

**SECTION D. Application of a monitoring methodology and plan****D.1. Name and reference of approved monitoring methodology applied to the project activity:**

Approved monitoring methodology **AM0028** “Catalytic N<sub>2</sub>O destruction in the tail gas of Nitric Acid Plants”

This monitoring methodology shall be used in conjunction with the approved baseline methodology AM0028 “Catalytic N<sub>2</sub>O destruction in the tail gas of Nitric Acid Plants”.

**D.2. Justification of the choice of the methodology and why it is applicable to the project activity:**

The proposed project activity will be implemented at three existing nitric acid plant of Hu-Chems. The project comprises the installation of three catalytic N<sub>2</sub>O destruction facilities in the tail gas of Hu-Chems nitric acid plants II, III and IV. There is no indication that legal regulations and obligations regarding N<sub>2</sub>O emissions will be implemented in the Republic of Korea. Nevertheless observation of the Korean regulations on N<sub>2</sub>O emissions will be part of the monitoring.

The use of the methodology is justified because the following statements are true:

- The methodology will be applied to the existing production capacities installed at 31<sup>st</sup> December 2005.
- The Hu-Chems nitric acid plants II, III, IV have currently *not* installed any N<sub>2</sub>O destruction or abatement technology. The project activity will not result in any shut down of an existing N<sub>2</sub>O destruction or abatement facility at Hu-Chems nitric acid plants II, III, IV.
- The project activity will not cause a nitric acid production increase.
- DeNO<sub>x</sub>-units are already installed at Hu-Chems II, III, IV. The project activity will result in NO<sub>x</sub> emission reductions that are at least as effective as the existing DeNO<sub>x</sub>-units.
- The DeNO<sub>x</sub>-units installed at Hu-Chems II, III, IV are SCR DeNO<sub>x</sub>-units.
- The N<sub>2</sub>O concentrations will be measured in real time at the inlet and the outlet of the N<sub>2</sub>O destruction facilities.
- Relevant historical data and manufacturer information are available.
- The monitoring methodology will be used in conjunction with the “Baseline Methodology for Catalytic N<sub>2</sub>O destruction in the tail gas of Nitric Acid Plants”.

The accuracy of the N<sub>2</sub>O emissions monitoring results will be ensured by installing a monitoring system that has been certified to meet (or exceeds) the requirements of the prevailing best industry practice or monitoring standards in terms of operation, maintenance and calibration.

**D.2. 1. Option 1: Monitoring of the emissions in the project scenario and the baseline scenario**

The monitoring methodology follows Option 1.

In order to calculate the baseline and project emissions Hu-Chems and CARBON will provide data on:

- Legal regulations on N<sub>2</sub>O and NO<sub>x</sub>;
- The production capacities of Hu-Chems II, III and IV nitric acid plants measured in tonnes of nitric acid;
- The composition of the ammonia oxidation catalyst of Hu-Chems II, III and IV nitric acid plants;
- The ammonia flow rate to the ammonia oxidation reactor of Hu-Chems II, III and IV nitric acid plants;
- The propane input to the EnviNOx®-Systems at Hu-Chems II and III;
- The operating temperature and pressure range of the ammonia oxidation reactor of Hu-Chems II, III and IV nitric acid plants;
- Concentration of N<sub>2</sub>O and NO<sub>x</sub> at EnviNOx®-Systems inlet and outlet of Hu-Chems II, III and IV nitric acid plants;
- Tail gas flow rates (adjusted to standard temperature and pressure) of Hu-Chems II, III and IV nitric acid plants;

Measurement of tail gas flow (Hu-Chems II, III, IV):

The tail gas flow is measured by using a venturi tube, which is designed and manufactured in accordance with ISO 5167-4:2003. The venturi tube is of rough welded sheet iron type with annular pressure tapping chambers. Differential pressure is measured with two (redundant) differential pressure transmitters. For calculation of the volume flow rate at standard conditions or (with known molecular weight) the mass flow, the system is equipped with two (redundant) pressure transmitters and two (redundant) temperature measurements.

On-line analysis of tail gas feed (Hu-Chems II, III, IV):

In the feed of the EnviNOx®- system, the concentrations of nitrous oxide (N<sub>2</sub>O), nitric oxide (NO) and nitrogen dioxide (NO<sub>2</sub>) are analysed continuously. Analysis is done by using non-dispersive infrared photometry in a combined analyser device. Sample handling includes provisions for pressure reduction, separation of residual solids, sample flow adjustment, and supply with test gases. The analyser is, as far as technically possible, corrected for any applicable cross sensitivity.

On-line analysis of tail gas effluent (Hu-Chems II, III, IV):

In the effluent of the EnviNOx®- system, the concentrations of nitrous oxide (N<sub>2</sub>O), nitric oxide (NO) plus nitrogen dioxide (NO<sub>2</sub>) are analysed continuously. Analysis is done by using non-dispersive infrared photometry for N<sub>2</sub>O and chemoluminescence for NO and NO<sub>2</sub>. Sample handling includes provisions for pressure reduction, separation of residual solids, sample flow adjustment, and supply with test gases. The analysers are, as far as technically possible, corrected for any applicable cross sensitivity.

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Actual production of Nitric Acid (Hu-Chems II, III, IV):

The actual nitric acid production is measured according to the already installed instruments. The instrument signals will be recorded in control rooms and used to determine whether the nitric acid production is within the historical designed capacity. Recorded nitric acid production data considers concentration and density.

Actual temperature and pressure of the ammonia oxidation reactor (Hu-Chems II, III, IV):

The actual temperature and pressure of the ammonia oxidation reactor is monitored using the calibrated existing (or exchanged) instruments in the nitric acid plants Hu-Chems II, III, IV. The instrument signals will be recorded in the control rooms and used to determine whether the nitric acid plant is being operated within the normal range of operation (daily basis).

Actual ammonia input to the ammonia oxidation reactor (Hu-Chems II, III, IV):

The actual ammonia flow to the ammonia oxidation reactor is monitored using the existing instruments in the nitric acid plants Hu-Chems II, III and IV. The instrument signals will be recorded in the control rooms and used to determine whether the nitric acid plant is being operated within the normal range of operation (daily basis). Ammonia flow is converted to standard conditions based on temperature and pressure measurement.

Composition of the ammonia oxidation catalyst (Hu-Chems II, III, IV):

The composition of the ammonia oxidation catalyst will be monitored according to catalyst supplier information.

Propane input (Hu-Chems II, III):

The propane used as reducing agent will be measured by standard flow meters. Flow is converted to standard conditions based on temperature and pressure measurement.

Operation and data storage:

The monitoring system is designed for automatic operation, so that activities by operation personnel are not required during normal operation. However, it is required to observe the system for possible failures, and to perform required maintenance activities on a regular basis. The measured values are transferred to a digital process control system (Delta V, M/s. Emerson process management), where they are displayed, evaluated, and stored. Evaluation includes calculation of flow rate at standard conditions and mass flow rates of  $N_2O$ . Based on raw data the system also performs calculation of daily mean values and generates reports. Data storage for raw data as well as for evaluated data is done on a computer network which is directly connected to the process control system. Data storage is designed redundantly on two separate computers, located at different locations (control rooms of (1) Hu-Chems II, III and (2) Hu-

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Chems IV), each equipped with a redundant array of hard disks. Network connections are redundant fibre optic links. The software for data storage is designed in a way that manipulation of data is excluded, and that any change of configuration is recorded. Time stamps are generated by a GPS clock. In addition, a shift report on the operation of the EnviNOx<sup>®</sup>-System and emission reductions will be prepared by Hu-Chems nitric acid process team.

Information and data mentioned above are integrated part of the monitoring reports. Data collected to monitor emissions of the project scenario and the baseline scenario are given below:

**D.2.1.1. Data to be collected in order to monitor emissions from the project activity, and how this data will be archived:****Overall:**

ID number	Data Variable	Source of data	Data unit	Measured (m), calculated (c) or estimated (e)	Recording frequency	Proportion of data to be monitored	How will the data be archived? (electronic/ paper)	For how long is achieved data to be kept	Comment
P1	PE_y Project emissions	Monitoring system	tCO <sub>2</sub> e	Calculated	Annual	100%	Electronic	Crediting period +2yrs	
P2	PE_ND,y Project emissions from N <sub>2</sub> O not destroyed	Monitoring system	tCO <sub>2</sub> e	Calculated	Annual	100%	Electronic	Crediting period +2yrs	
P3	PE_DF,y Project emissions from destruction facility	Monitoring system	tCO <sub>2</sub> e	Calculated	Annual	100%	Electronic	Crediting period +2yrs	

**Hu-Chems II:**

ID number	Data Variable	Source of data	Data unit	Measured (m), calculated (c) or estimated (e)	Recording frequency	Proportion of data to be monitored	How will the data be archived? (electronic/paper)	For how long is achieved data to be kept	Comment
P4	PE <sub>y,II</sub> Project emissions	Monitoring system	tCO <sub>2</sub> e	Calculated	Annual	100%	Electronic	Crediting period +2yrs	
P5	PE <sub>ND,y,II</sub> Project emissions from N <sub>2</sub> O not destroyed	Monitoring system	tCO <sub>2</sub> e	Calculated	Annual	100%	Electronic	Crediting period +2yrs	
P6	PE <sub>DF,y,II</sub> Project emissions from destruction facility	Monitoring system	tCO <sub>2</sub> e	Calculated	Annual	100%	Electronic	Crediting period +2yrs	
P7	PE <sub>N2O,y,II</sub> N <sub>2</sub> O not destroyed by facility	Monitoring system	tN <sub>2</sub> O	Calculated	Daily	100%	Electronic	Crediting period +2yrs	
P8	F <sub>TG,I,II</sub> Volume flow tail gas at N <sub>2</sub> O destruction facility	Flow meter	m <sup>3</sup> /h	Measured continuously	Daily	100%	Electronic	Crediting period +2yrs	Flow metering system will automatically record volume flow adjusted to standard

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									temperature and pressure.
P9	CO_N2O,i,II N <sub>2</sub> O concentration at destruction facility outlet	Non-dispersive infrared photometry analyser.	tN <sub>2</sub> O/ m <sup>3</sup>	Measured continuously	Daily	100%	Electronic	Crediting period +2yrs	Plausibility Check by Gas Chromatography analysis.
P10	M_i,II Measuring Interval	Measuring device, data management system	h	Measured continuously	Daily	100%	Electronic	Crediting period +2yrs	
P11	PE_HC,y,II Emissions from hydrocarbon use in destruction facility	Monitoring system	tCO <sub>2</sub> e	Calculated	Annual	100%	Electronic	Crediting period +2yrs	
P12	HCE_C,y,II Converted hydrocarbon emissions	Monitoring system	tCO <sub>2</sub> e	Calculated	Annual	100%	Electronic	Crediting period +2yrs	
P13	Q_HC,y,II Hydrocarbon input (reducing agent)	Measuring device	m <sup>3</sup>	Measured	Daily	100%	Electronic	Crediting period +2yrs	
P14	ρ_HC,II Hydrocarbon density	Certificate hydrocarbon supplier or default value	t/m <sup>3</sup>	Measured	Yearly	100%	Electronic	Crediting period +2yrs	



P15	EF_HC,II Hydrocarbon CO <sub>2</sub> emission factor	IPCC	tCO <sub>2</sub> /t	Calculated	Once	100%	Electronic	Crediting period +2yrs	Propane: 3 tCO <sub>2</sub> /tC <sub>3</sub> H <sub>8</sub>
P16	OXID_HC,II Hydrocarbon oxidation factor	Measuring device	%	Measured continuously	Daily	100%	Electronic	Crediting period +2yrs	
P17	Type_HC,II Type of hydrocarbon	Hydrocarbon supplier	-		Once	100%	Electronic	Crediting period +2yrs	

Note, in case of the catalytic N<sub>2</sub>O destruction project at the nitric acid plant Hu-Chems II a SCR DeNO<sub>x</sub>-unit is already installed prior to the starting date of the project activity. Propane will be used as reducing agent.

### Hu-Chems III:

ID number	Data Variable	Source of data	Data unit	Measured (m), calculated (c) or estimated (e)	Recording frequency	Proportion of data to be monitored	How will the data be archived? (electronic/paper)	For how long is achieved data to be kept	Comment
P18	PE_y,III Project emissions	Monitoring system	tCO <sub>2</sub> e	Calculated	Annual	100%	Electronic	Crediting period +2yrs	



P19	PE_ND,y,III Project emissions from N <sub>2</sub> O not destroyed	Monitoring system	tCO <sub>2</sub> e	Calculated	Annual	100%	Electronic	Crediting period +2yrs	
P20	PE_DF,y,III Project emissions from destruction facility	Monitoring system	tCO <sub>2</sub> e	Calculated	Annual	100%	Electronic	Crediting period +2yrs	
P21	PE_N2O,y,III N <sub>2</sub> O not destroyed by facility	Monitoring system	tN <sub>2</sub> O	Calculated	Daily	100%	Electronic	Crediting period +2yrs	
P22	F_TG,I,III Volume flow tail gas at N <sub>2</sub> O destruction facility	Flow meter	m <sup>3</sup> /h	Measured continuously	Daily	100%	Electronic	Crediting period +2yrs	Flow metering system will automatically record volume flow adjusted to standard temperature and pressure.
P23	CO_N2O,i,III N <sub>2</sub> O concentration at destruction facility outlet	Non-dispersive infrared photometry analyser.	tN <sub>2</sub> O/ m <sup>3</sup>	Measured continuously	Daily	100%	Electronic	Crediting period +2yrs	Plausibility Check by Gas Chromatography analysis.
P24	M_i,III Measuring Interval	Measuring device, data management system	h	Measured continuously	Daily	100%	Electronic	Crediting period +2yrs	



P25	PE_HC,y,III Emissions from hydrocarbon use in destruction facility	Monitoring system	tCO <sub>2</sub> e	Calculated	Annual	100%	Electronic	Crediting period +2yrs	
P26	HCE_C,y,III Converted hydrocarbon emissions	Monitoring system	tCO <sub>2</sub> e	Calculated	Annual	100%	Electronic	Crediting period +2yrs	
P27	Q_HC,y,III Hydrocarbon input (reducing agent)	Measuring device	m <sup>3</sup>	Measured	Daily	100%	Electronic	Crediting period +2yrs	
P28	ρ_HC,III Hydrocarbon density	Certificate hydrocarbon supplier or default value	t/m <sup>3</sup>	Measured	Yearly	100%	Electronic	Crediting period +2yrs	
P29	EF_HC,III Hydrocarbon CO <sub>2</sub> emission factor	IPCC	tCO <sub>2</sub> /t	Calculated	Once	100%	Electronic	Crediting period +2yrs	Propane: 3 tCO <sub>2</sub> /tC <sub>3</sub> H <sub>8</sub>
P30	OXID_HC,III Hydrocarbon oxidation factor	Measuring device	%	Measured continuously	Daily	100%	Electronic	Crediting period +2yrs	
P31	Type_HC,III Type of hydrocarbon	Hydrocarbon supplier	-		Once	100%	Electronic	Crediting period +2yrs	



Note, in case of the catalytic N<sub>2</sub>O destruction project at the nitric acid plant Hu-Chems III a SCR DeNO<sub>x</sub>-unit is already installed prior to the starting date of the project activity. Propane will be used as reducing agent.

#### Hu-Chems IV:

ID number	Data Variable	Source of data	Data unit	Measured (m), calculated (c) or estimated (e)	Recording frequency	Proportion of data to be monitored	How will the data be archived? (electronic/paper)	For how long is achieved data to be kept	Comment
P32	PE <sub>y,IV</sub> Project emissions	Monitoring system	tCO <sub>2</sub> e	Calculated	Annual	100%	Electronic	Crediting period +2yrs	
P33	PE <sub>ND,y,IV</sub> Project emissions from N <sub>2</sub> O not destroyed	Monitoring system	tCO <sub>2</sub> e	Calculated	Annual	100%	Electronic	Crediting period +2yrs	
P34	PE <sub>DF,y,IV</sub> Project emissions from destruction facility	Monitoring system	tCO <sub>2</sub> e	Calculated	Annual	100%	Electronic	Crediting period +2yrs	
P35	PE <sub>N2O,y,IV</sub> N <sub>2</sub> O not destroyed by facility	Monitoring system	tN <sub>2</sub> O	Calculated	Daily	100%	Electronic	Crediting period +2yrs	



P36	F_TG,I,IV Volume flow tail gas at N <sub>2</sub> O destruction facility	Flow meter	m <sup>3</sup> /h	Measured continuously	Daily	100%	Electronic	Crediting period +2yrs	Flow metering system will automatically record volume flow adjusted to standard temperature and pressure.
P37	CO_N2O,i,IV N <sub>2</sub> O concentration at destruction facility outlet	Non-dispersive infrared photometry analyser.	tN <sub>2</sub> O/ m <sup>3</sup>	Measured continuously	Daily	100%	Electronic	Crediting period +2yrs	Plausibility Check by Gas Chromatography analysis.
P38	M_i,IV Measuring Interval	Measuring device, data management system	h	Measured continuously	Daily	100%	Electronic	Crediting period +2yrs	

Note, in case of the catalytic N<sub>2</sub>O destruction project at the nitric acid plant Hu-Chems IV a SCR DeNO<sub>x</sub>-unit is already installed prior to the starting date of the project activity.



**D.2.1.2. Description of formulae used to estimate project emissions (for each gas, source, formulae/algorithm, emissions units of CO<sub>2</sub> equ.)**

The direct emissions from the project activity are equivalent to the N<sub>2</sub>O emissions not destroyed plus emissions related to the operation of the N<sub>2</sub>O destruction facility (emissions from additional ammonia and hydrocarbon input).

### Project Emissions

The emissions due to the project activity are composed of (a) the emissions of not destroyed N<sub>2</sub>O and (b) emissions from auxiliary ammonia and hydrocarbons input resulting from the operation of the N<sub>2</sub>O destruction facility. The procedure of determining the project N<sub>2</sub>O emissions is similar to that used for determining baseline emissions. Project emissions are defined by the following equation:

$$PE_y = PE_{y,II} + PE_{y,III} + PE_{y,IV} = PE_{ND,y} + PE_{DF,y} \quad (32)$$

$$PE_{ND,y} = PE_{ND,y,II} + PE_{ND,y,III} + PE_{ND,y,IV} \quad (33)$$

$$PE_{DF,y} = PE_{DF,y,II} + PE_{DF,y,III} + PE_{DF,y,IV} \quad (34)$$

where:

PE <sub>y</sub>	Project emissions in year y (tCO <sub>2</sub> e)
PE <sub>y,II</sub>	Project emissions Hu-Chems II in year y (tCO <sub>2</sub> e)
PE <sub>y,III</sub>	Project emissions Hu-Chems III in year y (tCO <sub>2</sub> e)
PE <sub>y,IV</sub>	Project emissions Hu-Chems IV in year y (tCO <sub>2</sub> e)
PE <sub>ND,y</sub>	Project emissions from N <sub>2</sub> O not destroyed in year y (tCO <sub>2</sub> e)
PE <sub>DF,y</sub>	Project emissions related to the operation of the destruction facility in year y (tCO <sub>2</sub> e)
PE <sub>ND,y,II</sub>	Project emissions in year y Hu-Chems II (tCO <sub>2</sub> e)
PE <sub>ND,y,III</sub>	Project emissions in year y Hu-Chems III (tCO <sub>2</sub> e)
PE <sub>ND,y,IV</sub>	Project emissions in year y Hu-Chems IV (tCO <sub>2</sub> e)
PE <sub>DF,y,II</sub>	Project emissions related to the operation of the destruction facility in year y Hu-Chems II (tCO <sub>2</sub> e)
PE <sub>DF,y,III</sub>	Project emissions related to the operation of the destruction facility in year y Hu-Chems III (tCO <sub>2</sub> e)
PE <sub>DF,y,IV</sub>	Project emissions related to the operation of the destruction facility in year y Hu-Chems IV (tCO <sub>2</sub> e)

The following equations have to be applied for Hu-Chems II, Hu-Chems III and Hu-Chems IV

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**N<sub>2</sub>O emissions not destroyed by the project activity:**

N<sub>2</sub>O emissions not destroyed by the project activity are calculated based on the continuous measurement of the N<sub>2</sub>O concentration in the tail gas of the N<sub>2</sub>O destruction facility and the volume flow rate of the tail gas stream.

The emissions of non destroyed N<sub>2</sub>O are given by:

$$PE_{ND,y} = PE_{N_2O,y} \times GWP_{N_2O} \quad (35)$$

where:

PE<sub>ND,y</sub> Project emissions from N<sub>2</sub>O not destroyed in year y (tCO<sub>2</sub>e)

PE<sub>N<sub>2</sub>O,y</sub> Project emissions of N<sub>2</sub>O in year y (tN<sub>2</sub>O)

GWP<sub>N<sub>2</sub>O</sub> Global warming potential of N<sub>2</sub>O = 310

$$PE_{N_2O,y} = \sum_{i=1}^n F_{TG,i} \times CO_{N_2O,i} \times M_i \quad (36)$$

where:

PE<sub>N<sub>2</sub>O,y</sub> Project emissions of N<sub>2</sub>O in year y (tN<sub>2</sub>O)

F<sub>TG,i</sub> Volume flow rate tail gas at destruction facility during interval i (m<sup>3</sup>/h)

CO<sub>N<sub>2</sub>O,i</sub> N<sub>2</sub>O concentration in the tail gas of the N<sub>2</sub>O destruction facility during interval i (tN<sub>2</sub>O/m<sup>3</sup>)

M<sub>i</sub> Length of measuring interval i (h)

i interval

n number of intervals during the year

**Project emissions from the operation of the destruction facility:**

The operation of the N<sub>2</sub>O destruction facilities Hu-Chems II and Hu-Chems III require the use of hydrocarbon (propane) as input streams.

The emissions related to the operation of the N<sub>2</sub>O destruction facility are given by on-site emissions due to the hydrocarbons used as input to the N<sub>2</sub>O destruction facility:

$$PE_{DF,y} = PE_{NH3,y} + PE_{HC,y} \quad (37)$$

where:

PE <sub>DF,y</sub>	Project emissions related to the operation of the destruction facility in year y (tCO <sub>2</sub> e)
PE <sub>NH3,y</sub>	Project emissions related to ammonia input to destruction facility in year y (tCO <sub>2</sub> e)
PE <sub>HC,y</sub>	Project emissions related to hydrocarbon input to destruction facility in year y (tCO <sub>2</sub> e)

Ammonia input:

In case of Hu-Chems II, III and IV, project emissions related to ammonia input to destruction facilities (PE<sub>NH3,y</sub>) are zero.

Hydrocarbon Input:

Propane is used as reducing agent at Hu-Chems II and Hu-Chems III to enhance the catalytic N<sub>2</sub>O reduction efficiency. In this case hydrocarbons are completely converted to water, carbon monoxide and carbon dioxide. The fraction of the converted hydrocarbons is OXID<sub>HC</sub>.

$$PE_{HC,y} = HCE_{C,y} + HCE_{NC,y} \quad (38)$$

where:

PE <sub>HC,y</sub>	Project emissions related to hydrocarbon input to destruction facility in year y (tCO <sub>2</sub> e)
HCE <sub>C,y</sub>	Converted hydrocarbon emissions in year y (tCO <sub>2</sub> )
HCE <sub>NC,y</sub>	Methane emissions in year y (tCO <sub>2</sub> e)

For calculation of the GHG emissions related to the hydrocarbons converted, the following formulae are used:

$$HCE_{C,y} = \rho_{HC} \times Q_{HC,y} \times EF_{HC} \times OXID_{HC}/100 \quad (39)$$

where:

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HCE_C,y	Converted hydrocarbon emissions in year y (tCO <sub>2</sub> e)
ρ <sub>HC</sub>	Hydrocarbon density (t/m <sup>3</sup> )
Q_HC,y	Hydrocarbon input in year y (m <sup>3</sup> )
OXID_HC	Oxidation factor of hydrocarbon (%)
EF_HC	Carbon emission factor of hydrocarbon (tCO <sub>2</sub> /t HC)

The hydrocarbon CO<sub>2</sub> emission factor is given by the molecular weights and the chemical reaction when hydrocarbons are converted (carbon emission factor of propane is 3 tCO<sub>2</sub>/tC<sub>3</sub>H<sub>8</sub>).

Project emissions are limited to the design capacity of the existing nitric acid plants Hu-Chems II, III and IV. If the actual production of nitric acid (P<sub>HNO<sub>3</sub>,y</sub>) exceeds the design capacity (P<sub>HNO<sub>3</sub>,max</sub>) then emissions related to the production above P<sub>HNO<sub>3</sub>,max</sub> will neither be claimed for the baseline nor for the project scenario.



**D.2.1.3. Relevant data necessary for determining the baseline of anthropogenic emissions by sources of GHGs within the project boundary and how such data will be collected and archived :**

**Hu-Chems II:**

ID number	Data Variable	Source of data	Data unit	Measured (m), calculated (c) or estimated (e)	Recording frequency	Proportion of data to be monitored	How will the data be archived? (electronic/ paper)	For how long is achieved data to be kept	Comment
B1	P_HNO <sub>3</sub> ,y,II Plant output of HNO <sub>3</sub>	Production reports	tHNO <sub>3</sub>	Measured	Daily	100 %	Electronic	Crediting period + 2 yrs	
B2	QI_N <sub>2</sub> O,y,II Quantity of N <sub>2</sub> O at inlet of destruction facility		tN <sub>2</sub> O	Calculated	Daily	100 %	Electronic	Crediting period + 2 yrs	
B3	CI_N <sub>2</sub> O,I,II N <sub>2</sub> O concentration at N <sub>2</sub> O destruction facility inlet	Non-dispersive infrared photometry analyser.	tN <sub>2</sub> O/m <sup>3</sup>	Measured continuous	Daily	100 %	Electronic	Crediting period + 2 yrs	Plausibility Check by Gas Chromatography analysis.
B4	QR_N <sub>2</sub> O,y Regulation I: annual quantity N <sub>2</sub> O limited	National legislation	tN <sub>2</sub> O	Calculated	Date of regulation	100 %	Electronic	Crediting period + 2 yrs	



B5	RSE_N2O,y  Regulation II: N <sub>2</sub> O emissions per unit of nitric acid	National legislation	tN <sub>2</sub> O/t HNO <sub>3</sub>	Calculated	Date of regulation	100 %	Electronic	Crediting period + 2 yrs	
B6	CR_N2O  Regulation III: N <sub>2</sub> O concentration in tail gas limited	National legislation	tN <sub>2</sub> O/m <sup>3</sup>	Calculated	Date of regulation	100 %	Electronic	Crediting period + 2 yrs	
B7	P_HNO3,hist,II  Design capacity	Manufacturer's specifications	t	Measured / calculated	Once	100 %	Electronic	Crediting period + 2 yrs	
B8	T_g,hist,II  Historical opera-ting temperature range of the ammonia oxidation reactor	Production reports / manufacturer's specification	°C	Measured / calculated	Once	100 %	Electronic	Crediting period + 2 yrs	
B9	P_g,hist,II  Historical operating pressure range of the ammonia oxidation reactor	Production reports / manufacturer's specifications	Pa	Measured / calculated	Once	100 %	Electronic	Crediting period + 2 yrs	
B10	T_g,II  Actual operating temperature ammonia oxidation reactor	Measuring device	°C	Measured	Continuous	100 %	Electronic	Crediting period + 2 yrs	
B11	P_g,II  Actual operating pressure ammonia oxidation reactor	Measuring device	Pa	Measured	Continuous	100 %	Electronic	Crediting period + 2 yrs	

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B12	Reg_NOx  National regulation on NO <sub>x</sub> emissions	National regulations, Ministry of Environment	tNO <sub>x</sub> /m <sup>3</sup>	Calculated	Date of regulation	100 %	Electronic	Crediting period + 2 yrs	
B13	G_sup,II  Supplier of the ammonia oxidation catalyst	Supplier's information	-					Crediting period + 2 yrs	
B14	G_com,II  Composition of the ammonia oxidation catalyst	Annual reports, supplier's information	%		Date of changing gauze composition	100 %	Electronic	Crediting period + 2 yrs	
B15	G_sup,hist,II  Historical supplier of ammonia oxidation catalyst	Annual reports, supplier's information	-		Once	100 %	Electronic	Crediting period + 2 yrs	
B16	G_com,hist,II  Historical composition of the ammonia oxidation catalyst	Supplier's information	%		Date of start of use of catalyst	100 %	Electronic	Crediting period + 2 yrs	
B17	SE_N2O,II  N <sub>2</sub> O emission rate per ton of nitric acid	Monitoring reports	tN <sub>2</sub> O/t HNO <sub>3</sub>	Calculated	Yearly	100 %	Electronic	Crediting period + 2 yrs	
B18	A_OR,hist,II  Max. historical ammonia flow rate to the ammonia oxidation reactor	Production reports / manufacturer's specifications / literature	tNH <sub>3</sub> /day	Measured / calculated	Once	100 %	Electronic	Crediting period + 2 yrs	

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B19	A_OR,d,II  Actual ammonia flow rate to the ammonia oxidation reactor	Measuring device	tNH <sub>3</sub> /day	Measured	Continuous	100 %	Electronic	Crediting period + 2 yrs	
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**Hu-Chems III:**

ID number	Data Variable	Source of data	Data unit	Measured (m), calculated (c) or estimated (e)	Recording frequency	Proportion of data to be monitored	How will the data be archived? (electronic/ paper)	For how long is achieved data to be kept	Comment
B20	P_HNO <sub>3</sub> ,y,III  Plant output of HNO <sub>3</sub>	Production reports	tHNO <sub>3</sub>	Measured	Daily	100 %	Electronic	Crediting period + 2 yrs	
B21	QI_N <sub>2</sub> O,y,III  Quantity of N <sub>2</sub> O at inlet of destruction facility		tN <sub>2</sub> O	Calculated	Daily	100 %	Electronic	Crediting period + 2 yrs	
B22	CI_N <sub>2</sub> O,I,III  N <sub>2</sub> O concentration at N <sub>2</sub> O destruction facility inlet	Non-dispersive infrared photometry analyser.	tN <sub>2</sub> O/m <sup>3</sup>	Measured continuous	Daily	100 %	Electronic	Crediting period + 2 yrs	Plausibility Check by Gas Chromatography analysis.



B23	T_g,hist,III Historical operating temperature range of the ammonia oxidation reactor	Production reports / manufacturer's specification	°C	Measured / calculated	Once	100 %	Electronic	Crediting period + 2 yrs	
B24	P_g,hist,III Historical operating pressure range of the ammonia oxidation reactor	Production reports / manufacturer's specifications	Pa	Measured / calculated	Once	100 %	Electronic	Crediting period + 2 yrs	
B25	T_g,III Actual operating temperature ammonia oxidation reactor	Measuring device	°C	Measured	Continuous	100 %	Electronic	Crediting period + 2 yrs	
B26	P_g,III Actual operating pressure ammonia oxidation reactor	Measuring device	Pa	Measured	Continuous	100 %	Electronic	Crediting period + 2 yrs	
B27	G_sup,III Supplier of the ammonia oxidation catalyst	Supplier's information	-					Crediting period + 2 yrs	
B28	G_com,III Composition of the ammonia oxidation catalyst	Annual reports, supplier's information	%		Date of changing gauze composition	100 %	Electronic	Crediting period + 2 yrs	
B29	G_sup,hist,III Historical supplier of ammonia oxidation catalyst	Annual reports, supplier's information	-		Once	100 %	Electronic	Crediting period + 2 yrs	

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B30	G_com,hist,III  Historical composition of the ammonia oxidation catalyst	Supplier's information	%		Date of start of use of catalyst	100 %	Electronic	Crediting period + 2 yrs	
B31	SE_N2O,III  N <sub>2</sub> O emission rate per ton of nitric acid	Monitoring reports	tN <sub>2</sub> O/t HNO <sub>3</sub>	Calculated	Yearly	100 %	Electronic	Crediting period + 2 yrs	
B32	A_OR,hist,III  Max. historical ammonia flow rate to the ammonia oxidation reactor	Production reports / manufacturer's specifications / literature	tNH <sub>3</sub> /day	Measured / calculated	Once	100 %	Electronic	Crediting period + 2 yrs	
B33	A_OR,d,III  Actual ammonia flow rate to the ammonia oxidation reactor	Measuring device	tNH <sub>3</sub> /day	Measured	Continuous	100 %	Electronic	Crediting period + 2 yrs	

**Hu-Chems IV:**

ID number	Data Variable	Source of data	Data unit	Measured (m), calculated (c) or estimated (e)	Recording frequency	Proportion of data to be monitored	How will the data be archived? (electronic/paper)	For how long is achieved data to be kept	Comment



B34	P_HNO <sub>3</sub> ,y,IV Plant output of HNO <sub>3</sub>	Production reports	tHNO <sub>3</sub>	Measured	Daily	100 %	Electronic	Crediting period + 2 yrs	
B35	QI_N <sub>2</sub> O,y,IV Quantity of N <sub>2</sub> O at inlet of destruction facility		tN <sub>2</sub> O	Calculated	Daily	100 %	Electronic	Crediting period + 2 yrs	
B36	CI_N <sub>2</sub> O,I,IV N <sub>2</sub> O concentration at N <sub>2</sub> O destruction facility inlet	Non-dispersive infrared photometry analyser.	tN <sub>2</sub> O/m <sup>3</sup>	Measured continuous	Daily	100 %	Electronic	Crediting period + 2 yrs	Plausibility Check by Gas Chromatography analysis.
B37	P_HNO <sub>3</sub> ,hist,IV Design capacity	Manufacturer's specifications	t	Measured / calculated	Once	100 %	Electronic	Crediting period + 2 yrs	
B38	T_g,hist,IV Historical operating temperature range of the ammonia oxidation reactor	Production reports / manufacturer's specification	°C	Measured / calculated	Once	100 %	Electronic	Crediting period + 2 yrs	
B39	P_g,hist,IV Historical operating pressure range of the ammonia oxidation reactor	Production reports / manufacturer's specifications	Pa	Measured / calculated	Once	100 %	Electronic	Crediting period + 2 yrs	
B40	T_g,IV Actual operating temperature ammonia oxidation reactor	Measuring device	°C	Measured	Continuous	100 %	Electronic	Crediting period + 2 yrs	

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B41	P_g,IV  Actual operating pressure ammonia oxidation reactor	Measuring device	Pa	Measured	Continuous	100 %	Electronic	Crediting period + 2 yrs	
B42	G_sup,IV  Supplier of the ammonia oxidation catalyst	Supplier's information	-					Crediting period + 2 yrs	
B43	G_com,IV  Composition of the ammonia oxidation catalyst	Annual reports, supplier's information	%		Date of changing gauze composition	100 %	Electronic	Crediting period + 2 yrs	
B44	G_sup,hist,IV  Historical supplier of ammonia oxidation catalyst	Annual reports, supplier's information	-		Once	100 %	Electronic	Crediting period + 2 yrs	
B45	G_com,hist,IV  Historical composition of the ammonia oxidation catalyst	Supplier's information	%		Date of start of use of catalyst	100 %	Electronic	Crediting period + 2 yrs	
B46	SE_N2O,IV  N <sub>2</sub> O emission rate per ton of nitric acid	Monitoring reports	tN <sub>2</sub> O/t HNO <sub>3</sub>	Calculated	Yearly	100 %	Electronic	Crediting period + 2 yrs	
B47	A_OR,hist,IV  Max. historical ammonia flow rate to the ammonia oxidation reactor	Production reports / manufacturer's specifications / literature	tNH <sub>3</sub> /day	Measured / calculated	Once	100 %	Electronic	Crediting period + 2 yrs	

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B48	A_OR,d,IV  Actual ammonia flow rate to the ammonia oxidation reactor	Measuring device	tNH <sub>3</sub> /day	Measured	Continuous	100 %	Electronic	Crediting period + 2 yrs	
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#### D.2.1.4. Description of formulae used to estimate baseline emissions (for each gas, source, formulae/algorithm, emissions units of CO<sub>2</sub> equ.)

Baseline emissions of the project activity are determined based on the quantity of N<sub>2</sub>O emitted in the baseline scenario, taking national regulations, production levels and operating conditions into consideration. The quantity of N<sub>2</sub>O is determined based on the measurement of the N<sub>2</sub>O at the inlet of the N<sub>2</sub>O destruction facility (EnviNOx<sup>®</sup>-System), which results in a conservative estimation of baseline emissions.

The N<sub>2</sub>O baseline emissions monitoring equipment will measure (1) the tail gas volume flow rate (temperature and pressure are also measured and the volume flow rate is automatically adjusted to standard temperature and pressure), (2) the N<sub>2</sub>O concentration at the inlet of the EnviNOx<sup>®</sup>-System, (3) the output of nitric acid and (4) the operating conditions of the ammonia oxidation reactor (temperature, pressure, ammonia flow rate). The amount of N<sub>2</sub>O baseline emissions can then directly be calculated by multiplying the tail gas volume flow rate and the N<sub>2</sub>O concentration or if the actual operating parameters and pressure are outside the range of permitted operating parameters by applying conservative default values. The baseline emissions are limited to the historical production levels of the existing nitric acid plant.

#### Baseline Emissions

Baseline emissions are given by the following equation:

$$BE_y = BE_{y,II} + BE_{y,III} + BE_{y,IV} = BE_{N_2O} \times GWP_{N_2O} \quad (40)$$

$$BE_{N_2O} = BE_{N_2O,II} + BE_{N_2O,III} + BE_{N_2O,IV} \quad (41)$$

where:

BE <sub>y</sub>	Baseline emissions in year y (tCO <sub>2</sub> e)
BE <sub>y,II</sub>	Baseline emissions Hu-Chems II in year y (tCO <sub>2</sub> e)
BE <sub>y,III</sub>	Baseline emissions Hu-Chems III in year y (tCO <sub>2</sub> e)
BE <sub>y,IV</sub>	Baseline emissions Hu-Chems IV in year y (tCO <sub>2</sub> e)
BE <sub>N<sub>2</sub>O,y</sub>	Baseline emissions of N <sub>2</sub> O in year y (tN <sub>2</sub> O)

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GWP_N2O	Global warming potential of N <sub>2</sub> O = 310
BE_N2O,II	Baseline emissions of N <sub>2</sub> O in year y at Hu-Chems II (tN <sub>2</sub> O)
BE_N2O,III	Baseline emissions of N <sub>2</sub> O in year y at Hu-Chems III (tN <sub>2</sub> O)
BE_N2O,IV	Baseline emissions of N <sub>2</sub> O in year y at Hu-Chems IV (tN <sub>2</sub> O)

The following equations have to be applied for Hu-Chems II, Hu-Chems III and Hu-Chems IV

Depending on the implementation of regulations on N<sub>2</sub>O emissions and the character of the regulation, baseline N<sub>2</sub>O emissions (BE<sub>N2O,y</sub>) are calculated as shown below:

**Case 1:** The most plausible baseline scenario is that no N<sub>2</sub>O would be abated in the absence of the project activity (i.e. no secondary or tertiary reductions measures and no NSCR DeNO<sub>x</sub> unit would be installed).

$$BE_{N2O,y} = QI_{N2O,y} \quad (42)$$

where:

BE_N2O,y	Baseline emissions of N <sub>2</sub> O in year y (tN <sub>2</sub> O)
QI_N2O,y	Quantity of N <sub>2</sub> O supplied to the destruction facility in year y (tN <sub>2</sub> O)

The quantity of N<sub>2</sub>O supplied to the N<sub>2</sub>O destruction facility (DF) is calculated based on continuous measurement of the tail gas volume flow rate and the N<sub>2</sub>O concentration at the inlet of the N<sub>2</sub>O destruction facility. Therefore the quantity of the N<sub>2</sub>O at the inlet is given by:

$$QI_{N2O,y} = \sum_{i=1}^n F_{TG,i} \times CI_{N2O,i} \times M_i \quad (43)$$

where:

QI_N2O,y	Quantity of N <sub>2</sub> O emissions at the inlet of the destruction facility in year y (tN <sub>2</sub> O)
F_TG,i	Volume flow rate at the inlet of the destruction facility during interval i (m <sup>3</sup> /h)
CI_N2O,i	N <sub>2</sub> O concentration at destruction facility inlet during interval i (tN <sub>2</sub> O/m <sup>3</sup> )
M_i	Length of measuring interval i (h)
i	Interval
n	Number of intervals during the year



Baseline emissions are limited to the design capacity of the existing nitric acid plant. If the actual production of nitric acid ( $P_{\text{HNO}_3,y}$ ) exceeds the design capacity ( $P_{\text{HNO}_3,\text{max}}$ ) then emissions related to the production above  $P_{\text{HNO}_3,\text{max}}$  will neither be claimed for the baseline nor for the project scenario.

If,  $P_{\text{HNO}_3,y} > P_{\text{HNO}_3,\text{max}}$  (44)

then

$BE_{\text{N}_2\text{O},y} = SE_{\text{N}_2\text{O},y} \times P_{\text{HNO}_3,\text{max}}$  (45)

where:

$BE_{\text{N}_2\text{O},y}$	Baseline emissions of $\text{N}_2\text{O}$ in year $y$ ( $\text{tN}_2\text{O}$ )
$SE_{\text{N}_2\text{O},y}$	Specific $\text{N}_2\text{O}$ emissions per output nitric acid in year $y$ ( $\text{tN}_2\text{O}/\text{tHNO}_3$ )
$P_{\text{HNO}_3,\text{max}}$	Design capacity ( $\text{tHNO}_3$ )

The specific  $\text{N}_2\text{O}$  emissions per unit of output nitric acid is defined as:

$SE_{\text{N}_2\text{O},y} = QI_{\text{N}_2\text{O},y} / P_{\text{HNO}_3,y}$  (46)

where:

$SE_{\text{N}_2\text{O},y}$	Specific $\text{N}_2\text{O}$ emissions per output nitric acid in year $y$ ( $\text{tN}_2\text{O}/\text{tHNO}_3$ )
$QI_{\text{N}_2\text{O},y}$	Quantity of $\text{N}_2\text{O}$ emissions at the inlet of the destruction facility in year $y$ ( $\text{tN}_2\text{O}$ )
$P_{\text{HNO}_3,y}$	Production of nitric acid in year $y$ ( $\text{tHNO}_3$ )

**Case 2:** Legal regulations for  $\text{N}_2\text{O}$  are implemented:

In case national regulations concerning  $\text{N}_2\text{O}$  emissions are implemented during the crediting period, the impact on baseline  $\text{N}_2\text{O}$  emissions is considered without any delay by adjusting the measured  $\text{N}_2\text{O}$  emissions at the time the regulation has to be implemented. Depending on the character of the regulation the adjustment is done as shown below:

**Case 2.1:** Regulation setting of a threshold for an absolute quantity of  $\text{N}_2\text{O}$  emissions per nitric acid plant over a given time period:

Baseline  $\text{N}_2\text{O}$  emissions are limited by the absolute quantity of  $\text{N}_2\text{O}$  emissions given by the regulation. If the measured baseline  $\text{N}_2\text{O}$  emissions are exceeding the regulatory limit, then measured baseline  $\text{N}_2\text{O}$  emissions are substituted by the regulatory limit.

This leads to the following condition:

If,

$QI_{\text{N}_2\text{O},y} > QR_{\text{N}_2\text{O},y}$  (47)

then,

$BE_{\text{N}_2\text{O},y} = QR_{\text{N}_2\text{O},y}$  (48)

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else,

$$BE_{N_2O,y} = \min \text{ of } [QI_{N_2O,y}, SE_{N_2O,y} \times P_{HNO_3,max}] \quad (49)$$

where:

$QI_{N_2O,y}$	Quantity of $N_2O$ emissions at the inlet of the destruction facility in year y (t $N_2O$ )
$QR_{N_2O,y}$	Regulatory limit of $N_2O$ emissions in year y (t $N_2O$ )
$BE_{N_2O,y}$	Baseline emissions of $N_2O$ in year y (t $N_2O$ )
$SE_{N_2O,y}$	Specific $N_2O$ emissions per output nitric acid in year y (t $N_2O$ /t $HNO_3$ )
$P_{HNO_3,y}$	Production of nitric acid in year y (t $HNO_3$ )

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 (see equation 11).



**Case 2.2:** Regulation setting of a threshold for specific N<sub>2</sub>O emissions per unit of product:

This leads to the following condition:

If,

$$SE_{N_2O,y} > RSE_{N_2O} \quad (50)$$

then,

$$BE_{N_2O,y} = \min \text{ of } [RSE_{N_2O} \times P_{HNO_3,y}, SE_{N_2O,y} \times P_{HNO_3,max}] \quad (51)$$

else,

$$BE_{N_2O,y} = \min \text{ of } [QI_{N_2O,y}, SE_{N_2O,y} \times P_{HNO_3,max}] \quad (52)$$

where:

SE <sub>N<sub>2</sub>O,y</sub>	Specific N <sub>2</sub> O emissions per output nitric acid in year y (tN <sub>2</sub> O/tHNO <sub>3</sub> )
RSE <sub>N<sub>2</sub>O</sub>	Regulatory limit of N <sub>2</sub> O emissions per output nitric acid (tN <sub>2</sub> O/tHNO <sub>3</sub> )
BE <sub>N<sub>2</sub>O,y</sub>	Baseline emissions of N <sub>2</sub> O in year y (tN <sub>2</sub> O)
P <sub>HNO<sub>3</sub>,y</sub>	Production of nitric acid in year y (tHNO <sub>3</sub> )
QI <sub>N<sub>2</sub>O,y</sub>	Quantity of N <sub>2</sub> O emissions at the inlet of the destruction facility in year y (tN <sub>2</sub> O)

The specific N<sub>2</sub>O emissions per unit of output nitric acid are defined as:

$$SE_{N_2O,y} = QI_{N_2O,y} / P_{HNO_3,y} \quad (53)$$

where:

SE <sub>N<sub>2</sub>O,y</sub>	Specific N <sub>2</sub> O emissions per output nitric acid in year y (tN <sub>2</sub> O/tHNO <sub>3</sub> )
QI <sub>N<sub>2</sub>O,y</sub>	Quantity of N <sub>2</sub> O emissions at the inlet of the destruction facility in year y (tN <sub>2</sub> O)
P <sub>HNO<sub>3</sub>,y</sub>	Production of nitric acid in year y (tHNO <sub>3</sub> )

The quantity of N<sub>2</sub>O emissions at the inlet of the N<sub>2</sub>O destruction facility is calculated based on continuous measurement of the tail gas volume flow rate and the N<sub>2</sub>O concentration at the inlet of the N<sub>2</sub>O destruction facility (see equation 11).



**Case 2.3:** Regulation setting of a threshold for N<sub>2</sub>O concentration in the tail gas

This leads to the following condition:

If,

$$C_{N_2O,y} > CR_{N_2O} \quad (54)$$

then

$$BE_{N_2O,y} = \sum_i^n C_{N_2O,i} \times [F_{TG,i} \times M_i] \quad (55)$$

where  $C_{N_2O,i}$  is  $\min [C_{N_2O,y}, CR_{N_2O}, \text{ and } \{(SE_{N_2O,y} \times P_{HNO_3,max}) / (\sum(F_{TG,i} \times M_i))\}]$

else,

$$BE_{N_2O,y} = QI_{N_2O,y} \quad (56)$$

where:

$C_{N_2O,i}$	N <sub>2</sub> O concentration at destruction facility inlet during interval i (tN <sub>2</sub> O/m <sup>3</sup> )
$CR_{N_2O,i}$	Regulatory limit for specific N <sub>2</sub> O concentration during interval I (tN <sub>2</sub> O/m <sup>3</sup> )
$BE_{N_2O,y}$	Baseline emissions of N <sub>2</sub> O in year y (tN <sub>2</sub> O)
$F_{TG,i}$	Volume flow rate of tail gas at destruction facility during interval i (m <sup>3</sup> /h)
$M_i$	Length of measuring interval i (h)
$i$	Interval
$n$	Number of intervals during the year
$QI_{N_2O,y}$	Quantity of N <sub>2</sub> O emissions at the inlet of the destruction facility in year y (tN <sub>2</sub> O)

The quantity of N<sub>2</sub>O emissions at the inlet of the N<sub>2</sub>O destruction facility is calculated based on continuous measurement of the tail gas volume flow rate and the N<sub>2</sub>O concentration at the inlet of the N<sub>2</sub>O destruction facility (see equation 11).

Change in NO<sub>x</sub> or N<sub>2</sub>O regulations will automatically cause a re-assessment of the baseline scenario.

**Procedures used to determine the permitted operating conditions of the nitric acid plants:**

In order to avoid that the operation of the nitric acid production plant is manipulated in a way to increase the N<sub>2</sub>O generation, thereby increasing the CERs, the following procedures relating to the operating temperature and pressure and the use of ammonia oxidation catalysts is applied.

**1. Operating temperature and pressure of the ammonia oxidation reactors (AOR) Hu-Chems II, III and IV:**

If the actual average daily operating temperatures or pressures in the ammonia oxidation reactors ( $T_g$  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 4.05 kg N<sub>2</sub>O/ton nitric acid, (b)  $SE_{N_2O,y}$  and (c) any related value as a result of legal regulations (e.g.  $RSE_{N_2O,y}$ ).

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)
$P_{g,hist}$	Historical operating pressure range AOR (Pa)

The Hu-Chems nitric acid plants II, III and IV are equipped with three ammonia oxidation reactors. AOR at Hu-Chems II and Hu-Chems III are identical. The gauze temperature in each burner is continuously measured by two sensors in each AOR. Theoretically both temperature sensors in one AOR should show the same value.

In fact, the historical data show rather large differences between the measured temperatures inside the same AOR. In the years 2003-2005 the difference between the indicated temperature in e.g. Hu-Chems IV (Sensor 1: 324TI4116A; Sensor 2: 324TI4116C) was about 20K in lower measuring range and about 10K in the higher measuring range, with sensor 2 apparently being higher. These differences are technically impossible and are most likely to be attributable to loss of calibration or to deterioration of the thermoelements over time. It is very unlikely that the indicated temperatures correspond to the true gauze temperatures.

Since the gauze temperatures are important parameters in the operation of the nitric acid plants, Hu-Chems will either change the thermoelements in the AOR or calibrate them prior to the starting date of the project activity (during the shutdown for project implementation), to obtain more accurate gauze temperature measurements.

After the calibration or exchange of the thermoelements the historical operating temperatures will not be directly related to the new, measured values, so an interpretation and definition of normal range of operation based on the values of the recalibrated / exchanged temperature elements will be uncertain or even wrong. Therefore the permitted operating range of temperature in the ammonia oxidation reactor is based on the normal range of operating conditions for the ammonia oxidation reactors according to Uhde’s operating manual for the Hu-Chems nitric acid plants.



Therefore the permitted range of operation temperature is determined by

<b>T<sub>g,hist,II</sub></b>	880°C to 910°C from the operating manual provided by the technology provider Uhde
<b>T<sub>g,hist,III</sub></b>	880°C to 910°C from the operating manual provided by the technology provider Uhde
<b>T<sub>g,hist,IV</sub></b>	860°C to 910°C from the operating manual provided by the technology provider Uhde

The operating pressure is continuously measured by pressure transmitter in the air compressor discharge line. In fact historical data are available for the Hu-Chems nitric acid plants, but due to loss of calibration or possible deterioration of the measuring devices over time it is very unlikely that the indicated pressures correspond to the true gauge pressures.

Since also the gauge pressure is an important parameter in the operation of the nitric acid plants, Hu-Chems will either change the pressure measuring devices or calibrate them prior to the starting date of the project activity (during the shutdown for project implementation), to obtain more accurate pressure measurements. After the calibration or exchange of the pressure measurement devices the historical operating pressures will not be directly related to the new, measured values, so an interpretation and definition of normal range of operation based on the values of the recalibrated / exchanged pressure elements will be incorrect. Therefore the permitted operating range of pressure is based on normal operating conditions for the ammonia oxidation reactors according to Uhde's operating manual for the Hu-Chems nitric acid plants II, III and IV.

The effect of pressure in the ammonia oxidation catalyst on N<sub>2</sub>O generation in ammonia oxidation on gauzes:

Lower pressure in the burner leads to lower formation of N<sub>2</sub>O. This can be concluded from the following. The effect of pressure on the amount of N<sub>2</sub>O formed in the ammonia oxidation reactor is well-known and is the reason for monitoring this and other operating parameters that may influence N<sub>2</sub>O formation according to AM0028 and applying a conservative default value if a parameter goes out of range.

- Kongshaug (1998)<sup>5</sup> states, for example, that the N<sub>2</sub>O concentration in nitric acid tail gases ranges from about 700 – 1300 ppm (corresponding to 4.4 to 8.1 kg N<sub>2</sub>O / t HNO<sub>3</sub>) and goes on to say in the next sentence that increasing the pressure slightly increases N<sub>2</sub>O emission.
- Further support for the effect of pressure on N<sub>2</sub>O generation is provided by the IPCC Guidelines. Given N<sub>2</sub>O generation factors [kg N<sub>2</sub>O / t HNO<sub>3</sub>] clearly demonstrate that higher pressure in the burner leads to higher formation of N<sub>2</sub>O.
- Hand in hand with reduced N<sub>2</sub>O generation at lower pressures goes an increase in ammonia burner efficiency. That is, the proportion of the ammonia entering the burner which is converted to nitric oxide (NO) increases as the pressure is reduced. This is documented, for example, by Keleti (1985)<sup>6</sup> The ammonia conversion efficiency ranges from 94%-95% for 10.5 bar burners up to 97%-98% for atmospheric pressure burners.

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<sup>5</sup> Kongshaug (1998): Energy Consumption and Greenhouse Gas Emissions in Fertilizer Production. Kongshaug, G. IFA Technical Conference, Marrakech, Morocco, 1998. Available from the International Fertilizer Industry Association at <[http://www.fertilizer.org/ifa/publicat/pdf/1998\\_biblio\\_65.pdf](http://www.fertilizer.org/ifa/publicat/pdf/1998_biblio_65.pdf)>

<sup>6</sup> Keleti (1985): Nitric Acid and Fertilizer Nitrates", Cornelius Keleti (Ed.), p.67, Marcel Dekker Inc., New York, 1985 ISBN,0-8247-7332-2  
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- The effect is also illustrated in Ullmann (1991)<sup>7</sup> on page 298, which shows ammonia conversion efficiency (to NO) as a function of gauze temperature for pressures of 1 bar abs and 4 bar abs. The conversion efficiency is 2-3% points lower at 4 bar than at 1 bar.

It is therefore obvious to conclude that if the burner pressure is lower the amount of N<sub>2</sub>O generated will decrease and the upper limit of permitted operating pressure is the deciding factor in order to avoid gaming.

The permitted operating range of pressure is based on normal operating conditions for the ammonia oxidation reactors according to Uhde's operating manual for the Hu-Chems nitric acid plants II, III and IV.

**P\_g,hist,II** 5.0 barg to 9.8 barg from the operating manual provided by the technology provider Uhde.

**P\_g,hist,III** 5.0 barg to 9.8 barg from the operating manual provided by the technology provider Uhde.

**P\_g,hist,IV** 2.2 barg to 4.4 barg from the operating manual provided by the technology provider Uhde.

If the permissible operating limit recommended in Uhde's operating manual is exceeded for either temperature or pressure, the baseline N<sub>2</sub>O emissions for the relevant period are capped at the conservative level of 4.05 kgN<sub>2</sub>O/tHNO<sub>3</sub>.

## 2. Composition of ammonia oxidation catalysts Hu-Chems II, III and IV:

Hu-Chems 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<sub>2</sub>O baseline emissions.

In case Hu-Chems 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<sub>2</sub>O baseline emissions.

In case Hu-Chems 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<sub>2</sub>O 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<sub>2</sub>O baseline emissions.

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<sup>7</sup> Ullmann (1991): Ullmann's Encyclopedia of Industrial Chemistry, 5th Ed. Vol. A17, Naphthalene to Nuclear Technology, p.315 VCH Verlagsgesellschaft mbH, Weinheim, Germany, (1991), ISBN 3-527-20117-3



The first composition of ammonia oxidation catalyst used during the crediting period shall be of the same kind of catalyst composition already in operation in the specific nitric acid plant. This is to avoid gaming at the beginning of the project activity.

In case Hu-Chems 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<sub>2</sub>O emissions of previous periods (tN<sub>2</sub>O/tHNO<sub>3</sub>), documented in the verified monitoring reports.

Required monitoring parameters:

G <sub>sup</sub>	Supplier of the ammonia oxidation catalyst
G <sub>sup,hist</sub>	Historical supplier of the ammonia oxidation catalyst
G <sub>com</sub>	Composition of the ammonia oxidation catalyst
G <sub>com,hist</sub>	Historical composition of the ammonia oxidation catalyst
SE <sub>N2O,y</sub>	Specific N <sub>2</sub> O emissions per ton HNO <sub>3</sub> in year y (tN <sub>2</sub> O/tHNO <sub>3</sub> )

The specification for catalyst gauzes at Hu-Chems nitric acid plants is:

- Hu-Chems II and III: 90% Platinum, 5% Rhodium and 5% Palladium manufactured by the reputable manufacturers Umicore and/or Johnson Matthey;
- Hu-Chems IV: 95% Platinum, 5% Rhodium and/or 92% Platinum, 8% Rhodium manufactured by the reputable manufacturers Umicore and/or Johnson Matthey.

It is Hu-Chems intention to continue using a common ammonia oxidation catalyst produced by a reputable manufacturer during the crediting period. The composition of the ammonia oxidation catalysts to be used for the first campaign after project start will be of the same kind of catalyst compositions as already in operation in Hu-Chems nitric acid plants.



### 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 is determined by plant specific historical operating data on the maximum daily average ammonia flow.

Required monitoring parameters on daily basis:

A\_OR,d                      Actual ammonia input to oxidation reactor (tNH<sub>3</sub>/day)

A\_OR,hist                Maximum historical ammonia input to oxidation reactor (tNH<sub>3</sub>/day)

Analysis of the historical data for the years 2000-2005 for Hu-Chems II, III and 2003-2005 for Hu-Chems IV documents the maximum ammonia input to the ammonia oxidation reactor of Hu-Chems II, III and IV:

**A\_OR,hist,II**    91.82 tNH<sub>3</sub>/day

**A\_OR,hist,III**   92.57 tNH<sub>3</sub>/day

**A\_OR,hist,IV**   355.50 tNH<sub>3</sub>/day

If the daily ammonia input to the oxidation reactor exceeds the limit on permissible ammonia input, baseline N<sub>2</sub>O emissions are capped at conservative IPCC default values.

**D. 2.2. Option 2: Direct monitoring of emission reductions from the project activity (values should be consistent with those in section E).**

Not applicable, Option 1 is chosen.

**D.2.2.1. Data to be collected in order to monitor emissions from the project activity, and how this data will be archived:**

ID number (Please use numbers to ease cross-referencing to table D.3)	Data variable	Source of data	Data unit	Measured (m), calculated (c), estimated (e),	Recording frequency	Proportion of data to be monitored	How will the data be archived? (electronic/paper)	Comment

**D.2.2.2. Description of formulae used to calculate project emissions (for each gas, source, formulae/algorithm, emissions units of CO<sub>2</sub> equ.):**

Not applicable, Option 1 is chosen.

**D.2.3. Treatment of leakage in the monitoring plan****D.2.3.1. If applicable, please describe the data and information that will be collected in order to monitor leakage effects of the project activity**

ID number (Please use numbers to ease cross-referencing to table D.3)	Data variable	Source of data	Data unit	Measured (m), calculated (c) or estimated (e)	Recording frequency	Proportion of data to be monitored	How will the data be archived? (electronic/paper)	Comment

**D.2.3.2. Description of formulae used to estimate leakage (for each gas, source, formulae/algorithm, emissions units of CO<sub>2</sub> equ.)**

At the nitric acid plants Hu-Chems II, III and IV energy converters (tail gas turbines) are installed at the end of the pipe. The installation of the N<sub>2</sub>O destruction facilities will therefore not result in significant additional energy consumption and no leakage is expected. Therefore no monitoring mechanism is being suggested.

**D.2.4. Description of formulae used to estimate emission reductions for the project activity (for each gas, source, formulae/algorithm, emissions units of CO<sub>2</sub> equ.)**

The emission reduction (ER<sub>y</sub>) by the project activity during a given year y is the difference between the baseline emissions (BE<sub>y</sub>) and project emissions (PE<sub>y</sub>), as follows:

$$ER_y = BE_y - PE_y - LE_y \quad . \quad (57)$$

where:

ER <sub>y</sub>	emissions reductions of the project activity during the year y (tCO <sub>2</sub> e)
BE <sub>y</sub>	baseline emissions during the year y (tCO <sub>2</sub> e)
PE <sub>y</sub>	project emissions during the year y (tCO <sub>2</sub> e)
LE <sub>y</sub>	leakage emissions in year y (tCO <sub>2</sub> e)



<b>D.3. Quality control (QC) and quality assurance (QA) procedures are being undertaken for data monitored</b>		
Data (Indicate table and ID number e.g. 3.-1.; 3.2.)	Uncertainty level of data (High/Medium/Low)	Explain QA/QC procedures planned for these data, or why such procedures are not necessary.
B.1, B20, B34	Low	<p><i>Meters used to measure the nitric acid production are already installed at Hu-Chems II, III, IV and are integrated in Hu-Chems quality management system (ISO 9002). The calculation of nitric acid production considers the daily average concentration and density.</i></p> <p><b>Check at the beginning of the project:</b></p> <ul style="list-style-type: none"> <li><i>The nitric acid flow meter and the density meter will be checked by Hu-Chems instrumentation technician to ensure it is operating in accordance with the manufactures' instructions.</i></li> </ul> <p><b>Regular check during the project lifetime:</b></p> <ul style="list-style-type: none"> <li><i>Maintenance and checking are carried out as specified by manufacturer. All work carried out will be documented.</i></li> <li><i>The acid density and concentration is measured on regular basis by Hu-Chems laboratory and compared with any online measurements. If the acid density / concentration measurement is made by means of a portable device the portable device is to be compared with laboratory results, or calibrated at supplier-specified intervals. All observations are to be recorded. If deviations are found appropriate remedial action is to be taken.</i></li> <li><i>Hu-Chems will also contact plausibility checks on a regular basis based on the ammonia nitrogen balance of the plant. The input of ammonia nitrogen is the ammonia flow to the ammonia oxidation reactor. The outputs are N<sub>2</sub>O at the inlet of the N<sub>2</sub>O destruction facility and NO<sub>x</sub> at the inlet of the N<sub>2</sub>O destruction facility. The major output is product acid. An assumption must be made about the amount of ammonia nitrogen converted to elemental nitrogen, N<sub>2</sub>. Before carrying out a plausibility check of this kind, the nitric acid plant should be operated at constant conditions for several hours to minimise the effects of tower sump pumpout and time delays between the ammonia oxidation reactor and the product nitric acid.</i></li> </ul> <p><i>QA/QC program will be integrated in Hu-Chems management systems ISO 9002 and ISO 14001.</i></p>



<p>B.10, B25, B38 B11, B26, B41</p>	<p>Low</p>	<p><i>The actual temperature and pressure at the ammonia oxidation catalyst will be measured with the already installed or exchanged measuring devices (see below). After temperature measurement maintenance and testing regime the following accuracies are expected:</i></p> <p><i>Temperature Hu-Chems II: 322-TR-2-115 and 322-TIAS-2-116 (Degree of accuracy about +/- 0.1 %)</i>  <i>Temperature Hu-Chems III: 323-TR-3-115 and 323-TIAS-3-116 (Degree of accuracy about +/- 0.1 %)</i>  <i>Temperature Hu-Chems IV: 324-TI-4-106A and 324-TI-4-106C (Degree of accuracy about +/- 0.1 %)</i></p> <p><i>Pressure Hu-Chems II: 322-PRAH-2-304 (Degree of accuracy about +/- 0.1%)</i>  <i>Pressure Hu-Chems III: 323-PRAH-3-304 (Degree of accuracy about +/- 0.1%)</i>  <i>Pressure Hu-Chems IV: 324-PI-305A and 305B (Degree of accuracy about +/- 0.1%)</i></p> <p><i>Check at the beginning of the project:</i></p> <ul style="list-style-type: none"> <li><i>Temperature measurement devices will be tested, calibrated and if required exchanged to ensure it is operating in accordance with the manufactures' instructions.</i></li> <li><i>Pressure measurement device will be tested, calibrated and if required exchanged to ensure it is operating in accordance with the manufactures' instructions.</i></li> </ul> <p><i>Regular check during the project lifetime:</i></p> <ul style="list-style-type: none"> <li><i>Maintenance and testing are carried out as specified by manufacturer. All work carried out will be documented.</i></li> </ul> <p><i>Temperature and pressure sensors, transmitters and recording devices will be subject to a regular maintenance and testing regime according to manufacturer instruction – unless it is seen from recorded data that the readings are abnormal.</i></p>
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P.8, P22, P36	Low	<p><i>The tail gas flows are measured by using venturi tubes, which are designed and manufactured in accordance with ISO 5167-4:2003. The venturi tubes are of rough welded sheet iron type with annular pressure tapping chambers. Differential pressure is measured with two (redundant) differential pressure transmitters. For calculation of the volume flow rate at standard conditions or (with known molecular weight) the mass flow, the system is equipped with two (redundant) pressure transmitters and two (redundant) temperature measurements.</i></p> <p><i>The uncertainty of the mass flow measurement with the venturi tube is to be calculated with the formula given in ISO 5167-1:2003, chapter 8.2.2. Numerical evaluation of the formula given in ISO 5167 results in a total uncertainty of the flow measurement of about 2 % of the actual value. Details are described in the Monitoring Plan.</i></p> <p><i>Standard Conditions:</i> <i>Temperature: 273.15 K</i> <i>Pressure: 1013.25 hPa</i></p> <p><i>Flow meter and associated transmitter and recoding devices will be subject to maintenance and testing regime to ensure accuracy (according to manufacturer instructions).</i></p>
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<p>P9, P23, P37 B3, B22, B36</p>	<p>Low</p>	<p><u>Hu-Chems II,III,IV:</u> In the feed of the EnviNOx®- system, the concentrations of nitrous oxide (N<sub>2</sub>O), nitric oxide (NO) and nitrogen dioxide (NO<sub>2</sub>) are analysed continuously. Analysis is done by using non-dispersive infrared photometry in a combined analyser device. Sample handling includes provisions for pressure reduction, separation of residual solids, sample flow adjustment, and supply with test gases. The analyser is, as far as technically possible, corrected for any applicable cross sensitivity.</p> <p>In the effluent of the EnviNOx®- system, the concentrations of nitrous oxide (N<sub>2</sub>O), nitric oxide (NO) plus nitrogen dioxide (NO<sub>2</sub>) are analysed continuously. Analysis is done by using non-dispersive infrared photometry for N<sub>2</sub>O and chemoluminescence for NO and NO<sub>2</sub>. Sample handling includes provisions for pressure reduction, separation of residual solids, sample flow adjustment, and supply with test gases. The analysers are, as far as technically possible, corrected for any applicable cross sensitivity.</p> <p>The manufacturer specifies a relative accuracy of 1 % of the measuring range, assuming that zero and span adjustment is performed regularly as requested in instrument documentation. This accuracy refers to the applied calibration standard, which again has an uncertainty. Best commercially available test gases for calibration have an uncertainty of 1 %. So, using the gaussian law of error propagation, the accuracy of the analysers is 1.41%.</p> <p>Both N<sub>2</sub>O concentration measurement devices will be subject to regular maintenance and testing regime to ensure accuracy.</p>
<p>P10, P24, P38</p>	<p>Low</p>	<p>Time stamps are generated by a GPS clock module.</p>
<p>P13, P27 B19, B33, B48</p>	<p>Low</p>	<p>The propane used as reducing agent will be measured by standard flow meters manufactured by. Flow is converted to standard conditions based on temperature and pressure measurement.</p> <p>Flow meter: Degree of accuracy: +/- 1.6% of adjusted range Temperature: Degree of accuracy: +/- 0.1% of adjusted range Pressure: Degree of accuracy: +/- 0.1% of adjusted range</p> <p>The actual ammonia flow to the ammonia oxidation reactor will be measured with the already installed measuring devices. Flow is converted to standard conditions based on temperature and pressure measurements.</p> <p>All meters will be subject to regular maintenance and testing regime once per year to ensure accuracy.</p>

**D.4 Please describe the operational and management structure that the project operator will implement in order to monitor emission reductions and any leakage effects, generated by the project activity**

Hu-Chems will operate the EnviNOx<sup>®</sup>-System and the measurement equipment. The company has been operating the nitric acid plants plant since the commissioning of the plant and has sufficient and well experienced staff to operate similar technologies (like the existing DeNO<sub>x</sub>-unit) and is quite experienced in calibrating and maintaining monitoring equipment.. The company is ISO 9002 and ISO 14001 certified and received the Korean safety and health management system certificate (KGS18001 & OHSAS18001).

CARBON has concluded a contract with UHDE as well as with the provider of the measurement equipment for a continuously supervision and maintenance of the EnviNOx<sup>®</sup>-System as well as the measurement equipment. In case of any emergencies, such as failure of the EnviNOx<sup>®</sup>-System or failure of the measurement equipment, the technology provider Uhde and the supplier of the measurement equipment will be available.

The supplier of the measurement equipment will carry out an on-site training course for operation and maintenance of the measurement equipment prior to the start of the crediting period. Contents and procedures are detailed in the manufacturer's documentation. Uhde will also carry out an on-site training for operation and maintenance of the EnviNOx<sup>®</sup> system. Contents and procedures are also detailed in the manufacturer's documentation. For these purposes a training protocol will be prepared.

The EnviNOx<sup>®</sup>-System and the monitoring is designed for automatic operation, so that activities by operation personnel are not required during normal operation. However, it is required to observe the system for possible failures, and to perform required maintenance activities on a regular basis. All operational requirements are described the operating manuals for the EnviNOx<sup>®</sup>-System and the measurement equipment.

Malfunction of system components is indicated on the operator (Hu-Chems) console in the control room as an alarm. Occurrence of such an alarm requires the operator to immediately take measures to remedy the problem. This is normally done by informing the instrument department, which is then deciding whether the problem can be fixed immediately by themselves, or whether external support from manufacturer is required. In such a case it is important to act immediately in order to avoid loss of valuable data. The technology provider is also readily available for electronic consultations. Detailed instructions on how to proceed in such cases are given in manufacturer's documentation.

**D.5 Name of person/entity determining the monitoring methodology:**

(The following are not project participants)

<i>Name</i>	<i>Project Participant Yes / No</i>
CARBON Projektentwicklung GmbH Ortsring 41 A-3485 Grunddorf AUSTRIA Tel. +43 2735 77 135 Fax. +43 2735 20 531  Gerald Dunkel Ferdinand Heilig  Email: dunkel@carbon-austria.com Email: heilig@carbon-austria.com	<b>NO</b>



#### **Annex 4**

### **MONITORING PLAN**

The “Catalytic N<sub>2</sub>O destruction project in the tail gas of three Nitric Acid Plants at Hu-Chems Fine Chemical Corp.” employs the latest state of the art monitoring and control equipment that measures, records and reports all key parameters to determine the GHG emission reductions.

The Monitoring Plan describes the procedures for data collection and auditing required for the project in order to determine and verify the emission reductions achieved by the project activity. Historical data required for the project monitoring are already being collected and documented in this Project Design Document. All remaining required data are automatically transferred to the digital process control system where they are displayed, evaluated, and stored. Evaluation includes calculation of flow rate at standard conditions and mass flow rates of N<sub>2</sub>O. The system also performs calculation of daily mean values and generates automated reports.

The monitoring methodology for the project is fully activity in compliance with the applied approved monitoring methodology AM0028. The monitoring procedures will be fully integrated in Hu-Chems quality and environmental management system. Please note, Hu-Chems is already ISO 9002 and ISO 14001 certificated. All monitoring equipment will be serviced, calibrated and maintained according to the manufacturers’ instructions and international standards. Parameters to be monitored are described in section D.

It is the responsibility of the Project Developer and Project Operator to ensure that required and experienced capacity is available and that their operational staffs participate in training to be enable to operate the monitoring system properly. Initial training will be provided to the staff before the project activity starts operation. It is also the responsibility of the Project Developer and Project Operator to organize and implement a quality management system that ensures the integrity of the data.

#### **Monitoring equipment:**

To permit the greenhouse gas emission reduction to be calculated accurately, a direct measurement of the quantity of tail gas flowing through the EnviNOx® reactor is necessary. A venturi tube located downstream of the reactor and designed and installed according to the international standard ISO 5167:2003 Part 4 provides the required flow rate. The measurement is temperature and pressure compensated.

As the tail gas flow rate is an important parameter for the greenhouse gas emission reduction calculation several special measures have been taken to ensure that the indicated flow rate is accurate.

These are:

1. Before the venturi tube is installed the dimensions of the venturi tube will be checked and verified at the manufacturer’s factory.
2. The differential pressure, temperature and pressure transmitters that provide the signals from which the tail gas flow rate is calculated are installed in duplicate. This enables problems with faulty transmitters to be identified at an early stage and rectifying action taken.
3. Connections for independent measurement of the primary process parameters during normal operation are provided. Thus a thermowell and a connection for a manometer are installed



upstream of the venturi tube. The venturi tube is fitted with additional fittings for connecting a differential pressure gauge.

Tail gas is drawn off continuously from upstream of the tail gas / ammonia / propane mixer and downstream of the EnviNOx® reactor. The two analyser chains are independent of one another but located in a common instrument container. The concentrations of the components N<sub>2</sub>O, NO<sub>x</sub> (inlet and outlet) are measured.

Measured data are stored and evaluated in a digital process control system, which also provides control functions for the EnviNOx®- system. Data storage is multiple redundant and manipulation-proof.

Measurement of tail gas flow (Hu-Chems II, III, IV):

The tail gas flow is measured by using a venturi tube, which is designed and manufactured in accordance with ISO 5167-4:2003. The venturi tube is of rough welded sheet iron type with annular pressure tapping chambers. Differential pressure is measured with two (redundant) differential pressure transmitters. For calculation of the volume flow rate at standard conditions or (with known molecular weight) the mass flow, the system is equipped with two (redundant) pressure transmitters and two (redundant) temperature measurements.

On-line analysis of tail gas feed (Hu-Chems II, III, IV):

In the feed of the EnviNOx®- system, the concentrations of nitrous oxide (N<sub>2</sub>O), nitric oxide (NO) and nitrogen dioxide (NO<sub>2</sub>) are analysed continuously.

	N <sub>2</sub> O	NO	NO <sub>2</sub>
	ppm	ppm	ppm
Hu-Chems II	0 - 3000	0 - 150	0 - 100
Hu-Chems III	0 - 3000	0 - 150	0 - 100
Hu-Chems IV	0 - 2000	0 - 400	0 - 400

Analysis is done by using non-dispersive infrared photometry in a combined analyser device. The analyzer will take readings at least at 1 minute intervals. Readings of these raw data will be stored. Based on the raw data average daily figures will be calculated, reported and stored at the data storage system. Sample handling includes provisions for pressure reduction, separation of residual solids, sample flow adjustment, and supply with test gases. The analyser is, as far as technically possible, corrected for any applicable cross sensitivity.

Plausibility is regularly checked by laboratory measurement of N<sub>2</sub>O concentrations. Hu-Chems staff regularly is taking samples from the sampling systems of the analysers and Hu-Chems laboratory is analysing N<sub>2</sub>O concentrations using Gas Chromatography, following the respective ISO Quality Management Procedure.

On-line analysis of tail gas effluent (Hu-Chems II, III, IV):

In the effluent of the EnviNOx®- system, the concentrations of nitrous oxide (N<sub>2</sub>O) and nitric oxide (NO) plus nitrogen dioxide (NO<sub>2</sub>) are analysed continuously.

	N <sub>2</sub> O	NO + NO <sub>2</sub>
	ppm	ppm
Hu-Chems II	0 – 200	0 - 20
Hu-Chems III	0 - 200	0 - 20
Hu-Chems IV	0 - 100	0 - 50

Analysis is done by using non-dispersive infrared photometry for N<sub>2</sub>O and chemoluminescence for NO and NO<sub>2</sub>. The analyzer will take readings continuously (at least at 1 minute intervals) with a lag time of less than 200 seconds. Readings of these raw data will be stored. Based on the raw data average daily figures will be calculated, reported and stored at the data storage system. Sample handling includes provisions for pressure reduction, separation of residual solids, sample flow adjustment, and supply with test gases. The analysers are, as far as technically possible, corrected for any applicable cross sensitivity.

Plausibility is regularly checked by laboratory measurement of N<sub>2</sub>O concentrations. Hu-Chems staff regularly is taking samples from the sampling systems of the analysers and Hu-Chems laboratory is analysing N<sub>2</sub>O concentrations using Gas Chromatography, following the respective ISO Quality Management Procedure.

Actual production of Nitric Acid (Hu-Chems II, III, IV):

The actual nitric acid production is measured according to the already installed instruments. The instrument signals will be recorded in control rooms and used to determine whether the nitric acid production is within the historical designed capacity. Recorded nitric acid production data considers concentration and density. Analysis is done by the Hu-Chems laboratory three times a day.

Actual temperature and pressure of the ammonia oxidation reactor (Hu-Chems II, III, IV):

Since the gauze temperatures and pressures are important parameters in the operation of the nitric acid plant, Hu-Chems will either change the thermoelements in the burners / pressure measuring devices or calibrate them prior to the starting date of the project activity (during the shutdown for project implementation), to obtain more accurate gauze temperature measurements.

The actual temperature and pressure of the ammonia oxidation reactor is monitored using the calibrated existing (or exchanged) instruments in the nitric acid plants Hu-Chems II, III, IV. The instrument signals will be recorded in the control rooms and used to determine whether the nitric acid plant is being operated within the normal range of operation (daily basis).

Actual ammonia input to the ammonia oxidation reactor (Hu-Chems II, III, IV):

The actual ammonia flow to the ammonia oxidation reactor is monitored using the existing instruments in the nitric acid plants Hu-Chems II, III and IV. The instrument signals will be recorded in the control rooms and used to determine whether the nitric acid plant is being operated within the normal range of operation (daily basis). Ammonia flow is converted to standard conditions based on temperature and pressure measurement.

**Composition of the ammonia oxidation catalyst (Hu-Chems II, III, IV):**

The composition of the ammonia oxidation catalyst will be monitored according to catalyst supplier information.

**Propane input (Hu-Chems II, III):**

The propane used as reducing agent will be measured by standard flow meters. Flow is converted to standard conditions based on temperature and pressure measurements.

**Data acquisition and storage Hu-Chems II, III, IV:**

The measured values are transferred to a digital process control system (Delta V, M/s. Emerson Process Management), where they are displayed, evaluated, and stored. Evaluation includes calculation of flow rate at standard conditions and mass flow rates of N<sub>2</sub>O. The system also performs calculation of daily mean values and generates reports. Data storage for raw data as well as for evaluated data is done automatically on a computer network which is directly connected to the process control system. Data storage is designed redundantly on two separate computers, located at different locations, each equipped with a redundant array of hard disks. Network connections are redundant fibre optic links. The software for data storage is designed in a way that manipulation of data is excluded, and that any change of configuration is recorded. Time stamps are generated by a GPS clock.

**Instrument Container, DCS and data logging:**

The instrument containers house the analysers, parts of the sample handling system, and the controllers of the DCS (three containers, one for each nitric acid plant). Data logging is carried out with redundant storage on two computers. It controls the EnviNOx® system, generates alarm and trip signals as necessary and logs all process data in the EnviNOx® system area and, in addition, selected operating data from the nitric acid plants, as required by the relevant CDM methodology AM0028. These are mainly the operating parameters of the ammonia oxidation burners.

**Operation of the Monitoring system:**

The system is designed for automatic operation, so that activities by operation personnel are not required during normal operation. However, it is required to observe the system for possible failures, and to perform required maintenance activities on a regular basis.

**Training:**

As mentioned above the proposed project activity also includes training course for operation of the EnviNOx® system and also for accurate monitoring. It is Hu-Chems responsibility to ensure that the required capacity and internal training is made available to assigned staff, to enable them to undertake the tasks required by the project operation and monitoring. All staff involved in any procedures will be trained before the start of the crediting period.



The supplier of the measurement equipment will carry out an on-site training course for operation and maintenance of the measurement equipment prior to the start of the crediting period. Contents and procedures of the training are detailed in the operating manual of the monitoring system. Uhde will also carry out an on-site training for operation and maintenance of the EnviNOx® system. For these purposes a training protocol will be prepared.

#### Troubleshooting procedures:

Malfunction of system components is indicated on the operator console in the control room as an alarm. The occurrence of such an alarm requires the operator to immediately take measures to remedy the problem. This is normally done by informing the instrument department, which then decides whether the problem can be fixed immediately by themselves, or whether external support from manufacturer is required. In such a case it is important to act immediately in order to avoid loss of valuable data. Detailed instructions on how to proceed in such cases are given in the manufacturer's documentation.

The probability of downtime or malfunctions of the measuring instruments and/or data storage is very low. In those cases (data availability of raw data for certain day is less than 90%) the following procedures should be applied:

- Concentration measurements: If the plant operator can provide suitable operating parameters (e.g. nitric acid production, ammonia flow to ammonia oxidation gauzes) to demonstrate that the plant is operating under normal conditions, then the estimation of emission reduction will be based on correlation methods, applying the parameter with the highest historical correlation to the missing parameter (e.g. efficiency of the EnviNOx® system; the reactor inlet or outlet temperature; the flow of N<sub>2</sub>O reducing agent to the reactor). Historical data on the last campaign shall provide evidence on correlation.
- Flow measurements: If the plant operator can provide suitable operating parameters (e.g. nitric acid production, ammonia flow to ammonia oxidation gauzes) to demonstrate that the plant is operating under normal conditions and the plant operator can demonstrate that the EnviNOx® reactor bypass was closed, then the estimation of emission reduction will be based on correlation methods, applying the parameter with the highest historical correlation to the missing parameter (e.g. specific tail gas flow per nitric acid output). Historical data on the last campaign shall provide evidence on correlation.

In such cases it is indispensable to act immediately in order to avoid further loss of valuable data.

#### Adjustment, calibration and maintenance:

The analysers need an adjustment ('calibration') on a regular basis (e.g. zero point: every 2 days). This adjustment procedure is done automatically, and can be triggered manually from the operating console or automatically on a time basis.

Since adjustment is done with test gases, it is essential that availability of test gases is ensured. Hu-Chems instrument technician are responsible for the availability of test gas. Stock of test gases will be controlled regularly, and spare supply is made available in proper time. Test gas consumption is approximately one cylinder per year of each type of span gas, and two cylinders per year of zero gas (nitrogen 99.999 %). A detail specification for the various test gases to be used will be available from analyser manufacturer.

A general revision of the system is advised to be performed once a year. Such a revision shall include (but not be limited to) following activities:



- Check of calibration and zero adjustment of all pressure transmitters, readjustment where required (as long as not required otherwise by manufacturer).
- Check of contamination of sample lines and impulse lines, cleaning if required.
- Check of correct function of analyser sampling system by applying test gas at the begin of the sample lines.

Further activities may be requested by manufacturer or other parties, also depending on results from test run.

#### Internal control process:

Hu-Chems will perform a visual inspection of system on a regular basis by the operating staff (e.g. once every week). Such an inspection can give indications on oncoming problems and allow to be prepared for them.

Data export from the data storage is to be done manually upon operational requests, but at least once a month. Detailed instructions are given by the manufacturer.

Hu-Chems already conduct periodic plausibility checks based on the ammonia nitrogen balance of the plant. Such plausibility checks will be conducted and documented for nitric acid production during the crediting period.

Internal review of project performance and calculation of emission reductions will be executed by CARBON CDM Korea with the support of Hu-Chems on a regular basis (e.g. daily). Weekly reports will be reviewed by CARBON Projektentwicklung GmbH. Note, compliance with operational requirements (e.g. temperature and pressure of ammonia oxidation reactor) is fully integrated in the digital process control system.

#### Verification:

Quarterly verification will be executed for this CDM project.

#### Uncertainties of measurement:

Analysers: The manufacturer specifies a relative accuracy of 1 % of the measuring range, assuming that zero and span adjustment is performed regularly as requested in instrument documentation. The analysis of N<sub>2</sub>O downstream of the EnviNOx®- reactor, in particular, requires a regular (e.g. every second day) zero adjustment to achieve this accuracy.

This accuracy refers to the applied calibration standard, which again has an uncertainty. Best commercially available test gases for calibration have an uncertainty of 1 %. So, using the gaussian law of error propagation, the accuracy of the analysers is

$$\frac{\delta c}{c} = \sqrt{\left(\frac{\delta a}{a}\right)^2 + \left(\frac{\delta g}{g}\right)^2} = 1,41 \%$$

where  $\delta a/a$  = uncertainty of analyser and  $\delta g/g$  = uncertainty of test gas.



Flow: The uncertainty of the mass flow measurement with the venturi tube is to be calculated with the formula given in ISO 5167-1:2003, chapter 8.2.2:

$$\frac{\delta q_m}{q_m} = \sqrt{\left(\frac{\delta C}{C}\right)^2 + \left(\frac{\delta \varepsilon}{\varepsilon}\right)^2 + \left(\frac{2\beta^4}{1-\beta^4}\right)^2 \left(\frac{\delta D}{D}\right)^2 + \left(\frac{2}{1-\beta^4}\right)^2 \left(\frac{\delta d}{d}\right)^2 + \frac{1}{4} \left(\frac{\delta \Delta p}{\Delta p}\right)^2 + \frac{1}{4} \left(\frac{\delta \rho_1}{\rho_1}\right)^2}$$

where

$\delta C/C$  = uncertainty of discharge coefficient,

$\delta \varepsilon/\varepsilon$  = uncertainty of expansion factor,

$\delta D/D$  = uncertainty of tube entrance diameter,

$\delta d/d$  = uncertainty of throat diameter,

$\delta \Delta p/\Delta p$  = uncertainty of differential pressure,

$\delta \rho_1/\rho_1$  = uncertainty density.

$\beta$  = ratio of diameters

The uncertainty of the mass flow  $\delta q_m/q_m$  is mainly governed by the term  $\delta C/C$ , which is to be assumed to be 2 % according to ISO 5167-4:2003, chapter B.3.4, since the Reynolds number, at which the venturi tube is operated, is above  $2 \times 10^6$ .

The other factors contribute only little. Numerical evaluation of the formula above results in a total uncertainty of the flow measurement of about **2,05%** of the actual value.

The amount of  $N_2O$  and  $NO_x$  which is destructed by the EnviNOx® - system is calculated by subtracting the mass flows of the respective components downstream of the reactor from those upstream. The mass flows themselves are obtained by multiplying the measured concentration with the tail gas flow rate (described in more detail in the operating manual).

Since concentration and flow rate are independent variables, the total uncertainty of these destruction rates is to be calculated by using the gaussian law of error propagation, as described above.

**Annex 5****Confirmation letter****Confirmation letter Yeongsan River Basin Environmental Office on EIA:**

According to Article 4 of the Korean Environmental Impact Assessment Law and the item 3 of the Article 2 of its Enforcement Ordinance, **no** Environmental Impact Assessment is required for the proposed CDM Project at Hu-Chems Fine Chemical (Catalytic N<sub>2</sub>O destruction project in the tail gas of three Nitric Acid Plants at Hu-Chems Fine Chemical Corp.).

“아름다운 환경, 건강한 미래”

**영산강유역환경청**


수신자 전남 여수시 월내동 7-6 휴켄스(주) (기술본부, 공장장)  
(경유)

제목 **질산공장 CDM사업 환경영향평가 대상사업 여부 회신**

1. 휴켄스(주) - 125(2006.6.20)과 관련됩니다.

2. 귀사에서 문의하신 질산공정 첨정개발제제(CDM)사업의 환경영향평가 대상사업 해당여부를 검토한 결과, 질산공정 CDM사업은 환경·교통·재해 등에 관한 영향평가법 제4조 및 같은법 시행령 제2조 제3항에서 정하는 영향평가를 실시 해야 하는 대상사업에 해당되지 않음을 알려드립니다. 끝

영산강유역환경청장



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제일 06/20

영산강유역환경청장 김성민

발주자

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홈페이지 www.yre.go.kr

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