Update of Dry Scrubbing Experience on European Waste-to-Energy Facilities

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INTRODUCTION

Disposal of municipal solid waste by incineration is a well established technology in Europe. Over the past decades emission requirements from these waste-to-energy facilities have gradually been tightened (1). The most stringent requirements in Europe are in the Central European countries like Germany, Holland, Switzerland and Austria. In these countries the latest, most stringent regulations, i.e. the German 17th Federal Immission Control Regulation (17th BImSchV) is setting the emission standard. In contrary, the emission standards set currently by the European Union (EU) are less stringent, but are expected to be tightened in the future, see Table 1.

Based on the difference in the emission requirements locally and presumably also based on the difference in attitude, countries like Denmark, Sweden, Finland, England, France, Spain, Portugal and Italy have chosen to comply with the emission standards by using less complicated and less expensive air pollution control equipment compared to the Central European countries. Air pollution control equipment in Central Europe has over the last decade advanced to such complexity and costs that the price of the air pollution control equipment far exceeds the incinerator per se (1,2). As prices for air pollution control equipment have sky-rocketed, the societies in Central Europe have realized that this is not a sustainable development and the trend has now reversed such that simpler and more cost-effective solutions are considered, while at the same time still fulfilling the 17th BImSchV-regulation.

One of the cost-effective options being considered is the spray dryer absorption technology, including a spray dryer and fabric filter. The paper describes four commercial spray absorption systems in different countries. They include various design modification, however they all are able to meet the most stringent European regulations.

DESCRIPTION OF PLANTS

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

1. Amager - Denmark
2. Turku - Finland
3. IBW - Belgium
4. Mallorca - Spain

These facilities are geographically located far apart from the far North (Turku) to the Southern part of Europe (Mallorca). Design data for the waste-to-energy facility per se is given in Table 2.

The spray dryer absorption systems were all built by ABB under a license agreement with Niro. Of the four plants in question the Amager and Turku plants are designed as a traditional spray dryer absorption (SDA) process. The SDA process combines spray drying technology with efficient particulate collection in a down-stream filter, which usually is a fabric filter. The system is designed to removed acid gases and particulates from flue gases without saturating the flue gas and therefore producing a dry product for disposal. Figure 1 is showing a simplified diagram of the four SDA systems incorporating the general design features for the Niro system:

- Use of a single spray dryer per incinerator unit.
- Use of a single rotary atomizer per spray dryer producing a cloud of fine reagent droplets.
- Use of a single gas disperser to control the shape of the droplet cloud and achieve intimate mixing in the flue gas and the reagent slurry.
- Inclusion of a 2-point product discharge designed to ensure an open gas passage.
- Sufficient spray dryer residence time to ensure adequate drying of disposal product.

The SDA system consists of a reagent preparation system, a spray dryer absorber, a dust collector and an ash transport system. Most commonly the SDA system is designed for single-pass operation.

Quicklime is delivered by truck and conveyed pneumatically to a storage silo. From the silo, the lime is transferred to a paste or detention slaker, where an approx. 20% lime slurry is prepared. The lime slurry is transferred via a grid screen to a feed tank with final dilution of the lime slurry accomplished either in a small dilution head tank located above the spray dryer absorber, or in the rotary atomizer itself utilizing a dual-liquid distributor. By using the latter method, lime slurry and water are mixed directly in the atomizer wheel. The degree of dilution is controlled by a signal from an HCl or SO_2 analyzer located in the stack; the total liquid flow to the rotary atomizer is controlled to maintain a constant spray dryer absorber outlet temperature.

The atomized lime slurry enters the spray dryer, where it is mixed with the hot incoming flue gas; simultaneously lime reacts with the acid gases present and the reaction product is dried into free-flowing powder. A portion of the dried product is removed from the base of the spray dryer, while the majority is entrained with the off-gases and recovered in the particulate collector. Additional acid gas absorption takes place in the particulate collector, while the dust is being removed from the flue gas. The dried product from the spray dryer absorber and the particulate collector is conveyed either mechanically or pneumatically to a waste disposal silo. Normally, this product is hygroscopic due to the content of chlorides.The spray dryer outlet gas temperature is controlled as low as possible to give a high efficiency of acid gas removal, while simultaneously ensuring a dry product. Factors which influence the selection of spray dryer outlet temperature include: level of chlorides in the disposal product, water vapor content of the flue gas leaving the spray dryer absorber, solids content of the feed slurry and whether the system is operating in single-pass or recycle mode.

For additional control of vapor phase emissions such as mercury and dioxins, the SDA system can be augmented with an activated carbon injection system. This consists of a patented, dry additive system for injection of activated carbon, either up-stream, in or down-stream of the spray dryer, depending on the temperature level throughout the SDA system. The activated carbon injection technology for mercury control was developed and patented by Niro. It seems like this technology is the preferred technology for mercury control on waste-to-energy plants, and as a consequence Niro has through its licensee, the Babcock & Wilcox Co., and previously through Joy Technologies granted sub-licensees to main contractors of waste-to-energy plants, operators of waste-to-energy plants as well as vendors of air pollution control equipment. It is Niro's policy to continue this sub-licensing of the patented mercury control technology to any interested party.

The above description of the generic SDA system used at Amager and Turku applies for more than 65 waste-to-energy trains having installed the Niro SDA system.

Further development of the basis SDA system has been made at the IBW and the Mallorca plant. The basic layout of those two plants are shown in Figure 1.

The system at IBW is the so-called High-Performance Spray Dryer Absorber (HPSDA). The HPSDA-system consists of a normal spray dryer absorber system which at IBW includes a spray dryer absorber with down-stream electrostatic precipitator. In addition, the HPSDA-system further includes a fabric filter installed down-stream of the electrostatic precipitator. The flue gas between the two filters can optionally be cooled in a heat-exchanger to a lower and for the process more optimum temperature. In the fabric filter, hydrated lime is introduced by dry injection in the duct up-stream of the fabric filter. The spent and partially reacted hydrated lime from the second fabric filter may then be used for dry injection up-stream of the electrostatic precipitator. By this method, the overall disposal quantities are reduced to a level comparable to disposed quantities from the wet scrubbing system. The advantages of cooling the flue gas in a heat-exchanger is twofold. First of all heat is recovered and secondly mercury removal in the fabric filter is improved, even without active carbon injection. Thus mercury emission requirements can be met with no or very little active carbon injection.

The Mallorca incinerator plant is a completely new facility consisting of two 450 TPD incinerator trains each equipped with identical dry scrubbing units. The Mallorca dry scrubbers are designed with dry recycle to enhance the performance. The recycle system is designed as follows: Dry scrubber waste with excess lime from the fabric filter is transported pneumatically to an intermediate silo. Next to this silo is a silo with activated carbon. The alkaline dry scrubber waste is then mixed with activated carbon and pneumatically injected into the duct between the spray dryer and fabric filter. This process modification is increasing the alkalinity ratio into the fabric filter and thereby improving the absorption performance. The recycle rate of dry scrubber waste is set to 5 times the amount of solids being introduced via the rotary atomizer. The amount of active carbon injected is relatively high, i.e. 240 mg/Nm^3. This is due to the fact that the system has been designed for an outlet spray dryer temperature of 160^{o}C, at which temperature mercury removal is more difficult than at the normal dry scrubber outlet temperatures for incinerators (130-140^{0}C).

The plant is designed for emission limits according to the Spanish legislation, i.e. HCl emissions of 50 mg/Nm^3, and SO_2 emissions of 300 mg/Nm^3, both at 11% O_2 dry, so today the dry scrubber systems are fulfilling the present EU legislation.

Design data for the four air pollution control systems are shown in Table 3.

TEST RESULTS

Amager

The Amager incinerator plant has four 288 TPD incinerator trains, each equipped with identical dry scrubbing units. The plant was originally designed for emission limits according to the Danish 1986 legislation, i.e. HCl emissions of 100 mg/Nm^3 and SO_2 emissions of 300 mg/Nm^3 both at 10% O_2 dry. Today the dry scrubber systems are operated with a lower set-point for the HCl emission, fulfilling the present EU legislation, i.e. HCl emission equal to 50 mg/Nm^3 and SO_2 emissions of 300 mg/Nm3 both at 11% O_2 dry.

In the winter and spring of 1995, the Amager incinerator plant decided to enter into a test program with the purpose of demonstrating that the Niro dry scrubbing system was capable of meeting the 17th BImSchV emission limits regarding HCl and SO_2 and at the same time to estimate the corresponding lime consumption. The test program was carried out jointly by I/S Amagerforbrænding (Amager Incinerator), Kemp & Lauritzen A/S, MILJØKEMI Dansk Miljøcenter A/S and Niro A/S. The companies Kemp & Lauritzen A/S and MILJØKEMI Dansk Miljøcenter A/S were supplying a multi-component FT-IR gas analyzer type KL2000 developed by Kemp & Lauritzen A/S. I/S Amagerforbrænding was responsible for the daily operation, and Niro A/S was responsible for temporarily installed gas analyzers on the inlet and outlet side of the dry scrubbing system, calibration of analyzers and plant instrumentation using reference methods, data-logging and reporting of measurements. Hence, during the tests continuous emission monitors were installed both at the inlet of the dry scrubber and in the stack measuring HCl, SO_2, H_2O and O_2.

During the tests, the only modification to normal operation of the plant was the lowering of the spray dryer absorber outlet temperature to 135°C and an adjustment of the HCl emission set-point from 50 mg/Nm^3 down to 10 and 5 mg/Nm^3 respectively. The HCl emission signal was utilized to control the lime feed.

All measurements from the plant instrumentation or temporarily installed instruments were logged in a temporarily installed data-logging system. The data were logged as 1 minute, 5 minutes or one half hour averages. The test program was carried out without any major operational problems although the set-point for the spray dryer outlet temperature was lowered to 135°C and 130°C respectively. No drying problems or product handling problems were encountered.

The inlet HCl distribution during the test is shown in Figure 2. As can be seen most values are in the range from 600 - 1000 mg/Nm^3. The half-hour emission average with a HCl set-point of 10 mg/Nm^3 is shown in Figure 3, and the half-hour average using a set-point of 5 mg/Nm^3 is shown in Figure 4. From these results it can be seen that the dry scrubber without problems can meet the German 17th Federal Emission Control Regulation of 10 mg/Nm^3 and that it is further possible to meet half this emission standard.

During the test program also the inlet SO_2 concentration was measured as shown in Figure 5. The corresponding SO_2 outlet emissions on a half-hour averaging basis for a HCl set-point of 10 mg/Nm^3 and 5 mg/Nm^3 are shown in Figure 6 and 7 respectively. As it can be seen, the SO_2 emission can be kept way below the 50 mg/Nm^3 specified in the German 17th Federal Immission Control Regulation.

Turku

As mentioned before, the Turku plant consists of two 120 TPD incinerator lines originally built by Von Roll in 1975. The dry scrubber system that was retrofitted in 1995 was designed to treat the flue gas from the two existing incinerators plus a future 3rd train of 240 TPD.

The dry scrubbing system is characterized by having a 1-field electrostatic precipitator as a pre-collector, a spray dryer absorber and a downstream fabric filter. The dry scrubber system is equipped with an activated carbon injection system for mercury control.

This dry scrubber system is unique in the sense that this is the first Niro dry scrubbing system in which the German 17th BImSchV regulation of 10 mg/Nm^3 HCl was guaranteed.

The active carbon injection system is used for control of heavy metals like mercury and dioxins. The very small amount of active carbon is continuously injected into the flue gas duct between the absorber and the bagfilter. A static mixer is installed for distribution of the active carbon.

The Turku retrofit dry scrubbing system was started-up and tested in 1996. Responsible for the test program was the engineering company IVO International Oy.

The performance test data for acid gases and particulate are shown in Table 4. The particulate concentration into the SDA is low due to the use of an electrostatic precipitator as precollector. As can be seen from the performance test results, the plant clearly met the German 17th BImSchV regulation.

Results of the performance testing for heavy metals and dioxins are shown in Table 5. During the test, activated carbon was injected in a rate of approx. 40 mg/Nm^3. The flue gas flow during the performance testing was between 40,000 and 47,000 Nm^3/h.

IBW

The performance test of the IBW dry scrubbing system was accomplished in September 1996. The company SGS Ecocare Analytical Services was in charge of the measurements. Results of the testing are shown in Table 6, 7 and 8. As it can be seen from the results, the High-Performance SDA system is achieving very good emission values. The sulfur dioxide is the most difficult to remove in the spray dryer, but with the additional fabric filter, very low outlet emissions can be achieved.

The results from the IWB plant show that the dry scrubber system can achieve emission values corresponding to half the German 17th Imission Control Regulation.

Mallorca

The Mallorca incinerator system was started-up in the fall of 1996 and preliminary performance tests were made in late November 1996. At this point, the final performance tests have been made, but the data are not yet available.

As it appears from the preliminary performance test results in Table 9, the dry scrubber at Mallorca was easily able to meet the present EU legislation of 50 mg/Nm^3 HCl and 300 mg/Nm^3 SO_2.

CONCLUSION

Results from testing of four commercial dry scrubber units in Europe have proven that dry scrubbing technology today can meet the performance required by the most stringent European regulation enacted in the German 17th Federal Immission Control Regulation. The paper further documents that half the

German emission standards can be obtained with dry scrubbing technology. These emission values are comparable to what can be achieved with more complex systems using wet scrubber technology.

REFERENCES

1. Karsten Felsvang et al, Recent Experience with Air Pollution Control on Sewage Sludge, Municipal Solid Waste and Industrial Incinerators, 4th International Symposium on Solid Waste Management: Thermal Treatment and Waste-to-Energy Technology, April 18-21, 1995, Washington, D.C., USA

2. Georg Schaub, Rauchgasreinigung mit Reststoffbehandlung und Wertstoffgewinnung in der Abfallverbrennung - Stand und Tendenzen, Chemie Ingenieurtechnik (68), 11/96

Table 1: Emission requirements for European waste-to-energy facilities

Pollutant	German 17th BImSchV	EU 1989 -	EU Future expected
HCl	10	50	10
SO_2	50	300	50
Hg	0.05	0.2*)	0.05
Particulate	10	30	10

mg/Nm^3 at 11% O_2 *) Hg + CD

Table 2: Design data for waste-to-energy facilities

Plant	Amager	Turku	IBW	Mallorca
Capacity, TPD	4 x 288	2 x 120	1 x 120 1 x 240	2 x 450
Incinerator manufacturer	Vølund	Von Roll	B&S Bartholomeis	DBA
Type of kiln	Travelling grate + rotary	Travelling grate	Travelling grate	Travelling grate
Economizer	Yes	Yes	Yes	Yes
Type of waste	Household & hospital waste	Household	Household	Household
Plant start-up	1989/91	1994	1995 1997	1996

Table 3: Design data for air pollution control systems

Plant	Amager	Turku	IBW	Mallorca
Flue gas flow, Nm^3/h	95,500	77,000	35,000 60,000	110,000
Flue gas temp. °C	180-228	180-250	210-300	190-260
Pollutants Concentration				
HCl, mg/Nm^3 d, 11% O_2	≤ 1,636	1000-1500	≤ 2000	≤ 1800
HF, mg/Nm^3 d, 11% O_2	≤ 14	≤ 7	≤ 8	≤
SO_2, mg/Nm^3 d, 11% O_2	≤ 364	≤ 400	≤ 500	≤ 1200
Hg, mg/Nm^3 d, 11% O_2	0.35	0.1	-	1.0
Particulate, g/Nm^3 d	≤ 7	≤ 7	≤ 1	≤ 4
Emission requirements				
HCl, mg/Nm^3 d, 11% O_2	≤ 100	≤10	≤ 5	50
SO_2, mg/Nm^3 d, 11% O_2	≤ 300	≤150	≤ 25	300
HF, mg/Nm^3 d, 11% O_2	2	≤1	≤1	2
Hg, mg/Nm^3 d, 11% O_2	≤0.20	≤0.05	≤0.05	< 0.20
PCDD/PCDF, ng TE/Nm^3 d,11% O_2	-	≤0.1	≤0.1	≤0.1

Table 4: Performance test results - Turku
Acid gas and particulate removal

Component		System Inlet	System Outlet
HCl	mg/Nm^3	420	9.6
HF	mg/Nm^3	2.1	0.1
SO_2	mg/Nm^3	200	43
Particulate	mg/Nm^3	9	2

Table 5: Performance test results - Turku
Heavy metal and dioxin removal

Component		System Inlet	System Outlet
Pb + Cr + Cu + Mn	mg/Nm^3	2.2	0.74
Ni +As,	mg/Nm^3	-	0.007
Cd	mg/Nm^3	0.008	0.00006
Hg	mg/Nm^3	0.023	0.002
PCDD/PCDF	Eadon eqv. (ng/Nm^3)	17.5	0.007

Table 6: Performance test results - IBW
SO_2 removal - SO_2 concentration in mg/Nm^3

Date	Raw gas	Downstream electro-static precipitator	Downstream fabric filter
September 12, 1996	164	43	< 25
September 13, 1996	370	54	< 24

Table 7: Performance test results - IBW
HF removal - HF concentration in mg/Nm^3

	Raw gas	Downstream electro-static precipitator	Downstream fabric filter
September 10, 1996	0.1 - 1.5	< 0.1	< 0.1
September 11, 1996	0.1 - 0.8	< 0.1	< 0.1
September 12, 1996	0.1 - 3.4	< 0.1	<0.1
September 13, 1996	0.1 - 0.4	<0.1	<0.1

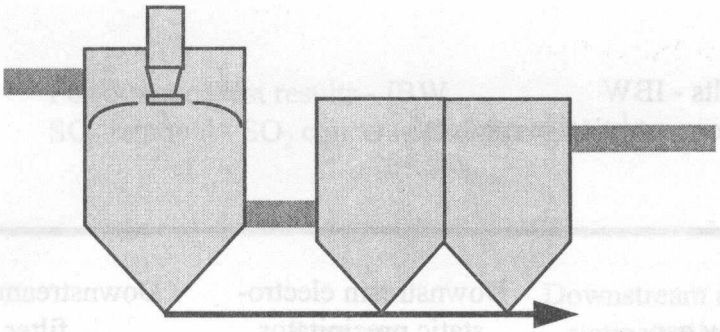
Table 8: Performance test results - IBW
HCl removal - HCl concentration in mg/Nm^3

	Raw gas	Downstream electro-static precipitator	Downstream fabric filter
September 10, 1996	138 - 907	2.6	-
September 11, 1996	493 - 771	3.0	-
September 12, 1996	210 - 393	1.8	<1
September 13, 1996	1382 - 3618	<1	<1

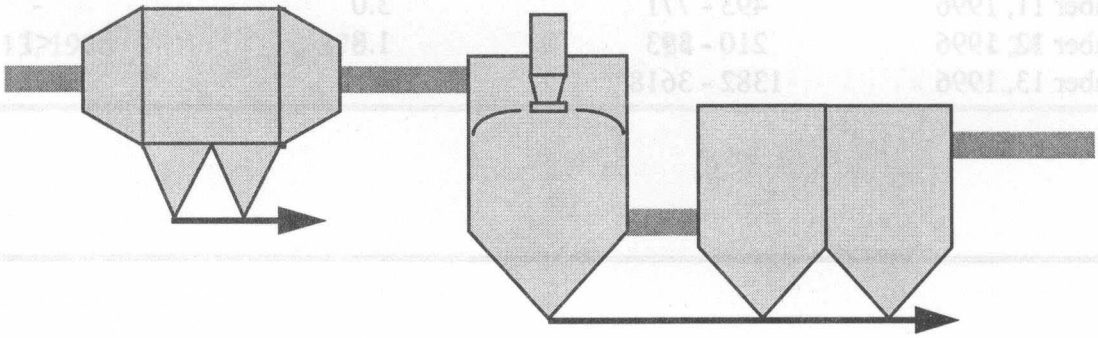
Table 9: Preliminary performance
Test results - Mallorca

Component		System inlet	System outlet
HCl	mg/Nm^3	753	33
SO_2	mg/Nm^3	97	38

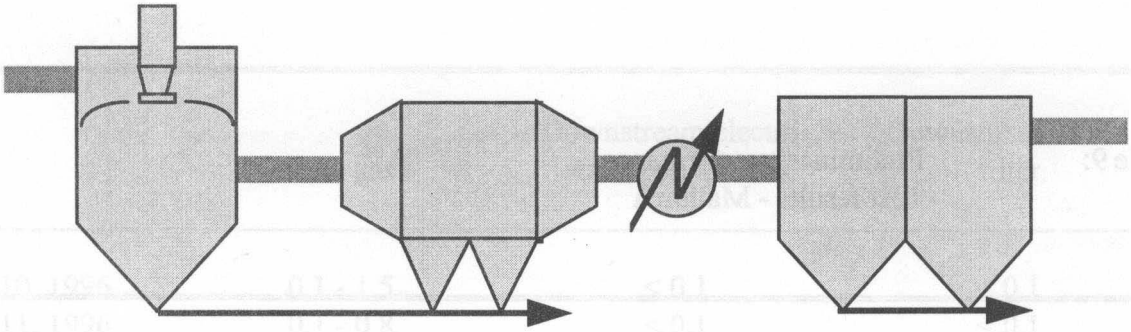
Amager



Turku



IBW



Mallorca

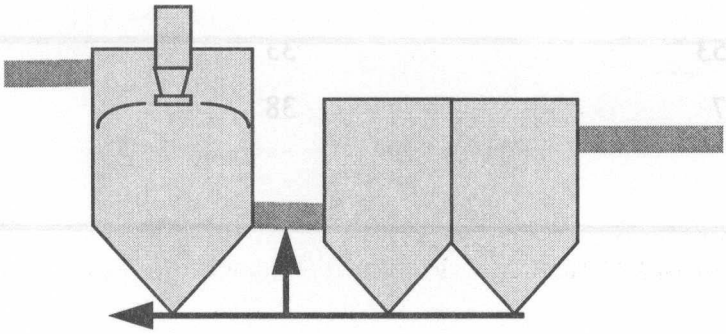


Figure 1: Design of air pollution control equipment

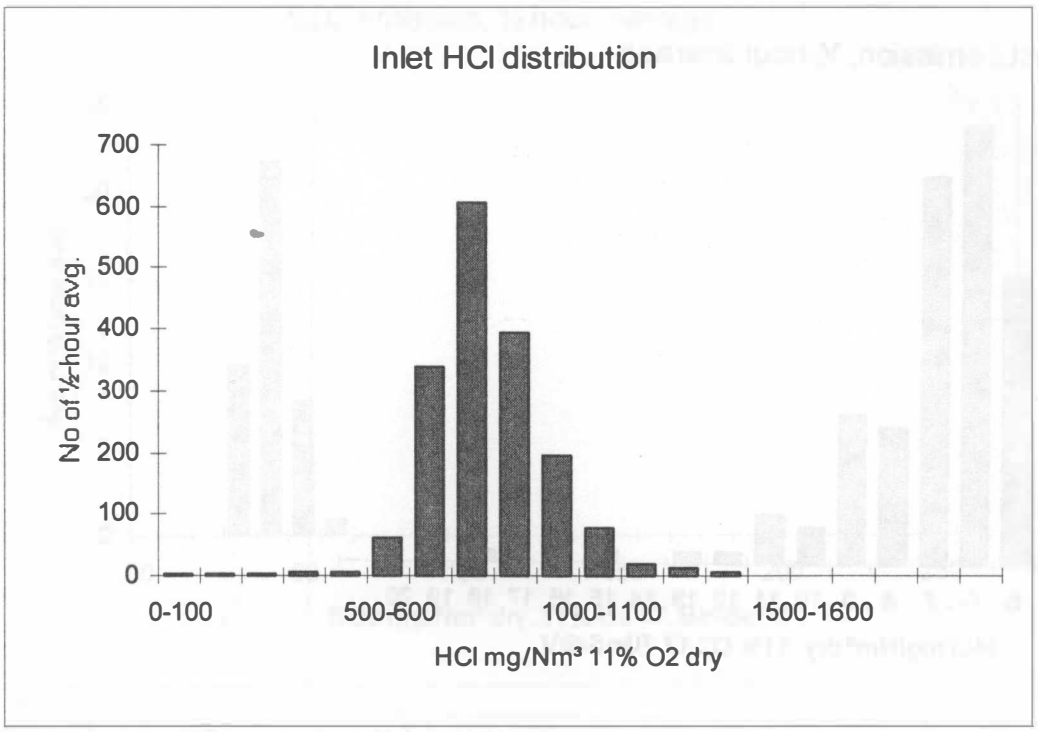


Figure 2: Inlet HCl distribution

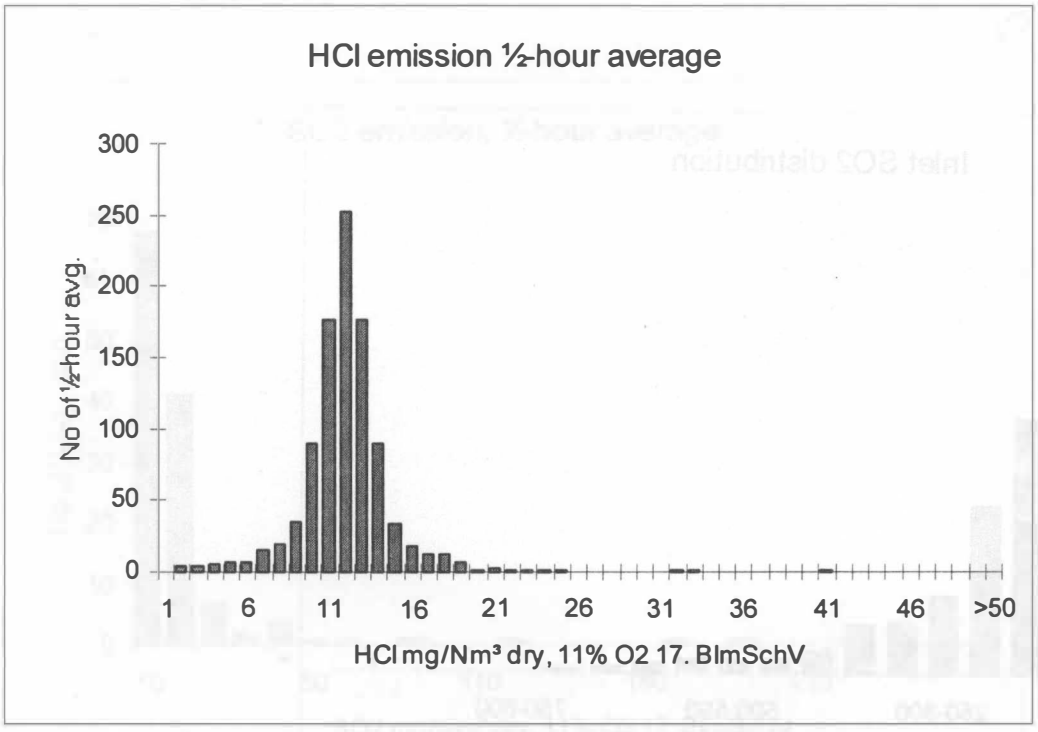


Figure 3: HCl emission ½ hour average
Temp. SDA outlet 130-140°C, Set Point HCl 10 mg/Nm^3 wet at actual O_2

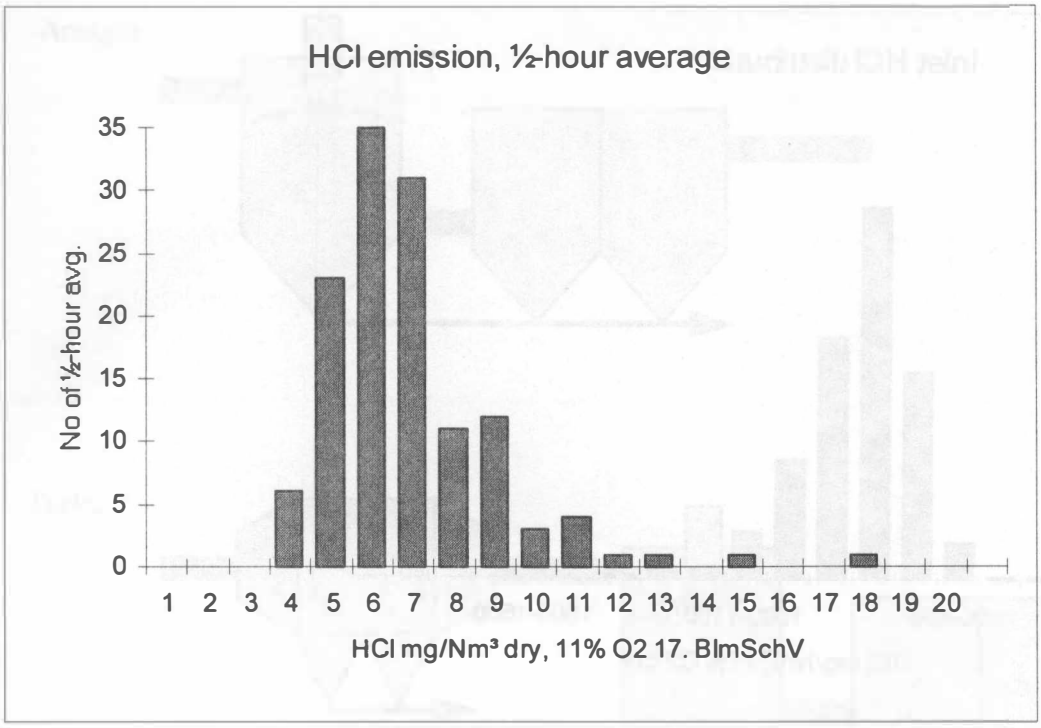


Fig 4: HCl emission ½ hour average
Temp. SDA outlet 130-140°C , Set Point HCl 5 mg/Nm^3 wet at actual O_2

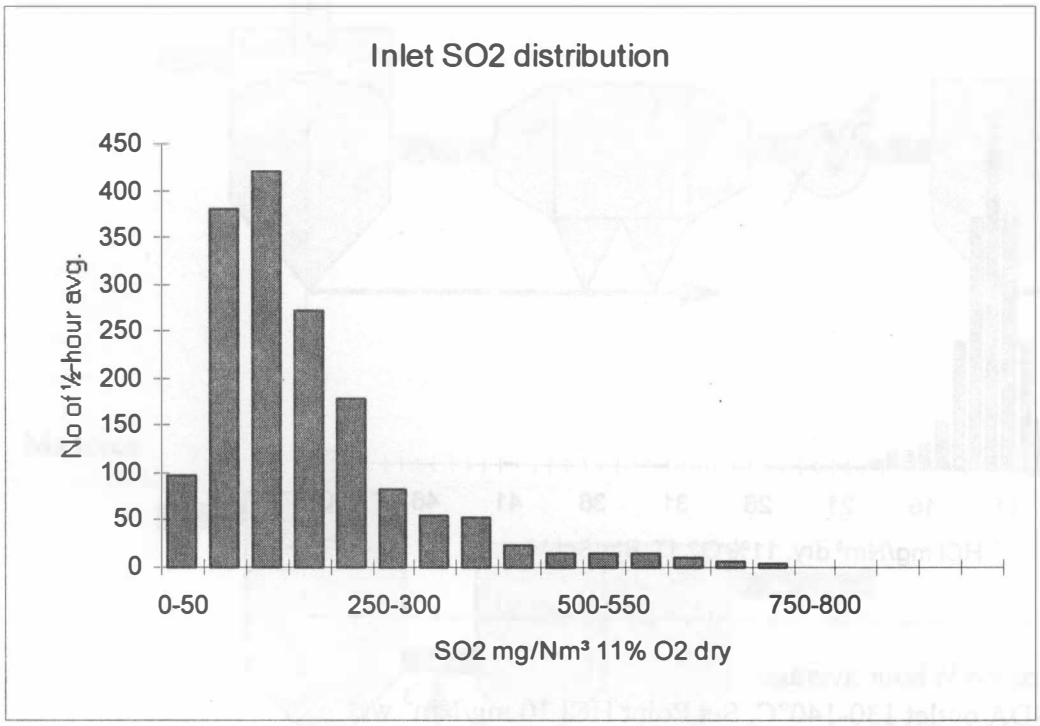


Figure 5: Inlet SO_2 distribution

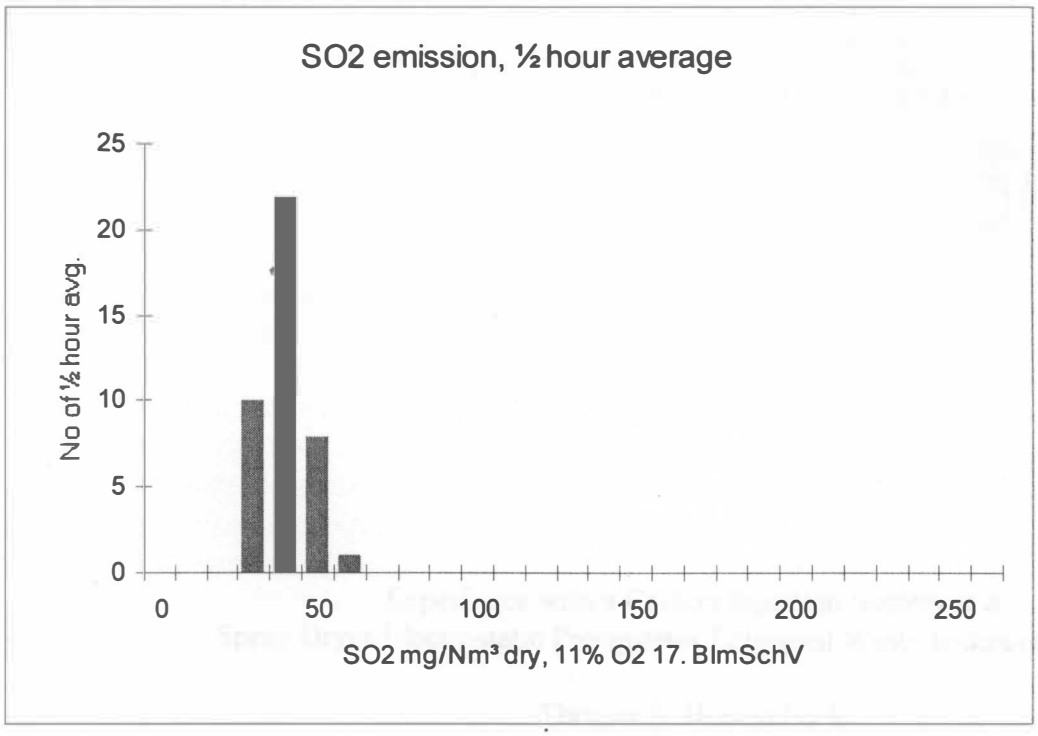


Figure 6: SO_2 emission, ½ hour average
Temp. SDA outlet 130-135°C, Set Point HCl 10 mg/Nm^3
at actual O_2

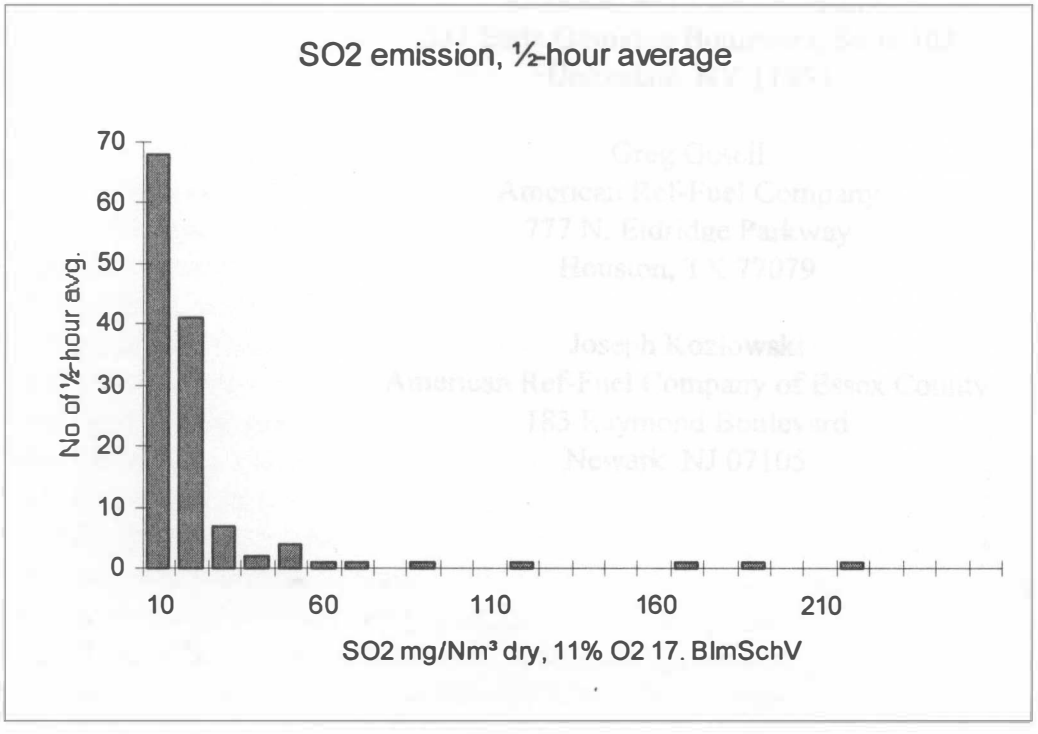


Figure 7 SO_2 emission, ½ hour average
Temp. SDA outlet 130-140°C, Set Point HCl 5 mg/Nm^3
at actual O_2