Experience with FLS-GSA Dry Scrubbing Technology for Waste-to-Energy Applications

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ABSTRACT

In the United States and in Europe, Conditions in the Municipal Solid Waste (MSW) or Waste-to-Energy marked are constantly changing. Permitting new waste-to-energy plants is becoming increasingly difficult and changing legislation makes it a challenge to operate existing incinerator facilities. Compliance with new legislation in Europe and the United States requires a retrofit scrubbing technology on a large number of existing waste-to-energy plants to control emissions of acid gasses. dioxins/furans and heavy metals, especially mercury.

The paper describes the gas suspension absorber (GSA) dry scrubbing technology developed by FLS miljø a/s, Denmark. The GSA is a new generation of semi-dry technology utilizing a circulating fast fluidised bed as absorber for acid gasses, dioxins and heavy metals. The paper gives a detailed description of the GSA which differs from conventional spray-dryer absorber systems in that it provides an extreme high dust concentration in the absorber. The high specific surface area of the dust combined with the quenching action of the atomized lime slurry provides excellent conditions for heat and mass transfer as well as secondary nucleation sites for the condensation/adsorption of dioxins and heavy metals.

The paper focuses on the GSA as a retrofit technology for waste-to-energy plants. As retrofit the GSA is advantageous due to the compact design, small footprint and the ability to use the existing electrostatic precipitator (ESP) for particulate control. The grain loading leaving the GSA system and entering the ESP, is controlled by the efficiency of the GSA cyclone, and for this reason the grain loading entering the ESP is less than or equal to the grain loading leaving the incinerator. The retrofit with a GSA system will furthermore reduce the actual flue gas volume to the ESP, which means an increased specific collection area. In addition the increased moisture content in the flue gas improves the collection efficiency. The paper compares this retrofit option to conventional spray-dryer absorption technology.

The paper describes the operating experience with the GSA technology for waste-to-energy plants. The FLS-GSA dry scrubbing technology has gained wide acceptance in the European waste-to-energy industry, especially in the Nederlands which have the most stringent emission regulation in Europe. More than 26 trains have been installed and successfully operated since 1988. Operating experience and performance test results for acid gasses, dioxins and heavy metals, especially mercury, from several European waste-to energy are reported.

The results shows that the GSA technology can comply with the most stringent European emission regulations.

INTRODUCTION

The company, FLS miljø a/s and its subsidiaries have installed more than 7,000 highly efficient flue gas cleaning systems worldwide. FLS miljø's flue gas cleaning technology has been applied to power stations, incinerator plants, cement factories, pulp and paper plants, metallurgical industries and a wide range of other industries (Ref. 1 and 2). FLS miljø has in the last decade emerged as a major supplier of air pollution control (APC) equipment worldwide.

The GSA dry scrubbing technology, part of FLS miljø's comprehensive product range for flue gas cleaning, was developed, designed and patented by FLS miljø a/s. The FLS miljø GSA dry scrubbing technology has gained wide acceptance in the European waste-to-energy industry, where it is considered to be proven technology. A total of 26 trains have been installed and successfully operated since 1988.

DESCRIPTION OF GSA TECHNOLOGY

The GSA technology combines the circulating fluidised bed technology with efficient particulate collection in either an electrostatic precipitator (ESP) or a fabric filter (FF). The system has been designed to remove acid gasses, heavy metals, dioxins and particulates from flue gases without saturating the flue gas and thereby producing a dry product.

Figure 1 shows a simplified flow diagram of the GSA system incorporating the design features common to FLS miljø's GSA technology. These features include:

* Single GSA module per incinerator unit
* Cyclone for primary particulate removal
* Recirculation of dry solids
* Single, highly reliable dual-fluid nozzle to produce a cloud of fine lime droplets
* Compact design - small foot print
* Particulate collector

The flue gas from the incinerator enters the bottom of the GSA reactor and flows upwards through a venturi in the vessel. An injection lance with a single nozzle is located in the centre of the venturi spraying co-currently with the flue gas flow. The injection lance assembly is connected to lime slurry, cooling water and compressed air feed lines. The lime slurry is atomized by the compressed air in the dual-fluid nozzle.

Recycled solids from the cyclone are introduced into the GSA reactor just above the venturi, where the solids become coated with lime slurry. A very highly specific surface area is thus created, which provides excellent conditions for heat and mass transfer as well as secondary nucleation sites for condensations/adsorption of dioxins and heavy metals. Acid gasses, such as SO_2, HCl and HF are effectively removed from the flue gas by reaction with the lime coated particles. More than 95% of the acid gas removal is accomplished in the GSA, which is considerably higher than the performance of a conventional spray dryer absorber. Drying of the particles takes place simultaneously with the absorption and leaves suspended solids, which are carried upwards in the GSA under great turbulence and keep the walls free from dust build-up.

The flue gas flows through the cyclone where the solids are separated from the gas stream. The cyclone separates more than 98% of the solids that are fed back to the reactor via a feeder box. The remaining solids continue with the flue gas to the particulate collector.

The purpose of dry solids recirculation is to maintain a large reaction surface for the fresh lime slurry, to utilise unreacted lime and to keep the reactor clean from dust build-up.

Dry solids are recirculated to maintain a concentration of solids inside the GSA reactor of 400-1000 g/Nm^3. This very high particle concentration has the advantage that the GSA system is not vulnerable to operational upsets. Furthermore, the high particle density promotes the agglomeration of particles. The fine particles entering the system form large agglomerates which are then more efficient captured by a conventional ESP. The number of sub-micron particles escaping the GSA is substantially reduced by operating with high particle density (Ref. 3).

The flue gas leaving the cyclone, now free from acid gasses, with a particulate concentration of 6 g/Nm^3 enters the particulate collects and the dusst is now removed. The flue gas is now cleaned for acid gasses, heavy metals, and dioxins and furans is released out into the atmosphere.

Lime slurry is prepared from pebble lime and water in a slaking unit. The slurry is sprayed into the bottom of the reactor through a special two fluid nozzle system. The quantity of slurry is automatically adjusted according to acid gas removal requirements.

Water is likewise sprayed into the reactor through the nozzle. The quantity of water is automatically adjusted to maintain the optimal temperature in the GSA reactor. FLS miljø have developed a unique atomising nozzle, which is very sturdy and wear-resistant and is not prone to plugging.

RETROFIT APPLICATION

This question is often asked: How does an existing ESP serve as the main particulate collector in a situation where a semi-dry scrubber is retrofitted upstream of the precipitator? When retrofitting with GSA, the flue gas is conditioned to provide optimal operating conditions for the precipitator, i.e.

* Reduced or equal grain loading
* Reduced quantity of fine particles
* Lower flue gas volume - higher SCA
* Higher moisture content
* Uniform temperature conditions

This conditioning often leads to a lower dust emission from the precipitator after retrofit with the GSA system compared to the dust emission by the precipitator system originally installed. This is evident by measurements at the FLS miljø retrofit installations, as shown in Table 14.

In contrast to conventional spray dryer absorber (SDA) systems, the GSA technology is well suited for retrofit application. Due to its small foot print, the GSA system can readily be retrofitted upstream of an existing ESP.

The GSA can be retrofitted in two different ways when the availible space is limitted;

* Shoe horned in between the boiler and the ESP, with the advantage the work can be arranged with a very short tie-in (a few days).

* Build above the ESP, reducing the needed space to a minimum.

The GSA has the advantage of being able to use the existing precipitator without any or with only minor modifications, whereas the SDA system would require a major rebuild of the precipitator and in some cases it would be uneconomical to use the existing precipitator. One of the reasons why the GSA has this advantage over the conventional SDA systems, is seen by looking at Table 1. Here an incinerator with a typical fly ash grain loading of 7 g/Nm^3 at the inlet to the APC system is considered. The grain loading in the flue gas leaving the GSA system and entering the ESP is equal to or less than the grain loading from the incinerator per se, whereas the grain loading in the flue gas leaving the SDA is 2-3 times as high (Ref. 4). This means that the required ESP efficiency for the SDA system would be higher than for the GSA.

In general, the reduced volumetric gas flow out of the GSA leads to an increased specific collection area (SCA, ratio of flue gas flow to collection area) in the precipitator and in addition, the increased moisture content in the flue gas improves the collection efficiency (Ref. 5). The overall resulting effect is that many existing ESP's can be used for particulate control downstream of a GSA system.

The tall, slim GSA reactor lends itself well to a retrofit situation, with little space available between the incinerator and the electrostatic precipitator. Figures 2 and 3 show examples of such GSA retrofits. Figure 3 clearly shows that the whole GSA plant can be built without interrupting the operation of the incinerator. A minimum down time is required to cut into the existing duct work and put dampers in place.

The retrofit of a GSA to an existing incinerator offers substantial economical advantages compared to retrofit of a new spray dryer and fabric filter.

OPERATING EXPERIENCE

Plant description

The waste-to-energy plants in question are the following:

Retrofits
1 Kara, Denmark
2 Reno Nord, Denmark
3 Hallingdal, Norway
4 Heeren, The Nederlands

New installations
1 Aarhus Nord, Denmark
2 Houthalen, Belgium

These facilities are geographically located far apart from the far north (Hallingdal) to central Europe (Houthalen). Design data for the waste-to-energy facilities is given in Table 2. The capacity of the systems vary from 72 TPD to 224 TPD. All plants burn primarily household waste, however, both industrial and hospital waste is burned occasionally.

Four of the facilities, i.e. Kara, Reno Nord, Hallingdal and Heeren were existing operating plants, when environmental legislation forced them to retrofit APC equipment. In the first three cases, a GSA system was retrofitted upstream of an existing ESP. At Heeren the GSA with a fabric filter was installed downstream the existing ESP. This was done for two reason, mainly because the "pure" fly ash separated in the existing ESP is used for road construction, but also because the one field ESP would never be able to meet the emission regulation on particulate of 5 mg/Nm^3, dry, 11 vol% O_2.

The plants Houthalen and Aarhus Nord are new plants. They also use an ESP downstream of the GSA. Design data for the APC systems at the six facilities is shown i Tables 3 and 4. Further information on the ESP is given in Table 5.

The APC systems were originally designed for emission limits according to the local and state legislation. However, today the GSA systems are routinely operated with lower set points for the HCl emission, fulfilling the present and future expected European Union (EU) legislation. In Europe, the most stringent requirements are in the central European countries, such as the Nederlands and Germany. In these countries, the latest, most stringent regulations, i.e. the Nederlands emissions Regulation (NeR) set the emission standard. The emission standards currently valid for all European Union countries are less stringent, but are expected to be tightened in the near future (Ref. 6), as shown in Table 6.

Performance test results

After successful start up, the plants were performance tested by outside contractors. Performance test results for acid gas and particulate removal are shown in Tables 7 - 10. It is worth noticing that although these plants have all been designed to meet the local emission standards, they all can operate at the level of the much more stringent EU standards.

Tables 11-13 provide information regarding heavy metal and dioxin removal at the plants. Due to the high particulate density in the GSA reactor, the inherent removal efficiency of mercury is high regardless of the fact that no active carbon was injected for mercury control. Again, it is important to note that the GSA system provides a contact and condensation surface area that is orders of magnitude larger than in a conventional spray dryer system. These conditions also favour dioxin removal. The GSA can without active carbon injection meet the 0.1 ng/m^3 TEQ emission limitation.

Further testing

To further investigate the limits of capability of the GSA retrofitted on existing ESP´s, FLS miljø have undertaken a major demonstration and test programme at the Reno Nord incinerator in Denmark. The test programme is scheduled to be carried out in spring 1998.

The test programme is designed to provide performance data of the incinerator operating with the ESP as only APC equipment as well as data from the system after retrofit of the GSA.

CONCLUSION

Ten years of operating experience with the FLS miljø GSA dry scrubbing system in incinerator application have proven that this technology is an excellent choice for this application. Performance of the system has proven that the GSA technology can meet the most stringent emission requirements also with an ESP as main dust collector. The GSA technology has proven to be of great advantage when used for retrofit on existing incinerators having an ESP as dust collector.

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Table 1 Typical particulate concentrations (g/Nm^3) in GSA and SDA systems

	GSA	SDA
APC system inlet	7.0	7.0
Inside absorber	600-800	16.0
ESP inlet	6.0	16.0
ESP outlet	0.05	0.05
Required removal efficiency	99.2	99.69

Table 2 Design data for waste-to-energy facilities

Plant	Kara 4	Reno Nord 2	Aarhus Nord 3	Houthalen 1+2	Heeren	Hallingdal
Country	Denmark	Denmark	Denmark	Belgium	Nederland	Norway
Capacity, TPD	185	198	224	2x132	154	72
Incinerator manufacturer	Vølund	Vølund	Bruun and Sørensen	Vølund	KRC-Noell	Vølund
Type of kiln	Grate/ rotary	Grate	Rotary	Grate/ rotary	Grate	Grate
Type of waste	House-hold	House-hold	House-hold	House-hold	House-hold	House-hold
Plant start-up	1988	1991	1991	1995	1995	1995

Table 3 Design data for APC systems

Plant	Kara 4	Reno Nord 2	Aarhus Nord 3	Houtha-len 1+2	Heeren	Halling-dal
Retrofit	yes	yes	no	no	yes	yes
Filter	ESP	ESP	ESP	ESP	ESP/FF	ESP
Flue gas flow, Nm^3/hr	53,000	63,000	69,000	53,000	62,000	25,000
Flue gas temp., °C	185	200	190	250	250	160
Pollutant concentrations:						
HCl, mg/Nm^3 wet	1000	1000	512	1200	1500	800
HF, mg/Nm^3 wet	10	10	10	9	10	10
SO_2, mg/Nm^3 wet	400	400	342	200	400	400
Hg, mg/Nm^3 wet	2	2	2	2.3	1,5	2
Particulate, mg/Nm^3 wet	5000	5500	8000	3000	200	6000
Dioxin, μg/Nm^3 wet	NA	NA	NA	5	10	8-10

Table 4 Current emission requirements for APC systems

Plant Component at 11% O_2	Kara 4	Reno Nord 2	Aarhus Nord 3	Houtha-len 1+2	Heeren	Halling-dal
HCl, mg/Nm^3, dry	50	50	50	50	10	50
SO_2, mg/Nm^3, dry	300	300	300	300	40	300
HF, mg/Nm^3, dry	2	2	2	2	1	2
Cd+Hg, mg/Nm^3, dry	0.2	0.2	0.2	0.2	0.05(Cd) 0.05(Hg)	0.2
Particulate, mg/Nm^3, dry	30	40	30	30	5	30
Dioxin, $\mu g/Nm^3$, dry	Na	Na	Na	Na	0.1	2

Table 5 ESP data

	Kara 4	Reno Nord 2	Aarhus Nord 3	Houtha-len 1+2	Heeren[1)]	Hallingdal
No. of fields	2	2	2	3	Na	1
Plate spacing, mm	400	250	400	400	Na	300
Guarantee emission before the GSA was installed, mg/Nm^3	150	150	Na	Na	Na	100
Guarantee after the GSA was installed emission mg/Nm^3	40	40	40	30	Na	30
Temperature °C	130	130	132	130	Na	130

[1)] ESP before the GSA

Table 6 Emission requirements for European/US waste-to-energy facilities

Component	Unit	NeR (97% of hourly averages)	EU 1989	EPA requirements	EU Future expected (Daily averages)
Particulate	mg/Nm^3, dry, 11 vol% O_2	5	30	24 mg/dscm at 7 vol% O_2	10
HCl	mg/Nm^3, dry, 11 vol% O_2	10	50	25 ppmvd/95% at 7 vol% O_2	10
HF	mg/Nm^3, dry, 11 vol% O_2	1	2	Na	1
NO_x as NO_2	mg/Nm^3, dry, 11 vol% O_2	70	Na	180(150) ppmvd at 7 vol% O_2	200
SO_2	mg/Nm^3, dry, 11 vol% O_2	40	300	30 ppmvd/80% at 7 vol% O_2	50
Cd	mg/Nm^3, dry, 11 vol% O_2	0.05	Na	0.02 mg/dscm at 7 vol% O_2	0.05
Hg	mg/Nm^3, dry, 11 vol% O_2	0.05	Na	0.080 mg/dscm/85% at 7 vol% O_2	0.05
Hg and Cd	mg/Nm^3, dry, 11 vol% O_2	Na	0.2	Na	Na
Ni and As	mg/Nm^3, dry, 11 vol% O_2	Na	1	Na	Na
Pb	mg/Nm^3, dry, 11 vol% O_2	Na	Na	0.20 mg/dscm at 7 vol% O_2	Na
Pb, Cr, Cu and Mn	mg/Nm^3, dry, 11 vol% O_2	Na	5	Na	Na
Heavy metals *	mg/Nm^3, dry, 11 vol% O_2	1	Na	Na	1
Dioxin and furan	ng/Nm^3, dry, 11 vol% O_2	0.1	Na	30(13) ng/dscm at 7 vol% O_2	0.1

* Included are the following heavy metals: Sb, Pb, Cr, Cu, Mn, V, Sn, As, Co, Ni, Se and Te.

Table 7 Performance test results (1993) - Kara 4, acid gas and particulate removal

Component at 11% O_2	Measurement	Permit
HCl, mg/Nm^3	9	50
HF, mg/Nm^3	0.2	2
SO_2, mg/Nm^3	51	300
Particulate, mg/Nm^3	15	30

Table 8 Performance test results (1996) - Reno Nord 2, acid gas and particulate emissions

Component at 11% O_2	Measurement	Permit/Guarantee
HCl, mg/Nm^3	34	65
HF, mg/Nm^3	0.4	1.2
SO_2, mg/Nm^3	45	300
Particulate, mg/Nm^3	17	40

Table 9 Performance test results - Hallingdal, acid gas and particulate removal

Component at 11% O_2	Measurement	Permit/Guarantee
HCl, mg/Nm^3	12	50
HF, mg/Nm^3	0.006	2
SO_2, mg/Nm^3	58	300
Particulate, mg/Nm^3	8.6	30

Table 10 Results from Heeren.

Component	Unit	Measured during performan-ce test	2. quarter 1997	1. quarter 1997	4. quarter 1996
Particulate	mg/Nm^3, dry, 11 vol%O_2	1	1	1	1
HCl	mg/Nm^3, dry, 11 vol%O_2	5	5.6	8	2,9
HF	mg/Nm^3, dry, 11 vol%O_2	0.1	0.23	0.1	0.63
NO_x as NO_2	mg/Nm^3, dry, 11 vol%O_2	40	46	41	29
SO_2	mg/Nm^3, dry, 11 vol%O_2	3	19	16	28
Cd	mg/Nm^3, dry, 11 vol%O_2	0.001	0.0004	0.0003	0.0002
Hg	mg/Nm^3, dry, 11 vol%O_2	0.002	0.009	0.002	0.035
Heavy metals [1)]	mg/Nm^3, dry, 11 vol%O_2	0.02	0.064	0,2	0.05
Dioxin and furan	ng/Nm^3, dry, 11 vol%O_2	0.01	Na	0.046	Na

[1)] Included are the following heavy metals: Sb, Pb, Cr, Cu, Mn, V, Sn, As, Co, Ni, Se and Te.

Table 11 Performance test results (1995) - Kara 4, mercury and dioxin removal

Component	System inlet	System outlet	% Removal
Hg, mg/Nm^3	0.122	0.007	94
Dioxin, ng/Nm^3 (TEQ	2.2	0.0024	99+

Table 12 Performance test results (1996) - Reno Nord 2, heavy metal emissions

Component	Measurement	Permit/Guarantee
Pb + Cr + Cu+ Mn	0.32	5
Pb	0.32	1
Ni + As	0.03	1
Cd + Hg	0.05	0.2

Table 13 Performance test results - Hallingdal, heavy metals and dioxin

Component	System inlet	System outlet	% Removal
Hg, mg/Nm^3	0.19	0.03	84
Cd, mg/Nm^3	0.80	0.03	96
Pb+Cr+Cu+Mn, mg/Nm^3	34.3	0.80	98
Ni+As, mg/Nm^3	0.8	0.27	66
Dioxin, ng/Nm^3 (TEQ)	6.3	0.08	99

Table 14 ESP performance before and after GSA retrofit

Plant	Particulate emission before mg/Nm^3	Particulate emission after mg/Nm^3
Kara 4	25	15
Reno Nord 2	33	17
Hallingdal	19	8.6

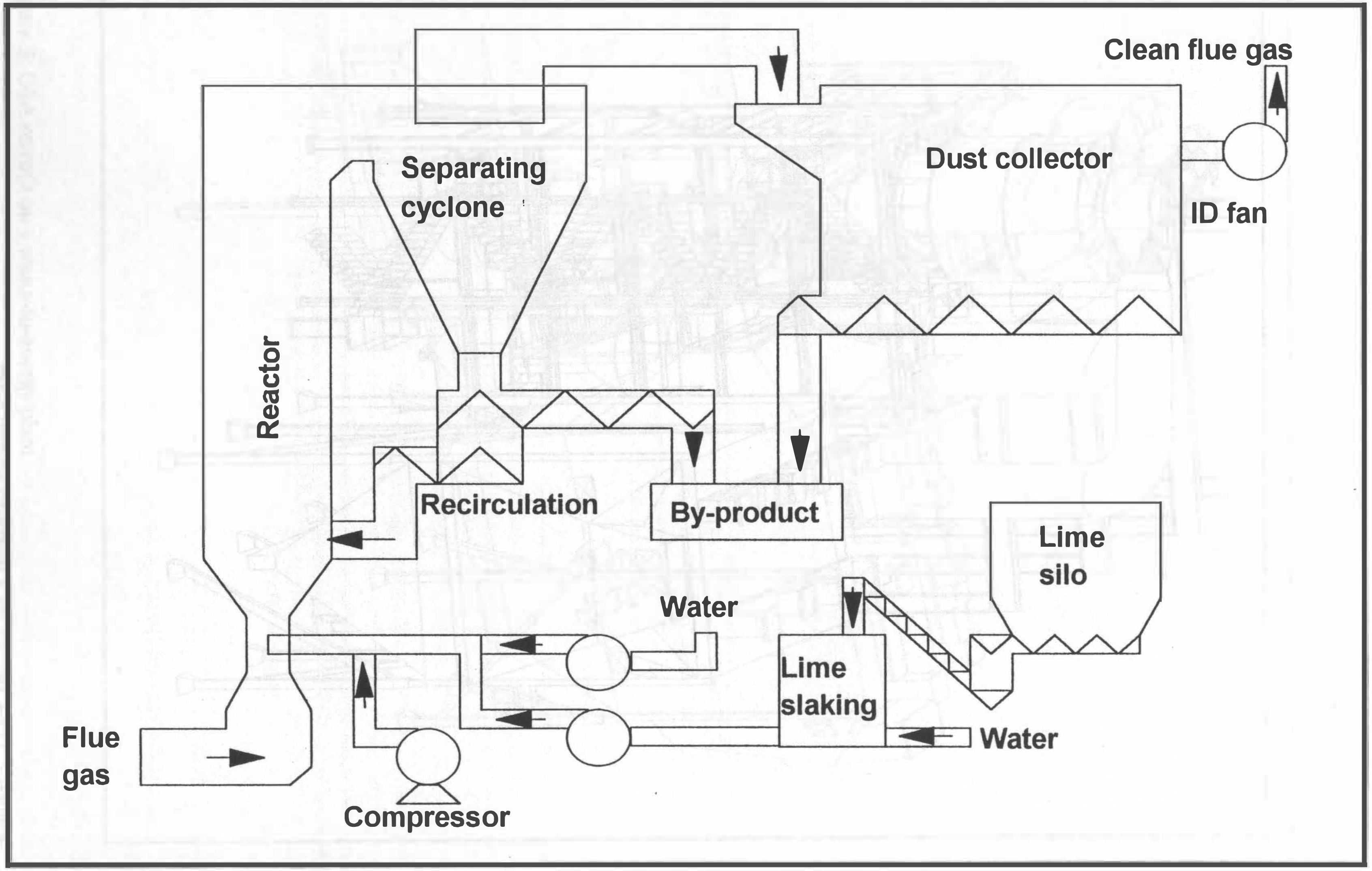

Figure 1: Simplified FLS-GSA process flow diagram.

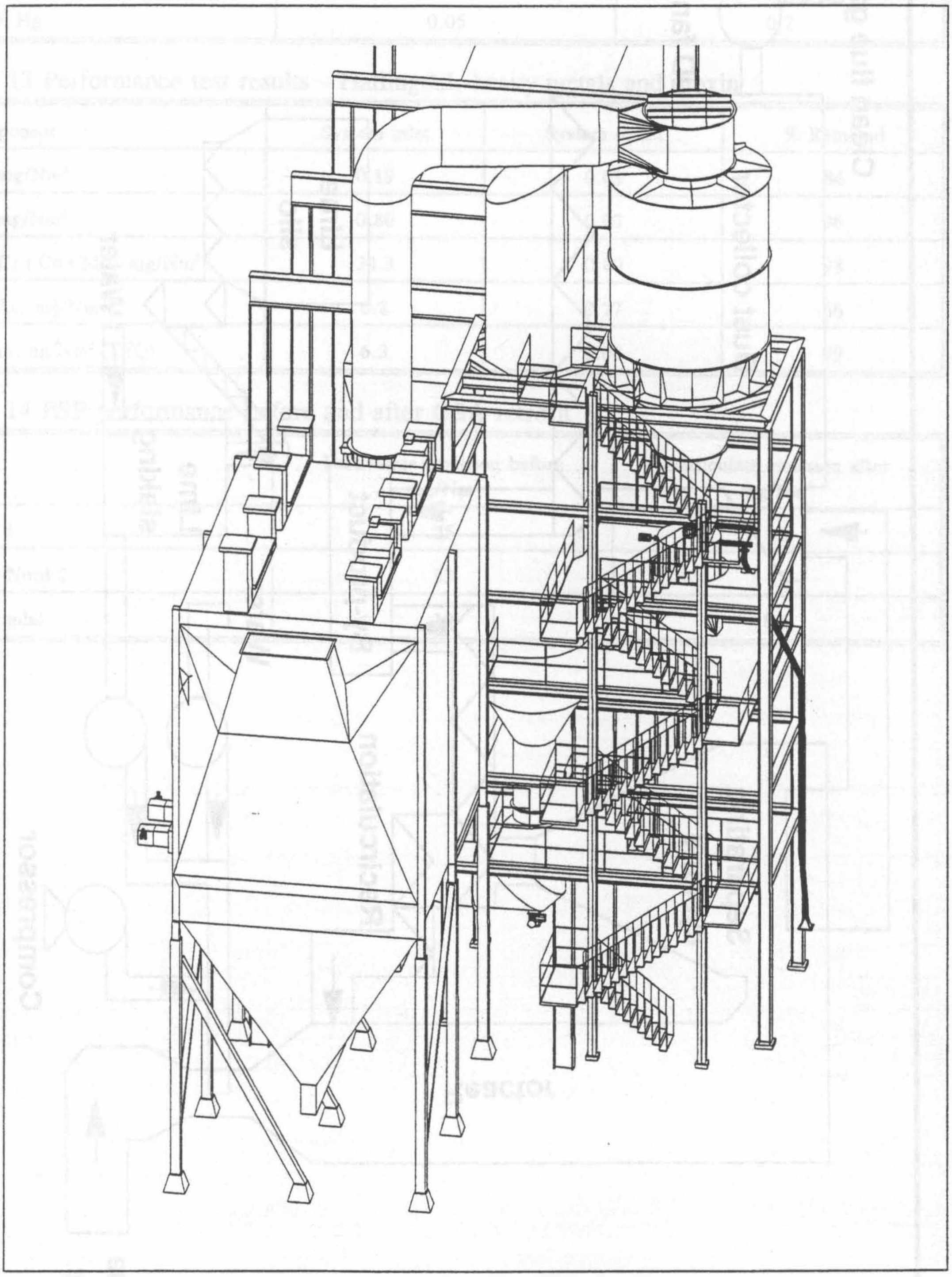

Figure 2: GSA retrofit on a waste-to-energy plant

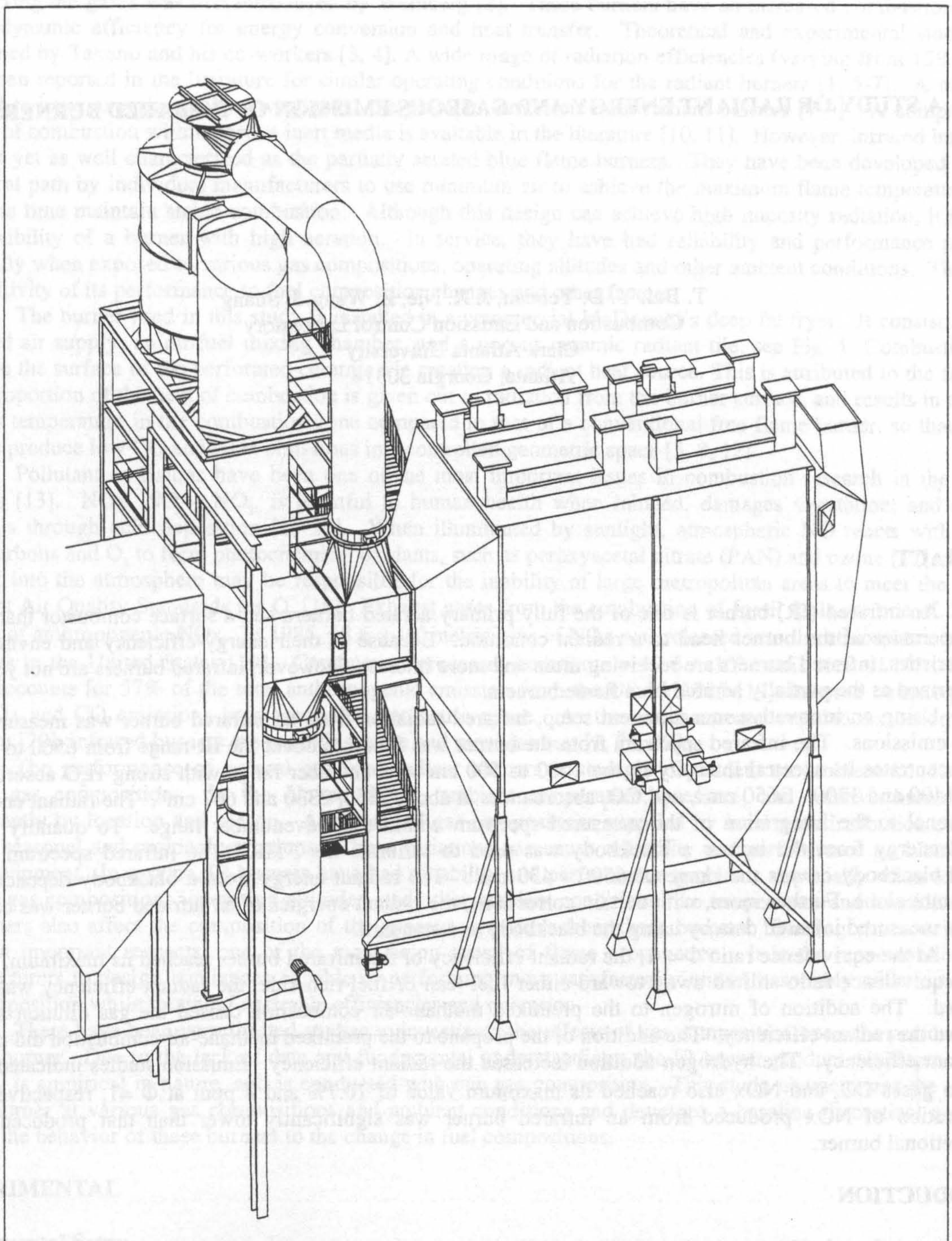

Figure 3: GSA retrofit on a waste-to-energy plant