EPRI REPORT ON DR. RAY WESP INSTALLATION

CITATIONS

The following organization(s), under contract to the **Electric Power Research Institute (EPRI),** prepared this report:

Particulate Control Technologies, Inc.
511 Creekside Court
Helena, AL 35080

Principal Investigators
R. Altman
B. Scherer

This report describes research sponsored by the Electric Power Research Institute (EPRI).

This publication is a corporate document that should be cited in the literature in the following manner:

Survey of Wet Electrostatic Precipitators, EPRI, Palo Alto, CA 2012, Product No. _______

Key Words

Wet Electrostatic Precipitator
Filterable Particulate Material Polishing
Condensable Particulate Material
SO_3 Capture

PRODUCT DESCRIPTION

This report summarizes the physical installations, specifications, operating environments and operational experience of wet electrostatic precipitators (wet ESPs) currently operating in the United States on power generation facilities as part of air quality control system (AQCS) trains. Some large industrial facilities are included, due to their potential application on smaller power generation facilities to meet recently promulgated stringent particulate material (PM) emissions limits.

Results and Findings

This effort included site visits to the majority of currently operating power generation wet ESPs in the U.S., conversations with engineers and operators, review of design and operating conditions, and internal inspections of the wet ESPs and associated equipment. Also included is a review of performance data and conversations with wet ESP original equipment manufacturers (OEMs). While wet ESP technology has a long history in industrial applications, the current generation of large, horizontal flow power plant wet ESP's represent a significant extension of the technology used in industrial applications. The data and information in this report should allow power producers to install this technology with more confidence in the future.

Challenges and Objectives

The objective of this survey was to compile as much specific information as could be obtained to fully describe currently operating power plant wet ESPs. The fact that the application of this technology is rapidly evolving presented the most significant challenge during the study. In addition, there are wide variations in wet ESP equipment, flue gas streams, water supply systems and unit specific conditions so there is no "typical" design to use for comparison. However, even in this environment, it has been possible to gather enough data to draw useful conclusions about both the design parameters and the operating procedures needed to successfully employ this technology.

Applications, Values and Use

The results of this study will be useful to both existing and future users of WET ESP technology to allow a confident assessment of the state-of-the-art of its use, to either remediate or avoid problems and issues encountered by the existing installations, and to optimize the size, material of construction and performance of future installations.

Vertical wet ESP Designs

Vertical wet ESPs are equipped with round, hexagonal or rectangular gas passages. For full scale power plant wet ESPs, the gas passages are rectangular. Of these geometries, the rectangular and hexagonal cross sectional geometry provides the greatest specific collection area (SCA) for any given volume. The rectangular, for any given alloy metal thickness, uses the least material for a given SCA since both sides of all non-peripheral gas pass plates are collecting surfaces. This is not the case for round tubes, which have dead air space separating them. The fields in these vertical flow wet ESP's are relatively short, in the 10 ft to 15 ft range. Usually there are two mechanical fields in series. The material of construction for collecting electrodes includes both stainless steel and fabric. Fabric plates, utilizing felted polypropylene as the "plate" material are in operation in some industrial applications. Higher temperature applications would require Ryton or other high temperature tolerant materials.

The vertical wet ESP discharge electrodes in the surveyed units were all RDEs, as opposed to weighted wires. The geometry of the discharge points vary, depending on the gas passage geometry.

The smaller installations typical of industrial vertical wet ESPs have moved to modular construction, with the completed modules transported from the fabrication shop to the end user's site. Surveyed modules were in the general size range of 12' x 12' x 40', with two series fields. Each module is able to handle a flue gas volume of about 72,000 acfm, and can be transported on flatbed trucks. Larger flue gas flow applications gang these modules together in parallel. In other large applications, the vertical wet ESP is constructed on-site, as is the case with all the horizontal flow units.

SECTION 1 – INTRODUCTION AND BACKGROUND

INTRODUCTION

This report is designed to survey and investigate the current fleet of operating wet electrostatic precipitators (Wet ESPs), both horizontal and vertical flow, and report on the state-of-the-art for their construction, operation and performance. Most of the report is concerned with domestic power plant wet ESP's, but information on both industrial and a few foreign units is included so that information is applicable to power plant installations. In the process, site visits were made and internal inspections conducted on four of the nine domestic, horizontal flow, wet ESPs recently commissioned. Examples from both of the major domestic suppliers are included. In addition, information was collected on three industrial vertical flow wet ESPs along with information on the vertical flow wet ESP at the Sherburne County (Sherco) Generating Station.

The objective of this survey was to compile as much specific information as could be obtained and to fully describe currently operating power plant wet ESPs. The fact that this application of the technology is rapidly evolving presented the most significant challenge during the study. In addition, there are wide variations in wet ESP equipment, flue gas streams, water supply systems and unit specific conditions, so there is no "typical" design to use for comparison. However, even in this environment, it has been possible to gather enough data to draw useful conclusions about both the design parameters and the operating procedures needed to successfully employ this technology.

A discussion of each wet ESP will be offered, with photographs and process flow diagrams to familiarize the reader with these installations. This will be followed by a more general discussion of the various systems making up the installations in general, with enough detail to allow a general conclusion on performance and system limitations. Included will be excerpts from the Institute of Clean Air Companies (ICAC) criteria for specifying wet ESPs (Reference #2).

In addition to the wet ESPs surveyed, comprehensive installation lists for both domestic and foreign installations were provided by three manufacturers, and are included in Appendix A.

PCS PHOSPHATE
Aurora, North Carolina

Figure 4-16 – WET ESP Array at PCS Phosphate

Overview

This series of wet ESPs, designed by Dr. Isaac Ray and his team, currently with EnviroEnergy Solutions, was sold through the then CR Clean Air Technology Company.

This plant utilizes coal for the heat source to the fluidized bed phosphate calciner that has a marble bed particulate control/scrubber system installed prior to a vertical Wet ESP. Flue gas is introduced to the marble bed from underneath. The bed is comprised of 1” diameter glass marbles that have a lower diameter size limit of about 0.75”, resting on a horizontal perforated plate. The marble layer is approximately 4 inches thick, and they are covered with water. Pressure drop for up-flowing flue gas across the bed is approximately 1” wg per inch of thickness, and flow velocity has an upper limit of approximately 450 ft/min (7.5 ft/sec). As the flue gas and sprayed liquid flows upwards through the bed, a layer of foam approximately 5 inches thick forms on the top of the marbles and liquid, which has a large surface area that contributes to particulate and gas phase pollutant capture. In addition, as the foam bubbles burst, they contribute to wetting of the vertical wet ESP, positioned just downstream of the marble bed. The marbles are in a constant fluidized state, rotating and cleaning themselves from particles, allowing them to flow with the fluid down to the sump via overflow nozzles. The bed collects close to 90% of the incident particulate matter above 3 microns efficiently, leaving the smaller fraction entrained in the flue gas for the wet ESP.

The current wet ESP design is constructed in modules, 12 feet square in plan view, and 40 feet high. This allows them to be fabricated in the fab shop and trucked to the site for installation. The flow rating on each module is a nominal 72,000 acfm for the saturated flue gas, and there are six modules at PCS Phosphate for a total Plant flow capability of 432,000 ACFM. The superficial flue gas flow velocity works out to be 8.63 ft/second. This is, if extrapolated to non-saturated flue gas, sufficient capacity for all modules to treat flue gas for approximately 125Mw of coal fired generation. Filterable particulate removal rates at PCS were tested in the 92-95% range for this single field. The addition of a second field on top in series, (not implemented at PCS) with an interstage drain, is claimed by the supplier to increase the total efficiency to 99.9%.

Figure 4-17 – Units 5&6 under construction

Each module contains the marble bed and the mechanical field of 255 round CE tubes, 10 inches in diameter and 10 feet in length. Discharge electrodes are RDEs, supported top and bottom by 8 total insulators, located in a patented compartment that provides protection from flue gas and moisture contamination. Energization is accomplished with 70kV supplies rated at 2500 mA, equipped with adjustable linear reactors to provide full conduction angle performance. They operate at about 55kV and 1800mA normally.

<u>Mechanical Design</u>

Type	Vertical Up-flow Modular Construction
Material	316L Casing, Collecting Electrodes, Discharge Electrodes
Chambers	1 per module
Number of Fields	1 per module
Gas Passes per Field	255
Gas Pass Geometry	Round, 10" in diameter, 10 feet long (in direction of gas flow)
Total Collection area	6,676 ft^2
SCA	92.7 @ 72,000acfm

Electrical Design

Bus Sections	1 per mechanical field or module
Power Supplies	1 NWL 60Hz T-R set rated 2500mA; 70kV with adjustable CLRs
Voltage Controllers	NWL
DE suspensions	Dual insulator constraints top and bottom

Water System

Water Treatment	pH control only, pond water used has low suspended/disolved solids
Plate Irrigation	Implemented by condensing of flue gas moisture
Casing Wash	Spray nozzle system

Flue Gas Conditions (EACH UNIT) , Total Gas Flow ….429,600 acfm **(252,705 m^3/hr)**

Rated Flow Rate	71,600 acfm
Rated Gas Temp	165°F (saturated)
Flow Distribution	Marble Bed inlet produces near ideal gas distribution
Superficial Flow Vel.	8.63 ft/sec

Performance

Inlet Filterable PM	0.045 – 0.05 gr/dscf (68°F, 29.92 in Hg)
Particle Size Dist.	Marble bed removes ~90% of 3 micron and larger dust
Filterable Efficiency	92-95%

Contacts	Isaac Ray, PhD, EnviroEnergy Solutions (917) 640-4453
	Barry Winn at PCS Phosphate, (252) 322-8188

References to call on Dr. Isaac Ray

1. **Peter Johnson P.E. Moore Inc…………401-596-2816 ext.201**
2. **John Elder P.E. ATI Metals…………… 541-926-4211 ext 6333**
3. **John D. Hall Shaw Inc………………706-532- 4829**
4. **Tony Kuipers P.E. HTI Inc…………… 616-551-5420 ext.226**
5. **Dean Rose, QCI Inc…………………… 734-395-7740**

INSTALLATION LISTINGS BY VENDOR

WESP INSTALLATIONS DESIGNED BY DR. ISAAC RAY AND HIS TEAM CURRENTLY

WITH ENVIROENERGY SOLUTIONS, INC.

#	Year		Customer		Industry	Units	Outlet flow/ea. ACFM	Total Flow ACFM	Out Temp. °F	Inlet Loading gr/dscfm
1	1997		Dynamotive		Incin Wood Tar	1	800	800	95	n/a
2	1997		Fablok		Textile	1	11,500	11,500	100	0.04
3	1997		Dupont		Plastics	1	12,173	12,173	65	0.0273
4	1998		IT/ETG		Incin Soil	2	784	1,568	117	n/a
5	1998		Monsanto-Sadaci		Sulphur Incin	1	7,400	7,400	107	0.0675
6	1998		Smith- Canfibre		Wood MDF	2	64,400	128,800	116	0.044
7	1998		Shaw -Valley Head		Textile Yarn	1	20,980	20,980	113	0.025
8	1999		Lucent		Fiber Optic	2	4,250	8,500	61	n/a
9	1999		Tenn.. Eastman 1		Incin Haz	2	20,000	20,000	120	0.11
10	1999		Work Area		Plastics	1	40,000	40,000	112	n/a
11	1999		Wheel Pittsburgh Steel		Coal Tar	1	22,150	22,150	150	1.0
12	1999		ACTEA - Mizar		Textile	1	29,540	29,540	98	0.015
13	1999		Kyanite-Willis Mtn.		Ore Roast	1	9,840	9,840	162	1.0
14	1999		Kyanite-East Ridge.		Ore Roast	1	27,200	27,200	148	3.0
15	1999		Tenn. Eastman-2		Incin Haz	4	36,049	36,049	120	0.11
16	1999		ACTEA- Radicifil		Textile	2	34,200	68,400	88	0.0168
17	1999		M&M Mars		Peanut Roast	1	4,950	4,950	107	0.04
18	1999		Mohawk		Textile	1	8,700	8,700	122	0.08
19	2000		Eisenmann- Smurfit		Paper	1	52,200	52,200	178	0.124
20	2000		Shaw- Stevenson		Textile Yarn	1	49,960	49,960	121	0.04
21	2000		ACTEA - HT Italia		Polyethyelene Foam	1	18,000	18,000	89	0.0184
22	2000		Westpoint Stevens		Textile printing	1	39,000	39,000	102	0.06
23	2000		Lucent Denmark		Fiber Optic	4	664	2,656	91	0.387
24	2000		ACTEA - Lineltex		Textile	1	18,000	18,000	100	n/a
25	2000		PILOT - American		Food Process	1	5,000	5,000	125	1.4

			Proteins		PILOT					
26	2000		Flomet		Parrifin Wax	1	6,800	6,800	200	n/a
27	2000		Durez/Occidental Chemical		Incin Haz	1	9,265	9,265	173	0.068
28	2000		Shaw -Trenton		Textile Yarn	1	18,300	18,300	133	0.049
29	2001		ACTEA - Fibrex		Textile	1	7,800	7,800	95	0.034
30	2001		PCS Phosphate		Mining	2	71,600	143,200	165	0.085
31	2001		ACTEA-Carvico		Textile	1	35,000	35,000	300	0.048
32	2001		PILOT - First Energy		Utility PILOT	1	5,000	5,000	125	1.4
33	2001		Johnson Matthey		Precious Metals	1	10,000	10,000	70	0.175
34	2001		ACTEA - Korea		Haz Waste	1	20,000	20,000	150	0.219
35	2001		PILOT - ADM Corn		Food Process PILOT	1	2,000	2,000	17	0.1
36	2002		PCC-ASM		Incinerator	4	12,000	24,000	184	3.69
37	2002		TDI		Semiconductor	1	100	100	120	2.72
38	2002		TDI		Semiconductor	1	400	400	120	2.72
39	2002		SE-GSA		Incinerator	2	250,000	250,000	142	0.14
40	2002		PCS Phosphate		Mining	2	71,600	143,200	165	0.085
41	2002		ACTEA - SITIP		Textile	1	29,540	29,540	98	0.015
42	2002		ACTEA - Russia NOY		Polyethyelene Foam	1	7,800	7,800	95	0.026
43	2002		NETL Membrane		Utility	1	5,000	5,000	125	1.4
44	2002		ACTEA Astigiane		Grappa	1	9,000	9,000	127	0.0363
45	2002		Bechtel Idaho		Pilot	1	114	114	178	0.121
46	2002		Chemsource		Haz Waste	1	10,000	10,000	179	0.074
47	2002		ACTEA Francoli		Food Process	1	15,000	15,000	127	0.352
48	2003		ACTEA Sifta		Food Process	1	29,540	29,540	98	0.015
49	2003		PCS Phosphate		Mining	6	71,600	429,600	165	0.085
50	2003		EPRI Pilot Unit		Utility	1	5,000	5,000	190	0.028
51	2003		MAZDA- GHCL		Mining	1	23,611	23,611	104	0.116
52	2005		Darlington fabrics		**Textile**	1	15,000	15,000	120	0.06
53	2006		Moore textiles		Textile	1	25,000	25,000	135	0.04
54	2007		Shaw		Carpet	1	31,000	31,000	130	0.08
55	2009		Moore San Salvador		Textile	1	15,000	15,000	120	0.06
56	2010		Allegheny Technology		Metallurgical	1	18,000	18,000	600	0.1
57	2012		HTI International		Waste to power	1	12,000	12,000	400	0.15
58	2013		QCI , Inc		Waste to Power	1	30,000	30,000	140	0.1
59	2014		QCI, Inc.		Mining	1	15,000	15,000	400	1.2