Revised Monitoring Plan

Catalytic N_2O Abatement Project in Tail Gas of the Nitric Acid Plant of the Hanwha Corporation (HWC) in Ulsan, Republic of Korea

Registration No. 0922

Version – 1.0
Date : June 1, 2010

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B.7.1 Data and parameters monitored:	
(Copy this table for each data and parameter)	
Data / Parameter:	$F_{\mathrm{TE},i}$
Data unit:	m^3/h
Description:	Volume flow rate at the exit of the destruction facility
Source of data to be used:	Flow meter
Value of data applied for the purpose of calculating expected emission reductions in section B.5	Normally 44,000 Nm^3/hr (33,000–48,000 Nm^3/hr) in nitric acid production of 294 ton/day Here, this value is regarded as being equivalent to $F_{\mathrm{TI},i}$
Description of measurement methods and procedures to be applied:	● Measuring device : Multiple-point sampling tube type flow meter ● Measuring period : Continuously ● Data record : New logging system ● Sampling range :0–60,000 Nm^3/hr Flow metering system will automatically record continuously volume flow adjusted to standard temperature and pressure. The estimated total uncertainty is 2.5%.
QA/QC procedures to be applied:	Refer to QA / QC procedures cited below. $F_{\mathrm{TE},i}$ and $F_{\mathrm{TI},i}$ are cross-checked to ensure that no leak of N_2O is taking place. In case of discrepancy, conservative calculation of emission reduction shall be provided. Calibration details are shown in Annex 4.
Any comment:	Key parameter

Data / Parameter:	$CO_{\mathrm{N2O},i}$
Data unit:	tN_2O/m^3
Description:	N_2O concentration at destruction facility outlet.
Source of data to be used:	Non-dispersion infrared absorption analyzer (NDIR)

Value of data applied for the purpose of calculating expected emission reductions in section B.5	$2.95 * 10^{-7}$ tN_2O/Nm^3 150 [ppmv] $=150 * 10^{-6} * 44/22.4 / 1000$ [tN_2O/Nm^3]
Description of measurement methods and procedures to be applied:	● Measuring device : Non-dispersion infrared absorption analyzer ● Measuring period : Continuously ● Data record : New logging system ● Sampling range : 0–500 ppmv The estimated total uncertainty is 4%.
QA/QC procedures to be applied:	In case Non-dispersion infrared absorption analyzer is used, it shall be checked by sampling by gas chromatography periodically. QA/QC for the analyzer shall be subjected to the EN14181 or equivalent standards available in the Republic of Korea. Refer to Annex 4.
Any comment:	Contributes around 1/10 of the total emission reductions.

Data / Parameter:	$P_{product,y}$
Data unit:	$tHNO_3$/yr
Description:	Plant output of HNO_3.
Source of data to be used:	ERP (Enterprise Resource Planning) Report and magnetic flow meter
Value of data applied for the purpose of calculating expected emission reductions in section B.5	Not needed.
Description of measurement methods and procedures to be applied:	● Measuring device : Tank gauges and sale amount through ERP Report ● Measuring period : Once a day ● Data record : Existing ERP (Enterprise Resource Planning) Report Transcription of data from ERP Report prepared by sales amount and tank gauging data with expected uncertainty of ± 6.0 ton. Sale amount may include weighing loss which is negligible.
QA/QC procedures to be applied:	Cross – check of production, marketing and stock change data. Measurement devices can be subjected to QA /QC scheme consistent with the procedures in T_g, P_g, $F_{TI,i,}$

	$F_{TE,i}$, *and* $Q_{HC,y}$ with respect to equipment certification, installation and performance.
Any comment:	No.

Data / Parameter:	$F_{TI,i}$
Data unit:	m^3/h
Description:	Volume flow rate at the inlet of the destruction facility
Source of data to be used:	Flow meter
Value of data applied for the purpose of calculating expected emission reductions in section B.5	Normally 44,000 Nm^3/hr (33,000–48,000 Nm^3/hr) in nitric acid production of 294 on/day Based on historical records.
Description of measurement methods and procedures to be applied:	● Measuring device : Multiple-point sampling tube type flow meter ● Measuring period : Continuously ● Data record : New logging system ● Sampling range :0–60,000 Nm^3/hr Flow metering system will automatically record continuously volume flow rate adjusted to standard temperature and pressure. The estimated total uncertainty is 2.5%.
QA/QC procedures to be applied:	Refer to QA / QC procedures cited below. $F_{TE,i}$ and $F_{TI,i}$ are cross-checked to ensure that no leak of N_2O is taking place. In case of discrepancy, conservative calculation of emission reduction shall be provided. Calibration details are shown in Annex 4.
Any comment:	Key parameter

Data / Parameter:	$CI_{N2O,i}$
Data unit:	tN_2O/m^3
Description:	N_2O concentration at destruction facility inlet.
Source of data to be used:	Non-dispersion infrared absorption analyzer (NDIR)

Value of data applied for the purpose of calculating expected emission reductions in section B.5	$2.95 * 10^{-6}$ tN_2O/Nm^3 1,500 [ppmv] $=1,500 * 10^{-6} * 44/22.4 / 1000$ [tN_2O/Nm^3] Based on gas chromatography analysis data (conservative number).
Description of measurement methods and procedures to be applied:	● Measuring device : Non-dispersion infrared absorption analyzer ● Measuring period : Continuously ● Data record : New logging system ● Sampling range :0–3,000 ppmv The estimated total uncertainty is 4%.
QA/QC procedures to be applied:	In case Non-dispersion infrared absorption analyzer is used, it shall be checked by sampling by gas chromatography periodically. QA/QC for the analyzer shall be subjected to the EN14181 or equivalent standards available in the Republic of Korea. Refer to Annex 4.
Any comment:	Key parameter

Data / Parameter:	T_g
Data unit:	°C
Description:	Actual operating temperature of the ammonia oxidation reactor
Source of data to be used:	Thermo-couple
Value of data applied for the purpose of calculating expected emission reductions in section B.5	Not needed.
Description of measurement methods and procedures to be applied:	● Measuring device : Existing thermo-couple ● Measuring period : Continuously ● Measuring range : 0 - 1,200 °C ● Data record : Existing DCS system (distributed control system) This parameter is measured at catalyst basket filled with Raschig ring Estimated uncertainty from temperature measurement with thermo-couple : ± 6 °C

	If the actual average daily operating temperature in the ammonia oxidation reactor (T_g) is outside this "permitted range", the baseline N_2O emissions for that period are capped at 4.5kgN_2O/tonne of nitric acid conservatively applying the IPCC default value.
QA/QC procedures to be applied:	Maintenance and testing regime
Any comment:	To check whether "normal" operation is undertaken.

Data / Parameter:	P_g
Data unit:	Pa
Description:	Actual operating pressure of the ammonia oxidation reactor
Source of data to be used:	Pressure transmitter
Value of data applied for the purpose of calculating expected emission reductions in section B.5	Not needed.
Description of measurement methods and procedures to be applied:	● Measuring device : Existing pressure transmitter═ ● Measuring period : Continuously ● Measuring range : 0-16 kgf/cm^2 gauge (-7.18 – 1,570,000 Pa gauge) ● Measuring point : Two points. One is between air compressor and NH_3 air mixer (since Jan.2000), and the other is between NH_3 air mixer and NH_3 air filter (since Jan.2005). $P_{g,hist}$ is based on data measured at the former which the number of acquisition records is larger. ● Data record : Existing DCS system (distributed control system) Estimated uncertainty from this pressure measurement: ±4.0 Pa If the actual average daily operating pressure in the ammonia oxidation reactor (P_g) is outside this "permitted range", the baseline N_2O emissions for that period are capped at 4.5kgN_2O/tonne of nitric acid conservatively applying the IPCC default value.
QA/QC procedures to be applied:	Maintenance and testing regime
Any comment:	To check whether "normal" operation is undertaken.

Data / Parameter:	G_{sup}
Data unit:	-
Description:	Supplier's information of the ammonia oxidization catalyst
Source of data to be used:	Ammonia oxidization catalyst supplier
Value of data applied for the purpose of calculating expected emission reductions in section B.5	Johnson Matthey
Description of measurement methods and procedures to be applied:	HWC will most likely use Johnson Matthey in the future. However, HWC does not guarantee to use only Johnson Matthey in the future. So the supplier's information will be monitored.
QA/QC procedures to be applied:	Not needed
Any comment:	No.

Data / Parameter:	G_{com}
Data unit:	%
Description:	Composition of the ammonia oxidization catalyst
Source of data to be used:	Ammonia oxidization catalyst supplier
Value of data applied for the purpose of calculating expected emission reductions in section B.5	Pt: 95%, Rh: 5%
Description of measurement methods and procedures to be applied:	HWC has been using the Pt 95%, Rh 5% catalyst of Johnson Matthey. HWC will use the catalyst which is common practice in the region and supplied by a reputable manufacturer or which composition is reported as being in use in the relevant literature.
QA/QC procedures to be applied:	Not needed

Any comment:	No.

Data / Parameter:	$A_{OR,d}$
Data unit:	tNH_3/day
Description:	Actual ammonia flow rate to the ammonia oxidation reactor
Source of data to be used:	Orifice flow meter and differential pressure transmitter
Value of data applied for the purpose of calculating expected emission reductions in section B.5	If the daily ammonia input to the oxidation reactor ($A_{OR,d}$) exceeds maximum historical ammonia input to oxidation reactor ($A_{OR,hist}$), the baseline N_2O emissions for that period are capped at 4.5kgN_2O/tonne of nitric acid conservatively applying the IPCC default value.
Description of measurement methods and procedures to be applied:	● Measuring device : Orifice flow meter and differential pressure transmitter ● Measuring period : Once a day ● Measuring range : 0-6,000 Nm^3/hr ● Measuring position : NH_3 air mixer ● Data record : Existing DCS system (distributed control system) Estimated uncertainty from this flow measurement : ± 5,760 Nm^3/day (= 4.4 tonNH_3/day
QA/QC procedures to be applied:	Maintenance and testing regime
Any comment:	To check whether "normal" operation is undertaken.

Data / Parameter:	$EI_{RCS,y}$
Data unit:	MWh/yr
Description:	Additional electricity input for running the DeN_2O unit
Source of data to be used:	Wattmeter or electricity accumulator
Value of data applied for the purpose of calculating expected emission reductions in section B.5	316.8MWh/yr in nitric acid production of 97,020 ton/yr (normally) ● 0.040 MWh/hr in nitric acid production of 294 ton/day (normally) ● Operating days : 330 days(normally) Therefore, yearly value is as follows;

	0.040[MWh/hr]*24[hr/day]*330[day/yr] Specs by the manufacturer.
Description of measurement methods and procedures to be applied:	● Measuring device : Wattmeter or electricity accumulator ● Measuring period : Monthly ● Data record : Handwriting
QA/QC procedures to be applied:	Not needed because its contribution is much below the uncertainty level
Any comment:	No.

Data / Parameter:	$Q_{NG,y}$
Data unit:	m^3
Description:	Hydrocarbon (natural gas) input
Source of data to be used:	Vortex flow meter or other measuring device
Value of data applied for the purpose of calculating expected emission reductions in section B.5	356,400Nm^3/yr in nitric acid production of 97,020 ton/yr (normally) ● 45 Nm^3/hr in nitric acid production of 294 ton/day(normally) ● Operating day : 330days (normally) Therefore, yearly value is as follows; 45[Nm^3/hr]*24[hr/day]*330[day/yr] Here, this value is in normal condition (0 ^{o}C,1atm) and is based on the Technical Proposal by Sumiko Eco-Engineering For this project, the value converted into the normal condition is applied as this parameter.
Description of measurement methods and procedures to be applied:	● Measuring device : Vortex flow meter or other measuring device is installed═ ● Measuring period : Once a day ● Data record : Handwriting Estimated uncertainty from this flow measurement : ± 21.6 Nm^3/day
QA/QC procedures to be applied:	Not needed because its contribution is much below the uncertainty level. Flow of hydrocarbon is measured at atmospheric condition. Temperature and pressure adjustments are preferable but not necessary if it costs a lot.

Any comment:	No.

Data / Parameter:	$Q_{NMHC,y}$
Data unit:	m^3
Description:	Hydrocarbon (Non-methane part of the natural gas) input
Source of data to be used:	Calculated by the flow rate and the methane concentration of the natural gas
Value of data applied for the purpose of calculating expected emission reductions in section B.5	33,900Nm^3/yr in nitric acid production of 97,020 ton/yr (normally) ● Natural gas input: 45 Nm^3/hr in nitric acid production of 294 ton/day(normally) ● Methane concentration of the natural gas:90.48 % by the natural gas supplier ● Operating day : 330days (normally) Therefore, yearly value is as follows; 45[Nm^3/hr]*(1-0.9048)*24[hr/day]*330[day/yr] Here, this value is in normal condition (0 ^{o}C,1atm)
Description of measurement methods and procedures to be applied:	As for flow rate of the natural gas, based on $Q_{NG,y}$ As for methane concentration of the natural gas, once measurement prior to the project start. (This value should be replaced when the Hydrocarbon (natural gas) component is changed.)
QA/QC procedures to be applied:	Not needed.
Any comment:	No.

Data / Parameter:	$Q_{HNC,y}$
Data unit:	m^3
Description:	Methane(Methane part of the natural gas) used
Source of data to be used:	Calculated by the flow rate and the methane concentration of the natural gas
Value of data applied for the purpose of calculating expected emission reductions in section B.5	322,500 Nm^3/yr in nitric acid production of 97,020 ton/yr. Here, this value is given at the normal condition (0^{o}C,1atm). For this project, the value converted into the normal condition is applied as this parameter. ● Natural gas input: 45 Nm^3/hr in nitric acid production of 294 ton/day(normally) ● Methane concentration of the natural gas:90.48 % by the natural gas supplier

	● Operating day : 330days (normally) Therefore, yearly value is as follows; 45[Nm^3/hr]*0.9048*24[hr/day]*330[day/yr] Here, this value is in normal condition (0 ^{o}C,1atm) and is based on the Technical Proposal by Sumiko Eco-Engineering For this project, the value converted into the normal condition is applied as this parameter.
Description of measurement methods and procedures to be applied:	As for flow rate of the natural gas, based on $Q_{NG,y}$ As for methane concentration of the natural gas, once measurement prior to the project start. (This value should be replaced when the Hydrocarbon (natural gas) component is changed.)
QA/QC procedures to be applied:	Not needed.
Any comment:	No.

Data / Parameter:	ρ_{NG}
Data unit:	t/m^3
Description:	Density of the hydrocarbon (natural gas).
Source of data to be used:	Hydrocarbon supplier
Value of data applied for the purpose of calculating expected emission reductions in section B.5	0.0008093 t/m^3 Here, this value is given at the normal condition (0^{o}C,1atm). For this project, the value converted into the normal condition is applied as this parameter.
Description of measurement methods and procedures to be applied:	Local data are preferable. Once measurement prior to the project start. (This value should be replaced when the hydrocarbon (natural gas) density is changed.)
QA/QC procedures to be applied:	Not needed because its contribution is much below the uncertainty level
Any comment:	No.

Data / Parameter:	ρ_{HNC}
Data unit:	t/m^3

Description:	Density of the hydrocarbon (Methane part of the natural gas).
Source of data to be used:	Theoretical calculation
Value of data applied for the purpose of calculating expected emission reductions in section B.5	0.000714 t/m^3 Here, this value is given at the normal condition (0^oC,1atm). For this project, the value converted into the normal condition is applied as this parameter. In case of the normal condition, this parameter can be given by theoretical value ($16gCH_4$/22.4liter).
Description of measurement methods and procedures to be applied:	Theoretical calculation
QA/QC procedures to be applied:	Not needed.
Any comment:	No.

Data / Parameter:	ρ_{NMHC}
Data unit:	t/m^3
Description:	Density of the hydrocarbon (Non-methane part of the natural gas).
Source of data to be used:	Calculated by data of the natural gas and methane
Value of data applied for the purpose of calculating expected emission reductions in section B.5	0.001715 t/m^3 Here, this value is given at the normal condition (0^oC,1atm). For this project, the value converted into the normal condition is applied as this parameter. Major components for non-methane part of the natural gas are ethane and propane (see Annex3). This parameter is estimated by the data of the natural gas and methane as follows; $\rho_{NMHC} = (\rho_{NG} - \rho_{HNC} *CF_{CH4})/ (1-CF_{CH4})$ where CF_{CH4}:Methane concentration of the natural gas[-] 0.9048[-]by the natural gas supplier
Description of	Calculated by data of the natural gas and methane

measurement methods and procedures to be applied:	
QA/QC procedures to be applied:	Not needed.
Any comment:	No.

Data / Parameter:	EF_{NG}
Data unit:	tCO_2/tNG
Description:	Emission factor of the hydrocarbon (natural gas)
Source of data to be used:	IPCC 1996 GHG Inventory Guidelines and data provided by the natural gas supplier
Value of data applied for the purpose of calculating expected emission reductions in section B.5	2.77(tCO_2/tNG) Local data for composition of the hydrocarbon (natural gas) is applied as per methodology. $EF_{NG} = COEF_{NG} * 44/12 * NCV_{NG} * 4.18605/\rho_{NG} * 10^{-9}$ where $COEF_{NG}$: Hydrocarbon emission factor [tC/TJ] 15.3[tC/TJ]by IPCC 1996 GHG Inventory Guidelines NCV_{NG} : Net calorific value of the natural gas [$kcal/Nm^3$] 9,550[$kcal/Nm^3$]by the natural gas supplier ρ_{NG} : Density of the natural gas[tNG/Nm^3] 0.0008093[tNG/Nm^3] The value does not affect the final results significantly.
Description of measurement methods and procedures to be applied:	Local data are preferable. Once measurement prior to the project start. (This value should be replaced when the hydrocarbon (natural gas) density is changed.)
QA/QC procedures to be applied:	Not needed because its contribution is much below the uncertainty level
Any comment:	No.

Data / Parameter:	EF_{HNC}
Data unit:	tCO_2/tCH_4
Description:	Emission factor of methane
Source of data to be used:	Theoretical calculation
Value of data applied for the purpose of	2.75(tCO_2/tCH_4) This value is calculated as follows;

calculating expected emission reductions in section B.5	44 $gCO_2/16gCH_4$
Description of measurement methods and procedures to be applied:	Theoretical calculation
QA/QC procedures to be applied:	Not needed because its contribution is much below the uncertainty level
Any comment:	No.

Data / Parameter:	EF_{NMHC}
Data unit:	$tCO_2/tNMHC$
Description:	Emission factor of hydrocarbon (Non-methane part of the natural gas)
Source of data to be used:	Calculated by data of the natural gas and methane
Value of data applied for the purpose of calculating expected emission reductions in section B.5	2.85$tCO_2/tNMHC$ Major components for non-methane part of the natural gas are ethane and propane (see Annex3). This parameter is estimated by the data of the natural gas and methane as follows; $EF_{NMHC} = (EF_{NG} * \rho_{NG} - EF_{HNC} * \rho_{HNC} * CF_{CH4}) / (1-CF_{CH4}) / \rho_{NMHC}$ where CF_{CH4}:Methane concentration of the natural gas[-] 0.9048[-]by the natural gas supplier
Description of measurement methods and procedures to be applied:	Calculated by data of the natural gas and methane
QA/QC procedures to be applied:	Not needed.
Any comment:	No.

Data / Parameter:	$Type_{HC}$
Data unit:	-
Description:	Hydrocarbon (natural gas) supplier information

Source of data to be used:	Hydrocarbon supplier
Value of data applied for the purpose of calculating expected emission reductions in section B.5	Kyungdong City Gas Corporation
Description of measurement methods and procedures to be applied:	For this project, natural gas will be used, but this parameter is monitored.
QA/QC procedures to be applied:	Not needed.
Any comment:	No.

Data / Parameter:	$QR_{N2O,y}$
Data unit:	tN_2O
Description:	Regulation based on annual quantity N_2O limited
Source of data to be used:	National environmental legislation in the Republic of Korea In case national regulations concerning N_2O emissions are implemented during the crediting period, the impact on baseline N_2O emissions is considered without any delay by adjusting the measured N_2O emissions at the time the regulation has to be implemented.
Value of data applied for the purpose of calculating expected emission reductions in section B.5	Baseline N_2O emissions are limited by the absolute quantity of N_2O emissions given by the regulation. If the measured baseline N_2O emissions are exceeding the regulatory limit, then measured baseline N_2O emissions are substituted by the regulatory limit.
Description of measurement methods and procedures to be applied:	If, $QI_{N2O,y} > QR_{N2O,y}$ then, $BE_{N2O,y} = QR_{N2O,y}$ else, $BE_{N2O,y} = \min \text{ of } [QI_{N2O,y}, SE_{N2O,y} * P_{product,max}]$ where: $QI_{N2O,y}$: Quantity of N_2O emissions at the inlet of the destruction facility in year y (tN_2O) $QR_{N2O,y}$: Regulatory limit of N_2O emissions in year y (tN_2O) $BE_{N2O,y}$: Baseline emissions of N_2O in year y (tN_2O)

	$SE_{N2O,y}$: Specific N_2O emissions per unit of output of nitric acid in year y ($tN_2O/tHNO_3$) $P_{product,y}$: Production of nitric acid in year y ($tHNO_3$) The quantity of N_2O emissions at the inlet of the N_2O destruction facility (DF) is calculated based on continuous measurement of the tail gas volume flow rate and the N_2O concentration at the inlet of the N_2O destruction facility.
QA/QC procedures to be applied:	Not needed.
Any comment:	Change in NO_X or N_2O regulations will automatically cause a re-assessment of the baseline scenario.

Data / Parameter:	$RSE_{N2O,y}$
Data unit:	$tN_2O/tHNO_3$
Description:	Regulation based on N_2O emissions per unit of nitric acid
Source of data to be used:	National environmental legislation in the Republic of Korea In case national regulations concerning N_2O emissions are implemented during the crediting period, the impact on baseline N_2O emissions is considered without any delay by adjusting the measured N_2O emissions at the time the regulation has to be implemented.
Value of data applied for the purpose of calculating expected emission reductions in section B.5	Regulation setting of a threshold for specific N_2O emissions per unit of product
Description of measurement methods and procedures to be applied:	If, $SE_{N2O,y} > RSE_{N2O}$ then, $BE_{N2O,y}$ = min of [RSE_{N2O} *$P_{product,y}$, $SE_{N2O,y}$ *$P_{product,max}$] else, $BE_{N2O,y}$ = min of [$QI_{N2O,y}$, $SE_{N2O,y}$ *$P_{product,max}$] where: $SE_{N2O,y}$: Specific N_2O emissions per unit of output of nitric acid in year y ($tN_2O/tHNO_3$) RSE_{N2O} : Regulatory limit of N_2O emissions per unit of output of nitric acid ($tN_2O/tHNO_3$) $BE_{N2O,y}$: Baseline emissions of N_2O in year y (tN_2O) $P_{product,y}$: Production of nitric acid in year y ($tHNO_3$) $QI_{N2O,y}$: Quantity of N_2O emissions at the inlet of the destruction facility in year y

	(tN_2O) The specific N2O emissions per unit of output of nitric acid is defined as: $SE_{N2O,y} = QI_{N2O,y} / P_{product,y}$ where: $SE_{N2O,y}$: Specific N_2O emissions per unit of output of nitric acid in year y ($tN_2O/tHNO_3$) $QI_{N2O,y}$: Quantity of N_2O emissions at the inlet of the destruction facility in year y (tN_2O) $P_{product,y}$: Production of nitric acid in year y ($tHNO_3$) The quantity of N_2O emissions at the inlet of the N_2O destruction facility is calculated based on continuous measurement of the tail gas volume flow rate and the N_2O concentration at the inlet of the N_2O destruction facility.
QA/QC procedures to be applied:	Not needed.
Any comment:	Change in NO_X or N_2O regulations will automatically cause a re-assessment of the baseline scenario.

Data / Parameter:	$CR_{N2O,y}$
Data unit:	tN_2O/m^3
Description:	Regulation based on N_2O concentration in tail gas limited
Source of data to be used:	National environmental legislation in the Republic of Korea In case national regulations concerning N_2O emissions are implemented during the crediting period, the impact on baseline N_2O emissions is considered without any delay by adjusting the measured N_2O emissions at the time the regulation has to be implemented.
Value of data applied for the purpose of calculating expected emission reductions in section B.5	Regulation setting of a threshold for N_2O concentration in the tail gas
Description of measurement methods and procedures to be applied:	If, $C_{N2O,y} > CR_{N2O}$ then $BE_{N2O,y} = \sum_{i=1}^{n} C_{N2O,i} * [F_{TG,i} * M_i]$ where $C_{N2O,i}$: min [C_{N2O},y, CR_{N2O}, and {($SE_{N2O,y}$ *$P_{product,max}$)/(sum($F_{TE,i}$ * M_i)}] else, $BE_{N2O,y} = QI_{N2O,y}$

	where: $C_{N2O,I}$: N_2O concentration a destruction facility inlet during interval i (tN_2O/m^3) $CR_{N2O,i}$: Regulatory limit for specific N_2O concentration during interval i (tN_2O/m^3) $BE_{N2O,y}$: Baseline emissions of N_2O in year y (tN_2O) $F_{TE,i}$: Volume flow rate at the exit of the destruction facility during interval i (m^3/h) M_i : Length of measuring interval i (h) i : interval n : number of intervals during the year $QI_{N2O,y}$: Quantity of N_2O emissions at the inlet of the destruction facility in year y (tN_2O) The quantity of N_2O emissions at the inlet of the N_2O destruction facility is calculated based on continuous measurement of the tail gas volume flow rate and the N_2O concentration at the inlet of the N_2O destruction facility .
QA/QC procedures to be applied:	Not needed.
Any comment:	Change in NO_X or N_2O regulations will automatically cause a re-assessment of the baseline scenario.

Annex 4

MONITORING PLAN

1. Introduction

The purpose of Monitoring Plan (MP) is to provide standard by which HWC to conduct monitoring and record consistent record necessary for the verification of the Project.

The monitoring methodology for the Project is in compliance with the monitoring methodology AM0028 version03.

Specifically, the MP facilitates the following.

- Introduce suitable monitoring system
- Guide for the implementation of necessary measurement and management operation
- Guide for meeting CDM requirements for verification and certification

2. Operation and Monitoring Obligation

The quality of the tail gas to be treated by DeN_2O system is monitored in order to calculate the emission reductions.

Well-established monitoring and control equipment will be introduced to measure other parameters such as flow rate, pressure, temperature of the tail gas required by the baseline and emission reduction as directed in Section B.7.1 of this PDD

Tail gas flow:

Flow meters (Multiple-point sampling tube) are used to measure this important parameter. Differential pressure is measured with differential pressure transmitters. The flow rate is converted to the one at the standard conditions by temperature and pressure measured by temperature and pressure transmitters. Back up transmitters are installed for the case of the malfunction of the instrument and also for the back up during the calibration and maintenance according to the procedure of the supplier.

Continuous Analysis of the tail gas at inlet and outlet

The Project employs the latest state-of-art Non-Dispersive Infrared photometry system [(NDIR) AO2000 by ABB or equivalent system] to measure the concentration of N_2O at inlet of $DeNO_X$ and outlet of DeN_2O system which is the key parameter of the Project. NDIR will have measurement range of 0 – 3,000 ppmv for inlet of DeNOx and

0 – 500 ppmv for outlet of DeN_2O or other suitable ranges to obtain the accuracy of the analysis. Back up spare parts are prepared for the malfunction of the system.

The overall uncertainty for the “emission reduction” is dominated by that of the baseline emissions (project emission is around 10 % and the leakage is around 0.06% of the baseline emissions).

However in conservative manner, non-combusted CH_4 contribution, leakage from electricity consumption and fuel burning are counted after implementation of the project (emissions from ammonia is not counted).

Production of Nitric Acid

Production of the Nitric Acid is measured and recorded using the existing instruments and production monitoring system established and operated by HWC. Production data is monitored under the production control system of HWC to see whether the nitric acid plant is operated at normal condition.

Ammonia consumption to the ammonia oxidation reactor

Ammonia consumption as well as its operating conditions of the ammonia oxidation reactor as specified in Section B.6.2 is measured and recorded using existing instruments and production monitoring system established and operated by HWC. Ammonia reactor’s operating condition is monitored under the production control system of HWC to see whether it is operated under normal conditions.

Statistical analysis of historical AOR operating data (Jan.2000－Nov.2003 and Jan.2005－Oct.2006) is as follows;

(item)		(unit)	(value)
AOR operating temperature	Available data number		1,601
	Daily average	(°C)	890.9
	1.25% lower value of available data (lower limit of permitted range)	(°C)	843.0
	1.25% upper value of available data (upper limit of permitted range)	(°C)	906.8
AOR operating pressure	Available data number		1,619
	Daily average	(Pa abs) (Pa gauge)	$9.019*10^5$ $8.006*10^5$
	1.25% lower value of available data (lower limit of permitted range)	(Pa abs) (Pa gauge)	$8.035*10^5$ $7.022*10^5$

	1.25% upper value of available data (upper limit of permitted range)	(Pa abs) (Pa gauge)	$9.820*10^5$ $8.806*10^5$
Ammonia Consumption	Daily Maximum	(tNH_3/day)	88

If the permissible operating limit exceeds or the daily ammonia input to the oxidation reactor exceeds the limit on permissible ammonia input after the project implementation, baseline N_2O emissions are capped at conservative IPCC default values. The judgment whether normal operating conditions exceed the limit on permissible conditions shall be undertaken daily.

Composition of the ammonia oxidation catalyst

The Ammonia oxidation catalysts of 95% Pt and 5% Rh have been used, and from now on, the same ones will be used.

However, the composition of the Ammonia oxidation catalyst is monitored according to the catalyst supplier and plant design requirement.

3. Frequency of Monitoring and storage of the data

Data storage and data security are considered to be one of the most important part of the MP. The system is designed to be operated automatically. No operator is required for the daily operation of the system. However, monitoring engineer will ensure that the system is in normal operation and take necessary action to follow the MP.

Flow rate is measured continuously by the flow meter. An average of the readings is recorded electrically at 1 minute interval. Data will be compiled into hourly and daily and stored electric media in the redundant storage system. The flow rates are read manually and recorded in the log sheet at once every 8 hours and kept as a back-up data.

N_2O concentration is measured continuously by NDIR. An average of the readings is recorded electrically at 1 minute interval. Data will be compiled into hourly and daily data and kept in the electric media in the redundant storage system. NDIR data are also read manually and recorded in the log sheet at once every 8 hours and kept as a back-up data.

Other parameters are monitored periodically and recorded into electric media to suite the requirement of the CDM monitoring activity. Data are read manually and recorded on log sheet at once every 8 hours.

4. Management and Operational System

In order to ensure the successful operation of the Project and the creditability and verifiability of the CERs achieved, the Project will have a well-defined management and operational system. A system will include the operation and management of the monitoring and record keeping system that is described in this MP.

5. Allocation of the Project Management responsibility

The management and operation of the Project is handled by HWC ensuring the environmental creditability of the Project.

6. Quality assurance

6.1 Quality controls

Accuracy of the N_2O emissions monitoring results is to be ensured by installing a monitoring system that has been certified to meet or exceed the requirements of the prevailing best industry practice or monitoring standards in terms of operation, maintenance and calibration. In Non-dispersion infrared absorption analyzer (NDIR), the latest applicable European standards and norms (EN 14181) or equivalent standards available in the Republic of Korea, which prescribes the features needed for Automated Measuring Systems (AMS) need and how they are to be calibrated and maintained, will be used as the basis for selecting and operating the monitoring system.

(Detailed is described in 9 of this Annex 4.)

Competent Monitoring engineers who already monitor the operation parameters of the Nitric Acid plant will be trained for the additional operation of the Monitoring system. A Monitoring engineer will be on duty for every shift to ensure the operation of the Monitoring system.

6.2 Training

The Project will introduce a NDIR system well in advance of the start up of the DeN_2O system for the purpose of the training and preparation of the monitoring.

The Supplier of the NDIR system and supplier of the DeN_2O system will provide complete training to the Monitoring engineers on the operation and maintenance of the monitoring system.

6.3 Provision for the failure of NDIR

Zero and span check will be carried out periodically during operation in accordance with QAL3 of EN14181 or equivalent standards available in the Republic of Korea. In case where drift and/or repeatability of zero and/or span exceed the permissive limitation, NDIR supplier will be called for adjustment.

In addition in case deviation in the Monitoring data is found, the Monitoring engineer will study the operating parameters of the nitric acid plant to identify the reason(s) for the deviation and take remedial measures. The procedures taken are recorded. If there are no changes in the operating parameters of each ammonia reactor, the NDIR will be examined. Once the default is identified, the Quality & Technical management team and Environment & Safety management team will introduce a correction to the default. The Monitoring engineer will report such irregular event to Plant manager through daily report.

In case NDIR is found to be not performing according to its original performance, following measures are taken to assure the Monitoring of the data and immediate repair of the NDIR.

- Repair NDIR using spare parts.
- Call for the service of NDIR supplier.
- Arrange to ship the back-up system.

6.4 Provision of non availability of data

Following procures should be considered in the event that the data availability for one day falls below 90%.

- Concentration measurement of N_2O:

  If the plant is operated under normal operating conditions and operating parameters of nitric acid production and ammonium flow to the ammonium oxidation reactor can be provided to demonstrate such operation, then the correlation methods shall be used to estimate the emission reductions, applying the parameters with the highest historical correlation to the missing parameters. Historical data on the last campaign shall provide evidence on correlation.

  In the event that the monitoring system for N_2O concentration in inlet of the DeNOx unit is down, the lowest daily value in the past month is applied during around two weeks. Then in the event that the one in outlet of the DeN_2O unit is down, the highest daily value in the past month is applied during around two weeks.

  Next after around 2weeks, the N_2O concentration is monitored and recorded four times a day by gas chromatography and these values are applied until NDIR is repaired.

  Furthermore, in case that these cannot be implemented, the lowest between the conservative default value established in the methodology or the last measured by-product rate (whichever the lower) will be valid and applied for the downtime period for the baseline emission factor, and the highest measured by-product rate during the project activity will be applied for the downtime period for the campaign emission factor.

- Flow measurements of tail gas:

  If the plant is operated under normal operating conditions and operating parameters of nitric acid production and ammonium flow to the ammonium oxidation reactor can be provided to demonstrate such operation, then the correlation methods shall be used to estimate the emission reduction, applying the parameters with the highest historical correlation to the missing parameters. Historical data on the last campaign shall provide evidence on correlation.

  In the event that either monitoring system for tail gas flow rate in inlet of DeNOx unit or the one in outlet of DeN_2O unit is down, the lowest between the value of the flow rate for the functioning side or the one for average in the past month is applied. Furthermore, in case that the both systems are down, the lowest daily value in the past month is applied.

Every procedure taken and calculated results shall be recorded.

7. Key equipment of Analyzer System

7.1 Analyzer module

Infrared Analyzer Module consists of two N_2O sensors and associated electronics having its own processor. Non-dispersive infrared light is passed through measuring cells and absorption in the wave length 2.5 to 8 micro-meter is measured to monitor N_2O by means of selective N_2O absorption sensor. When N_2O molecule comes into the measuring cells, the infrared beam is absorbed by N_2O molecules.

The absorbed wave energy is measured selectively by N_2O absorption sensor. There will be cross sensitivity with carried gas, such as NO, NO_2, H_2O and CO_2. Those cross sensitivity shall be compensated by associated electronics and sensor technology.

7.2 N_2O measurement cell

There are two cells for monitoring each High and Low concentration of N_2O. Each cell has own sample line which is independent. Low N_2O measuring cell monitors 0–300 ppm N_2O and 0–500ppm N_2O, which range will be manually selected. High N_2O measuring cell monitors 0–3000 ppm N_2O and 0–5000 ppm N_2O, which range will be manually selected.

7.3 Calibration cell

Two calibration cells are installed. The calibration cells consists N_2O gas for span calibration of N_2O measuring cells. There are one for Low N_2O concentration and the other for High N_2O concentration. The calibration cell

technology has been tested at German TÜV for more than ten years, long operation use. It is clarified less than 1% full scale measurement variant during one-year operation.

7.4 Flow meter

Flow meters (Multiple-point sampling tube) are used to measure this important parameter. Differential pressure is measured with pressure transmitters. The flow rate of the operating condition is converted to the standard condition arithmetically by pressure transmitter using temperature measured by thermometer. Back up transmitter is installed to be changed in case of the malfunction of the instrument which can also be used as the back up for the calibration and maintenance according to the procedure of the supplier.

8. Procedures used to determine the permitted operating conditions of the nitric acid plant in order to avoid "overestimation of emission reductions":

In order to avoid that the operation of the nitric acid production plant is manipulated in a way to increase the N_2O generation, thereby increasing the CERs, the following procedures relating to the operating temperature and pressure and the use of ammonia oxidation catalysts shall be applied.

8.1 Operating temperature and pressure of the ammonia oxidation reactor (AOR):

If the actual average daily operating temperature or pressure in the ammonia oxidation reactor (T_g and P_g) are outside a "permitted range" of operating temperatures and pressures ($T_{g,hist}$ and $P_{g,hist}$), the baseline emissions are calculated for the respective time period based on lower value between (a) the conservative IPCC default values of 4.5 $kgN_2O/tHNO_3$, (b) $SE_{N2O,y}$ and (c) any related value as a result of legal regulations (*e.g.*, $RSE_{N2O,y}$).

Required monitoring parameters:

- $T_{g,d}$: Actual operating temperature AOR on day *d* (°C),
- $P_{g,d}$: Actual operating pressure AOR on day *d* (Pa),
- $T_{g,hist}$: Historical operating temperature range AOR (°C), and
- $P_{g,hist}$: Historical operating pressure range AOR (Pa).

In order to determine the "permitted range" of the operating temperature and pressure in the ammonia oxidation reactor (AOR), the project applicant has the obligation to determine the operating temperature and pressure range by:

a) Firstly, data on historical temperature and pressure ranges; or, if no data on historical temperatures and pressures are available, then

b) Secondly, by range of temperature and pressure stipulated in the operating manual for the existing equipment; or, if no operating manual is available or the operating manual gives insufficient information, then

c) Thirdly, by literature reference (*e.g.*, from Ullmann's Encyclopaedia of Industrial Chemistry, Fifth, completely revised edition, Volume A 17, VCH, 1991, P. 298, Table 3. or other standard reference work or literature source).

For the HWC plant, both a) and b) are available. Therefore, a) is applied as specified in the methodology.

As historical data on daily operating temperatures and pressures are available (*i.e.*, case a), statistical analysis shall be used for determining the permitted range of operating temperature and pressure. To exclude the possibility of manipulating the process, outliers of historical operating temperature and pressure shall be eliminated by statistical methods. Therefore, the time series data are interpreted as a sample from a stochastic variable. All data that are part of the 2.5% quantile or that are part of the (100–2.5) % Quantile of the sample distribution are defined as outliers and shall be eliminated. The permitted range of operating temperature and pressure is then calculated based on the remaining historical minimum and maximum operating conditions.

If a permissible operating limit is exceeded, the baseline N_2O emissions for that period are capped at the conservative IPCC default value of 4.5 $kgN_2O/tHNO_3$.

8.2. Composition of ammonia oxidation catalyst:

The plant operator is allowed to use compositions of ammonia oxidation catalysts that are common practice in the region or have been used in the nitric acid plant during the last three years without limitation of N_2O baseline emissions.

In case the nitric acid plant operator wishes to change to a composition not used during the last three years, but is common practice in the region and supplied by a reputable manufacturer, or if it corresponds to a composition that is reported as being in use in the relevant literature, the plant operator is allowed to use these ammonia oxidation catalysts without limitation of N_2O baseline emissions.

In case the nitric acid plant operator changes the composition of ammonia oxidation catalysts and the composition is not common practice in the region and not reported as being in use in the relevant literature, the project applicant has to demonstrate (either by economic or other arguments) that the choice of the new composition was based on considerations other than an attempt to increase the rate of N_2O production. If the project applicant can demonstrate appropriate and verifiable reasons, the plant operator is allowed to use new ammonia oxidation catalysts without limitation of N_2O baseline emissions.

HWC will use reputable suppliers like as Johnson Matthey, Engelhard, Dagusa etc. (HWC will not use the local catalyst suppliers). And HWC will most likely use Johnson Matthey in the future. However, HWC does not guarantee to use only Johnson Matthey in the future.

Correspondingly, HWC does not guarantee to use only the catalyst of the same composition in the future. For example, Johnson Matthey has the various ammonia oxidation catalysts. HWC has been using the Pt 95%, Rh 5% catalyst of Johnson Matthey.

In case the nitric acid plant operator changes the composition of ammonia oxidation catalysts and the composition is not common practice in the region and not reported as being in use in the relevant literature, and the project applicant cannot demonstrate appropriate and verifiable reasons for this, baseline emissions are limited to the maximum specific N_2O emissions of previous periods ($tN_2O/tHNO_3$), documented in the verified monitoring reports.

Required monitoring parameters:

- G_{sup} : Supplier of the ammonia oxidation catalyst,
- $G_{sup,hist}$: Historical supplier of the ammonia oxidation catalyst,
- G_{com} : Composition of the ammonia oxidation catalyst,
- $G_{com,hist}$: Historical composition of the ammonia oxidation catalyst, and
- $SE_{N2O,y}$: Specific N_2O emissions per ton HNO_3 in year y ($tN_2O/tHNO_3$).

8.3 Ammonia flow rate to the ammonia oxidation reactor:

If the actual daily ammonia flow rate exceeds the (upper) limit on maximum historical daily permitted ammonia flow rate, the baseline emissions for this operating day are calculated based on the conservative IPCC default values and are limited by the legal regulations. The upper limit on ammonia flow should be determined based on:

a) historical operating data on maximum daily average ammonia flow; or, if not existing, on

b) calculation of the maximum ammonia flow rate allowed as specified by ammonia oxidation catalyst manufacturer or on typical catalyst loadings; or, if not existing,

c) based on the literature.

If the daily ammonia input to the oxidation reactor exceeds the limit on permissible ammonia input, baseline N_2O emissions are capped at conservative IPCC default values.

For the HWC plant, both a) and b) are available. Therefore, a) is applied as specified in the methodology.

Required monitoring parameters on daily basis:

- $A_{OR,d}$: Actual ammonia input to oxidation reactor (tNH_3/day), and
- $A_{OR,hist}$: Maximum historical ammonia input to oxidation reactor (tNH_3/day).

9. Quality assurance for AMS (N_2O concentration analyzer)

Three levels of quality assurance tests and one annual functional test for AMS which are recommended to be used as guidance regarding the selection, installation and operation of the AMS by the EN 14181 or equivalent standards available in the Republic of Korea will be applied.

The three quality assurance levels (QALs) are as follows:

1. Quality assurance of tested AMS. AMS must have performance certificate (e.g. MCERTS), with calculation of uncertainty before installation according to approved methods such as ISO 14956 including:

a) Standard deviation; b) Lack of fit (linearity); c) Repeatability at zero and reference points; d) Time-dependent zero and span drift; e) Temperature dependence; f) Voltage fluctuation; g) Suitability test; h) Cross sensitivity to likely components of the stack gas; i) Influence of variations in flow rate on extractive Automated Measuring Systems; j) Response time; k) Detection limit; l) Influence of ambient conditions on zero and span readings; m) Performance and accuracy; n) Availability; o) Susceptibility to physical disturbances.

The specific performance characteristics of the monitoring system chosen by the project will be given at the time of validation.

2. Quality assurance of installation and calibration of the Automated Measuring System according to the Standard Reference Measurement Method (SRM), determination of the measurement uncertainty/variability of the AMS and inspection of the compliance with the prescribed measurement uncertainties. Such tests must be carried out by organizations that have an accredited quality assurance system such as one according to ISO/IEC 17025 or relevant standards. Items to be considered include the following:

a. Selection of the location of measurement;
b. Duly installation of the monitoring equipment;
c. Correct choice of measurement range;
d. Calibration of the AMS using the Standard-Reference-Method (SRM) as guidance;
e. Calibration curve either as linear regression or as straight line from absolute zero to centre of a scatter-plot;
f. Calculation of the standard deviation at the 95% confidence interval;
g. Inspection every three years.

3. Continuous quality assurance through the local operator/manager (drift and accuracy of the AMS, verification management and documentation).

a. Permanent quality assurance during the plant operation by the operating staff;

b. Assurance of reliable and correct operation of the monitoring equipment (maintenance evidence);

c. Regular controls: zero point, span, drift, meet schedule of manufacturer maintenance intervals;

In addition, annual functionality test including SRM measurements to check for uncertainties in the data measured by the AMS. Such tests must be carried out by organizations that have an accredited quality assurance system such as one according to ISO/IEC 17025 or relevant standards.

a. Annual confirmation of the calibration curve;

b. Validity proof of calibration curves;

c. Back-setting of excess meter of invalid calibration range.

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