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TEST REPORT

Ref. Report No.

PIS02239-1

Name and address of the applicant
GeoRi Co., Ltd.
739, Samsan-Ri Yeongok-Myon
Gangneung-City Gangwon-Do Korea

Standard / test methods
Korean Standard Methods of Air Pollution

Test conditions
Isokinetic Sampling (I Factor 100.9%)
HRGC-HRMS Analysis (Resolution > 10,000)

Test results
PCDD/Fs Concentration: 0.119 ng-TEQ/Sm^3

Purpose of test
Research & Development

Test date: Sep. 18, 2002-Oct. I, 2002 Issue date: Oct. 14, 2002

Test items: PCDD/Fs Sampling & Analysis in Flue Gas of Plastic-fueled Boiler
Model / Lot No.: ***
Manufacturer: ***
Additional information: ***

[Notice: Due to difficulties with electronic transmission of data, the original English version of this report has been reformatted by James W. Garthe, PE of The Pennsylvania State University on May 11, 2004. It has been confirmed accurate by the Korea Institute of Energy Research in conjunction with the Korea Testing Laboratory. Questions may be directed to Mr. Garthe at: 246 Agricultural Engineering Building, University Park, PA 16802. Ph: (814) 865-7154; Em: jwg10@psu.edu]

Tested and reported by

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PCDD/Fs Sampling & Analysis in Fluegas of Plastic-fueled Boiler

Oct. 2002

KOREA TESTING LABORATORY

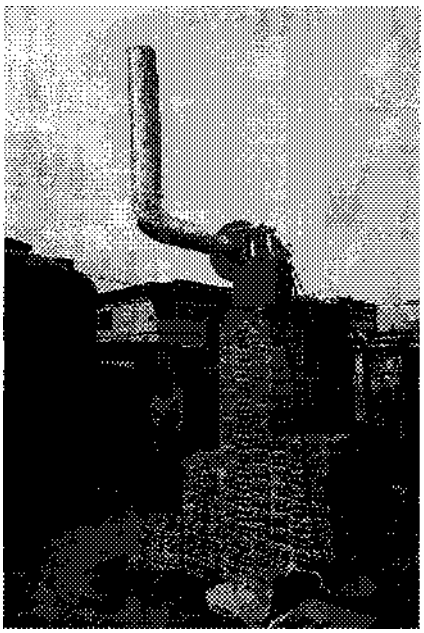
1. Introduction

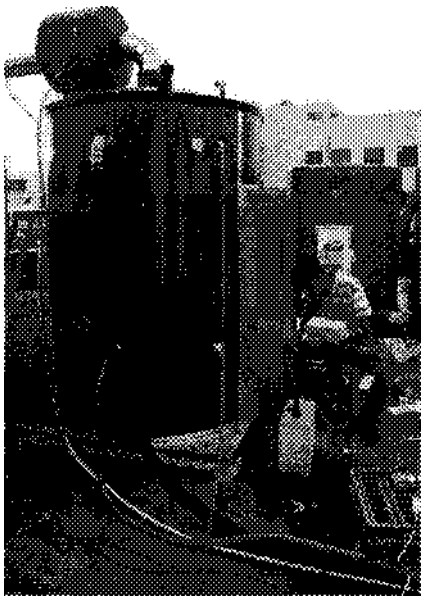
1.1 General information

- Project name: PCDD/Fs Sampling & Analysis of Fluegas from Plastic-fueled Boiler
- Applicant Name: GeoRi Co., Ltd.
- Applicant Address: 739, Samsan-Ri Yeongok-Myon Gangneung-City Gangwon-Do Korea

1.2 Device information

- Device name: Plastic-fueled boiler
- Device capacity: 15kg/hr
- Process: Fuel Injector => Combustor => Heat Exchanger => Wet Scrubber => Outlet
- Fuel Type: Plastic waste (PE + PP)
- Photographs of device:



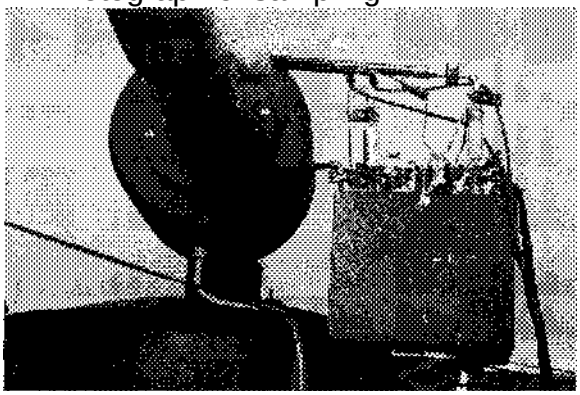


1.3 Test Information

A. Sampling

- Sampling date: 2002.09.18
- Sampling location / Number: Plastic-fueled boiler, 1
- Test method: Korean Standard Methods of Air Pollution (Isokinetic Sampling)

B. Photograph of sampling



< Sampling Impinger Box >

< Stack Sampler >

C. Analysis

- Korean Standard Methods of Air Pollution (HRGC/HRMS, Resolution over 10,000)

2. Test methods & results

2.1 Test methods

A. Sampling

- Sampling Method : Korean Standard Methods of Air Pollution (Isokinetic Sampling):

Item	Content
Sampling date	2002. 09. 18.
Sampling location	Plastic-fueled Boiler Outlet
Sampling device	Stack Sampler (CAE, S/N 28-102500-1)

B. Analysis

- Analysis Method: Korean Standard Methods of Air Pollution (HRGC/HRMS, Resolution > 10,000)

1) Sample Extraction & Concentration

- Liquid-Liquid Extraction
  - Distilled water, diethyleneglycol, wash solvent off impinger two times with toluene (10:1,V/V)
- Soxhlet Extraction
  - Filter, XAD-2 resin (toluene during 1 day)

2) Cleanup

- Sulfuric acid treatment, Multi-layered silica gel column chromatography, Alumina column chromatography

3) Conditions of column chromatography:

Item	Solvent	Volume
Multi-layered silica gel	n-Hexane	120ml
Alumina	2% CH_2Cl_2/n-Hexane	150ml
	50% CH_2Cl_2/n-Hexane	80ml

4) HRGC conditions:

Operator Name	K.S. Kim
Instrument	HP6890GC with Autosampler
Column	SP-2331 60m*0.32mm*0.20um
Oven Temp.	100°C(1min)-20°C/min-180°C-3°C/min-260°C(24min)
Carrier Gas	He (11.5psi)
Injector	Splitless
Inj. Temp.	270 °C
Purge Time	90 sec
Class	TCDD/Fs - OCDD/Fs

5) HRMS Conditions

Operator Name	K.S. Kim
Instrument	JMS-700 Mstation
Principle	Double Focusing Type
Resolution	over 10,000
Detection Method	HRSIM (High Resolution Selected Ion Monitoring)
Ionizing Mode	EI (Electron Impact)
Temp. of Ion Chamber	270℃
Temp. of Pipe Line	270℃
Temp. of Glass Line	270℃

6) Standards for PCDD/Fs Analysis:

Internal standard	Injection Vol.	Syringe standard	Injection Vol.
$^{13}C_{12}$-2,3.7.8-TCDD	1ng	$^{13}C_{12}$-1.2.3.4-TCDD	1ng
$^{13}C_{12}$-1.2.3.7.8-PeCDD	1ng	$^{13}C_{12}$-1.2.3.7.8.9-HxCDD	1ng
$^{13}C_{12}$,-1.2.3.4.7.8-HxCDD	1ng	^{37}Cl-2,3,7,8-TCDD	10ng
$^{13}C_{12}$-1.2.3.6.7.8-HxCDD	1ng		
$^{13}C_{12}$-1 .2.3.4.6.7.8-HpCDD	1ng		
$^{13}C_{12}$-OCDD	2ng		
$^{13}C_{12}$-2.3.7.8-TCDF	1ng		
$^{13}C_{12}$-1.2.3.7.8-PeCDF	1ng		
$^{13}C_{12}$-2.3.4.7.8-PeCDF	1ng		
$^{13}C_{12}$-1.2.3.4.7.8-HxCDF	1ng		
$^{13}C_{12}$-1.2.3.6.7.8-HxCDF	1ng		
$^{13}C_{12}$-1,2,3,7.8.9-HxCDF	1ng		
$^{13}C_{12}$-2.3.4.6.7.8-HxCDF	1ng		
$^{13}C_{12}$-1.2.3.4.6 7.8-HpCDF	1ng		
$^{13}C_{12}$-1.2.3.4.7.8.9-HpCDF	1ng		

Analyte	CS1 (ng/ml)	CS2 (ng/ml)	CS3 (ng/ml)	CS4 (ng/ml)	CS5 (ng/ml)
2.3.7.8-TCDD	0.5	2	10	40	200
1.2.3.7.8-PeCDD	2.5	10	50	200	1000
1.2.3.4.7.8-HxCDD	2.5	10	50	200	1000
1.2.3.6.7.8-HxCDD	2.5	10	50	200	1000
1 2 3.7.8 9-HxCDD	2.5	10	50	200	1000
1.2.3.4.6.7.8-HpCDD	2.5	10	50	200	1000
OCDD	5	20	100	400	2000
2.3.7.8-TCDF	0.5	2	10	40	200
1.2.3.7.8-PeCDF	2.5	10	50	200	1000
2.3.4.7.8-PeCDF	2.5	10	50	200	1000
1.2.3. 4.7. 8-HxCDF	2.5	10	50	200	1000
1.2.3.6.7.8-HxCDF	2.5	10	50	200	1000
1.2.3.7.8,9-HxCDF	2.5	10	50	200	1000
2.3.4.6.7.8-HxCDF	2.5	10	50	200	1000
1.2.3,4.6.7.8-HpCDF	2.5	10	50	200	1000
1.2.3,4.7.8.9-HpCDF	2.5	10	50	200	1000
OCDF	5	20	100	400	2000
$^{13}C_{12}$-2,3.7.8-TCDD	100	100	100	100	100
$^{13}C_{12}$-1.2.3.4-TCDD	100	100	100	100	100
$^{37}Cl_{12}$-2.3.7.8-TCOD	0.5	2	10	40	200
$^{13}C_{12}$-1.2.3.7.8-PeCDD	100	100	100	100	100
$^{13}C_{12}$-1.2.3.4.7.8-HxCDD	100	100	100	100	100
$^{13}C_{12}$-1.2.3.6.7.8-HxCDD	100	100	100	100	100
$^{13}C_{12}$-1.2.3.7.8.9-HxCDD	100	100	100	100	100
$^{13}C_{12}$-1.2.3.4.6.7 8-HpCDD	100	100	100	100	100
$^{13}C_{12}$-OCDD	200	200	200	200	200
$^{13}C_{12}$-2.3.7.8-TCDF	100	100	100	100	100
$^{13}C_{12}$-1.2.3.7.8-PeCDF	100	100	100	100	100
$^{13}C_{12}$-2.3.4.7.8-PeCDF	100	100	100	100	100
$^{13}C_{12}$-1.2.3.4.7.8-HxCDF	100	100	100	100	100
$^{13}C_{12}$-1.2.3.6.7.8-HxCDF	100	100	100	100	100
$^{13}C_{12}$-1.2.3,7.8.9-HxCDF	100	100	100	100	100
$^{13}C_{12}$-2.3.4.6.7.8-HxCDF	100	100	100	100	100
$^{13}C_{12}$-1.2,3.4.6.7.8-HpCDF	100	100	100	100	100
$^{13}C_{12}$-1.2.3.4.7.8.9-HpCDF	100	100	100	100	100

2.2 Test results

A. Sampling results

1) Sampling data:

Item	Sampling Date	Sample Vol (Sm^3)	I Factor (%)	Water Content (%)	FlueGas Temp. (^0C)	Gas Flow Rate (Sm^3/hr)	0_2 (%)	$C0_2$ (%)	CO (ppm)	NO_x (ppm)	SO_x (ppm)
									0_2=12%		
Plastic-fueled Boiler Outlet	2002/9/18	2.1212	100.9	6.39	151.4	412	15.55	2.99	108.02	26.71	6.73

2) Sampling results

- Refer to attached graph

B. Analysis results

1) PCDD/Fs Concentration:

Item	PCDD/Fs Concentration (Unit:ng-TEQ/SM^3 at O_2 =12%)
Plastic-fueled Boiler Outlet	0.119

2) Analysis results

- Refer to attached graph

PCDD/Fs Sampling Data

Applicant Name: GeoRi Co., Ltd.

Sampling Location : Plastic Fueled Boiler Outlet

Sep. 18, 2002

KOREA TESTING LABORATORY

Sampling Data

Sampling Details	
Applicant	GeoRi Co., Ltd.
Sampling Location	Plastic-fueled Boiler Outlet
Manufacturer	GeoRi Co., Ltd., 2002
SampIe No	KR-1
Capacity	0.015 ton/hr
Sampling Date	2002/9/18

Sampling Device Information	
DGM Calibration Factor, Y_d	1.0033
Pitot Tube Coefficient, Cp	0.84
Calibration Factor in English units, A H_g	1.8667
Sampling Standard Injection Vol. of $^{37}Cl_4$-2,3,7,8-T_4CDD	10 ng

Sampling Point Information	
Duct I.D., mm	218
Flange, mm	0
Sampling point	Center
Sampling point, mm	109
Probe Length,mm	600

Isokinetic Sampling Data Information

Item	Symbol	Unit	Regulation	Actual	Remarks
I Factor	I	%	95 - 105%	100.9	
K Factor	K	-		14.51	
Dry Gas Vol.(Std.)	Vstd	Sm^3	Over $3Sm^3$	2.1212	
Dry Gas Vol. (Natural)	V'm	m^3	-	2.3569	
Avg. 0_2 Conc.	0_2	%	-	15.55	
Sampling Time	t	min		160	
I factor check interval	-	min	Occasionally	5.0	
Sampling Time	-	min		160	
Avg. Flue Gas Temp.	Ts	°C	-	151.4	
Avg. Filter Temp.	-	°C	Under 120°C	108.2°C	
Avg. XAD-Resin Temp. (Impinger Outlet)	-	°C	Under 30°C	17.2	
Avg. DGM Temp.	Tm	°C	-	29.9	
Atmospheric Pressure	Pa	mm Hg	-	758	
Avg. Static Pressure	Ps	mm H_2O	-	-0.7	-0.1 mm Hg
Avg. Dynamic Pressure	Δ P	mm H_2O	-	1.6	
Avg. Flue Gas Flowrate	υ	m/sec	-	5.11	
Avg. orifice pres. drop	Δ H	mm H_2O	-	11.9	0.9 mm Hg

Isokinetic Sampling (I Factor)

Item	Symbol	English Unit	Metric Unit	Remarks
I Factor (95 - 105%)	I		100.9 %	
Avg. 0_2 Conc.	O_2	15.55 %	15.55 %	
Avg. $C0_2$ Conc.	CO_2	2.99 %	3.0 %	
Avg. N_2 Conc.	N_2	81.46 %	81.46 %	
Condensated Water Vol .	Vic	116.4 g	116.4 g	
Water Content	Xw	6.39 %	6.39 %	
Atmospheric Pressure	Pa	29.84 inch Hg	758 mm Hg	
Avg. Static Pressure	Ps	-0.03 inch H_2O	-0.7 mm H_2O	-0.05 mm Hg
Avg. Flue Gas Temp.	Ts	304.5 ^{0}F	151.4 °C	
Avg. Dynamic Pressure	Δ P	0.062 inch H_2O	1.6 mm H_2O	
DGM Calibration Factor	Yd	1.0033	1.0033	
Sampling Time	t	160 min	160 min	
DGM Avg. Temp.	Tm	85.8 °F	29.9 °C	
Pitot Tube Coefficient	Cp	0.84	0.84	
Nozzle I.D.	Dn	3/8 inch	9.53 mm	
Nozzle Section Area	An	inch^2	0.713 cm^2	
Dry Gas Vol. (Natural)	V'm	83.223 ft^3	2.3569 m^3	
Dry Gas Vol. (Std.)	Vstd	-	2.1212 Sm^3	
Avg. Orifice Pressure Drop	Δ H	0.47 inch H_2O	11.9 mm H_2O	0.88 mm Hg
Avg. Flue Gas Density	Y	-	0.834 Kg/m3	
Avg. Flue Gas Flowrate	υ	-	5.11 m/sec	
Avg. Flue Gas Absolute Temp.	T's	-	424.4	
Flue Gas (760-fPs)	P's	-	759.9 mm Hg	
DGM Av'g. Absolute Temp.	T'm	-	302.9	

I-Factor Equation used in the Korean Standard Method

$$I(\%) = \frac{T's(424.4)x\left[0.00346xVic(116.4) + \frac{V'm(2.3569)x[Pa(758) + \Delta H(0.88)]}{T'm(302.9)}\right]}{P's(759.9)xt(160)xv(5.11)xAn(0.713)} x16670$$

Equation used for Determining Dry Gas Volumes under Standard Conditions used in the Korean Standard Method

$$Vstd\left(Sm^3\right) = V4'(2.3569)x\frac{273}{273 + Tm(29.9)}x\frac{[Pa(758) + \Delta H(0.88)]}{760}$$

Flue Gas Concentration

Sampling Time, hh: mm	0_2, %	$C0_2$, %	CO, ppm	NOx, ppm	SOx, ppm
Avg. Conc.	**15.55**	**2.99**	**65.44**	**16.18**	**4.07**
Conversion Conc. (12% 0_2)		**4.84**	**108.02**	**26.71**	**6.73**
0:00	16.6	2.4	18	10	1
0:01	18.0	1.6	25	6	1
0:02	16.9	2.2	24	9	1
0:03	17.0	2.2	20	9	1
0:04	16.0	2.7	12	15	0
0:05	14.6	3.5	6	22	0
0:06	16.6	2.4	21	10	1
0:07	15.1	3.2	9	21	0
0:08	15.0	3.3	5	22	0
0:09	14.6	3.5	4	24	0
0:10	14.2	3.7	2	26	0
0:11	13.4	4.2	1	30	0
0:12	12.9	4.5	0	34	0
0:13	11.7	5.1	1	40	0
0:14	11.2	5.4	2	41	0
0:15	12.2	4.9	1	38	0
0:16	12.5	4.7	0	37	0
0:17	13.7	4.0	1	31	0
0:18	14.6	3,5	2	26	0
0:19	14.8	3.4	3	25	0
0:20	15.1	3.3	2	23	0
0:21	15.2	3.2	4	22	0
0:22	14.3	3.7	2	25	0
.. 0:23	15.0	3.3	4	22	0
0:24	14.5	3.6	4	24	0
0:25	14.4	3.6	2	24	0
0:26	14.9	3.4	4	21	0
0:27	16.2	2.6	10	15	0
0:28	16.7	2.4	13	12	0
0:29	15.5	3.0	8	17	0
0:30	16.5	2.5	11	12	0
0:31	16.4	2.5	13	12	0
0:32	16.7	2.4	14	11	0
0:33	16,3	2.6	11	13	0
0:34	16.2	2.6	10	13	0
0:35	16.2	2.6	10	13	0
0:36	15.6	3.0	8	17	0
0:37	16.0	2.7	10	14	0
0:38	15.5	3.0	7	18	0
0:39	14.2	3.8	3	26	0

0:40	14.3	3.7	2	25	0
0:41	15.2	3.2	6	18	0
0:42	15 7	2.9	11	14	0
0:43	16.1	2.7	18	9	0
0:44	162	2.6	23	8	0
0:45	156	3.0	14	13	0
0:46	15.2	3.2	11	16	0
0:47	14.9	3.4	9	18	0
0:48	14.2	3.8	3	26	0
0:49	14.3	3.7	2	25	0
0:50	14.7	3.5	7	20	0
0:51	15.2	3.2	10	20	0
0:52	16.4	2.5	11	14	0
0:53	16.8	2.3	12	8	0
0:54	16.2	2.6	12	11	0
0:55	15,6	2.9	7	14	0
0:56	14.2	3.7	5	22	0
0:57	14.1	3.8	4	23	0
0:58	16.2	2.6	9	13	0
0:59	15.7	2.9	5	6	0
0:60	13.6	4.1	1879	7	29
0:61	16.3	2.6	808	6	27
0:62	17.3	2.0	284	5	24
0:63	16.3	2.6	95	10	22
0:64	15.8	2.8	44	13	18
0:65	15.2	3.2	132	16	15
0:66	16.1	2.7	19	12	13
0:67	17.4	2.0	24	6	11
0:68	18.0	1.6	40	2	10
0:69	16.9	2.2	19	8	8
0:70	17.7	1.8	25	4	7
0:71	17.7	1.8	24	4	6
0:72	17.4	2.0	21	5	6
0:73	16.6	2.4	15	8	5
0:74	16.3	2.6	88	6	8
0:75	14.7	3.5	19	16	7
0:76	12.7	4.6	6	28	5
0:77	11.0	5.5	84	31	6
0:78	10.7	5.7	1377	28	47
0:79	12.9	4.5	196	27	21
0:80	14.4	3.6	63	20	13
0:81	15.4	3.1	32	17	10
0:82	16.6	2.4	24	12	8
0:83	16.7	2.4	19	11	7
0:84	17.5	1.9	24	7	6
0:85	17.8	1.7	25	5	5
0:86	17.8	1.7	25	6	5
0:87	17.5	1.9	21	6	4

0:88	15 9	2.3	14	9	4
0:89	16.3	2.6	95	10	22
0:90	15,8	2.8	84	13	18
0:91	15,2	3.2	123	16	15
0:92	16.1	2.7	19	12	13
0:93	17.4	2.0	24	6	11
0:94	18.0	1.6	40	2	10
0:95	16.9	2.2	19	8	8
0:96	17.7	1.8	25	4	7
0:97	17.7	1.8	24	4	6
0:98	17.4	2.0	21	5	6
0:99	16.6	2.4	15	8	5
0:100	16.3	2.6	88	6	8
0:101	14.7	3.3	256	16	22
0:102	12.7	4.6	140	28	5
0:103	11.0	5.5	84	31	6
0:104	14.2	3.8	99	26	0
0:105	14.3	3.7	22	25	0
0:106	15.2	3.2	96	29	0
0:107	15.7	2.9	84	14	0
0:108	17.7	1.8	12	4	6
0:109	17.4	2.0	21	5	6
0:110	16.6	2.4	15	8	5
0:111	16.3	2.5	155	6	8
0:112	16.3	2.6	95	10	5
0:113	15.8	2.8	44	13	2
0:114	15.2	3.2	26	16	3
0:115	12.5	4.7	85	37	0
0:116	14.9	3.4	93	18	0
0:117	17.8	1.7	25	6	5
0:118	17.5	1.9	21	6	4
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0:120	15.2	3.2	84	20	0
0:121	16.9	2.3	14	9	4
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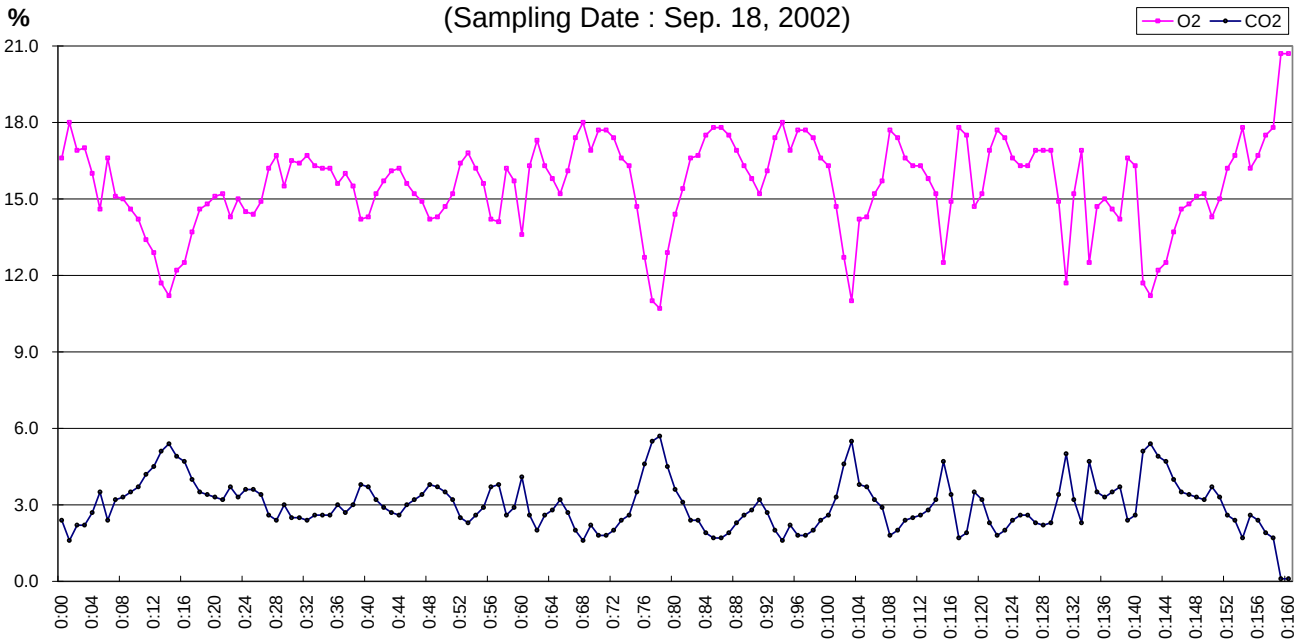
0:123	17.4	2.0	21	5	6
0:124	16.6	2.4	15	8	5
0:125	16.3	2.6	88	6	8
0:126	16.3	2.6	95	10	7
0:127	16.9	2.3	14	9	4
0:128	16.9	2.2	122	9	4
0:129	16.9	2.3	14	9	4
0:130	14.9	3.4	53	21	0
0:131	11.7	5.0	134	40	0
0:132	15.2	3.2	192	20	0
0:133	16.9	2.3	83	9	4
0:134	12.5	4.7	0	37	0
0:135	14.7	3.5	19	16	7
0:136	15.0	3.3	84	22	0
0:137	14.6	3.5	95	24	0

0:138	14.2	3.7	122	26	0
0:139	16.6	2.4	15	33	0
0:140	16.3	2.6	88	6	0
0:141	11.7	5.1	132	9	5
0:142	11.2	5.4	66	8	0
0:143	12.2	4.9	223	38	8
0:144	12.5	4.7	65	37	0
0:145	13.7	4.0	30	31	0
0:146	14.6	3.5	28	26	0
0:147	14.8	3.4	81	25	0
0:148	15.1	3.3	10	23	0
0:149	15.2	3.2	92	22	0
0:150	14.3	3.7	63	25	0
0:151	15.0	3.3	22	22	0
0:152	16.2	2.6	90	24	0
0:153	16.7	2.4	82	24	0
0:154	17.8	1 .7	25	5	5
0:155	16.2	2.6	10	15	0
0:156	16.7	2.4	13	12	0
0:157	17.5	1.9	24	7	6
0:158	17.8	1.7	25	5	5
0:159	20.7	0.1	0	2	0
0:160	20.7	0.1	0	2	0

Flue Gas Concentration(O_2 , CO_2)

(Sampling Date : Sep. 18, 2002)



Flue Gas Concentration (CO, SOx and Nox)

(Sampling Date : Sep. 18, 2002)