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Spray Dryers for Acid Gas Control of MSW Combustors

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Abstract

Air pollution control system design to achieve consistently low emission rates is essential to ensure that waste incineration facilities maintain continual environmental acceptability. This paper examines several semi dry scrubbing systems on waste incineration facilities in Asia and North America to illustrate the critical items required to ensure reliable system operation and continuous compliance with regulatory requirements.

The facilities examined include a 1600 TPD facility in North America, a 200 TPD facility in Korea which has been in operation for approximately 4 years, and a new facility in Korea which is designed meet very stringent emission standards. For the newest facility in Korea HCl and SO_2 are limited to 10 ppm. Particulate emissions must be below 10 mg/Nm^3. 50 ug/Nm^3 is the limit for mercury emissions and dioxin emissions must be less than 0.1 ng/Nm^3 TEQ. NO_x emissions must be lower than 50 ppm.

For each facility, the detailed design of the semi dry scrubber, pulse jet fabric filter, carbon injection system, and SCR(if applicable) is discussed, along with considerations to ensure continuous compliance with the emission levels. Operation of each facility is discussed, along with any special operating issues that have been encountered. Finally, performance tests and continuous emissions data is presented to illustrate the actual performance level of each facility.

Introduction

Semi dry scrubbing system have proven to be extremely effective in controlling emissions from municipal waste incinerators. While the basic semi dry scrubbing system typically consists of the semi dry scrubber, reagent preparation, and fabric filter, additional items are added as required to provide for a complete emissions control system. These additional items include activated carbon injection for the control of dioxins and heavy metals, and selective catalytic reduction (SCR) systems for the control of No_x.

Three different systems are examined in this paper. The first system, a single 200 TPD facility in Changwon City in Korea, consists of only a basic semi dry scrubbing system. Emissions limitations at this facility are 50 mg/Nm^3 @ 12% O_2 for particulate and 30 ppm @ 12% O_2 for both HCl and SO_2. The second system, consisting of two 800 TPD trains in Robbins, Illinois has a semi dry scrubbing system with activated carbon injection for the control of dioxins and mercury. The emission limitations at this facility are 0.010 gr/dscf for particulate emissions, 25 ppm for HCl, 30 ppm for SO_2, 80 ug/Nm^3 for mercury, 30 ng/Nm^3 for total dioxins, 10 ug/Nm^3 for cadmium, and 100 ug/Nm^3 for lead. All emissions are corrected to 7% O_2. The final facility, a 200 TPD plant located in Taejeon City, Korea consists of a semi dry scrubbing system with activated carbon injection plus an SCR system for control of No_x. The emission limitations at this facility are 10 mg/Nm^3 for particulate emissions, 10 ppm for Hcl, 10 ppm for SO_2, 50 ug/Nm^3 for mercury, 0.10 ng/Nm^3 TEQ for dioxins, and 50 ppm for No_x. All emissions are corrected to 12% O_2. A summary of the equipment for each facility is provided in Figure #1. Figure #2 provides a summary of the emissions limitations for each facility.

Semi Dry Scrubber

The flue gas from the incinerator enters the top of the semi-dry scrubber through flow tubes. In each flow tube, calcium hydroxide along with a small amount of activated carbon, if applicable, for dioxin and mercury control is introduced through a dual fluid nozzle in a finely atomized liquid form. The calcium hydroxide mixes with the flue gas and reacts with the acid gases to form solid particulate. As the flue gas and reaction products flow downward in the scrubber, the reaction products are completely dried. Although some of the particulate drops into the hopper under the semi-dry scrubber, most of the particulate is carried to the fabric filter where it is removed from the gas stream.

The design of the semi-dry scrubber for this process necessitates the satisfaction of two major criteria. First the reagent slurry must be atomized to produce a droplet spectrum that provides for the optimum acid gas absorption and reaction. Second, the vessel must be configured to ensure that the droplets evaporate and the reaction products produced dry before reaching the wall of the vessel or exiting the vessel. This prevents buildups which would impede the operation of the system.

The semi-dry scrubber utilizes dual fluid nozzles to atomize the lime slurry. A multiple number of nozzles are provided per scrubber vessel, depending on the amount of flue gas to be treated. The flue gas entering the vessel is equally divided into the multiple gas streams. Each gas stream passes through a "flow tube" where a dual fluid nozzle sprays the atomized slurry concurrently downward with the gas flow. The cool liquid contacting the hot flue gas induces turbulence and mixing. At the same time, a gas velocity reduction of approximately 90% occurs as the flue gas enters the main body of the scrubber vessel. The combination of these two processes induces a thorough mixing of the reagent and acid gases. During this mixing, the acid gases are absorbed by the reagent, creating solid particulate and removing the acid gases from the flue gas stream.

In order for this reaction to occur efficiently the droplet spectrum from the dual fluid nozzles must be such that the droplets are not too small and therefore flash dry nor are they too large, which reduces the surface area available for reaction and causes a problem with particle drying. A useful measurement of the droplet spectrum is the sauter mean diameter (SMD). The SMD is defined as the droplet diameter which has the same surface to volume population as the entire droplet population. This number helps define the size distribution of the droplets. A wide size distribution, which is not desirable for semi-dry scrubbing, will have a higher SMD than a narrow size distribution of droplets. Field testing on this process has shown that an SMD of 60 to 70 microns produces a droplet spectrum which does not have an excessive amount of large droplets and also does not have too many fine droplets. A sketch of the Belco nozzle used in the semi dry scrubber is shown in Figure #3.

Overall geometry of the scrubber vessel is also an important consideration. The vessel must be designed so that the flue gas expands and utilizes as much of the vessel as possible for drying of the particulate. The unit must also be designed such that, considering the trajectory of any large droplets, no large droplets reach any wall surface before drying. The flue gas exit from the vessel is arranged so that the gas is turned out of the vessel without disturbing the gas flow patterns in the vessel and without the use of any internal turning devices which would create a point of buildup for solids. The typical drying profile which incorporate the above items are shown in Figure #4.

Reagent Preparation and Delivery

A critical part of the system design is the delivery of slurry, dilution water, and compressed air for liquid atomization. The slurry must be prepared, stored, and delivered in a manner that avoids the typical operating and maintenance problems that are associated with slurry handling and delivery.

Lime is stored in a silo which typically has a capacity of storing sufficient lime for at least 7 days of operation. If hydrated lime is used, which is typical in Asia, the hydrated lime is metered into the slurry storage tank with water to produce a slurry of 10 to 15 percent by weight of calcium hydroxide. If pebble lime is used the pebble lime is slaked in a detention type slaker. Typically two slakers are provided, one operating and one spare. The lime slurry produced is stored in a tank, from which it can be fed to the semi dry scrubber.

If activated carbon is required for the system it is stored in a separate silo. If the activated carbon is fed to the scrubber with the lime slurry it is mixed with water and transported to the slurry storage tank. The amount of activated carbon added is adjustable and coordinated with the slaking operation so that the desired concentration of activated carbon in the slurry can be maintained. If the activated carbon is added to the scrubber dry it is metered into the ductwork upstream of the semi dry scrubber. This takes advantage of the mixing and retention time that occurs in the semi dry scrubber.

Slurry from the storage tanks is delivered to the scrubber vessel through a series of pumps. The first pumps deliver slurry to the atomization level of the scrubber. Most of the slurry pumped is recirculated back to the lime slurry storage tank. This allows for a slurry velocity of approximately 4 to 7 ft/sec in the piping which avoids erosion from high velocity or settling from low velocity. Redundant pumps and recirculation loops were provided to ensure the ability to continuously deliver slurry to the scrubbers. Slurry is delivered to the vessel by diaphragm type pumps. The speed of these pumps is variable and controlled by a signal from the acid gas monitor. This ensures that the proper and optimum amount of slurry is continuously delivered to the scrubber. Again, redundant pumps were provided to ensure continuous operation.

Dilution water is added for temperature control, assuming that the liquid in the slurry is insufficient to reduce the gas temperature to the desired level. A control valve regulates the amount of dilution water, which is mixed with the slurry in a small manifold just prior to entering the nozzles. The amount of compressed air delivered to the nozzles is controlled to ensure optimum atomization of the liquid. This entire system is shown in Figure #5.

Pulse Jet Fabric Filter

A modular pulse jet fabric filter with roof access doors has been utilized on all of the facilities. The use of full roof doors allows for easy accessibility and a large area for storage when maintenance or filter bag changeout is required. Flue gas enters each module in the hopper area where a manual damper is provided for insulation. A series of vanes turn the gases up toward the filter bags. Gas is drawn through the filter bags removing particulate and provided a surface for secondary removal of acid gases. The clean gas exits the module through a poppet valve which is used for module isolation during off line cleaning or module maintenance. Compressed air for cleaning the filter bags is provided through pulse pipes located above the filter bags. Cleaning air is controlled by Goyen valves located on each pulse pipe. A general schematic of a filtering module is shown in Figure #6.

Selective Catalytic Reduction

The SCR system is designed to reduce the levels of nitrogen oxides (essentially NO and NO_2) which are formed during the combustion process. The SCR system is located downstream of the semi dry scrubber and fabric filter. This is important since the semi dry scrubber and fabric filter has removed essentially all of the particulate, acid gases, and heavy metals. This means that a "clean" gas stream is processed by the SCR system. This prolongs the service life of the catalyst.

The SCR system basically consists of three basic components. The first is a flue gas reheat system. Since the flue gas temperature exiting the semi dry scrubbing system is only in the range of 140°C the gas temperature must be increased so that the reactions will occur. This is accomplished in two steps. First the gas passes through a gas to gas heat exchanger. This utilizes the heat in the flue gas exiting the SCR system to heat the gas coming into the SCR system so that the external heating required is kept to a minimum. The additional heating required is provided by a heat exchanger using steam from the facility.

After the gas temperature has been increased ammonia is injected into the flue gas stream. It is evenly distributed in the gas stream so that it is utilized as efficiently as possible and ammonia slip is kept to a minimum. Typically ammonia is stored as 25% aqueous NH_4OH in a tank. It is injected and evaporated directly upstream of the third part of the system, the catalytic reaction vessel. The rate of ammonia injection is controlled based on the inlet and outlet No_x levels so that excess ammonia is not emitted from the stack.

The catalytic reaction vessel consists of several layers of catalyst. The catalyst is composed of titanium oxide extruded blocks filled with the active elements vanadium oxide and tungsten oxide. They are assembled in identical modules so that they can be interchanged to different levels, thus prolonging the service life of the catalyst. A sketch of the SCR system is provided in Figure #7.

System Operation and Performance

The Chang Won facility has been in operation since January, 1995. Emissions testing performed in February 1995 illustrate the excellent emissions performance of this facility. A summary of these tests is provided in Figure #8. Much of the excellent performance can be attributed to the fact that the dual fluid nozzle system can be serviced on line in a very short period of time. Even when one nozzle has been removed for replacement there is no increase in the acid gas emission levels. An internal inspection of the semi dry scrubber was performed in October 1995 during the first scheduled plant outage. This inspection showed that material accumulation on the vessel wall was very light (less than one cm thick) and the material was dry and flaky. Reliability has been excellent and maintenance cost minimal.

The Robbins, Illinois facility was placed into service in October, 1996. Performance testing was performed in January, 1997, again with excellent results. These results are summarized in Figure #9. Internal inspections of the scrubber vessel during scheduled outages has shown material accumulations similar to that found in Chang Won. The accumulations were extremely light and the material was dry and flaky. No cleaning of the scrubber vessel has been required. The fabric filter pressure drop has remained low, with pressure drops still in the range of 140 mm w.c. after almost two years of operation with the original fiberglass bags still in service.

The Taejeon City facility was originally scheduled to go into service in August 1997. However, due to delays unrelated to the air pollution control equipment the facility is now scheduled to be placed into operation late in the third quarter of 1998.

Summary

These facilities illustrate that well designed refuse incineration facilities with state of the art air pollution control systems provide an efficient method of reducing waste volume. Semi dry scrubbers utilizing dual fluid atomizers have proven to provide excellent performance and on line availability to ensure continuous compliance with regulatory requirements. Environmentally sound emission levels are readily achievable, allowing a facility such as these to be a "good neighbor" to the community while helping to solve the problem of effective waste disposal.

Figure #1

Facility Descriptions

Facility Name	Chang Won City	Robbins, Illinois	Taejeon City
Capacity/ Train (Tons/Day)	200	800	200
Number of Trains	1	2	1
Semi Dry Scrubber	Yes	Yes	Yes
Hydrated Lime	Yes	No	Yes
Pebble Lime	No	Yes	No
Fabric Filter	Yes	Yes	Yes
SCR	No	No	Yes

Figure #2

Facility Emission Limitations

Facility Name	Chang Won City	Robbins, Illinois	Taejeon City
Particulate (mg/Nm^3)	50	23	10
HCl (ppm)	30	25	10
SO_2 (ppm)	30	30	10
Mercury (mg/Nm^3)	N/A	80	50
Dioxins (ug/Nm^3)	N/A	30 Total	0.10 TEQ
No_x (ppm)	N/A	N/A	50
Gas Correction ($\%O_2$)	12	7	12

Figure #3

Dual Fluid Nozzle

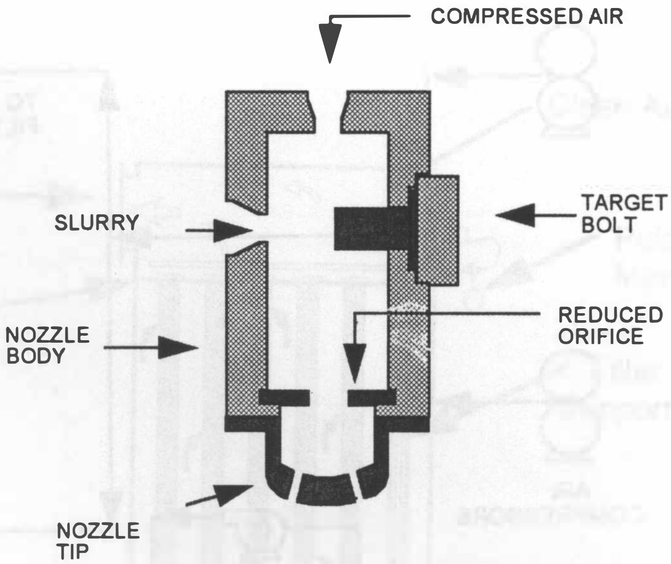

Figure #4

Typical Drying Profile

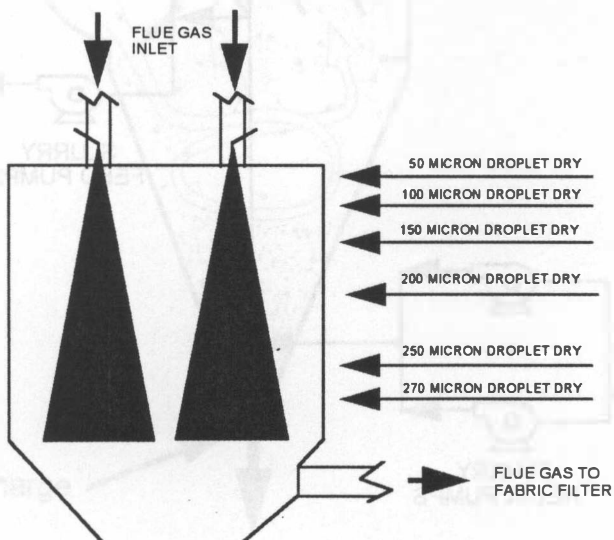

Figure #5

Reagent Delivery System

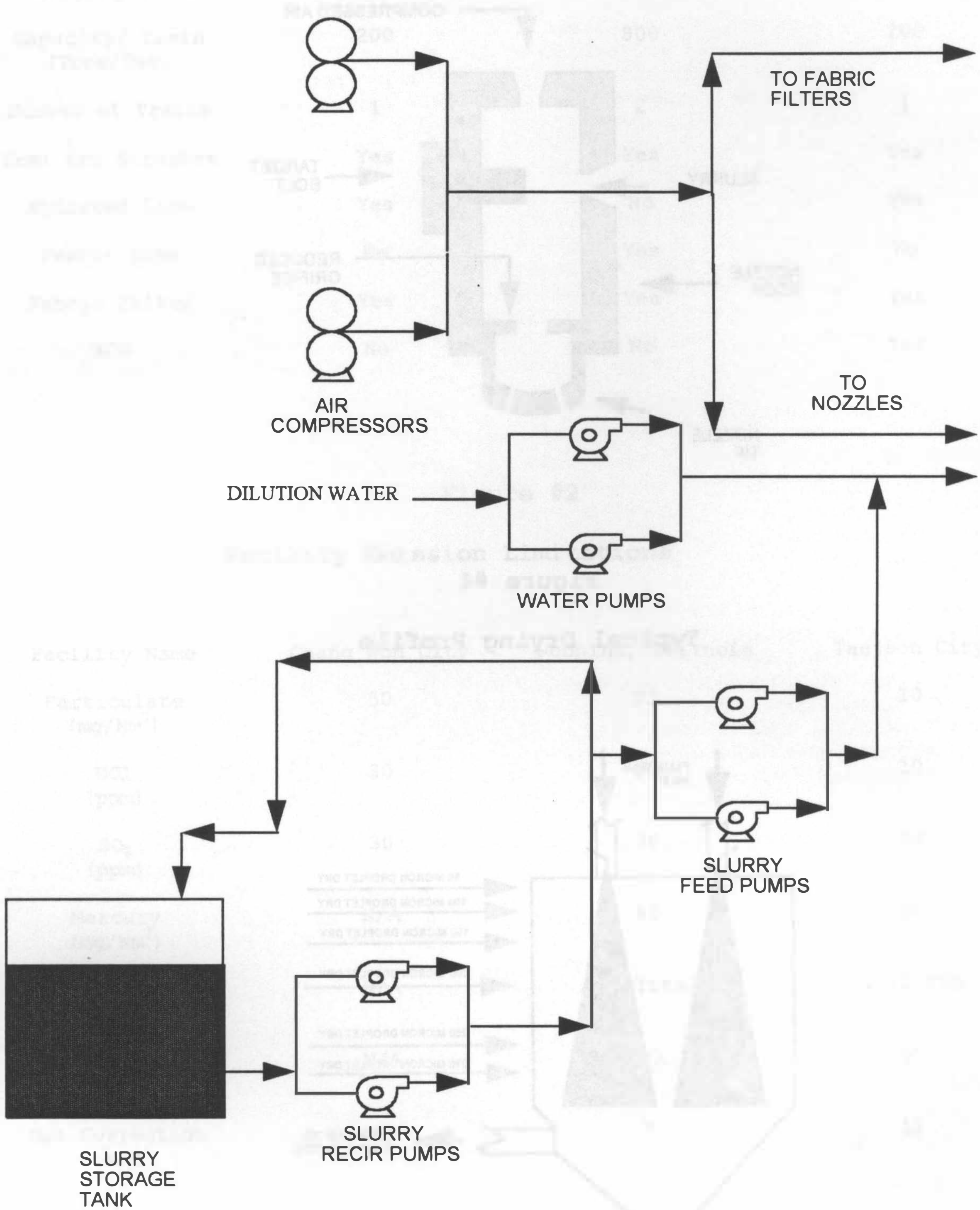

Figure #6

Pulse Jet Filtering Module

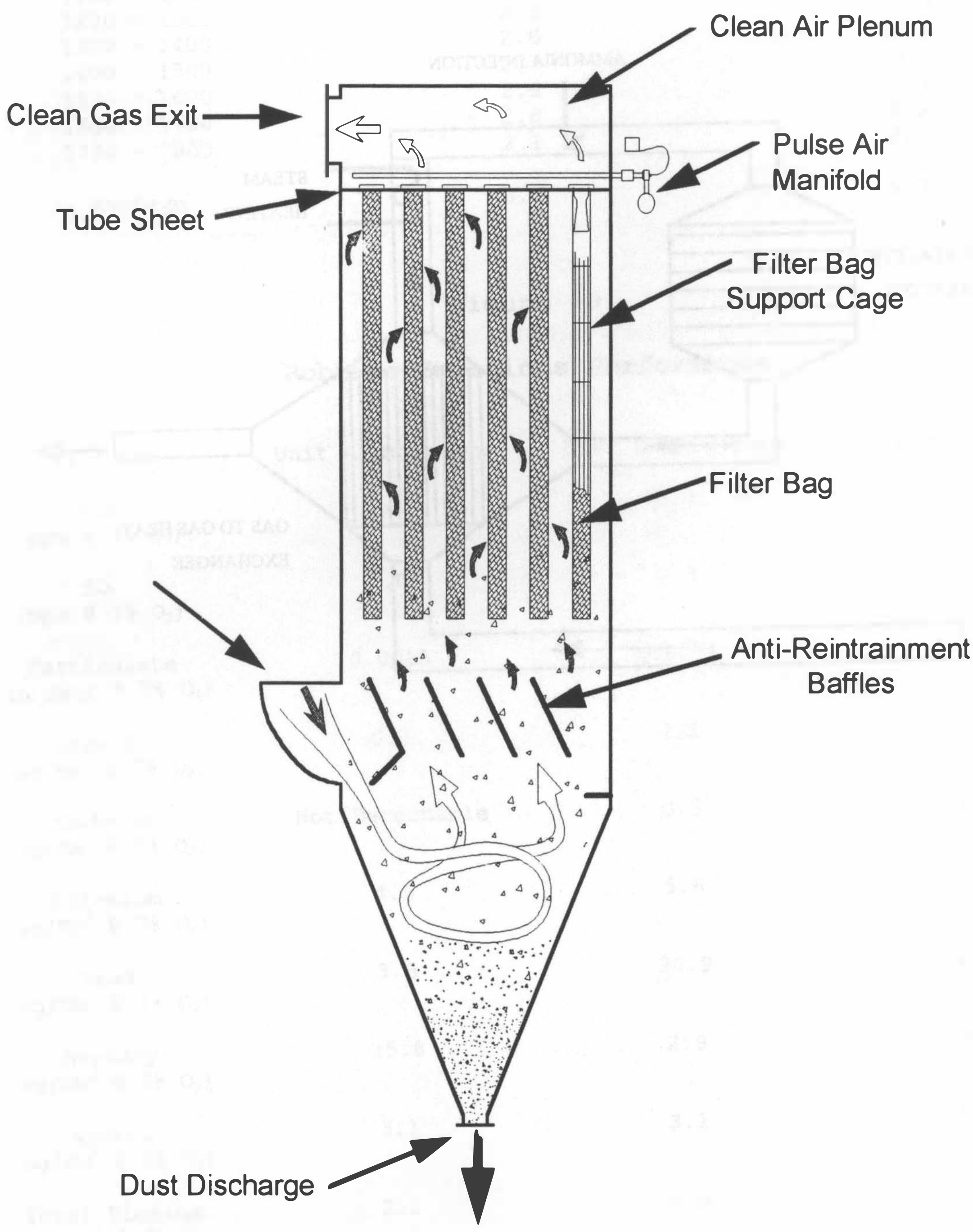

Figure #7

Selective Catalytic Reduction System

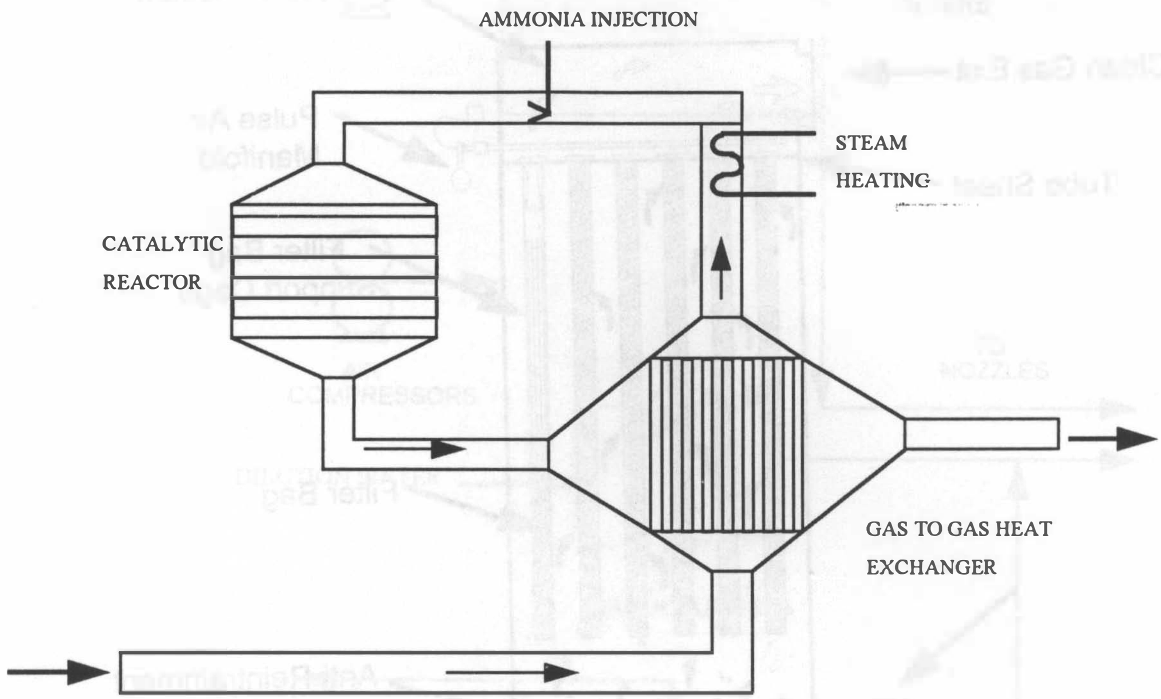

Figure #8

Chang Won Emissions Performance

Time	HCl Emissions (ppm @ 12% O_2)	SO_2 Emissions (ppm @ 12% O_2)
1100 - 1200	5.6	11.6
1200 - 1300	2.4	10.7
1300 - 1400	2.6	11.8
1400 - 1500	2.7	11.3
1500 - 1600	2.9	8.5
1600 - 1700	2.8	8.9
1700 - 1800	2.1	2.3
Average	3.0	9.3

Figure #9

Robbins Emissions Performance

Pollutant	Unit A Emissions	Unit B Emissions	Permit Limit
HCl (ppm @ 7% O_2)	4.6	6.2	25
SO_2 (ppm @ 7% O_2)	1.0	0.5	30
Particulate (gr/dscf @ 7% O_2)	0.0015	0.0056	0.010
Arsenic (ug/Nm^3 @ 7% O_2)	0.2	0.2	10
Cadmium (ug/Nm^3 @ 7% O_2)	Not Detectable	0.3	40
Chromium (ug/Nm^3 @ 7% O_2)	4.8	5.6	120
Lead (ug/Nm^3 @ 7% O_2)	3.6	30.9	490
Mercury (ug/Nm^3 @ 7% O_2)	15.8	2.9	80
Nickel (ug/Nm^3 @ 7% O_2)	3.1	3.1	100
Total Dioxins (ng/Nm^3 @ 7% O_2)	2.1	4.9	30