6.3.2 Environmental Conservation by TES4

(1) Exhaust Gas Countermeasures

1) Measurement Result of Exhaust Gas

TES4 has measured SO_2, NO_2 and the dust outlet electrostatic precipitator (ESP). The analysis method of each item is as follows:

Item	*Method*
SO_2	Controlled potential electrolysis method Model NOS-700
NO_2	Controlled potential electrolysis method Model NOS-700
Dust	Dust collector with tube filter
O_2	Zirconium-type oxygen method Model NOS-700 (Best Instrument Co., Ltd)

The results of the measurement carried out from 1998 to 2000 are shown in Table 6.3-11.

In addition, the measurement of SO_2 and NO_2 has not been carried out since the device broke down in 1999.

According to the measurement result of 1998, SO_2 and NO_2 concentrations (values revised by 6% O_2) from each boiler unit are within the range of 463 to 735 ppm and 142 to 475 ppm, respectively.

According to the measurement result from 1998 to 2000, dust concentration based on 6% O_2 is within the range of 190 to 942 mg/m^3N. Furthermore, the emission standard for the exhaust gas of the power plant does not exist at present in Mongolia.

2) Environmental Impact by Emissions

As a flue gas countermeasure, only a stack with a height of 250 m considering the dispersion effect and ESP with a removal efficiency of 90% or more is adopted at TES4.

In consideration of these measures, the impact on ambient air quality by emissions (SO_2, NO_2 and dust) during TES4 operation is examined as follows:

(a) Condition of Dispersion Prediction

In consideration of the annual change of the SO_2 value and others measured by the 4 monitoring stations, attention was paid to the impact on ambient air in the winter season of 2000.

Simple calculation of short-term dispersion (CONCAWE formula for effective stack height, Plume formula-PG diagram) was performed based on a general method of Japanese environmental assessment to evaluate the impact on the ambient air of the winter season in 2000.

The dispersion formula used for the examination is shown in Table 6.3-12.

Moreover, conditions of dispersion prediction such as weather data are as follows:

- Weather condition: Winter season (January, February, and December)

Ave temp.	-21.5°C
Ground wind velocity	Average velocity that appeared most: 1.9 m/s Maximum velocity: 9.0 m/s
Ambient air stability	Pasquill atmospheric stability level E~F corresponding to the Mongolian value of 81.1~100%

- Exhaust gas condition: The following conditions are based on the measurement result by TES4

SO_2	480 ppm (Average value of #3u, #5u and #6u in 1998)
NO_2	310 ppm (Setting value based on a later description)
Dust	950 mg/m^3N（Max. of the average of each unit from 1998~2000）
Moisture	6.3% (Average from 1998-2000)
Gas Temp.	141°C（Design value）

SO_2 concentration (value revised by 6% O_2) is set up to an average value of 480 ppm of boiler unit No.3, No.5 and No.6 measured on October 26, 1998.

As for NO_2 concentration (value revised by 6% O_2), two of the five boilers were considered to be a repaired boiler (average NO_2 of 142 ppm) the same as unit No.3. The remaining three boilers were considered to be not repaired like unit No.5 and No.6 with an average NO_2 of 422 ppm, the same as No.2 unit. Based on these assumptions, the average NO_2 value under the operation of five boilers was set up to 310 ppm.

Unit / *Items*	*3u*	*5u*	*6u*	*Set up value*
SO_2 ppm	463	530	458	480
NO_2 ppm	142	404	439	310

- Operation number of boiler and exhaust gas volume

Exhaust gas volume	Gas volume concerning stack design: 194 m^3N/sec/unit
Operation number of boiler	5 boilers (3,492,000 m^3N/h) in consideration of achievement in the winter season

- Objects for comparison for the contribution of pollutant concentration

(Average value measured by monitoring stations in winter 2000, etc.)

(Unit: μg/m^3N)

Items	*No.1 Station*	*No.2 Station*	*No.3 Station*	*No.4 Station*
SO_2	20	20	19	17
NO_2	—	48	22	32
Dust *1	150	150	150	150

**1: 150μg /m^3N corresponding to the daily standard level was set up because of the actual lack of data.*

(b) Prediction Result (Prediction and evaluation on the impact)

The result of short-term dispersion calculation is shown in Fig. 6.3-7 to 6.3-8, and Table 6.3-13 to 6.3-14.

In winter, the grounding inversion layer occurred frequently every morning and evening. Since the atmospheric stability is strong (corresponding to Pasquill stability E ~ F), exhaust gas from an effective stack height usually flutters horizontally without diffusion in the air and the distance to maximum ground concentration will be more than 30 km in general.

For this reason, the contribution of emission concentration is considered to be very small in the city.

a) Sulfur Dioxide

When SO_2 discharge concentration is set up to 480 ppm, the discharge amount of SO_2 is approx. 4,492 t/h under the operation of the five boilers in the winter season.

As a calculation result of the short-term dispersion by wind velocity of 1.9m/s, the distance point to maximum ground concentration is 30 km or more in the case of strong stability (corresponding to Pasquill stability E ~ G).

Moreover, in the case of atmospheric stability D (neutral condition), the SO_2 contributed concentration is a very small value of grade 2 $\mu g/m^3N$ at the 30-km point.

In this case, it is considered that there is almost no influence, even if the wind direction is in accordance with each monitoring station.

As a calculation result by the maximum wind velocity of 9.0 m/s, which appeared in December, the maximum ground level concentration point is 30 km or more in the case of atmospheric stability E to F, and the environmental impact is considered to be very small.

Furthermore, when atmospheric stability changes to a stability D level, the SO_2 contributed concentration is about 5 $\mu g/m^3N$ at the maximum ground level concentration point of 27.3 km. In this case, the contribution rate to the average value 17 to 20 $\mu g/m^3N$ for each monitoring station is about 0.4 to 9.2%, even if the wind direction is in accordance with each monitoring station.

Moreover, as the appearance frequency of the wind velocity of "6m/s or more" was about 1.1% in winter 2000, the environmental impact is considered to be very small.

Ground wind velocity	*Pasquill atmospheric stability*	*Maximum ground level concentration point*	*Maximum ground level concentration (Daily average)*	*Contribution rate to the monitoring station (Wind direction is in accordance with each monitoring station)*
1.9 m/s	E~ (Weak stability ~ strong stability)	30 km or more	-	Almost no influence
	D (Neutrality)	Ditto	2 $\mu g/m^3N$ at 30-km point	Ditto
9.0 m/s (Wind velocity occurring in Dec.)	E~ (Weak stability ~ strong stability)	Ditto	0.4 $\mu g/m^3N$ at 30-km point	Ditto
	D (Neutrality)	27.3 km	5 $\mu g/m^3N$	0.4~9.2%

b) Nitrogen Oxide

When NO_2 discharge concentration is set up to 310 ppm, the discharge amount of NO_2 is about 2.079 t/h under the operation of the five boilers in the winter season.

As a calculation result by wind velocity of 1.9m/s like SO_2, the maximum ground concentration point is 30 km or more in either stability.

Moreover, it is considered that there is no influence of NO_2 contribution concentration in the city.

As a calculation result by the maximum wind velocity of 9.0 m/s, which appeared in December, the maximum ground level concentration point is 30 km or more in the case of atmospheric stability E to F, and the environmental impact is considered to be very small.

Furthermore, when atmospheric stability changes to stability level D, the NO_2 contributed concentration is about 2 μg/m^{3}N at the maximum ground level concentration point of 27.3 km.

In this case, the contribution rate to the average value of 22 to 48 μg/m^{3}N for each monitoring station is about 0.1 to 1.6%, even if the wind direction is in accordance with each monitoring station.

Ground wind velocity	*Pasquill* *Atmospheric stability*	*Maximum ground level concentration point*	*Maximum ground level concentration (Daily average)*	*Contribution rate to the monitoring station* *(Wind direction is in accordance with each monitoring station)*
1.9 m/s	E~ (Weak stability ~ strong stability)	30 km or more	—	Almost no influence
	D (Neutrality)	Ditto	1 μg/m^{3}N at 30-km point	Ditto
9.0 m/s (Wind velocity occurring in Dec.)	E~ (Weak stability ~ strong stability)	Ditto	0.2 μg/m^{3}N at 30-km point	Ditto
	D (Neutrality)	27.3 km	2 μg/m^{3}N	0.1~2.3%

c) Dust (SPM)

When dust discharge concentration is set up to 950 mg/m^{3}N, the discharge amount of dust is approx. 3.108 t/h under the operation of the five boilers in the winter season.

As for the calculation result by wind velocity of 1.9m/s like SO_2, the maximum ground level concentration point is 30 km or more in either stability and it is considered that there is no influence of dust contribution in the city.

As a result of calculation by the maximum wind velocity of 9.0 m/s, which appeared in December, the dust contributed concentration is about 1 μg/m^{3}N under atmospheric stability E (weak stability).

Furthermore, when atmospheric stability changes to stability level D, the dust contributed concentration is about 3.5 μg/m^{3}N at the maximum ground level concentration point of 27.3 km. Even if the wind direction is in accordance with each monitoring station, the contribution rate is about 0.1~0.7% to 150 μg/m^{3}N (equivalent to the standard), and the environmental impact is considered to be very small.

Ground wind velocity	*Pasquill atmospheric stability*	*Maximum ground level concentration point*	*Maximum ground level concentration (Daily average)*	*Contribution rate to the monitoring station (wind direction is accord with each monitoring station)*
1.9 m/s	E ~ (Weak stability ~ strong stability)	30km or more	—	Influence does not almost exist
	D (Neutrality)	Ditto	1.4 μ g/m^{3}N at 30km point	Ditto
9.0 m/s (Wind velocity occurred in Dec.)	E ~ (Weak stability ~ strong stability)	Ditto	0.3 μ g/m^{3}N at 30km point	Ditto
	D (Neutrality)	27.3km	3.5 μ g/m^{3}N	0.1~0.7% to 150 μg/m^{3}N

Table 6.3-11 (1) Exhaust Gas Measurement Result of SO_2, NO_2 Outlet ESP (1998)

	Unit	#1u	#2u	#3u	#3u	#3u	#3u	#3u	#5u	#5u	#5u	#5u	#6u	#6u	#6u
	Date	Feb24	Feb24	Oct.8	Oct.26	Oct.26	Oct.26	Oct.26	Oct.8	Oct.26	Oct.26	Oct.26	Oct.8	Oct.26	Oct.26
SO_2	ppm	247	480	467	474	440	398	374	599	330	324	317	540	236	216
NO_2	ppm	190	296	178	141	148	120	110	320	252	247	242	274	225	208
O_2	%	15	11.2	9.6	5.5	5.6	8.7	9.3	11.4	11.7	11.8	12	8.8	13.4	13.8

Recorded by: TES4

SO_2, NO_2 Concentration revised by 6% O_2

	Unit	#1u	#2u	#3u	#3u	#3u	#3u	#3u	#5u	#5u	#5u	#5u	#6u	#6u	#6u
	Date	Feb24	Feb24	Oct.8	Oct.26	Oct.26	Oct.26	Oct.26	Oct.8	Oct.26	Oct.26	Oct.26	Oct.8	Oct.26	Oct.26
SO_2	ppm	618	735	614	459	429	485	479	936	532	528	528	664	466	450
NO_2	ppm	475	453	234	136	144	146	141	500	406	403	403	337	444	433

Average Value for each Unit revised by 6% O_2 (1998)

	Unit	#1u	#2u	#3u	#5u	#6u	AVE
SO_2	ppm	618	735	463	530	458	561
NO_2	ppm	475	453	142	404	439	383

Values of unit No.3, No.5 and No.6 measured on 8th October were regarded as an abnormal value and were excluded from calculation of each average.

Table 6.3-11 (2)　Exhaust Gas Measurement Result of Dust Outlet ESP (1998~2000)

Year	1998				1999				2000				AVE
Unit	#4u	#5u	#6u	#8u	#1u	#2u	#3u	#7u	#1u	#4u	#6u	#8u	
Inlet ESP (g/m^3N)	21.5	14.2	5.24	12.1	13.22	9.28	7.6	8.267	6.98	12.89	5.03	10.84	10.6
Outlet ESP (g/m^3N)	1.18	0.46	0.32	0.2	0.76	0.32	0.626	6.957	0.077	0.116	0.169	6.825	1.500
Efficiency %	95	97	94	98	94.3	96	92	15.84	98.8	99.1	96.6	37	84.4
CO_2 %	11.2	13	14	15	10.8	11.7	12.9	13.5	--	14.4	12.6	10.7	12.8
O_2 %	8.5	6.6	6.2	5.2	8.9	8	6.6	6.2	--	5.3	7.2	9.2	7.1
N_2 %	80.3	80.4	79.8	79.8	80.3	80.3	80.5	80.3	--	80.3	80.2	80.1	80.2
H_2O %	6.2	7.8	7	7.7	3.7	2.4	7.5	8.3	--	3.2	6.1	9.6	6.3

Recorded by: TES4

Dust Concentration based on 6% O_2

Year	1998				1999				2000			
Unit	#4u	#5u	#6u	#8u	#1u	#2u	#3u	#7u	#1u	#4u	#6u	#8u
Outlet ESP (g/m^3N)	1.416	0.479	0.324	0.190	0.942	0.369	0.652	7.051	--	0.111	0.184	8.676

Mean Dust Concentration (based on 6% O2)

Unit	#1u	#2u	#3u	#4u	#5u	#6u	#8u	AVE
Outlet ESP (g/m^3N)	0.942	0.369	0.652	0.763	0.479	0.254	0.190	0.521

Values of unit No.7 in 1999, No.8 in 2000 were regarded as an abnormal value
and were excluded from calculation of each average.

Table 6.3-12　Calculation Formula of Exhaust Gas Dispersion

(1) Calculation of Effective Stack Height（CONCAWE Formula）

$He = Ho + \Delta H$

$\Delta H = 0.17 \times QH^{(1/2)} \times U^{(-3/4)}$

$QH = \rho C_p Q (T-T1)$

Symbol	Item	Unit
Q	Exhaust gas quantity　(wet)	m^3N/s
U	Wind velocity at top of stack	m/s
ρ	Exhaust gas density at 0 ℃	g/m^3
Cp	Specific heat at constant pressure	Cal/kg
T	Exhaust gas temperature	° K
T1	Average air temperature	° K
QH	Discharged heat capacity	cal/s
ΔH	Height of exhaust gas ascent	m
Ho	Actual stack height	m
He	Effective stack height	m
q	Emission quantity	m^3N/s

(2) Calculation of Exhaust Gas Dispersion (Plum Formula）

$$C(X) = \frac{q}{\pi \times \delta y(X) \times \delta z(X) \times U} \times \exp\left(-\frac{He^2}{2\delta z(X)^2}\right) \times 10^6$$

$\delta y(X) = \gamma X \times X^{(\alpha y)} \times 1.82$

$\delta z(X) = \gamma z \times X^{\alpha z}$

Dispersion Parameter

Stability	αy	γ y	Downwind Distance (m)
A	0.901 0.851	0.426 0.602	0~1000 1001~
B	0.914 0.865	0.282 0.396	0~1000 1001~
C	0.924 0.885	0.1772 0.232	0~1000 1001~
D	0.929 0.889	0.1107 0.1467	0~1000 1001~
E	0.921 0.897	0.0864 0.1019	0~1000 1001~
F	0.929 0.889	0.0554 0.0733	0~1000 1001~
G	0.921 0.896	0.038 0.0452	0~1000 1001~

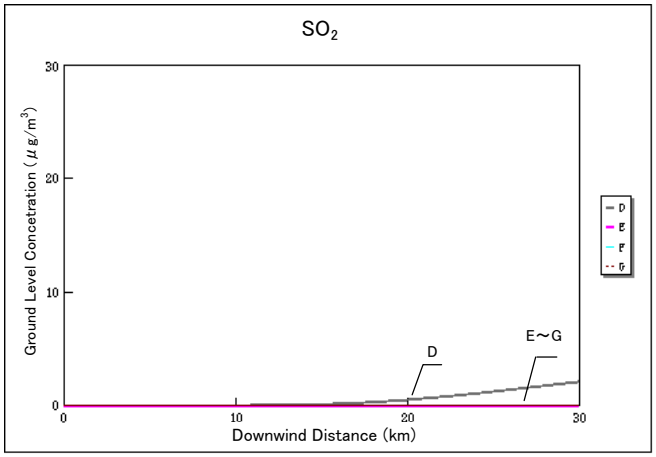
Stability	αz	γ z	Downwind Distance (m)
A	1.122 1.514 2.109	0.08 0.00855 0.000212	0~1000 301~500 501~
B	0.964 1.094	0.1272 0.057	0~500 501~
C	0.918	0.1068	0~
D	0.826 0.632 0.555	0.1046 0.4 0.811	0~1000 100~10000 10001~
E	0.788 0.565 0.415	0.0928 0.433 1.732	0~1000 100~10000 10001~
F	0.784 0.526 0.323	0.0621 0.37 2.41	0~1000 100~10000 10001~
G	0.794 0.637 0.431 0.222	0.0373 0.1105 0.529 3.62	0~1000 1001~2000 200~10000 10001~

Exhaust Gas Specification (Daily Average) **Five Boilers Operation**

[Project: Ulaanbaatar TES4]

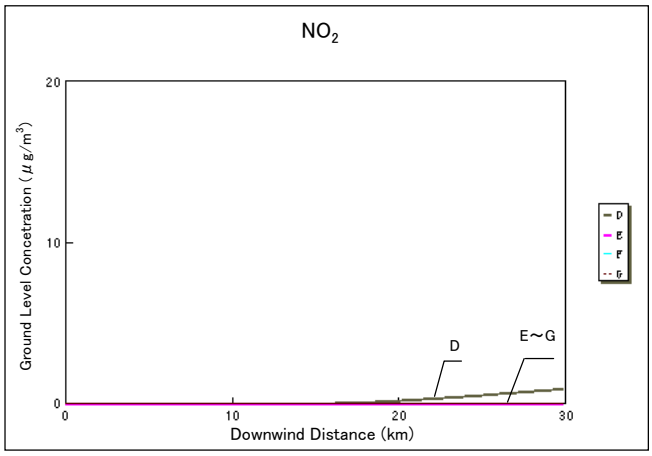
Items		Unit	Setup value	Items	Unit	Setup value
Gas volume (Wet)		m^3N/h	3492000	Ave.air temperature	℃	−21.5
Gas velocity		m/s	29.3	Gas temperature	℃	141
Actual stack height		m	250	Wind velocity at ground	m/s	1.9
Emission	SO_2	kg/h	4492	Daily ave.coefficient		0.51
discharge	NO_2	kg/h	2079			
quantity	Dust	kg/h	3108			

SO_2 ppm	480
NOx ppm	310
Dust mg/m^3	950

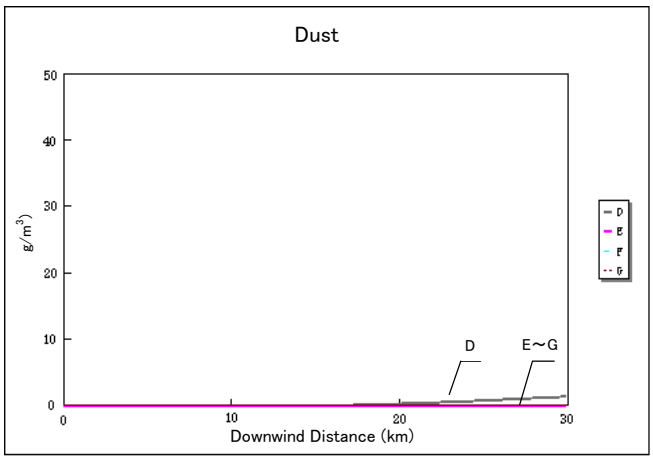


Dispersion parameter	Effective stack height	Cmax.	Xmax.
	m	$\mu g/m^3$	km
D	663.5	2.0850	30
E	663.5	0.0001	30
F	616.6	0.0000	30
G	616.6	0.0000	30

Cmax.: Maximum ground level concentratior
Xmax.: Distance to Cmax.



Dispersion parameter	Effective stack height	Cmax.	Xmax.
	m	$\mu g/m^3$	km
D	663.5	0.9650	30
E	663.5	0.0001	30
F	616.6	0.0000	30
G	616.6	0.0000	30



Dispersion parameter	Effective stack height	Cmax.	Xmax.
	m	$\mu g/m^3$	km
D	663.5	1.4426	30
E	663.5	0.0001	30
F	616.6	0.0000	30
G	616.6	0.0000	30

Fig. 6.3-7 Dispersion Calculation Result under 5 Boilers Operation in Winter
(Case of Ground Wind Velocity 1.9m/s)

Table 6.3-13 Impact on the Air Quality by Exhaust Gas Contamination in Winter
(Case of Average Wind Velocity 1.9m)

When the wind direction with average velocity 1.9 m/s is in accord with direction of each monitoring station in 2000 winter, the impact on each air quality is as follows.

1. SO_2

Air quality	No.1St.: 20 $\mu g/m^3$		No.2St.: 20 $\mu g/m^3$		No.3St.: 19 $\mu g/m^3$		No.4St.: 17 $\mu g/m^3$	
	Additional value ($\mu g/m^3$)	Additional rate (%)	Additional value ($\mu g/m^3$)	Additional rate (%)	Additional value ($\mu g/m^3$)	Additional rate (%)	Additional value ($\mu g/m^3$)	Additional rate (%)
Stability D	0	0	0	0	0	0	0.002	0
Stability E	0	0	0	0	0	0	0	0
Stability F	0	0	0	0	0	0	0	0
Stability G	0	0	0	0	0	0	0	0

2. NO_2

Air quality	No.1St: 40 $\mu g/m^3$		No.2St: 48 $\mu g/m^3$		No.3St: 22 $\mu g/m^3$		No.4St: 32 $\mu g/m^3$	
	Additional value ($\mu g/m^3$)	Additional rate (%)	Additional value ($\mu g/m^3$)	Additional rate (%)	Additional value ($\mu g/m^3$)	Additional rate (%)	Additional value ($\mu g/m^3$)	Additional rate (%)
Stability D	0	0	0	0	0	0	0.001	0
Stability E	0	0	0	0	0	0	0	0
Stability F	0	0	0	0	0	0	0	0
Stability G	0	0	0	0	0	0	0	0

3. Dust (SPM)

Air quality	No.1St:150 $\mu g/m^3$		No.2St:150 $\mu g/m^3$		No.3St:150 $\mu g/m^3$		No.4St:150 $\mu g/m^3$	
	Additional value ($\mu g/m^3$)	Additional rate (%)	Additional value ($\mu g/m^3$)	Additional rate (%)	Additional value ($\mu g/m^3$)	Additional rate (%)	Additional value ($\mu g/m^3$)	Additional rate (%)
Stability D	0	0	0	0	0	0	0.002	0
Stability E	0	0	0	0	0	0	0	0
Stability F	0	0	0	0	0	0	0	0
Stability G	0	0	0	0	0	0	0	0

Location each monitoring station from TES4

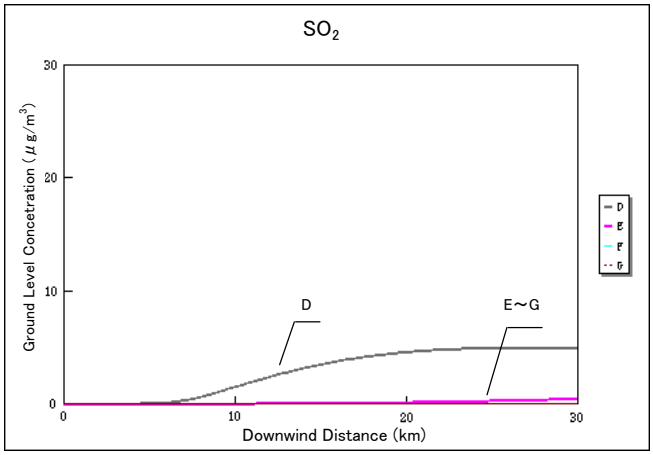
Monitoring St.	Direction	Distance
No.1	E	About 6km
No.2	ENE	About 7km
No.3	NNE	About 3km
No.4	ENE	About 10km

Exhaust Gas Specification (Daily Average) **Five Boilers Operation**

[Project: Ulaanbaatar TES4]

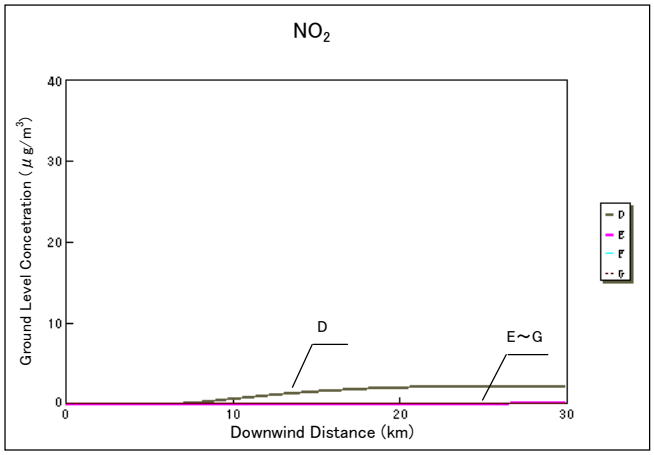
Items		Unit	Setup value	Items	Unit	Setup value
Gas volume (Wet)		m^3N/h	3492000	Ave.air temperature	℃	−21.5
Gas velocity		m/s	29.3	Gas temperature	℃	141
Actual stack height		m	250	Wind velocity at ground	m/s	9
Emission	SO_2	kg/h	4492	Daily ave.coefficient		0.51
discharge	NO_2	kg/h	2079			
quantity	Dust	kg/h	3108			

SO_2 ppm	480
NOx ppm	310
Dust mg/m^3	950

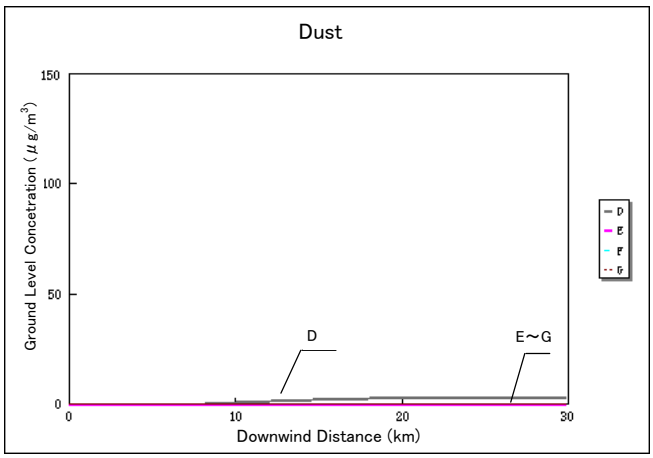


Dispersion parameter	Effective stack height	Cmax.	Xmax.
	m	$\mu g/m^3$	km
D	378.8	4.9850	27.3
E	378.8	0.4217	30
F	364.2	0.0000	30
G	364.2	0.0000	30

Cmax.: Maximum ground level concentratior
Xmax.: Distance to Cmax.



Dispersion parameter	Effective stack height	Cmax.	Xmax.
	m	$\mu g/m^3$	km
D	378.8	2.3072	27.3
E	378.8	0.1952	30
F	364.2	0.0000	30
G	364.2	0.0000	30



Dispersion parameter	Effective stack height	Cmax.	Xmax.
	m	$\mu g/m^3$	km
D	378.8	3.4491	27.3
E	378.8	0.2917	30
F	364.2	0.0000	30
G	364.2	0.0000	30

Fig. 6.3-8 Dispersion Calculation Result under 5 Boilers Operation in Winter
(Case of Ground Wind Velocity 9m/s)

Table 6.3-14 Impact on the Air Quality by Exhaust Gas Contamination in Winter
(Case of Max Wind Velocity 9 m)

When the wind direction with maximum velocity 9 m/s is in accord with direction of each monitoring station in 2000 winter, the impact on each air quality is as follows.

1. SO_2

Air quality	No.1St: 20 $\mu g/m^3$		No.2St: 20 $\mu g/m^3$		No.3St: 19 $\mu g/m^3$		No.4St: 17 $\mu g/m^3$	
	Additional value ($\mu g/m^3$)	Additional rate (%)	Additional value ($\mu g/m^3$)	Additional rate (%)	Additional value ($\mu g/m^3$)	Additional rate (%)	Additional value ($\mu g/m^3$)	Additional rate (%)
Stability D	0.080	0.4	0.327	1.6	0	0	1.572	9.2
Stability E	0	0	0	0	0	0	0.002	0
Stability F	0	0	0	0	0	0	0	0
Stability G	0	0	0	0	0	0	0	0

2. NO_2

Air quality	No.1St: 40 $\mu g/m^3$		No.2St: 48 $\mu g/m^3$		No.3St: 22 $\mu g/m^3$		No.4St: 32 $\mu g/m^3$	
	Additional value ($\mu g/m^3$)	Additional rate (%)	Additional value ($\mu g/m^3$)	Additional rate (%)	Additional value ($\mu g/m^3$)	Additional rate (%)	Additional value ($\mu g/m^3$)	Additional rate (%)
Stability D	0.037	0.1	0.151	0.3	0	0	0.728	2.3
Stability E	0	0	0	0	0	0	0.001	0
Stability F	0	0	0	0	0	0	0	0
Stability G	0	0	0	0	0	0	0	0

3. Dust(SPM)

Air quality	No.1St: 150 $\mu g/m^3$		No.2St: 150 $\mu g/m^3$		No.3St: 150 $\mu g/m^3$		No.4St: 150 $\mu g/m^3$	
	Additional value ($\mu g/m^3$)	Additional rate (%)	Additional value ($\mu g/m^3$)	Additional rate (%)	Additional value ($\mu g/m^3$)	Additional rate (%)	Additional value ($\mu g/m^3$)	Additional rate (%)
Stability D	0.056	0.1	0.226	0.2	0	0	1.088	0.7
Stability E	0	0	0	0	0	0	0.002	0
Stability F	0	0	0	0	0	0	0	0
Stability G	0	0	0	0	0	0	0	0

Location of each monitoring station from TES4

Monitoring St.	Direction	Distance
No.1	E	About 6km
No.2	ENE	About 7km
No.3	NNE	About 3km
No.4	ENE	About 10km