<u>DATE</u>	<u>POINT</u>	<u>O₂ CONCENTRATION, %</u>					
		<u>PORT 2</u>	<u>PORT 3</u>	<u>PORT 4</u>	<u>PORT 5</u>	<u>PORT 6</u>	<u>PORT 7</u>
8/05/90	1	4.0	4.2	4.2	4.2	4.2	4.1
	2	4.0	4.1	4.1	4.4	4.4	4.2
	3	3.5	4.3	4.8	5.8	4.7	4.8
		DUCT AVERAGE					4.3
		STD DEV					0.5
		COEFF OF VAR					0.107
8/06/90	1	5.0	4.8	4.9	4.9	5.0	5.2
	2	5.0	4.8	5.0	5.1	5.1	4.6
	3	4.8	4.9	5.1	5.1	5.8	5.0
		DUCT AVERAGE					5.0
		STD DEV					0.2
		COEFF OF VAR					0.048

NOTES: Point 1 is at the top of the duct.
 Port 1 is on the East side of the duct.
 NO and NO_x are actual measured dry concentrations.

Table 12

CRIST UNIT 5 ESP OUTLET
HIGH-LOAD FLUE GAS NO_x DISTRIBUTIONS

<u>DATE</u>	<u>POINT</u>	<u>NO_x CONCENTRATION, ppm</u>					
		<u>PORT 2</u>	<u>PORT 3</u>	<u>PORT 4</u>	<u>PORT 5</u>	<u>PORT 6</u>	<u>PORT 7</u>
8/05/90	1	347	372	354	347	335	329
	2	356	383	358	352	338	335
	3	366	383	364	357	341	340
		DUCT AVERAGE				353	
		STD DEV				15	
		COEFF OF VAR				0.044	
8/06/90	1	316	305	284	305	311	320
	2	315	296	315	306	305	312
	3	311	300	326	313	317	327
		DUCT AVERAGE				310	
		STD DEV				10	
		COEFF OF VAR				0.033	

NOTES: Point 1 is at the top of the duct.
 Port 1 is on the East side of the duct.
 NO and NO_x are actual measured dry concentrations.

Table 13

CRIST UNIT 5 ESP OUTLET
HIGH-LOAD FLUE GAS NO DISTRIBUTIONS

DATE	POINT	NO CONCENTRATION, ppm					
		PORT 2	PORT 3	PORT 4	PORT 5	PORT 6	PORT 7
8/05/90	1	347	367	352	345	334	329
	2	357	382	353	351	337	334
	3	359	382	362	356	337	337
		DUCT AVERAGE				351	
		STD DEV				15	
		COEFF OF VAR				0.04	
8/06/90	1	315	301	282	303	310	315
	2	313	295	309	301	301	312
	3	310	298	324	306	313	327
		DUCT AVERAGE				307	
		STD DEV				10	
		COEFF OF VAR				0.03	

NOTES: Point 1 is at the top of the duct.
 Port 1 is on the East side of the duct.
 NO and NO_x are actual measured dry concentrations.

Table 14

CRIST UNIT 5 ESP OUTLET
HIGH-LOAD FLUE GAS TEMPERATURE DISTRIBUTION

<u>DATE</u>	<u>POINT</u>	<u>GAS TEMPERATURE, °F</u>					
		<u>PORT 2</u>	<u>PORT 3</u>	<u>PORT 4</u>	<u>PORT 5</u>	<u>PORT 6</u>	<u>PORT 7</u>
8/05/90	1	616			620		611
	2		619	617		613	
	3	614			617		615
		DUCT AVG			616		
		STD DEVIATION			3		
		COEFF OF VAR			0.00		
8/06/90	1	611			616		603
	2		607	616		610	
	3	613			616		606
		DUCT AVG			611		
		STD DEVIATION			5		
		COEFF OF VAR			0.01		

NOTES: Port 1 is on the East side of the duct.
Point 1 is at the top of the duct.

Table 15

CRIST UNIT 5 ESP OUTLET
HIGH-LOAD FLUE GAS VELOCITY DISTRIBUTION

<u>DATE</u>	<u>POINT</u>	<u>GAS VELOCITY, ft/sec</u>					
		<u>PORT 2</u>	<u>PORT 3</u>	<u>PORT 4</u>	<u>PORT 5</u>	<u>PORT 6</u>	<u>PORT 7</u>
8/05/90	1	44.3			49.1		51.8
	2		44.7	49.6		47.1	
	3	47.6			51.4		51.3
		DUCT AVG				48.5	
		STD DEVIATION				2.7	
		COEFF OF VAR				0.05	
8/06/90	1	44.5			50.2		50.4
	2		46.3	49.6		45.2	
	3	48.9			52.5		50.5
		DUCT AVG				48.7	
		STD DEVIATION				2.6	
		COEFF OF VAR				0.05	

NOTES: Port 1 is on the East side of the duct.
Point 1 is at the top of the duct.

Table 16

CRIST UNITS 5 AND 6 DUCT STATIC PRESSURES

<u>DATE</u>	<u>UNIT</u>	<u>LOCATION</u>	<u>LOAD</u>	<u>in. H₂O</u>
7/28/90	5	Inlet	Low	-4.0
7/29/90	5	Inlet	Low	-3.5
7/30/90	5	Inlet	High	-6.5
7/31/90	5	Inlet	High	-6.5
8/2/90	5	Inlet	High	-6.7
8/3/90	6	Inlet	High	-7.7
8/4/90	6	Inlet	Low	-3.8
8/5/90	5	Outlet	High	-8.3
8/6/90	5	Outlet	High	-8.1

Figure 1. Crist Unit 5 ESP inlet duct sampling locations.

Figure 2. Crist Unit 6 ESP inlet duct sampling locations.

Figure 3. Crist Unit 5 ESP outlet duct sampling locations.

90 % CONFIDENCE LIMITS

CRIST SCR PRE-DESIGN TEST, UNIT 5 INLET, HIGH LOAD

RHO = 2.35 GM/CC MASS < 0.83 MICRONS INCLUDED IN FIT

Figure 4. Crist Unit 5 ESP Inlet, High Load, Cumulative Mass Particle Size Distribution.

90% CONFIDENCE LIMITS

CRIST SCR PRE-DESIGN TEST, UNIT 5 INLET, HIGH LOAD

RHO = 2.35 GM/CC MASS < 0.63 MICRONS INCLUDED IN FIT

Figure 5. Crist Unit 5 ESP Inlet, High Load, Cumulative Percent Particle Size Distribution.

90 % CONFIDENCE LIMITS

CRIST SCR PRE-DESIGN TEST, UNIT 5 INLET, HIGH LOAD

RHO = 2.35 GM/CC MASS < 0.63 MICRONS INCLUDED IN FIT

Figure 6. Crist Unit 5 ESP Inlet, High Load, Differential Mass Particle Size Distribution.

90 % CONFIDENCE LIMITS

CRIST SCR PRE-DESIGN TEST, UNIT 5 INLET, HIGH LOAD

RHO = 2.35 GM/CC MASS < 0.63 MICRONS INCLUDED IN FIT

Figure 7. Crist Unit 5 ESP Inlet, High Load, Differential Number Particle Size Distribution.

90 % CONFIDENCE LIMITS

CRIST SCR PRE-DESIGN TEST, UNIT 5 INLET, LOW LOAD

RHO = 2.35 GM/CC MASS < 0.61 MICRONS INCLUDED IN FIT

Figure 8. Crist Unit 5 ESP Inlet, Low Load, Cumulative Mass Particle Size Distribution.

90% CONFIDENCE LIMITS

CRIST SCR PRE-DESIGN TEST, UNIT 5 INLET, LOW LOAD

RHO = 2.35 GM/CC MASS < 0.61 MICRONS INCLUDED IN FIT

Figure 9. Crist Unit 5 ESP Inlet, Low Load, Cumulative Percent Particle Size Distribution.

90 % CONFIDENCE LIMITS

CRIST SCR PRE-DESIGN TEST, UNIT 5 INLET, LOW LOAD

RHO = 2.35 GM/CC MASS < 0.61 MICRONS INCLUDED IN FIT

Figure 10. Crist Unit 5 ESP Inlet, Low Load, Differential Mass Particle Size Distribution.

90 % CONFIDENCE LIMITS

CRIST SCR PRE-DESIGN TEST, UNIT 5 INLET, LOW LOAD

$\rho = 2.35 \text{ GM/CC}$ MASS < 0.61 MICRONS INCLUDED IN FIT

Figure 11. Crist Unit 5 ESP Inlet, Low Load, Differential Number Particle Size Distribution.

90 % CONFIDENCE LIMITS

CRIST SCR PRE-DESIGN TEST, UNIT 6 INLET, HIGH LOAD

RHO = 2.35 GM/CC MASS < 0.86 MICRONS INCLUDED IN FIT

Figure 12. Crist Unit 6 ESP Inlet, High Load, Cumulative Mass Particle Size Distribution.

90% CONFIDENCE LIMITS

CRIST SCR PRE-DESIGN TEST, UNIT 6 INLET, HIGH LOAD

RHO = 2.35 GM/CC MASS < 0.86 MICRONS INCLUDED IN FIT

Figure 13. Crist Unit 6 ESP Inlet, High Load, Cumulative Percent Particle Size Distribution.

90 % CONFIDENCE LIMITS

CRIST SCR PRE-DESIGN TEST, UNIT 6 INLET, HIGH LOAD

RHO = 2.35 GM/CC MASS < 0.86 MICRONS INCLUDED IN FIT

Figure 14. Crist Unit 6 ESP Inlet, High Load, Differential Mass Particle Size Distribution.

90 % CONFIDENCE LIMITS

CRIST SCR PRE-DESIGN TEST, UNIT 6 INLET, HIGH LOAD

RHO = 2.35 GM/CC MASS < 0.86 MICRONS INCLUDED IN FIT

Figure 15. Crist Unit 6 ESP Inlet, High Load, Differential Number Particle Size Distribution.

90 % CONFIDENCE LIMITS

CRIST SCR PRE-DESIGN TEST. UNIT 6 INLET. LOW LOAD

RND = 2.35 GM/CC MASS < 0.47 MICRONS INCLUDED IN FIT

Figure 16. Crist Unit 6 ESP Inlet, Low Load, Cumulative Mass Particle Size Distribution.

90% CONFIDENCE LIMITS

CRIST SCR PRE-DESIGN TEST, UNIT 6 INLET, LOW LOAD

RHO = 2.35 GM/CC MASS < 0.47 MICRONS INCLUDED IN FIT

Figure 17. Crist Unit 6 ESP Inlet, Low Load, Cumulative Percent Particle Size Distribution.

90 % CONFIDENCE LIMITS

CRIST SCR PRE-DESIGN TEST. UNIT 6 INLET. LOW LOAD

RHO = 2.35 GM/CC MASS < 0.47 MICRONS INCLUDED IN FIT

Figure 18. Crist Unit 6 ESP Inlet, Low Load, Differential Mass Particle Size Distribution.

90 % CONFIDENCE LIMITS

CRIST SCR PRE-DESIGN TEST. UNIT 6 INLET. LOW LOAD

RHO = 2.35 GM/CC MASS < 0.47 MICRONS INCLUDED IN FIT

Figure 19. Crist Unit 6 ESP Inlet, Low Load, Differential Number Particle Size Distribution.

90 % CONFIDENCE LIMITS

CRIST SCR PRE-DESIGN TEST. UNIT 5 OUTLET. HIGH LOAD

RHO = 2.35 GR/CC MASS < 0.40 MICRONS INCLUDED IN FIT

Figure 20. Crist Unit 5 ESP Outlet, High Load, Cumulative Mass Particle Size Distribution.

90% CONFIDENCE LIMITS

CRIST SCR PRE-DESIGN TEST. UNIT 5 OUTLET. HIGH LOAD

RHO = 2.35 GM/CC MASS < 0.40 MICRONS INCLUDED IN FIT

Figure 21. Crist Unit 5 ESP Outlet, High Load, Cumulative Percent Particle Size Distribution.

90 % CONFIDENCE LIMITS

CRIST SCR PRE-DESIGN TEST, UNIT 5 OUTLET, HIGH LOAD

RMD = 2.35 GM/CC MASS < 0.40 MICRONS INCLUDED IN FIT

Figure 22. Crist Unit 5 ESP Outlet, High Load, Differential Mass Particle Size Distribution.

90 % CONFIDENCE LIMITS

CRIST SCR PRE-DESIGN TEST, UNIT 5 OUTLET, HIGH LOAD

RHO = 2.35 GM/CC MASS < 0.40 MICROMS INCLUDED IN FIT

Figure 23. Crist Unit 5 ESP Outlet, High Load, Differential Number Particle Size Distribution.

END

DATE FILMED

02 / 08 / 91