

PERFORMANCE OF THE DRY SCRUBBING SYSTEM AT CANADA'S MOST RECENT EFW FACILITY

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ABSTRACT

An overview of the Air Pollution Control system at Canada's most recently retrofitted Energy-from-Waste facility is presented. The plant burns 100 tons per day of municipal solid waste in three modular incinerators, which are ducted to a common system for steam generation, heat recovery, and APC. Proceadair Industries Inc. provided an All-Dry Scrubbing System for the APC, consisting of a custom-designed venturi reactor, fabric filter, and reagent handling system. The reagent is hydrated lime and the filter bags are woven fiberglass with a Teflon 'B' finish. The system is designed for 35,100 Nm³/hr of flue gas at 138 to 184°F, and high concentrations of particulates and acid gases. Performance objectives included up to 95% removal efficiency in particulates, doxions/furans, and HCl concentration, and 80% reduction in SO₂. The system has been operating successfully since early 1997, and recent stack testing has shown that key performance targets are being easily met.

INTRODUCTION

The most recent Energy From Waste (EFW) installation in Canada to be upgraded and retrofitted with air pollution control technology was completed in 1997. The facility is rated to handle a total of 100 tons per day of Municipal Solid Waste (MSW), and provides hot water to a local district heating system as well as electricity to the local power grid. Proceadair Industries Inc., of Montreal, was selected in 1996 to supply the Air Pollution Control (APC) system for the retrofit. With the completion of this retrofit, the plant can burn either municipal solid waste or biomass in separate, parallel systems.

The highlights of the MSW system are listed in Table 1. It includes three modular two-stage incinerators operating in parallel. These are ducted together into a single Heat Recovery Steam Generator (HRSG). The exhaust of the HRSG is designed to pass first through a feed-water economizer and then through a district heating economizer before being treated in the Proceadair All-Dry Scrubbing System. The biomass system generates steam in a cascading bed boiler to augment the MSW system when needed. Most of the energy from both systems is used to heat the local district heating water, with the balance being converted to electricity and added to the local power grid.

The decision to retrofit the EFW Facility with an APC system was taken in 1995. Proceadair proposed to supply a dry lime injection system followed by a baghouse to control both acid gas and particulate emissions from the facility. Proceadair was awarded a contract in mid-1996. The system was designed and

supplied through the remainder of 1996, with installation taking place in early 1997. Startup occurred in the Spring of 1997, and performance testing was conducted in November.

DESCRIPTION OF THE PROCEDAIR DRY SCRUBBING SYSTEM

The Procedair Dry Scrubbing System controls pollutant emissions by reacting them with dry reagents to form inert salts. The process is illustrated in Figure 1. Flue gas from the Municipal Waste Combustor, containing particulate, acid gas constituents, metals and organic compounds, is ducted into the Venturi Reactor.

Venturi Reactor

The Procedair Venturi Reactor is a proprietary design and is the heart of the All Dry Scrubbing Process. (See Figure 2.) In the Venturi Reactor, a mixture of fresh and recycled reagent is introduced into the flue gas. The Venturi Reactor is a vertical reactor tower with a convergent/divergent venturi zone. Flue gas enters the bottom of the tower, passes upward through the venturi section and into the reaction zone, where it is internally redirected back downward before exiting horizontally to the dust collector.

Reagent is introduced into the flue gas near the throat of the venturi. Introduction is accomplished gravimetrically using feedpipes. The reagent entering the Venturi Reactor is a mixture of both fresh and recycled reagent.

The design of the Procedair Venturi Reactor assures intimate mixing of the sorbents with the flue gas, thereby maximizing reaction and adsorption via extensive gas/solids contact. The design also promotes the agglomeration of particles as they pass through the reactor, which is beneficial to the operation of the downstream particulate collector. The Venturi Reactor operates isothermally.

For Municipal Waste Combustor applications, the reagent utilized is hydrated lime ($\text{Ca}(\text{OH})_2$). The lime reacts with the acid gas constituents (HCl , SO_2 , HF) to form inert salts. To promote the capture of additional heavy metal and dioxin/furan compounds, powdered activated carbon can be added. The activated carbon would have a separate storage bin, metering system and feedpipe, although it would also be introduced near the venturi throat.

Fabric Filter

The flue gas that exits from the Venturi Reactor is laden with particulate, which is a mixture of flyash, reaction salts, and unused reagent. The flue gas passes through a compartmentalized pulse jet fabric filter. The mixture of solids is collected on the bags, and the clean flue gas exits to the Induced Draft Fan before passing up the stack to atmosphere.

The collected solids contain significant amounts of unused sorbent. Most of the collected solids are recycled to the Venturi Reactor. A portion is sent to disposal.

Although the grain loading into the fabric filter is high, the agglomeration that occurs in the Venturi Reactor allows for operation at typical pressure drops of 4 to 8 inches w.g. Fabric selection is governed by application, not by process consideration. Utilizing an all dry process eliminates the chance of incomplete slurry evaporation and carryover of moisture into the baghouse.

Reagent Feed

Since dry sorbents are employed throughout, there are no special reagent preparation requirements. Fresh lime and recycled material are stored in separate hoppers and conveyed individually to the feedpipes of the Venturi Reactor. Control of fresh lime feed rates is typically automated based on a signal taken from the stack gas Continuous Emission Monitor.

There is no need for slaking, pumping or piping, which simplifies the system and provides for much easier operation and maintenance as the need to handle slurries is eliminated.

Other Benefits

The Procedair All Dry Scrubbing Process offers other important benefits in addition to those discussed above. The recirculation of reagent/sorbent many times over allows for maximum utilization and minimum consumption. This is a particularly important feature where activated carbon is concerned, as dosing rates can be substantially lower than that achieved in once through systems.

The recirculation feature also provides for inherent system flexibility. Sudden changes in flue gas conditions (e. g. concentration spikes) are easily handled by the large inventory of sorbent being recirculated.

Another unique benefit of the Dry Scrubbing Process is that it can operate at lower inlet temperatures (e.g. 300°F) because it utilizes dry sorbents. The Dry Scrubbing Process does not require a thermal driving force to evaporate slurry. This feature makes the process particularly well suited to facilities that have very efficient energy recovery and thus exhaust flue gas at a lower temperature.

DETAILS OF THE CANADIAN EFW APPLICATION

A local engineering consulting firm prepared the specifications for the APC equipment. The nominal flue gas composition included 13.2% H₂O, 1100 mg/Nm³ HCl, 40 mg/Nm³ SO₂, and 210 mg/Nm³ of Particulate. Between 40-80% of the Particulate matter was less than 1 um in size. Flue gas flow rate ranged from 8,000 - 11,700 Nm³/hr for each combustor, and hence the APC system was designed for 35,100 Nm³/hr. (Table 2 provides more complete data on design flue gas analysis.)

Temperatures at the inlet to the APC system ranged from 138 to 184°C. The unusually large range in flue gas temperature results from the decision to simultaneously install a new feed water economizer to recover additional energy from the flue gas. The lower temperature (138°C) represents operation with the installation of a new feed water economizer, while the higher temperature (184°C) represents operation of the existing economizer only and bypass of the new unit.

For this application, Procedair selected a Dry Scrubbing System consisting of a single Venturi Reactor constructed of 3/16 thick carbon steel, followed by a single pulse jet Sonair filter. The Sonair filter is divided into four compartments and contains 560 bags, arranged in 40 rows of 14 bags each. Each bag is nominally 6" diameter by 14' long. The bags are constructed of 22-oz. woven fiberglass with a Teflon 'B' finish.

Hydrated lime reagent is stored in carbon steel silo capable of storing 40 metric tons of lime. Fresh lime is discharged through a rotary feeder to volumetric screw conveyor which transfers lime to the Venturi Reactor.

The fabric filter is equipped with a screw conveyor which collects the discharged material from the hoppers and conveys it via rotary valve to a pneumatic conveying system, which discharges into the recycle lime silo. A portion of the silo discharge is transported via screw conveyor to an ash bin, while the bulk flows gravimetrically into the Venturi Reactor.

PERFORMANCE REQUIREMENTS

Ambient Air Quality

The regulatory jurisdiction over Canada's air resources generally falls to the provinces as a result of the historically significant British North America Act. At the present time the federal authority, Environment Canada, plays a major role in atmospheric research and in establishing guidelines for the provinces to follow as desired. The provinces may or may not choose to adopt any or all of the federal recommendations. The ambient air quality regulatory limits for the USA and Canada are presented in Table 3 for comparison.

Emission Guidelines

In Canada, the regulation of pollutant emissions is generally accomplished through the Ambient Air Quality criteria. However certain guideline criteria have been published by intergovernmental agencies. These criteria are termed guidelines, as the intent was to provide examples of operating practices which accomplish acceptable levels of control of emissions. The best known of the operating guidelines are the "Operating and Emission Guidelines for Municipal Solid Waste Incinerators" (Report CCME-TS/WM-TRE003, June 1989). This report notes, in the footnote to its Table 4.1, "These are guidelines only; incinerator systems with operating parameters outside these ranges that meet the stack discharge limits would be acceptable."

The CCME recommended emission limits for the parameters measured at this source are listed in Table 4. When a corresponding dispersion model is applied to these data, it may be possible to show that ambient air quality in the surrounding area meets the regulatory limits such as those shown in Table 3.

Procedair Performance Objectives

The EFW facility assessed the regulatory limits and developed minimum performance requirements for Procedair to meet. These called for a maximum emission of 20 mg/Nm³ of particulate matter and 75 mg/Nm³ (or 90% reduction) for acid gases. Beyond this, performance objectives were set at up to 95% reduction of particulates (approximately 10 mg/Nm³ emissions), 95% reduction of HCl, 80% reduction of SO₂, and 75% reduction of dioxins and furans, depending on the amount of reagent used. With activated carbon as a second reagent, it was expected that 95% reduction of dioxins and furans could be achieved. Table 5 summarizes these goals.

PERFORMANCE TESTING

Performance testing of the Proceadair Dry Scrubbing System at the EFW Facility was conducted in November of 1997 by a local independent environmental testing services company, with their report being issued in early January, 1998. The testing included inlet and outlet gaseous and particulate flow measurements, as well as collection of process data for the EFW facility. The report included a full dispersion modeling of the resulting emissions in the surrounding area.

An interesting twist occurred during the performance tests. The original design specifications contemplated flue gas temperatures of 138 - 184°C entering the dry scrubbing system, in conjunction with the simultaneous installation of a new District Heating Economizer (not part of Proceadair's supply). However, problems with the new DHE resulted in the plant having to remove and replace the internal tubes. At the time of testing, the old tubes were removed but the new ones not yet installed. This resulted in inlet flue gas temperatures to the Dry Scrubbing System exceeding 200°C.

Because of the unusually high temperature, there was concern about the ability of the Proceadair system to achieve its guaranteed performance. Hence, the decision was taken to increase the amount of fresh lime feed and conduct the tests at the high temperatures anyway. Tables 6 & 7 present the measured results from the performance tests.

DISCUSSION OF TEST RESULTS

As can be seen from the measured test results, even at the unusually high flue gas temperatures, the Proceadair Dry Scrubbing system met and exceeded not only its performance guarantees, but also its more aggressive design objectives for the pollutants tested. Particulate emissions of 7.1 mg/Rm³ (96.7% reduction), and HCl emissions of 9.0 mg/Rm³ (98.8% reduction) were achieved. In addition, SO₂ reduction exceeded 93%. These are excellent results and demonstrate the capabilities of a well-designed and properly-operated dry scrubbing system.

When dispersion modeling of maximum ground-level concentrations was applied to the results, the testing company also concluded that they predicted concentrations well within the applicable criteria.

TABLE 1: EFW Facility Design Parameters

Number of Incinerators	3
Total Capacity (tpd)	100
Incinerator Type	Modular
Incinerator Design	Starved-Air Combustor
Number of APC Systems	1
APC Technology	Dry Lime Injection/Baghouse
APC Design	Procedair Industries All-Dry

TABLE 2: APC System Design Basis

Flow Rate (Nm ³ /hr)	35,100
Temperature (°C)	138-184
Gas Analysis (% by Vol.)	
H ₂ O	13.2
CO ₂	8.0
O ₂	12.0
N ₂	66.8
Constituents:	
Dust (mg/Nm ³)	210(*)
HCl (mg/Nm ³)	1100
SO ₂ (ppmv)	40
NO _x (ppmv)	200
CO (ppmv)	40

Note:

(*) 40-80% of dust is less than 1 um

TABLE 3: Ambient Air Quality Regulatory Limits (ug/m3)

Pollutant	Average Time	U.S.A.	Canada
Particulate Matter	1 hour	15*	-
	24 hours	150*	120
	Annual	50*	70
Sulphur Dioxide	1 hour	-	500
	24 hours	365	300
	Annual	80	60
Nitrogen Dioxide	1 hour	-	400
	24 hours	-	200
	Annual	100	100
Carbon Monoxide	1 hour	40,000	35,000
	8 hours	10,000	15,000
	Annual	-	-

* > 10 um in diameter

TABLE 4: CCME Recommended Emission Limits

Contaminant	Limit
Particulate Matter	20 mg/Rm ³
Hydrogen Chloride	75 mg/Rm ³ , or 90% removal, whichever is less restrictive
Carbon Monoxide	57 mg/Rm ³

* Corrected to 11% O₂, 25°C (77°F), 101.3 kPa, dry base

TABLE 5: APC System Performance Objectives

Particulate (mg/Nm ³)	10 (or 95% reduction)
HCl (mg/Nm ³)	75 (or 95% reduction)
SO ₂	80% reduction
PCDD/PCDF	75% reduction (95% with activated carbon)

Note:

All values corrected to 11% O₂, dry basis.

TABLE 6: Stack Gas Characteristics - Inlet Side

Parameter	Units	Test 1	Test 2	Test 3	Average
Temperature	K	498.4	492.3	485.3	492 K (219°C) (426°F)
Velocity	m/s	18.02	16.27	16.83	17.0 m/s 3346 fpm
Moisture Content	%	12.7	18.0	12.8	14.5
Gas Flow (Ref)	Rm ³ /s	8.19	7.04	7.64	7.62
Oxygen	%	16.7	14.0	15.3	15.3
Nitrogen Oxides*	mg/Rm ³	320	381	301	334
Particulate Loading*	mg/Rm ³	110.33	273.98	258.72	214.3
Sulphur Dioxide*	mg/Rm ³	484.1	432.8	303.5	406.8
Hydrogen Chloride*	mg/Rm ³	756.9	821.2	689.4	755.8

* Corrected to 11% O₂, 25C (298K), 101.3 kPa, dry basis

TABLE 7: Stack Gas Characteristics - Outlet Side

Parameter	Units	Test 1a	Test 1b	Test 2	Test 3	Average
Temperature	K	484.2	488	486.4	486.3	486 K (213°C) (416°F)
Velocity	m/s	24.81	25.94	24.98	26.3	25.5 m/s 5021 fpm
Moisture Content	%	12.8	13.2	12.5	13.0	12.9
Total Gas Flow	Rm ³ /s	7.53	8.70	8.68	9.02	8.48
Oxygen	%	14	12.6	13	14	13.4
Nitrogen Oxides*	ppm	212	200	266	241	230
Particulate Loading*	mg/Rm ³	6.69	na	7.26	7.43	7.13
Sulphur Dioxide*	mg/Rm ³	na	24.3	23.2	27.8	25.1
Hydrogen Chloride*	mg/Rm ³	5.2	na	7.06	14.8	9.02

* Corrected to 11% O₂, 25C (298K), 101.3 kPa, dry basis