MONITORING REPORT FORM (F-CDM-MR)
Version 02.0

MONITORING REPORT

Title of the project activity	N_2O Abatement Project of Capro Corporation
Reference number of the project activity	4665
Version number of the monitoring report	Ver4.0
Completion date of the monitoring report	03/12/2012
Registration date of the project activity	09/06/2011
Monitoring period number and duration of this monitoring period	Period Number 2 Duration : 01/09/2011 – 31/12/2011 (122days)
Project participant(s)	Capro Corporation Hyosung Ebara Engineering Co., Ltd. Hyosung Corporation
Host Party(ies)	The Republic of Korea
Sectoral scope(s) and applied methodology(ies)	• Sectoral scope Scope No. 5, Chemical industries • Applied methodology AM0028(Version 05) Catalytic N_2O destruction in the tail gas of Nitric Acid Plants or Caprolactam Production
Estimated amount of GHG emission reductions or net anthropogenic GHG removals by sinks for this monitoring period in the registered PDD	220,935 tCO_2e[1]
Actual GHG emission reductions or net anthropogenic GHG removals by sinks achieved in this monitoring period	216,537 tCO_2e

[1] Calculated as: 660,995 tCO_2e * 122 days / 365 days = 220,935 tCO_2e.

SECTION A. Description of project activity

A.1. Purpose and general description of project activity

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(a) Purpose of the project activity and the measures taken for GHG emission reductions;

The proposed project is to reduce N_2O emissions of the tail gas emitted from Caprolactam production process in Capro Corporation (hereinafter "Capro") by installing catalytic N_2O destruction system.

(b) Brief description of the installed technology and equipments;

N_2O treatment system for this project is CRI N_2O abatement system, which is N_2O decomposition catalyst at the tail gas. Therefore, CRI system applies to tertiary treatment, which does not affect the existing yield of caprolactam as it just treats the tail gas. In addition, the catalyst system is remarkably efficient as CRI technology is direct N_2O decomposition process that does not require the addition of any reductant and its pressure drop is small.

(c) Relevant dates for the project activity.

Relevant dates (dd/mm/yyyy)	The Actions for Implementation of Project activity
16/11/2010	Starting Construction of N_2O abatement system
20/04/2011	Commissioning start(Plant 1)
27/04/2011	Commissioning start(Plant 2)
02/05/2011	Completing Construction of N_2O abatement system and the N_2O abatement system started normal operation
23/05/2011 ~27/05/2011	Field Test for Quality Assurance of installation and calibration of AMS (QAL2)
09/06/2011	Registration date of Project The starting date of the crediting period
26/09/2011 ~29/09/2011	Additional Field Test for Quality Assurance of installation and calibration of AMS (QAL2)

(d) Total emission reductions achieved in this monitoring period: 216,537 tonCO_2e

A.2. Location of project activity

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(a) Host Parties

The Republic of Korea

(b) Region/State/Province, etc.

Ulsan Metropolitan City.

(c) City/Town/Community etc.

402-1, Bugok-dong, Nam-gu.

(d) Physical/ Geographical Location

The east longitude is about 129.3280 and the north latitude is about 35.4958.

A.3. Parties and project participant(s)

Party involved ((host) indicates a host Party)	Private and/or public entity(ies) project participants (as applicable)	Indicate if the Party involved wishes to be considered as project participant (Yes/No)
The Republic of Korea(host)	• Capro Corporation • Hyosung Ebara Engineering Co., Ltd. • Hyosung Corporation	No

A.4. Reference of applied methodology

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(a) The applied methodology :
AM0028 "Catalytic N2O destruction in the tail gas of Nitric Acid or Caprolactam Production Plants" (Version 05.0)

(b) Any tools to which the applied methodology refers :
"Version 05.2 of the"Tool for the demonstration and assessment of additionality"(Version 05.2)

(c) other methodologies to which the applied methodology refers: None

The methodology tool are available on the following website:
http://cdm.unfccc.int/methodologies/PAmethodologies/approved

A.5. Crediting period of project activity

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The type of Crediting Period		fixed
The starting date of the crediting period (dd/mm/yyyy)		09/06/2011
The length of the crediting period		10 years
Implemented Monitoring period	1st	09/06/2011–31/08/2011 (84days)
	2nd (this monitoring period)	01/09/2011 – 31/12/2011 (122days)
	Accumulated number of days	206days

SECTION B. Implementation of project activity

B.1. Description of implemented registered project activity

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<u>Technical description of the project</u>

1) **General Introduction**

Caprolactam is produced by cyclohexane, ammonia, and sulphur as its primary raw materials, and Ammonium sulfate comes out as a by-product, which is supplied as nitrogen fertilizer and a chemical feedstock for industrial uses. In Capro, the main process of caprolactam production is as follows:

Hydroxylamine sulfate preparation ;

Ammonium carbonate preparation

$2NH_4OH + CO_2 \rightarrow (NH_4)_2CO_3 + H_2O$

Ammonia oxidation

$4NH_3 + 5O_2 \xrightarrow{\text{Pt-Rh catalyst}} 4NO + 6H_2O$

$(2NO + O_2 \rightarrow 2NO_2)$

Ammonium Nitrite Preparation;

$(NH_4)_2CO_3 + NO + NO_2 \rightarrow 2NH_4NO_2 + CO_2$

Hydroxylamine disulfonic ammonia Preparation;

$NH_4NO_2 + NH_4OH + 2SO_2 \rightarrow NOH(SO_3NH_4)_2$

Hydroxylamine Sulfate Preparation;

$NOH(SO_3NH_4)_2 + H_2O \rightarrow NHOHSO_3NH_4 + NH_4HSO_4$

$2NHOHSO_3NH_4 + 2H_2O \rightarrow (NH_2OH)_2H_2SO_4$ (Hydroxylamine sulfate) + $(NH_4)_2SO_4$

Cyclohexanone preparation

$C_6H_{12} \xrightarrow{\text{Co catalyst, }[O_2]} C_6H_{10}O$ (Cyclohexanone)

Oximation Reaction;

$(NH_2OH)_2H_2SO_4 + 2C_6H_{10}O \rightarrow 2C_6H_{10}NOH$ (Cyclohexanone oxime)+ $H_2SO_4 + H_2O$

Beckmann rearrangement;

$C_6H_{10}NOH \xrightarrow{H_2SO_4\text{ catalyst}} C_6H_{10}NOH$ (Caprolactam)

Cyclohexanone oxime reacts with sulfuric acid catalyst to caprolactam as final product. The structural formula of Beckmann rearrangement is shown in Figure B1.

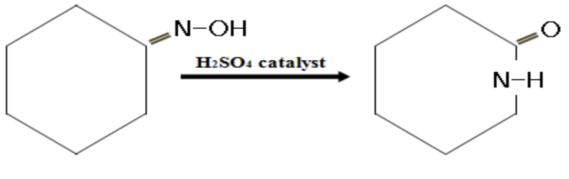

Figure B1. Structural formula of Beckmann rearrangement

The block flow diagram for existed caprolactam production process of Capro is shown in Figure B2.

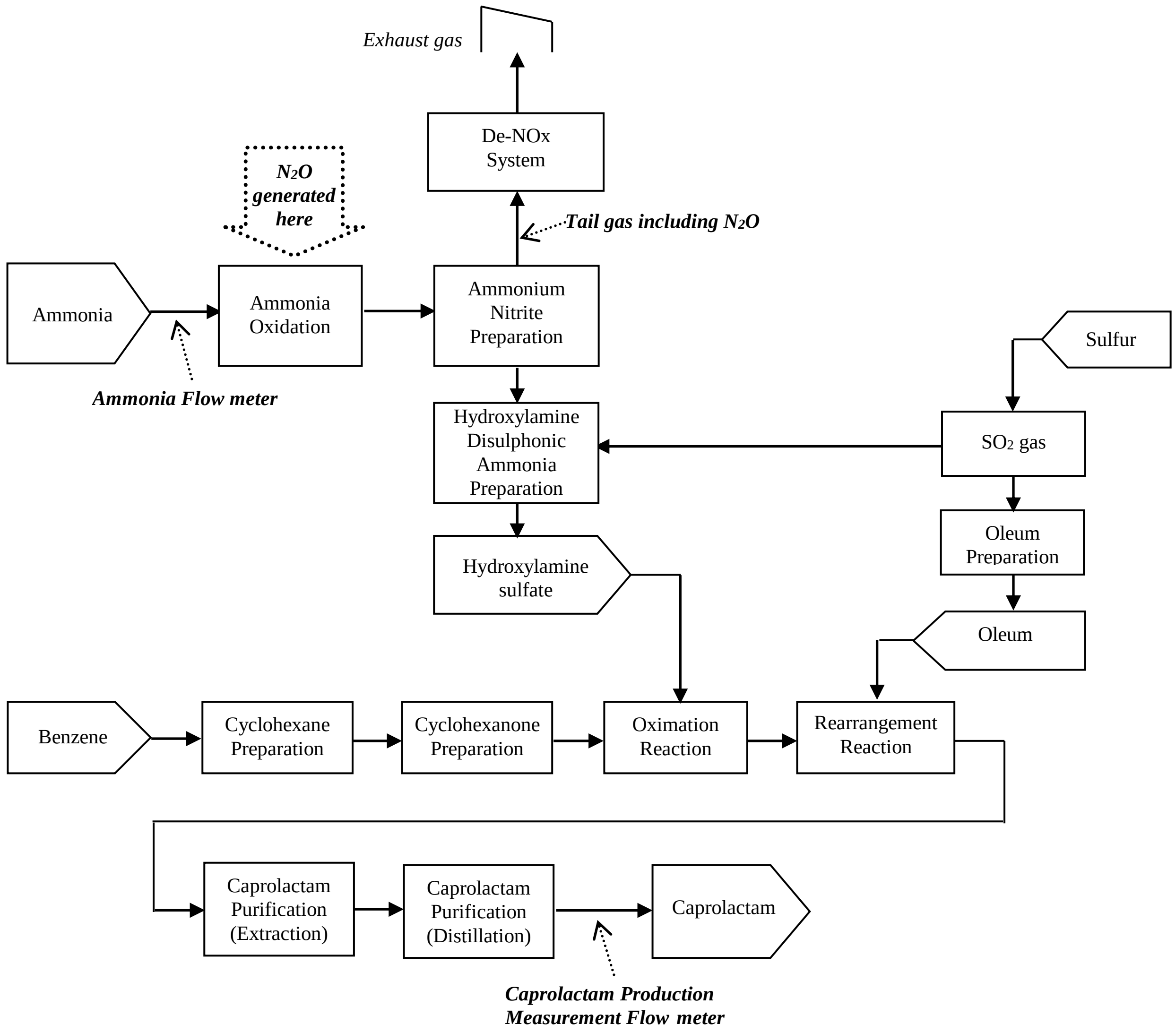

Figure B2. Block flow diagram for caprolactam production process

Ammonia oxidation reaction is necessary to generate NO and NO_2, which are going to be the reactants for Ammonium nitrite. (This Ammonium nitrite will induce Hydroxylamine sulphate, and finally caprolactam will be produced, through the complicated reaction pathway, as previous stated at the paragraph to explain the main process of caprolactam production.)
Nitrous oxide (N_2O) is generated as an undesired by-product through the side reaction of Ammonia oxidation as follows:

$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$	(Main reaction)
$(2NO + O_2 \rightarrow 2NO_2)$	(Desired in the NO oxidation process)
$4NH_3 + 3O_2 \rightarrow 2N_2 + 6H_2O$	(Side reaction)
$4NH_3 + 4O_2 \rightarrow 2N_2O + 6H_2O$	(Side reaction)

In this project, two plants (Plant I, Plant II) are included. In each plant, there are two of the Ammonium Oxidation Reactors (AORs), the ammonia gas is equally fed to the both of AORs through the one line with one flow meter. Input ammonia is oxidized by passing through the Pt-Rh Catalyst gauze located in AOR.

2) Project Specific description

De-N_2O system for this project is to destruct the N_2O included in tail gas by catalyst without any reducing agent.

$$2N_2O \xrightarrow{\text{Catalyst}} 2N_2 + O_2$$

The catalytic reactor designed by Hyosung Ebara Engineering Co. was derived from RTO (Regenerative Thermal Oxidizer), to save the energy required for catalytic reaction to decompose N_2O, and this N_2O destruction facility is the so-called "Regenerative Catalytic System" (Figure B3). Where, liquefied natural gas (LNG, hereafter "natural gas") is put in to this system as a fuel, not reducing agent, to supply the energy required for the de-N_2O catalytic reaction. Catalyst is provided by CRI.

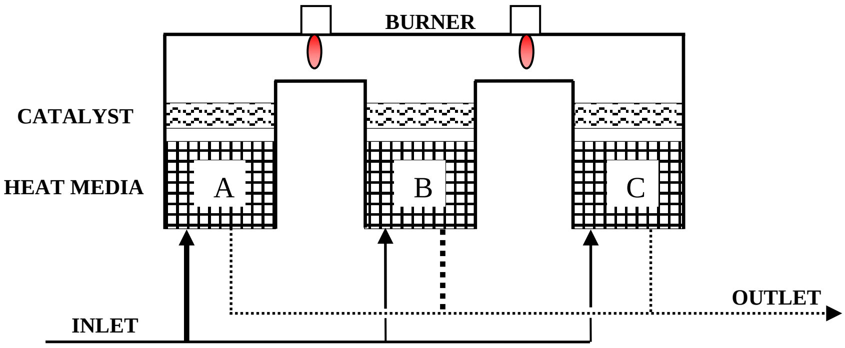

Figure B3. Overview of Regenerative Catalytic System

The principle of performance can be step-wisely described with Figure B4 as follows: At the inlet of De-N_2O system, in-flowed tail-gas is heated up to 550℃ by going to heat media A(previously heated), before N_2O included in the heated tail is decomposed while that tail gas is pass through catalytic bed located on the top of heat storage media A. And then, N_2O in the once treated tail gas is decomposed again by the next catalyst bed and the heat storage media B, to which the heat hold in two-times-treated tail gas is transfer. After this, two-times-treated tail gas is going out. Next, tail gas is injected in to the heat media B which is charged with heat transferred from the outflow according to the way explain just above. And the tail gas passed through the heat storage media B and the upper catalyst bed is going to the other catalyst bed and the heat media C. Finally, the tail gas from the plant goes to the media C heated by the previous outflow, this tail gas is flowed reversely to the media B and comes out. In this way, tail gas in-and-out is continuously rotated. The same De-N_2O processes have been applied to Plant I and II.

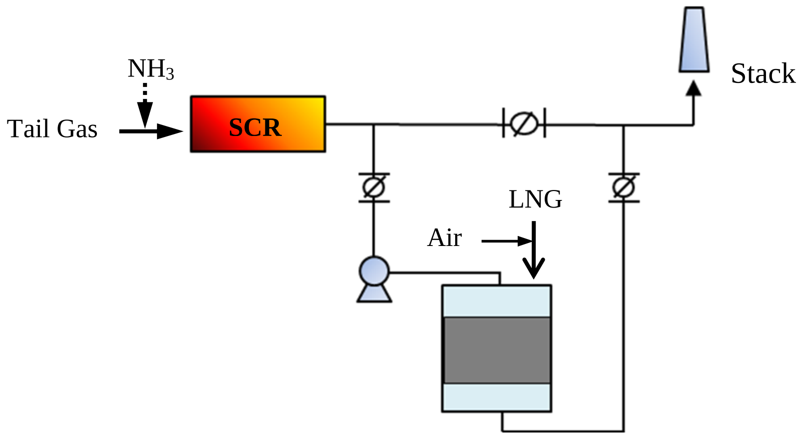

Figure B4. Overview of the De-N_2O process in Plant I and II

<u>Information on the operation of the project activity</u>

1) Operating condition of AOR

In order to avoid that the operation of the caprolactam production plant is manipulated in a way to increase the N_2O generation, thereby increasing the CERs, the operating temperature and pressure of the ammonia oxidation reactor (AOR), and NH_3 input to the AOR, have been monitored every working day. During the monitoring period #2, AOR operation conditions were deviated from the pemit ranges definite in PDD for 11days (09/10/2011~19/10/11) for which regular complete overhaul was performed, and the actual average daily AOR operation conditions are monitored as below Table B.1.

Table B.1 Summary of the AOR operation data

		$T_{g,a}$ (ºC)	$T_{g,b}$ (ºC)	$P_{g\text{-}1}$ (Pa)	$A_{OR,d\text{-}1}$ (NH_3/d)
Plant I	Permit range in PDD	656.57~731.66	662.08~743.92	43,320~98,564	42.250 (maximum)
	Actual average in period 2	699.67	728.99	84,719	36.427
	The number of days outside permit range	11	11	11	0
		$T_{g,c}$ (ºC)	$T_{g,d}$ (ºC)	$Pg_{\text{-}2}$ (Pa)	$A_{OR,d\text{-}2}$ (NH_3/d)
Plant II	Permit range in PDD	738.95~774.85	734.53~770.57	79,317~96,381	44.557 (maximum)
	Actual average in period2	752.20	749.11	87,338	41.220
	The number of days outside permit range	0	0	0	0

2) Ammonia Oxidation Catalyst

The all of catalysts for ammonia oxidation reaction used during the crediting period are the same as those described in registered PDD.

Table B.2 The status of ammonia oxidation catalysts installed in AOR

		Plant I	Plant II
Historical supplier of AOR catalyst $G_{com,hist}$		Pt(90%): Rh(10%)	Pt(90%): Rh(10%)
Historical composition of AOR catalyst $G_{sup,hist}$		Johnson Matthey	Johnson Matthey
in period 2	The composition (G_{com})	Pt(90%): Rh(10%)	Pt(90%): Rh(10%)
	Supplier (G_{sup})	Johnson Matthey	Johnson Matthey

3) Plant output of Caprolactam

In the case of a nitric acid plant or a caprolactam plant using the Raschig process, baseline emissions are limited to the design capacity of the existing nitric acid or caprolactam production plant. If the actual production of caprolactam ($P_{product}$) exceeds the design capacity ($P_{product,max}$) then emissions related to the production above $P_{product,max}$ will not be claimed for the baseline scenario. Therefore $P_{product}$ of each plant should be monitored.

However, it is not able to be decided whether the actual production of caprolactam exceeds $P_{product,max}$ or not, since those values should be compared on the annual values for comparing each other, and this period is second turn with the number of just 122 days. So, in order to simply make rough estimation to the status of production, the actual average daily output in period 2 was compared with the expected value of that on the basis of PDD, as shown in Table B.3. As a result, it can be said that actual values are lower for both of plants. All of the data for production of caprolactam were listed in detail in the emission reductions calculation spreadsheet.

Table B.3 the information of Caprolactam Production

		Plant I	Plant II
PDD	$P_{product,\ max}$ (tCaprolactam/yr)	63,307	64,965
	Maximum operating day(day/yr)	363	355
	Average daily output(ton/day)	174	183
Period 2	Sub-total output for period(tCaprolactam/day)	17,035	20,619
	No. of operating days(day/period)	111[2]	122
	Average daily output(ton/day)	153	169

<u>The events or situations occurred during the monitoring period</u>

1) Events of Plant I

<u>Events information</u>

Sites	No.	Date (dd/mm/yy) & Time		description
		from	to	
N_2O Abatement System	1	21/09/2011, 12:19	22/09/2011, 01: 29	Installed Sampling port for QAL2 & AST test
	2	01/10/2011, 03: 14	01/10/2011, 12:44	Solenoid valves to open dampers in NAS were replaced.

[2] There were 11 days (09/10/2011~19/10/2011) when the complete overhaul was performed

(NAS)	3	21/10/2011, 01:13	21/10/2011, 06:18	The recording system for data from NAS was on abnormal condition.
	4	21/10/2011, 13:18	21/10/2011, 23:55	The recording system for data from NAS was on abnormal condition.
	5	23/11/2011, 20:19	24/11/2011, 03:30	On/off valve for outlet damper for NAS was broken.
	6	06/12/2011, 14:20	07/12/2011, 13:30	Because of power outage in plant 1, the recording system for data from NAS was on abnormal condition.
Product Facility	7	21/09/2011, 12: 35	21/09/2011, 16: 40	The gas heater for SCR operation was broken with the pressure rising by malfunction of by-pass valve.
	8	08/10/2011, 03:54	20/10/2011, 20:39	All facilities of Plant 1 have been completely overhauled.
	9	17/10/2011, 13:00	17/10/2011, 15:00	The catalysts of AORs was replaced
	10	04/11/2011, 08:10	04/11/2011, 18:38	Some parts of comprising the production line were out of order, and fixed.
	11	08/11/2011, 12:55	09/11/2011, 00:20	Some parts of comprising the production line were out of order, and fixed.
	12	06/12/2011, 14:20	07/12/2011, 01:30	Power outage in plant 1.

Action to the events

For the events related N_2O Abatement System (NAS), the data on N_2O concentration (CI_{N2O-1}, CO_{N2O-1}) and volume flow rate (F_{TI-1} , F_{TE-1}) measured at the inlet and exit of the destruction facility in Plant 1 are cancelled. However, the data of the natural gas input (Q_{NG-1}) and CH_4 concentration (CO_{CH4-1}) measured at destruction facility outlet in Plant I are accepted to adopt a conservative manner.

For the events resulted from the malfunctions, inspections, and blackout of product facility in plant I, it is deleted that not only the data indicating AOR operation conditions ($A_{OR,d-1}$, P_{g-1} , T_{g-a} , T_{g-b}) ,and productivity of the caprolactam ($P_{product-1}$), but also the data on N_2O concentration (CI_{N2O-2}, CO_{N2O-2}) and volume flow rate (F_{TI-1} , F_{TE-1}) which are measured in N_2O Abatement System (NAS) in plant I.

Sites	No.	Relevant Time to Data cancelling		Parameters of the cancelled data
		from	to	
N_2O Abatement System (NAS)	1	21/09/2011, 12:00	22/09/2011, 02:00	• N_2O concentrations (CI_{N2O-1}, CO_{N2O-1}) • volume flow rate (F_{TI-1} , F_{TE-1})
	2	01/10/2011, 03: 00	01/10/2011, 13:00	
	3	21/10/2011, 01:00	21/10/2011, 07:00	
	4	21/10/2011, 13:00	21/10/2011, 24:00	
	5	23/11/2011, 20:00	24/11/2011, 04:00	
	6	06/12/2011, 14:00	07/12/2011, 14:00	
Product Facility	7	21/09/2011, 12: 00	21/09/2011, 17: 00	• N_2O concentrations (CI_{N2O-1}, CO_{N2O-1}) • volume flow rate (F_{TI-1} , F_{TE-1}) • AOR operation conditions ($A_{OR,d-1}$, P_{g-1} , T_{g-a} , T_{g-b}) • Plant output of caprolactam ($P_{product-1}$)
	8	08/10/2011, 03:00	20/10/2011, 21:00	
	9	17/10/2011, 13:00	17/10/2011, 15:00	
	10	04/11/2011, 08:00	04/11/2011, 19:00	
	11	08/11/2011, 12:00	09/11/2011, 01:00	
	12	06/12/2011, 14:00	07/12/2011, 02:00	

2) Events of Plant II

Events information

Sites	No.	Date (dd/mm/yy) & Time		description
		from	to	
N_2O Abatement System	1	21/09/2011, 07:56	21/09/2011, 18:39	Installed Sampling port for QAL2 & AST test
	2	14/10/2011, 09: 47	17/10/2011, 23:58	NAS was inspected, and some parts of NAS were replaced.
	3	06/12/2011, 14:20	13/12/2011, 10:40	Because of power outage in plant 2, the recording system for data from NAS was on abnormal condition.
Product Facility	4	02/11/2011, 04:55	02/11/2011, 21: 55	The catalysts of AORs was replaced
	5	28/11/2011, 09:00	28/11/2011, 13:48	The gas heater for SCR operation was out of order, and fixed and washed.
	6	06/12/2011, 14:20	07/12/2011, 13:20	Power outage in plant 2

Action to the events

For the events related N_2O Abatement System (NAS), the data on N_2O concentration (CI_{N2O-2}, CO_{N2O-2}) and volume flow rate (F_{TI-2} , F_{TE-2}) measured at the inlet and exit of the destruction facility in Plant 1are cancelled. However, the data of the natural gas input (Q_{NG-2}) and CH_4 concentration (CO_{CH4-2}) measured at destruction facility outlet in Plant I are accepted to adopt a conservative manner.

For the events resulted from the malfunctions, inspections, and blackout of product facility in plant II, it is deleted that not only the data indicating AOR operation conditions ($A_{OR,d-2}$, P_{g-2} , T_{g-c} , T_{g-d}) ,and productivity of the caprolactam ($P_{product-2}$), but also the data on N_2O concentration (CI_{N2O-2}, CO_{N2O-2}) and volume flow rate (F_{TI-2} , F_{TE-2}) which are measured in N_2O Abatement System (NAS) in plant II.

Sites	No.	Date (dd/mm/yy) & Time		description
		from	to	
N_2O Abatement System	1	21/09/2011, 07:00	21/09/2011, 19:00	• N_2O concentrations (CI_{N2O-2}, CO_{N2O-2}) • volume flow rate (F_{TI-2} , F_{TE-2})
	2	14/10/2011, 09: 00	17/10/2011, 24:00	
	3	06/12/2011, 14:00	13/12/2011, 11:00	
Product Facility	4	02/11/2011, 05:00	02/11/2011, 22: 00	• N_2O concentrations (CI_{N2O-2}, CO_{N2O-2}) • volume flow rate (F_{TI-2} , F_{TE-2}) • AOR operation conditions ($A_{OR,d-2}$, P_{g-2} , T_{g-c} , T_{g-d}) • Plant output of caprolactam ($P_{product-2}$)
	5	28/11/2011, 09:00	28/11/2011, 14:00	
	6	06/12/2011, 14:00	07/12/2011, 14:00	

B.2. Post registration changes

B.2.1. Temporary deviations from registered monitoring plan or applied methodology

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None

B.2.2. Corrections

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None

B.2.3. Permanent changes from registered monitoring plan or applied methodology

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None

B.2.4. Changes to project design of registered project activity

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None

B.2.5. Changes to start date of crediting period

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None

B.2.6. Types of changes specific to afforestation or reforestation project activity

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N/A

SECTION C. Description of monitoring system

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1. **Monitoring points to be measured**

1.1 Monitoring Points in Plant I

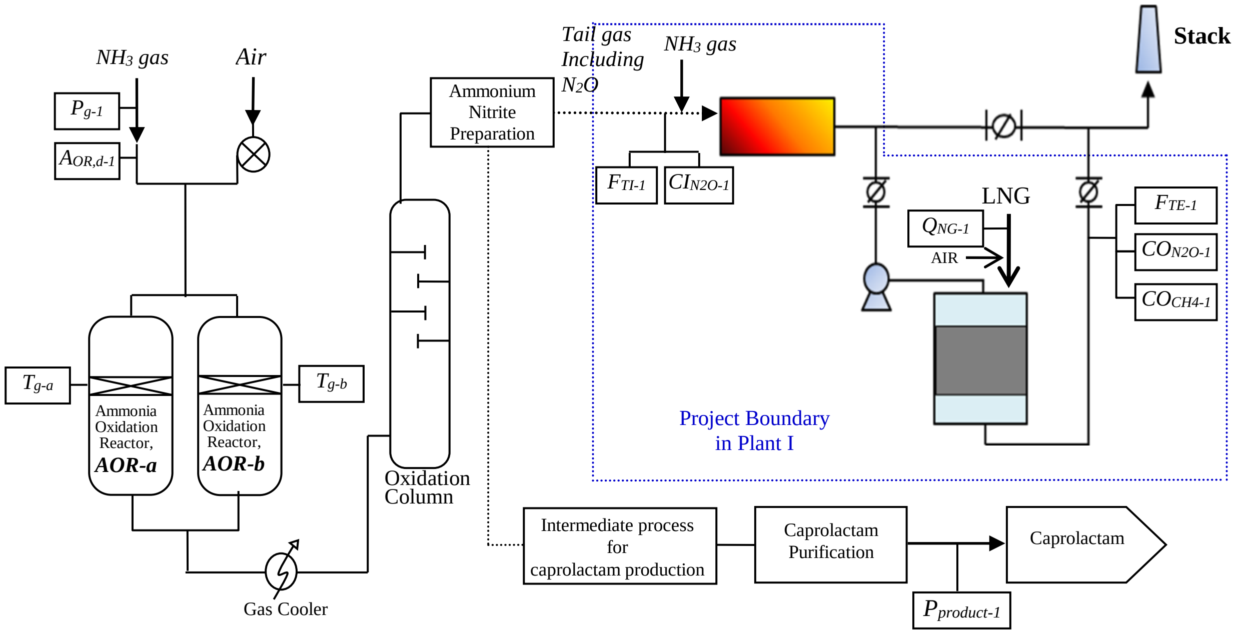

Figure C.1 Monitoring Points in Plant I

Parameter	Description	Tag No.

$A_{OR,d-1}$	Actual ammonia flow rate to AOR in Plant I	FIC-1201
P_{g-1}	Actual operating pressure of the AOR-a, b in Plant I	PI-1205
T_{g-a}	Actual operating temperature of the AOR-a in Plant I	TI-1204
T_{g-b}	Actual operating temperature of the AOR-b in Plant I	TI-1206
F_{TI-1}	Volume flow rate at the inlet of the destruction facility in Plant 1	FI-1521
F_{TE-1}	Volume flow rate at the exit of the destruction facility in Plant 1	FI-1522
CI_{N2O-1}	N_2O concentration at destruction facility inlet in Plant I	AI-1521
CO_{N2O-1}	N_2O concentration at destruction facility outlet in Plant I	AI-1522(a)
Q_{NG-1}	Additional natural gas input for re-heating the tail gas in Plant I	FI-1523
CO_{CH4-1}	CH_4 concentration at destruction facility outlet in Plant I	AI-1522(b)
$P_{product-1}$	Plant output of caprolactam in Plant I	FR-7705

Some tag numbers of measuring devices were specified to avoid confusion, because the same tag number had been allocated to two kind of different measuring devices described in PDD. Therefore new tag numbers were given to be clearly identified as follows:

	Parameters	Tag No. in PDD	Actual Tag No. in Period#2
Plant I	CO_{N2O-1}	AI-1522	AI-1522(a)
	CO_{CH4-1}	AI-1522	AI-1522(b)

1.2 Monitoring Points in Plant II

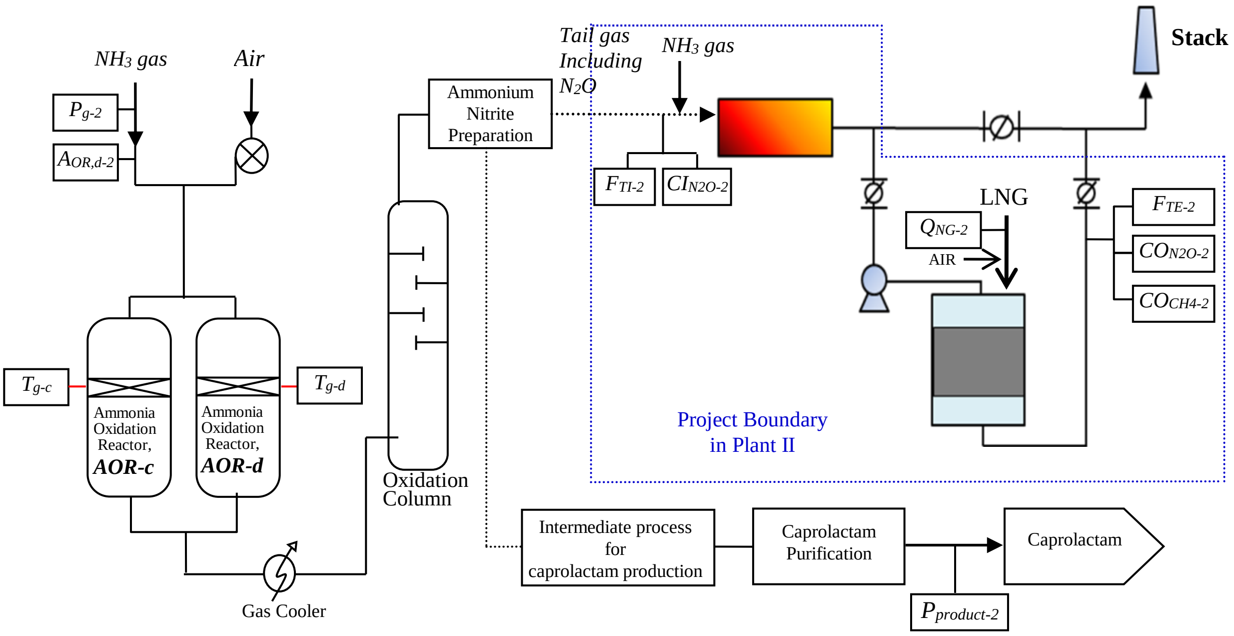

Figure C.2 Monitoring Points in Plant II

Parameter	Description	Tag No.

$A_{OR,d-2}$	Actual ammonia flow rate to AOR in Plant II	2FIC-1201
P_{g-2}	Actual operating pressure of the AOR-c, d in Plant II	2PI-1205
T_{g-c}	Actual operating temperature of the AOR-c in Plant II	2TI-1204
T_{g-d}	Actual operating temperature of the AOR-d in Plant II	2TI-1206
F_{TI-2}	Volume flow rate at the inlet of the destruction facility in Plant II	2FI-1521
F_{TE-2}	Volume flow rate at the exit of the destruction facility in Plant II	2FI-1522
CI_{N2O-2}	N_2O concentration at destruction facility inlet in Plant II	2AI-1521
CO_{N2O-2}	N_2O concentration at destruction facility outlet in Plant II	2AI-1522(a)
Q_{NG-2}	Additional natural gas input for re-heating the tail gas in Plant II	2FI-1523
CO_{CH4-2}	CH_4 concentration at destruction facility outlet in Plant II	2AI-1522(b)
$P_{product-2}$	Plant output of caprolactam in Plant II	2FI-7705

Some tag numbers of measuring devices were specified to avoid confusion, because the same tag number had been allocated to two kind of different measuring devices described in PDD. Therefore new tag numbers were given to be clearly identified as follows:

	Parameters	Tag No.in PDD	Actual Tag No. in Period#2
Plant II	CO_{N2O-2}	2AI-1522	2AI-1522(a)
	CO_{CH4-2}	2AI-1522	2AI-1522(b)

2. Data Collection procedure

The data of the AOR operating parameters (A_{OR}, T_g, P_g) and the productivity of caprolactam are logged and stored by the existed DCS (Distributed Control System) which has been independently operated for Plant I and II before starting this project. Besides, DAS (Data Acquisition System) is newly installed to log the relevant data to the N_2O decomposition amount and CH_4 emission by operating N_2O abatement system. DAS consists of an ‘Electronic Evaluation Unit (EEU)’ and two of ‘Data Communication Units (DCUs)’ located at Plant I and II.

Major function of DCU is to record the raw measurement data from Automated Measuring System (AMS), and to transmit those to EEU. DCU can store temporarily the record of raw measurement data with the ring memory of 16days minute values. In addition, the data of AOR operation and caprolactam productivity are delivered from DCS and recorded by DCU respectably, and then transmitted to EEU. Q_{NG} is measured by Flow meter separately installed from AMS and CO_{CH4} are also measured at the outlet by dual channel-NDIR by which the concentration of N_2O and CH_4 is measured separately. Therefore it is aggregated, recorded and stored by EEU that not only the AMS data but also the AOR data and productivity data. However, if there is a discrepancy between the DCS data and the EEU and/or DCU data, DCS data should be taken.

EEU satisfies the requirements described in AM0028 / Version 05 as below:

(a) Evaluation unit needs to take into account registration, mean average determination, validation, and evaluation;
(b) The system and concept of emission data processing needs to be described;
(c) Protocols and out-prints are required.

With EEU, these raw measurement data transmitted from DCUs are integrated after the measurement uncertainty determined by QAL 2 test is subtracted from them. Then, those are converted to the average values at the end of the every integration interval (1 hour), and validated. Negatively validated average values are set to zero. Validated average values outside the valid calibration range are to be stored with the associated time and with their status and are to be logged on EEU at the end of the day and year. EEU has the storage capacity of 5year-ring memory.
The calibration curve for the measuring instrument is determined using a standard reference method. The validity of the calibration curve is proved by EEU. The validity range for the calibration is specified in the calibration report. This calibration reports are printed and kept for back-up.
External hard disk drive (HDD) is installed for back-up and long storage of the data and relevant reports for verification, replaced by new one every 4 years, old HDDs are kept holding with attention during the 10years of crediting period and 2 additional years according to AM0028 / Version 05.

Table C.1 The information of the data collection and storage devices except DCS

		Supplier	**Model No.**	**Serial No.**
DCU(Data Communication Unit)	Plant 1	DURAG	D-EMS 500 KE	1301581
	Plant 2	DURAG	D-EMS 500 KE	1301582
EEU (Electronic Evaluation Unit)		DURAG	D-EMS 2000 SWE	1301567
External Hard disk drive(HDD) for backup		DURAG	D-EMS 2000 RED	1301578

The role of the new PC for back-up is to display and record the hourly data from EEU, the monthly data of supplied LNG, and the other information including the events list, working diary and so on.

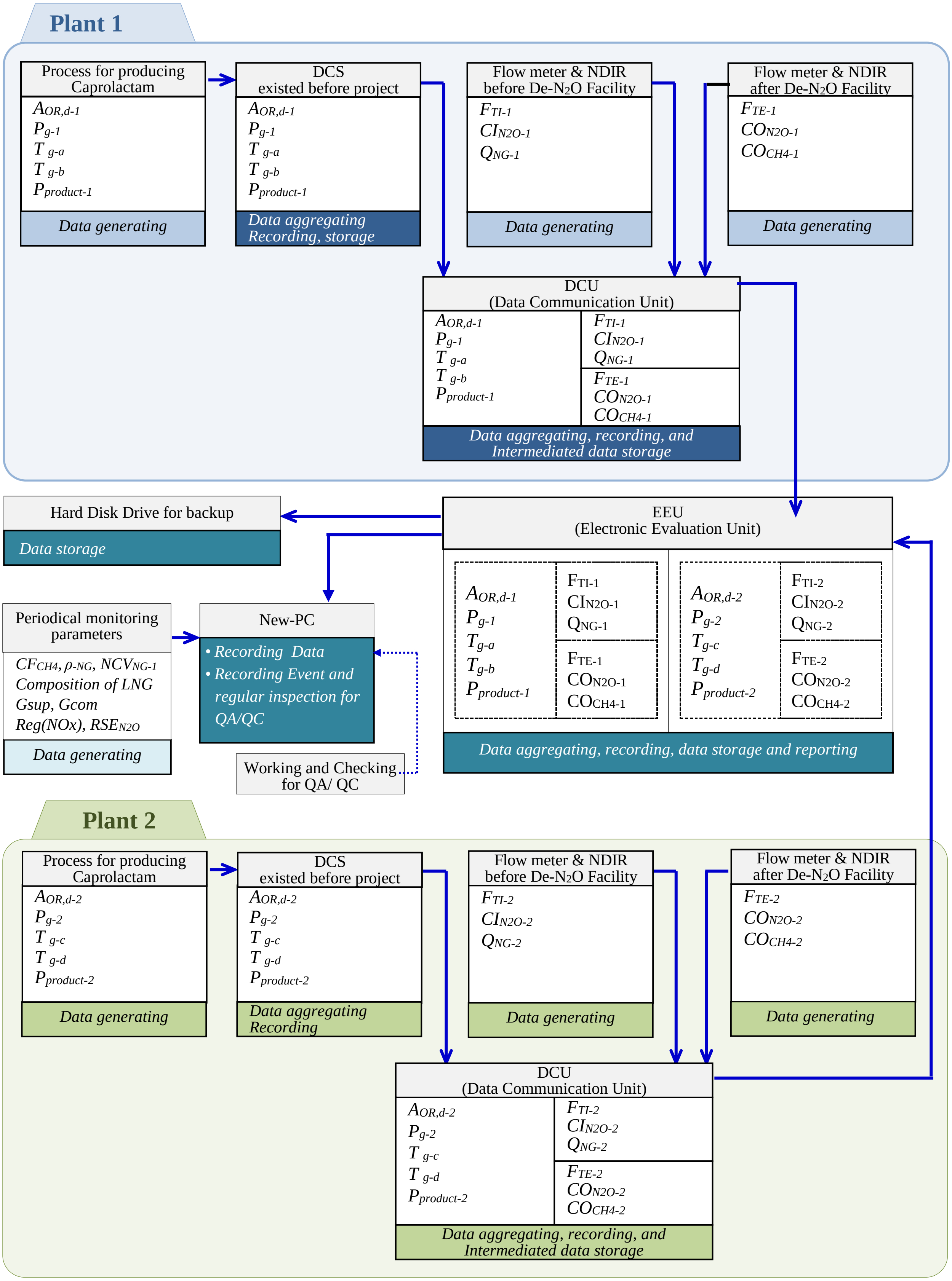

Figure C.3 Data Collecting Flow

3. <u>Organizational structure, roles and responsibilities of personel</u>

3.1 Organization Structure

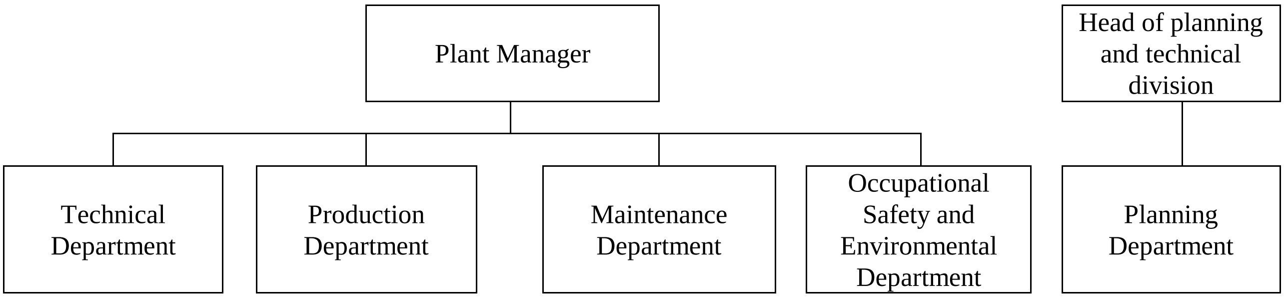

Figure C.4 The scheme of the operational and management structure

3.2 Roles and responsibilities of personnel

• Plant Manager

The Plant Manager takes overall responsibility for the operation and maintenance of the N_2O monitoring system. In addition, the Plant Manager has authority to approve monitoring report provided by the Technical Department.

• Production Department

The responsible Production Engineers in Production Department are in charge of the operation and supervision of N_2O monitoring system that will be implemented to record plant operation data.

• Technical Department

Monitoring engineers in Technical Department are responsible for collecting, validating and processing the data to determine GHG emission reduction and making report periodically. Moreover, the monitoring engineer is in charge of archiving the data as well. The monitoring engineers archive all required data and reports for verification.

• Maintenance Department

Maintenance Department is responsible for maintaining and repairing the instrument associated with this project. Calibration for instruments is concerned by maintenance department as well.

• Occupational Safety and Environment Department

The OSHES Department plays a role for indicating the direction and managing according to the monitoring plan.

• Planning Department

Planning Department conducts the internal audit of N_2O monitoring system periodically.

4. Emergency procedures for the monitoring system.

In case of the data deviation, following procedures are taken.

(a) Production Engineer in Production Department identifies whether the deviation results from processing or other factors such as temperature and pressures.

(b) Production engineer compares the deviated data with other parameter data if the deviation results from processing.

(c) If the reason for the data deviation is not identified, production engineer informs Maintenance Department to correct the error after inspecting all gauges and analysers.

If the data deviation is not covered by procedures above, Technical Department makes the decision to correct figures or to abandon the data. In addition, any data correction is in compliance with the applied methodology and done in a conservative bias

When the malfunction of measuring instruments is occurred, following procedures are taken.

(a) If production engineer recognizes the malfunction of measuring instruments, he informs person in Maintenance Department of this abnormal situation.

(b) Maintenance Department estimates whether performing repairing action to solve problem is appropriate or not.

(c) If it is decided that self-repairing by Maintenance Department is appropriate, self-repairing is carried out. However, if the instrument is out of repair, Maintenance Department requests external institution specialized in repairing to have it serviced.

If measuring devices have to be replaced, related supporting evidences should be checked and kept by Maintenance Department, in order to demonstrate that the quality of the replaced measuring devices is the same as the quality grade of existed devices, before the copies of the supporting evidences to replaced devices should be delivered to and kept in the Technical Department.

Specially, if any malfunction situation of the measuring devices composing AMS(Automated measuring system) is continued during the 8hrs after it is detected, Maintenance Department should request the service of official measuring agency to measuring the N_2O concentration or flow rate at the monitoring points of inlet and outlet of N_2O decomposition system. If the services by the official measuring agency cannot be taken for some unavoidable reason, it will be taken instead of measuring by the external official measuring agency that the AMS data measured at the most similar operating condition among those of the recent 1 month just before the abnormal situation is happen, with the conservative understanding of that the N_2O concentration of inlet is replaced with the lowest number, and that of outlet is with highest one.

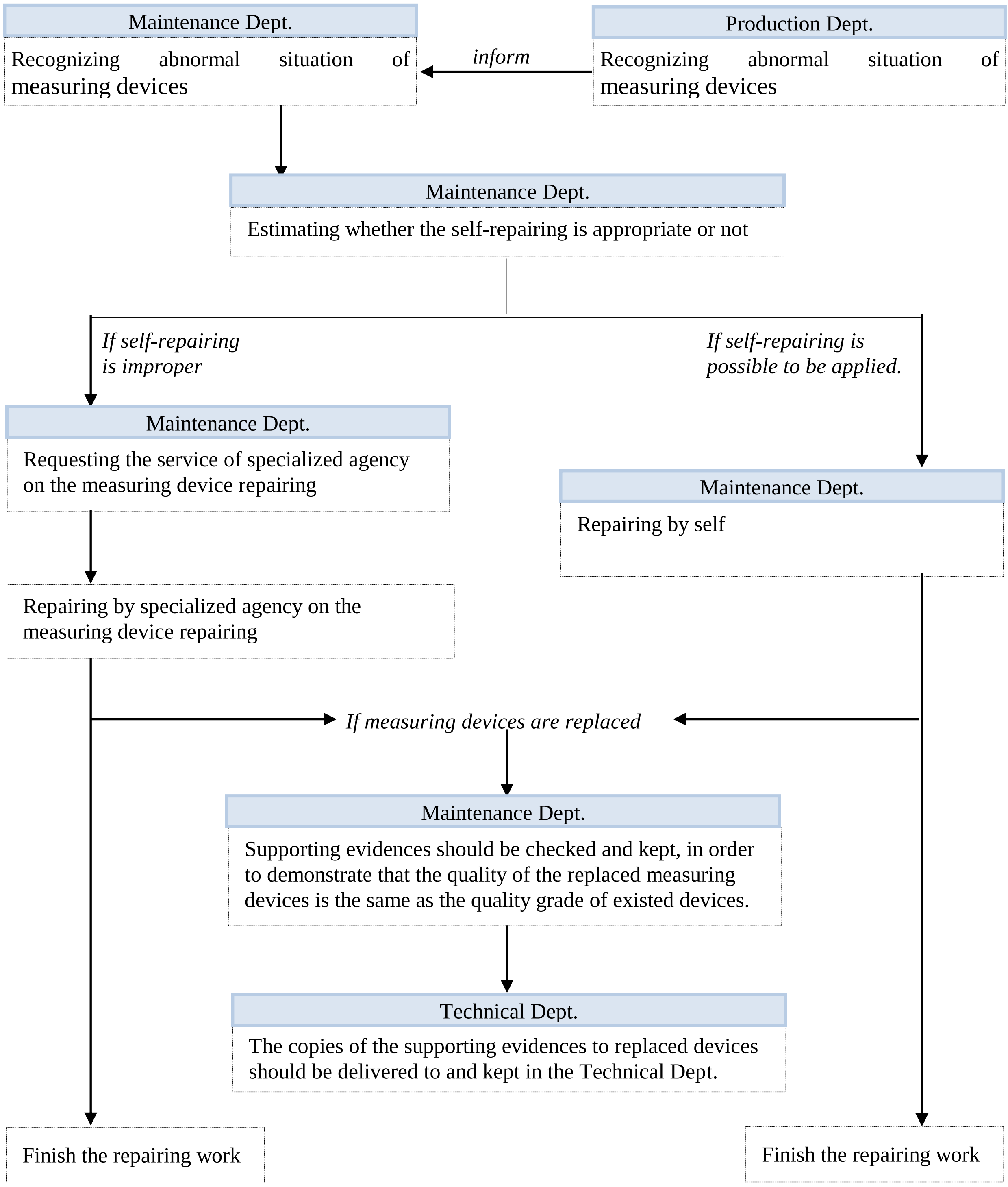

Figure C.5 Emergency Procedures for malfunctions of measuring devices in general

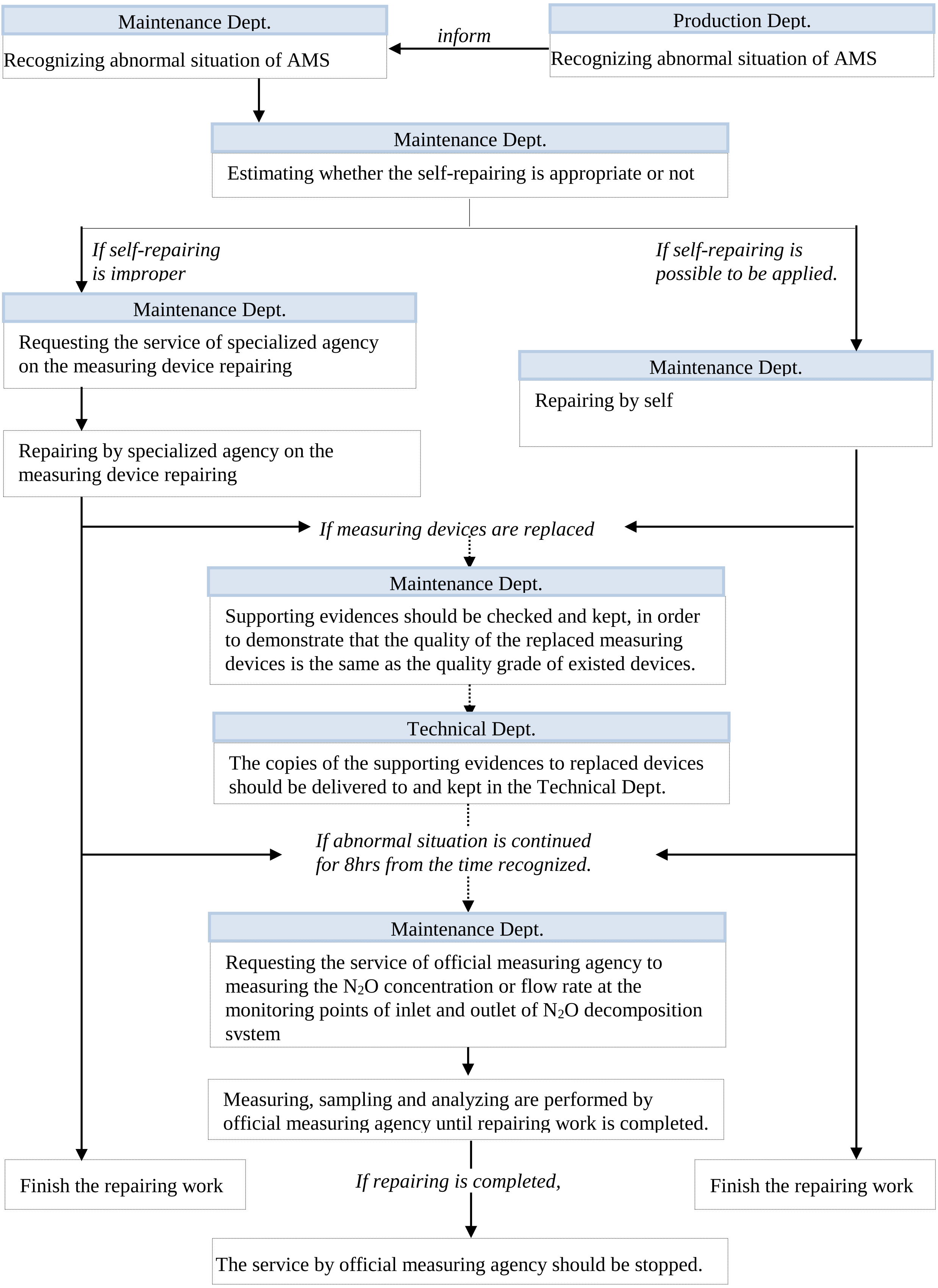

Figure C.6 Emergency Procedures for malfunction of AMS

5. Reporting

- **Daily report** consists of the parts printed out from EEU and from New-PC. EEU report is to show the data generated by AMS and related to the AOR operation condition and to the productivity of caprolactam. Daily value of each parameter is calculated based on hourly average or hourly total value on the EEU report. The situation of the AMS failure is also documented on the EEU report. The other hand, new-PC daily report is about checking and maintaining the measuring device and N_2O abatement system, and about monitoring events.
- **Monthly report** integrates the data and information in daily reports. LNG information is also reported monthly. Periodical monitoring parameters such as the composition and supplier of AOR catalysts, the national regulation on NOx and N_2O are checked by monthly report too.
- **Annual report** is a bunch of monthly report files. However there is no annual report, because this period is second and the total length of the period #1 and #2 is just 206 days.

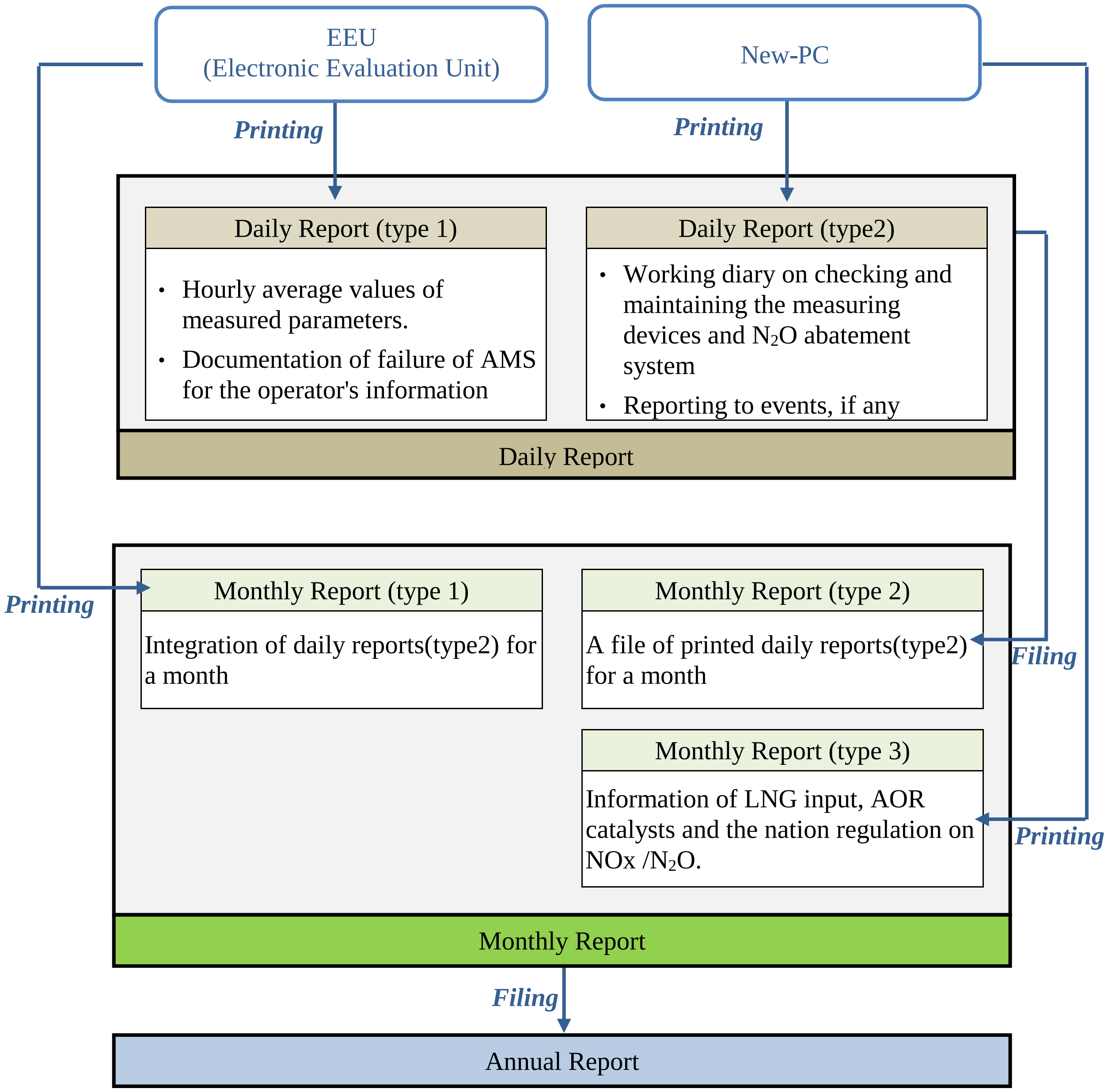

Figure C.7 The consists of the periodical reports

6. Quality Assurance of AMS(Automated measuring system)

AMS(Automated measuring system) has been applied to measure the amount of N_2O emission at the two monitoring points of the inlet and outlet of N_2O destruction facility of each plant involved in this project. By AMS, the concentration of N_2O and the volume flow rate of tail gas are measured simultaneously(F_{Ti}, CI_{N2O}, and F_{TE}, CO_{N2O}) at same basis (wet or dry), and these values are expressed on the same basis (wet or dry) with correcting to normal conditions (101.324kPa, 0deg C) through the algorithm based on procedures of EN14181.

"European Norm EN14181: Quality assurance of automated measuring systems, 2004" is selected as a guidance document to the Quality Assurance and Control procedure of the AMS for this project. This means that the three levels of quality assurance tests(QAL1, QAL2 and QAL3) and one annual functional test must be carried out regarding the selection, installation, and operation of AMS under the monitoring methodology in AM0028(ver.05).

Quality assurance of tested AMS (:QAL1)

The quality assurance of tested AMS was accomplished with that the flow meters and N_2O gas analyzers having the performance certificate with calculation uncertainty were selected as summarized in following tables.

Quality assurance of installation and calibration of AMS (:QAL2)

QAL 2 has been performed two times according to the Standard Reference Measurement Method (23/05/2011~27/05/2011 and 26/09/2011~29/09/2011) by AIR-TEC, which is the one of the organizations having an accredited quality assurance system on ISO/IEC 17025.

The results to the tests for QAL2 were summarized on the QAL 2 reports in the major items following:

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

Continuous quality Assurance through the local operator/manager (:QAL3)

QAL 3 has been implemented since the project start up. This includes:

- Permanent quality assurance during the plant operation by the operating staff
- Assurance of reliable and correct operation of the monitoring equipment
- Regular controls : zero point, span, drift, meet schedule of manufacturer maintenance intervals

Annual Surveillance test (AST)

Annual Surveillance test has not been carried out yet, because only 206 days have passed since the crediting period was started.

Table C.2 (a) Information of the quality assurance of tested AMS located in Plant I

Location	Parameters	Type	model	serial number	Standard for Performance certification	Certificate No.	The date of Certificate Issued (dd/mm/yyyy)	Approved methods to calculate of uncertainty
Inlet	F_{TI-1}	Ultrasonic flow meter	D-FL 200 System	HEAD A: 1217007 HEAD B: 1217008 EVALUATION UNIT : 1216861 CASE OF EVALUATION : 1216999	MCERTS	Sira MC 060072/01	22/05/2007	/
	CI_{N2O-1}	Non-dispersion infrared absorption analyzer (NDIR)	ULTRAMAT 6	AO-748	TUV	Report Nr. 1290727	May 2009	/
					TUV	BB-EG1-KAR Gr02X	29/07/2003	EN 50016 EN 60079-14 Guidelines for expolosion protection of GB Chemie(GRG 104)
					FM Approvals	3016050	15/07/2003	/
					CSA INTERNATIONAL	1431560	17/04/2003	/
Outlet	F_{TE-1}	Ultrasonic flow meter	D-FL 200 System	HEAD A: 1217009 HEAD B: 1217010 EVALUATION UNIT : 1216862 CASE OF EVALUATION : 1217001	MCERTS	Sira MC 060072/01	22/05/2007	/
	CO_{N2O-1}	NDIR	ULTRAMAT 6	AO-750	TUV	Report Nr. 1290727	May 2009	/
					TUV	BB-EG1-KAR Gr02X	29/09/2003	EN 50016 EN 60079-14 Guidelines for expolosion protection of GB Chemie(GRG 104)
					FM Approvals	3016050	15/07/2003	/
					CSA INTERNATIONAL	1431560	17/04/2003	/

Table C.2 (b) Information of the quality assurance of tested AMS located in Plant II

Location	Parameters	Type	model	serial number	Standard for Performance certification	Certificate No.	The date of Certificate Issued (dd/mm/yyyy)	Approved methods to calculate of uncertainty
Inlet	F_{TI-2}	Ultrasonic Flow meter	D-FL 200 System	HEAD A: 1217011 HEAD B: 1217012 EVALUATION UNIT : 1216866 CASE OF EVALUATION : 1217002	MCERTS	Sira MC 060072/01	22/05/2007	/
	CI_{N2O-2}	NDIR	ULTRAMAT 6	AO-749	TUV	Report Nr. 1290727	May 2009	/
					TUV	BB-EG1-KAR Gr02X	29/09/2003	EN 50016 EN 60079-14 Guidelines for expolosion protection of GB Chemie(GRG 104)
					FM Approvals	3016050	15/07/2003	/
					CSA INTERNATIONAL	1431560	17/04/2003	/
Outlet	F_{TE-2}	Ultrasonic Flow meter	D-FL 200 System	HEAD A: 1217013 HEAD B: 1217014 EVALUATION UNIT : 1216867 CASE OF EVALUATION : 1217003	MCERTS	Sira MC 060072/01	22/05/2007	/
	CO_{N2O-2}	NDIR	ULTRAMAT 6	AO-751	TUV	Report Nr. 1290727	May 2009	/
					TUV	BB-EG1-KAR Gr02X	29/09/2003	EN 50016 EN 60079-14 Guidelines for expolosion protection of GB Chemie(GRG 104)
					FM Approvals	3016050	15/07/2003	/
					CSA INTERNATIONAL	1431560	17/04/2003	/

7. Conservative calculation on tail gas flow

Measurement value by a flow meter at inlet of destruction facility (F_{TI}) and Measurement value by a flow meter at outlet of destruction facility (F_{TE}), both parameters shall be cross checked to ensure that no leak of N_2O is taking place, and in case of discrepancy, conservative calculation of emission reduction is provided. In order to achieve conservative approach, the measured inlet flow (F_{TI}) would be adjusted to the value (F_{TI}*) by the below equation.

$$F_{TI}^{*} = \min \left[F_{TI} ; \left(\frac{F_{TE}}{1+VEF} - Q_{NG} \times \frac{Q_{NG\ combustion\ gas}}{Q_{NG}} \right) \right]$$

Where:

F_{TI}^{*}	: Conservative volume flow at the inlet of destruction facility used for emission reduction calculation (Nm^3/h)
F_{TI}	: Measurement value by a flow meter at inlet of destruction facility (Nm^3/h)
F_{TE}	: Measurement value by a flow meter at outlet of destruction facility (Nm^3/h)
Q_{NG}	: Natural gas input for re-heating the tail gas (Nm^3/h)
$Q_{NG\ combustion\ gas}$	: Combustion gas of natural gas (Nm^3/h)
VEF	: Volumetric Expansion Factor

For monitoring, the gas generated by combusting natural gas($Q_{NG\ combustion\ gas}$) has been estimated on the supposition that air input according to the theoretical oxygen demand on the natural gas composition which information is provided by the natural gas supplier for Capro (Kyung Dong city gas CO., Ltd).

And for the conservative approach, any volume change from De-NOx and/or De-N_2O system will be considered by the Volumetric Expansion Factor (VEF). Before the first monitoring period, the Volumetric Expansion Factor (VEF) was determined as 0.001 which was provided by CRI, N_2O abatement catalysts supplier. This value of VEF is applied as a fixed official value.

8. Training

The supplier of the NDIR system provided complete training to the monitoring engineers in charge of operation and maintenance of the monitoring system. The provider of the De-N_2O system, (Hyosung Ebara Engineering Co., Ltd.) initiated the operation technique for the system to the staff in the Technical department of Capro.

SECTION D. Data and parameters
D.1. Data and parameters fixed ex ante or at renewal of crediting period

Data/Parameter	***GWP_{N2O}***
Unit	Not applicable
Description	Global warming potential of the nitrous oxide
Source of data	IPCC, The Second Assessment Report
Value(s) applied	310
Purpose of data	Baseline Emission / Project Emission Calculation
Additional comment	Not applicable

Data/Parameter	***GWP_{CH4}***
Unit	Not applicable
Description	Global warming potential of the methane
Source of data	IPCC, The Second Assessment Report
Value(s) applied	21
Purpose of data	Project Emission Calculation
Additional comment	Not applicable

Data/Parameter	***$P_{product, max}$***
Unit	t Caprolactam /yr
Description	Design capacity of caprolactam production of the targeted line
Source of data	PDD
Value(s) applied	$P_{product1, max}$: 63,307 ton/yr (design capacity in Plant I) for 363 days $P_{product2, max}$: 64,965 ton/yr (design capacity in Plant II) for 355 days Each plant has an individual design capacity.
Purpose of data	Baseline Emission Calculation
Additional comment	Not applicable

Data/Parameter	***$A_{OR,hist}$***
Unit	tNH_3/day
Description	Maximum of historical ammonia flow rate of the ammonia oxidation reactor (AOR)
Source of data	PDD
Value(s) applied	$A_{OR,hist-1}$: 42.250tNH_3/d (total flow rate for AOR-a and AOR-b in Plant I) $A_{OR,hist-2}$: 44.557tNH_3/d (total flow rate for AOR-c and AOR-d in Plant II)
Purpose of data	Baseline Emission Calculation
Additional comment	Not applicable

Data/Parameter	***$T_{g,hist}$***
Unit	^oC
Description	Historical operating temperature range of the ammonia oxidation reactor
Source of data	PDD

Value(s) applied	$T_{g,hist-a}$: 656.57− 731.66 ℃ (for AOR-a in Plant I) $T_{g,hist-b}$: 662.08−743.92 ℃ (for AOR-b in Plant I) $T_{g,hist-c}$: 738.95− 774.85 ℃ (for AOR-c in Plant II) $T_{g,hist-d}$: 734.53− 770.57 ℃ (for AOR-d in Plant II)
Purpose of data	Baseline Emission Calculation
Additional comment	Not applicable

Data/Parameter	$P_{g,hist}$
Unit	*Pa gauge*
Description	Historical operating pressure range of the ammonia oxidation reactor
Source of data	PDD
Value(s) applied	$P_{g,hist\_1}$: 43,320− 98,564 Pa gauge (for AOR-a and AOR-b in Plant I) $P_{g,hist\_2}$: 79,317− 96,381 Pa gauge (for AOR-c and AOR-d in Plant II)
Purpose of data	Baseline Emission Calculation
Additional comment	Not applicable

Data/Parameter	$G_{sup,hist}$
Unit	-
Description	Historical supplier of the ammonia oxidation catalyst
Source of data	PDD
Value(s) applied	Name of the supplier: Johnson Matthey
Purpose of data	Baseline Emission Calculation
Additional comment	Not applicable

Data/Parameter	$G_{com,hist}$
Unit	%
Description	Historical composition of the ammonia oxidation catalyst
Source of data	PDD
Value(s) applied	Pt (90%): Rh (10%)
Purpose of data	Baseline Emission Calculation
Additional comment	Not applicable

Data/Parameter	$OXID_{HC}$
Unit	%
Description	Oxidation factor of natural gas, with two or more molecules of carbon
Source of data	PDD
Value(s) applied	100%
Purpose of data	Project Emission Calculation
Additional comment	Not applicable

Data/Parameter	EF_{CH4}
Unit	tCO_2/tCH_4
Description	Emission factor of methane
Source of data	PDD

Value(s) applied	2.75(tCO_2/tCH_4)
Purpose of data	Project Emission Calculation
Additional comment	Not applicable

Data/Parameter	ρ_{CH4}
Unit	t/m^3
Description	Density of methane
Source of data	Tool to determine project emissions from flaring gases containing methane
Value(s) applied	0.000716 t/m^3 (0°C, 1atm)
Purpose of data	Project Emission Calculation
Additional comment	Not applicable

Data/Parameter	M_i
Unit	hour
Description	Length of measuring interval
Source of data	AMS
Value(s) applied	1 hour (to be measured continuously for 24 hours)
Purpose of data	Baseline Emission Calculation / Project Emission Calculation
Additional comment	Not applicable

Data/Parameter	Reg_{NOx}
Unit	tNO_X/Nm^3
Description	National regulation on NO_X emissions
Source of data	The “Clean Air Conservation Act”, one of the National environmental legislation, Ministry of Environment
Value(s) applied	4.10714×10^{-7} $tNOx/Nm^3$ (as a NO_2 concentration)
Purpose of data	Not applicable
Additional comment	Not applicable

D.2. Data and parameters monitored

Data/Parameter	$F_{TI,i}$
Unit	Nm^3/hr
Description	Volume flow rate at the inlet of the destruction facility
Measured/Calculated /Default	Measured
Source of data	Flow meter with normalizing functions
Value(s) of monitored parameter	For this period, the average values of F_{TI}

	Plant I ($F_{TI,1}$)	Plant II($F_{TI,2}$)
F_{TI} (Nm^3/hr) average	39,974	39,745

Monitoring equipment	<table><tr><td></td><td>Plant I ($F_{TI,1}$)</td><td>Plant II($F_{TI,2}$)</td></tr><tr><td>Type</td><td>Ultrasonic flow meter</td><td>Ultrasonic flow meter</td></tr><tr><td>Accuracy class</td><td>< 2%</td><td>< 2%</td></tr><tr><td>Serial No.</td><td>• HEAD A: 1217007 • HEAD B: 1217008 • Evaluation Unit :1216861 • Case of Evaluation : 1216999</td><td>• HEAD A: 1217011 • HEAD B: 1217012 • Evaluation Unit :1216866 • Case of Evaluation : 1217002</td></tr><tr><td>Calibration frequency</td><td>Every day by Auto calibration manner</td><td>Every day by Auto calibration manner</td></tr><tr><td>Date of last calibration</td><td>31/12/2011</td><td>31/12/2011</td></tr><tr><td>Validity</td><td>Yes</td><td>Yes</td></tr></table>
Measuring/Reading/ Recording frequency	•Measuring period : Continuously •Recording frequency : Hourly
Calculation method (if applicable)	Not applicable
QA/QC procedures	QAL 1, 2,3 and AST for AMS
Purpose of data	Baseline Emission Calculation
Additional comment	Not applicable

Data/Parameter	$F_{TE,i}$
Unit	Nm^3/hr
Description	Volume flow rate at the exit of the destruction facility
Measured/Calculated /Default	Measured
Source of data	Flow meter with normalizing functions
Value(s) of monitored parameter	For this period, the average values of F_{TE}<table><tr><td></td><td>Plant I ($F_{TE,1}$)</td><td>Plant II ($F_{TE,2}$)</td></tr><tr><td>F_{TE} as Nm^3/hr in average</td><td>43,031</td><td>46,570</td></tr></table>

Monitoring equipment	(see table below)

	Plant I ($F_{TE,1}$)	Plant II ($F_{TE,2}$)
Type	Ultrasonic flow meter	Ultrasonic flow meter
Accuracy class	< 2%	< 2%
Serial No.	•HEAD A: 1217009 •HEAD B: 1217010 • Evaluation Unit : 1216862 • Case of Evaluation : 1217001	•HEAD A: 1217013 •HEAD B: 1217014 • Evaluation Unit : 1216867 • Case of Evaluation : 1217003
Calibration frequency	Every day by Auto calibration manner	Every day by Auto calibration manner
Date of last calibration	31/12/2011	31/12/2011
Validity	Yes	Yes

Measuring/Reading/ Recording frequency	•Measuring period : Continuously •Recording frequency : Hourly
Calculation method (if applicable)	Not applicable
QA/QC procedures	QAL 1, 2,3 and AST for AMS
Purpose of data	Project Emission Calculation
Additional comment	Not applicable

Data/Parameter	$CI_{N2O,i}$
Unit	tN_2O/Nm^3
Description	N_2O concentration at destruction facility inlet
Measured/Calculated /Default	Measured
Source of data	Non-dispersion infrared absorption analyzer (NDIR)
Value(s) of monitored parameter	For this period, the average values of CI_{N2O} (see table below)

	Plant I(CI_{N2O-1})	Plant II(CI_{N2O-2})
$CI_{N2O,i}$ as tN_2O/Nm^3	4.2130×10^{-6}	3.4125×10^{-6}

Monitoring equipment	(see table below)

	Plant I(CI_{N2O-1})	Plant II(CI_{N2O-2})
Type	NDIR	NDIR
Accuracy class (repeatability)	>95%	>95%
Serial No.	AO-748	AO-749
Calibration frequency	Every 2weeks	Every 2weeks
Date of last calibration	28/12/2011	28/12/2011
Validity	Yes	Yes

Measuring/Reading/ Recording frequency	•Measuring period : Continuously •Recording frequency : Hourly
Calculation method (if applicable)	Not applicable
QA/QC procedures	QAL 1, 2,3 and AST for AMS
Purpose of data	Baseline Emission Calculation
Additional comment	Not applicable

Data/Parameter	$CO_{N2O,i}$
Unit	tN_2O/Nm^3
Description	N_2O concentration at destruction facility outlet
Measured/Calculated /Default	Measured
Source of data	Non-dispersion infrared absorption analyzer (NDIR)
Value(s) of monitored parameter	For this period, the average values of CO_{N2O}

	Plant I(CO_{N2O-1})	Plant II(CO_{N2O-2})
$CO_{N2O,i}$ as tN_2O/Nm^3	4.1148×10^{-7}	3.1459×10^{-7}

Monitoring equipment

	Plant I(CO_{N2O-1})	Plant II(CO_{N2O-2})
Type	NDIR	NDIR
Accuracy class (repeatability)	>95%	>95%
Serial No.	AO-750	AO-751
Calibration frequency	Every 2weeks	Every 2weeks
Date of last calibration	28/12/2011	28/12/2011
Validity	Yes	Yes

Measuring/Reading/ Recording frequency	•Measuring period : Continuously •Recording frequency : Hourly
Calculation method (if applicable)	Not applicable
QA/QC procedures	QAL 1, 2,3 and AST for AMS
Purpose of data	Project Emission Calculation
Additional comment	Not applicable

Data/Parameter	$P_{product,y}$
Unit	t Caprolactam/yr
Description	Plant output of caprolactam
Measured/Calculated /Default	Measured
Source of data	The value measured by Mass flow meter

Value(s) of monitored parameter	<table><tr><td></td><td>Plant I ($P_{product-1}$)</td><td>Plant II($P_{product-2}$)</td></tr><tr><td>$P_{product, period}$, (ton/period)</td><td>17,035</td><td>20,619</td></tr></table>
Monitoring equipment	<table><tr><td></td><td>Plant I ($P_{product-1}$)</td><td>Plant II($P_{product-2}$)</td></tr><tr><td>Type</td><td>Mass flow meter</td><td>Mass flow meter</td></tr><tr><td>Accuracy class</td><td>±0.1%</td><td>±0.15%</td></tr><tr><td>Serial No.</td><td>6T 681125</td><td>28 529138</td></tr><tr><td>Calibration frequency</td><td>Every 2years</td><td>Every 2years</td></tr><tr><td>Date of last calibration</td><td>07/10/2010</td><td>07/10/2010</td></tr><tr><td>Validity</td><td>Yes</td><td>Yes</td></tr></table>
Measuring/Reading/ Recording frequency	•Measuring period : Continuously •Recording frequency : Hourly
Calculation method (if applicable)	Not applicable
QA/QC procedures	Cross-check of amount of the produced caprolactam is performed on the basis of stock change data and weighbridge data.
Purpose of data	Baseline emission Calculation
Additional comment	Not applicable

Data/Parameter	$T_{g,d}$
Unit	ºC
Description	Actual daily (*d*) operating temperature of the ammonia oxidation reactor
Measured/Calculated /Default	Measured
Source of data	Thermocouple
Value(s) of monitored parameter	Average daily temperature (ºC) of AOR in period #2 <table><tr><td colspan="2">Plant I</td><td colspan="2">Plant II</td></tr><tr><td>$T_{g,a}$ (ºC)</td><td>$T_{g,b}$ (ºC)</td><td>$T_{g,c}$ (ºC)</td><td>$T_{g,d}$ (ºC)</td></tr><tr><td>699.67</td><td>728.99</td><td>752.20</td><td>749.11</td></tr></table>

Monitoring equipment	The measuring instrument for T_{g-b} which is indicated in the registered PDD was replaced on 17th October 2011. The following table is the information of the existing T_{g-b} and replaced T_{g-b}. The information of the measuring instrument for $T_{g,d}$ in plant are I,II as follows:

Plant I	T_{g-a}		T_{g-b} (before replacement)	T_{g-b} (after replacement)	
Type	Thermocouple K		Thermocouple K	Thermocouple K	
Accuracy class (Maximum error)	300 ℃	+0.00 ℃	± 0.75 ℃	300 ℃	+0.00 ℃
	500 ℃	+0.35 ℃		500 ℃	+0.35 ℃
	700 ℃	+0.98 ℃		700 ℃	+0.98 ℃
Serial No.	2170447		09002677	2170445	
Calibration frequency	2 years		2 years	2 years	
Date of last calibration	13/05/2011		13/05/2011	17/10/2011	
Validity	Yes		Yes	Yes	

Plant II	T_{g-c}		T_{g-d}	
Type	Thermocouple K		Thermocouple K	
Accuracy class (Maximum error)	300 ℃	-0.7 ℃	300 ℃	-0.7 ℃
	500 ℃	-0.1 ℃	500 ℃	-0.1 ℃
	700 ℃	-0.7 ℃	700 ℃	-0.7 ℃
Serial No.	24001		24002	
Calibration frequency	Every 2 years		Every 2 years	
Date of last calibration	23/05/2011		23/05/2011	
Validity	Yes		Yes	

Measuring/Reading/ Recording frequency	•Measuring period : Continuously •Recording frequency : Hourly
Calculation method (if applicable)	Not applicable
QA/QC procedures	Every two years, the measuring instrument is calibrated by the authorized organization providing the calibration service on the basis of the national standard. Otherwise, the measuring instrument is replaced with new instrument calibrated according to the national standard.
Purpose of data	Baseline emission Calculation
Additional comment	Not applicable

Data/Parameter	$P_{g,d}$
Unit	Pa gauge
Description	Actual operating pressure of the ammonia oxidation reactor on day *d*

Measured/Calculated /Default	Measured
Source of data	Pressure gauge
Value(s) of monitored parameter	Average daily Pressure (Pa/day) of AOR in period #2 | Plant I (P_{g-1}) | Plant II (P_{g-2}) $P_{g,d}$ (Pa/day) | 84,719 | 87,338
Monitoring equipment	See table below
Measuring/Reading/ Recording frequency	•Measuring period : Continuously •Recording frequency : Hourly
Calculation method (if applicable)	Not applicable
QA/QC procedures	Every two years, the measuring instrument is calibrated by the authorized organization providing the calibration service on the basis of the national standard. Otherwise, the measuring instrument is replaced with new instrument calibrated according to the national standard.
Purpose of data	Baseline emission Calculation
Additional comment	Not applicable

Monitoring equipment:

	Plant I (P_{g-1})	Plant II (P_{g-2})
Type	Gauge Pressure	Gauge Pressure
Accuracy class	±0.1%	±0.1%
Serial No.	10530360183	10530360212
Calibration frequency	Every 2 years	Every 2 years
Date of last calibration	11/01/2010	11/03/2010
Validity	Yes	Yes

Data/Parameter	$A_{OR,d}$
Unit	tNH_3/day
Description	Actual ammonia flow rate to the ammonia oxidation reactor (AOR)
Measured/Calculated /Default	Measured
Source of data	Differential pressure transmitter with normalizing functions
Value(s) of monitored parameter	Average ammonia flow rate a day (tNH_3/day) of AOR in period #2

	Plant I($A_{OR,d-1}$)	Plant II($A_{OR,d-2}$)
$A_{OR,d}$ (tNH_3/day)	36.427	41.220

Monitoring equipment	<table><tr><td></td><td>Plant I($A_{OR,d-1}$)</td><td>Plant II($A_{OR,d-2}$)</td></tr><tr><td>Type</td><td>Differential Pressure</td><td>Differential Pressure</td></tr><tr><td>Accuracy class</td><td>±0.1%</td><td>±0.1%</td></tr><tr><td>Serial No.</td><td>10530360038</td><td>10530360080</td></tr><tr><td>Calibration frequency</td><td>Every 2 years</td><td>Every 2 years</td></tr><tr><td>Date of last calibration</td><td>11/01/2010</td><td>11/03/2010</td></tr><tr><td>Validity</td><td>Yes</td><td>Yes</td></tr></table>
Measuring/Reading/ Recording frequency	•Measuring period : Continuously •Recording frequency : Hourly
Calculation method (if applicable)	Since this parameter is measured
QA/QC procedures	Every two years, the measuring instrument is calibrated by the authorized organization providing the calibration service on the basis of the national standard. Otherwise, the measuring instrument is replaced with new instrument calibrated according to the national standard.
Purpose of data	Baseline emission Calculation
Additional comment	Not applicable

Data/Parameter	G_{sup}
Unit	Not applicable
Description	Supplier of the ammonia oxidation catalyst
Measured/Calculated /Default	Not applicable
Source of data	Supplier information on catalyst delivery confirmation document
Value(s) of monitored parameter	Johnson Matthey
Monitoring equipment	Not applicable
Measuring/Reading/ Recording frequency	Recording frequency : Date of changing catalyst
Calculation method (if applicable)	Not applicable
QA/QC procedures	Not applicable
Purpose of data	Baseline emission Calculation
Additional comment	Not applicable

Data/Parameter	G_{com}
Unit	%
Description	Composition of the ammonia oxidation catalyst

Measured/Calculated /Default	Not applicable
Source of data	Supplier information on catalyst delivery confirmation document
Value(s) of monitored parameter	Pt (90)% : Rh(10)%
Monitoring equipment	Not applicable
Measuring/Reading/ Recording frequency	Recording frequency : Date of changing catalyst
Calculation method (if applicable)	Not applicable
QA/QC procedures	Not applicable
Purpose of data	Baseline emission Calculation
Additional comment	Not applicable

Data/Parameter	$Type_{HC}$
Unit	Not applicable
Description	Type of hydrocarbon / Natural gas
Measured/Calculated /Default	Not applicable
Source of data	Natural gas supplier : KyungDong city gas CO., Ltd. This company is one of the city gas companies in the Republic of Korea. The most of natural gas supplied by KyungDong city gas CO., Ltd. is provided from Korea Gas Corporation (hereafter, KOGAS), which imports natural gas from around the world and supplies it to power generation plants, gas-utility companies and city gas companies throughout the country.
Value(s) of monitored parameter	Natural Gas
Monitoring equipment	Not applicable
Measuring/Reading/ Recording frequency	Monthly
Calculation method (if applicable)	Not applicable
QA/QC procedures	Not applicable
Purpose of data	Project emission Calculation
Additional comment	Not applicable

Data/Parameter	CF_{CH4}
Unit	-
Description	Methane content of hydrocarbon, natural gas
Measured/Calculated /Default	Not applicable
Source of data	Information provided by the natural gas supplier

<table>
<tr><td>Value(s) of monitored parameter</td><td>The same kinds of natural gas are supplied to the Plant I and Plant II.
<table>
<tr><td>Date</td><td>September, 2011</td><td>October, 2011</td><td>November, 2011</td><td>December, 2011</td><td>Period2 Average</td></tr>
<tr><td>CF_{CH4}</td><td>0.9134</td><td>0.9142</td><td>0.9142</td><td>0.9154</td><td>0.9143</td></tr>
</table></td></tr>
<tr><td>Monitoring equipment</td><td>Not applicable</td></tr>
<tr><td>Measuring/Reading/ Recording frequency</td><td>Recording frequency : Monthly</td></tr>
<tr><td>Calculation method (if applicable)</td><td>Not applicable</td></tr>
<tr><td>QA/QC procedures</td><td>Not applicable</td></tr>
<tr><td>Purpose of data</td><td>Project emission Calculation</td></tr>
<tr><td>Additional comment</td><td>Not applicable</td></tr>
</table>

<table>
<tr><td>Data/Parameter</td><td>$Q_{NG,y}$</td></tr>
<tr><td>Unit</td><td>Nm^3</td></tr>
<tr><td>Description</td><td>Natural gas input for re-heating the tail gas</td></tr>
<tr><td>Measured/Calculated /Default</td><td>Measured</td></tr>
<tr><td>Source of data</td><td>Flow meter with normalizing functions</td></tr>
<tr><td>Value(s) of monitored parameter</td><td>Average daily value of Q_{NG} (Nm^3/day) in period #2
<table>
<tr><td></td><td>Plant I ($Q_{NG,1}$)</td><td>Plant II($Q_{NG,2}$)</td></tr>
<tr><td>Q_{NG} (Nm^3/day)</td><td>580.57</td><td>856.59</td></tr>
</table></td></tr>
<tr><td>Monitoring equipment</td><td>
<table>
<tr><td></td><td>Plant I ($Q_{NG,1}$)</td><td>Plant II($Q_{NG,2}$)</td></tr>
<tr><td>Type</td><td>Orifice</td><td>Orifice</td></tr>
<tr><td>Accuracy class</td><td>±0.90%</td><td>±0.90%</td></tr>
<tr><td>Serial No.</td><td>02319622</td><td>02319623</td></tr>
<tr><td>Calibration frequency</td><td>Every 2 years</td><td>Every 2 years</td></tr>
<tr><td>Date of last calibration</td><td>12/03/2010</td><td>12/03/2010</td></tr>
<tr><td>Validity</td><td>Yes</td><td>Yes</td></tr>
</table></td></tr>
<tr><td>Measuring/Reading/ Recording frequency</td><td>•Measuring period : Continuously
•Recording frequency : Hourly</td></tr>
<tr><td>Calculation method (if applicable)</td><td>Not applicable</td></tr>
<tr><td>QA/QC procedures</td><td>Every two years, the measuring instrument is calibrated by the authorized organization providing the calibration service on the basis of the national standard. Otherwise, the measuring instrument is replaced with new instrument calibrated according to the national standard.</td></tr>
</table>

Purpose of data	Project emission Calculation
Additional comment	Not applicable

Data/Parameter	$\boldsymbol{Q_{CH4,y}}$,
Unit	Nm^3/yr
Description	Methane part of the natural gas used.
Measured/Calculated /Default	Calculated
Source of data	Information provided by the natural gas supplier
Value(s) of monitored parameter	Average values of daily used ($\boldsymbol{Q_{CH4,d}}$) | | Plant I | Plant II | | $Q_{CH4,d}$ (Nm^3/day) | 466.48 | 746.54 |
Monitoring equipment	Not applicable
Measuring/Reading/ Recording frequency	Not applicable
Calculation method (if applicable)	$Q_{CH4,y} = Q_{NG,y} \times CF_{CH4}$
QA/QC procedures	Not applicable
Purpose of data	Project emission Calculation
Additional comment	Not applicable

Data/Parameter	$Q_{HC,y}$
Unit	Nm^3 / yr
Description	The hydrocarbon with two or more molecules of carbon in natural gas
Measured/Calculated /Default	Calculated
Source of data	Information provided by the natural gas supplier
Value(s) of monitored parameter	Average values of daily used ($\boldsymbol{Q_{HC,d}}$) | | Plant I | Plant II | | $Q_{HC,d}$ (Nm^3/day) | 43.70 | 69.97 |
Monitoring equipment	Not applicable
Measuring/Reading/ Recording frequency	Not applicable
Calculation method (if applicable)	$Q_{HC,y} = Q_{NG,y} \times (1 - CF_{CH4})$
QA/QC procedures	Not applicable
Purpose of data	Project emission Calculation
Additional comment	Not applicable

Data/Parameter	$\boldsymbol{\rho_{NG}}$

Unit	t/Nm³
Description	Density of the natural gas
Measured/Calculated /Default	Not applicable
Source of data	Monthly report provided by the fuel supplier
Value(s) of monitored parameter	(see table below)
Monitoring equipment	Not applicable
Measuring/Reading/ Recording frequency	Recording frequency : Monthly
Calculation method (if applicable)	Not applicable
QA/QC procedures	Not applicable
Purpose of data	Project emission Calculation
Additional comment	Not applicable

Date	September, 2011	October, 2011	November, 2011	December, 2011	Period2
ρ_{NG}(t/Nm³)	0.0008000	0.0008000	0.0008000	0.0007961	0.0007990

Data/Parameter	$\boldsymbol{\rho_{HC}}$
Unit	t/m³
Description	Density of the hydrocarbon with two or more molecules of carbon in natural gas
Measured/Calculated /Default	Calculated
Source of data	Information provided by the natural gas supplier
Value(s) of monitored parameter	(see table below)
Monitoring equipment	Not applicable
Measuring/Reading/ Recording frequency	Not applicable
Calculation method (if applicable)	$\rho_{HC} = (\rho_{NG}-\rho_{CH4} \times CF_{CH4}) / (1-CF_{CH4})$
QA/QC procedures	Not applicable
Purpose of data	Project emission Calculation
Additional comment	Not applicable

Date	September, 2011	October, 2011	November, 2011	December, 2011	Period2
$\boldsymbol{\rho_{HC}}$(t/Nm³)	0.0016860	0.0016950	0.0016950	0.0016628	0.0016847

Data/Parameter	$\boldsymbol{EF_{NG}}$
Unit	tCO_2/tNG
Description	Emission factor of the natural gas

Measured/Calculated /Default	Calculated
Source of data	Information provided by the natural gas supplier
Value(s) of monitored parameter	<table><tr><td>Date</td><td>September, 2011</td><td>October, 2011</td><td>November, 2011</td><td>December, 2011</td><td>Period2</td></tr><tr><td>EF_{NG}</td><td>2.7581</td><td>2.7586</td><td>2.7589</td><td>2.7727</td><td>2.7621</td></tr></table>
Monitoring equipment	Not applicable
Measuring/Reading/ Recording frequency	Not applicable
Calculation method (if applicable)	$EF_{NG} = COEF_{NG} \times NCV_{NG}/\rho_{NG} \times 44/12$ Where $COEF_{NG}$: Carbon Emission factor of natural gas [tC/TJ] 15.3[tC/TJ] is applied to this project as Ex-ante value by IPCC DEFAULT VALUES OF CARBON CONTENT of "Natural Gas" in TABLE 1.3 (2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 2, Energy) NCV_{NG} : Net calorific value of the natural gas [TJ/Nm^3] For this project, NCV_{NG} is offered by KOGAS. ρ_{NG} : Density of the natural gas[t/Nm^3] For this project, based on data source by natural gas supplier.
QA/QC procedures	Not applicable
Purpose of data	Project emission Calculation
Additional comment	Not applicable

Data/Parameter	EF_{HC}
Unit	tCO_2/tHC
Description	Emission factor of the hydrocarbon with two or more molecular of carbon, which is existed as a contents of the natural gas
Measured/Calculated /Default	Calculated
Source of data	Calculated based on the followings: Methane content offered by the fuel supplier ; The density of the natural gas provided by the fuel supplier ; Estimated emission factor of the natural gas, and Specified methane density
Value(s) of monitored parameter	<table><tr><td>Date</td><td>September, 2011</td><td>October, 2011</td><td>November, 2011</td><td>December, 2011</td><td>Period2</td></tr><tr><td>EF_{HC}</td><td>2.7944</td><td>2.7971</td><td>2.7991</td><td>2.8787</td><td>2.8173</td></tr></table>
Monitoring equipment	Not applicable

Measuring/Reading/ Recording frequency	Not applicable
Calculation method (if applicable)	$EF_{HC} = (EF_{NG} \times \rho_{NG} - EF_{CH4} \times \rho_{CH4} \times CF_{CH4}) / (1-CF_{CH4}) / \rho_{HC}$ Where EF_{NG} : CO_2 emission factor of NG[tCO_2/tNG ρ_{NG} : Density of natural gas (tNG/m^3) EF_{CH4} : CO_2 emission factor of CH_4(tCO_2/tCH_4). ρ_{CH4} : Density of methane (tCH_4/ m^3). CF_{CH4} : Methane fraction in the natural gas
QA/QC procedures	Not applicable
Purpose of data	Project emission Calculation
Additional comment	Not applicable

Data/Parameter	SE_{N2O}
Unit	kgN_2O/tCaprolactam
Description	N_2O emission rate per ton of caprolactam
Measured/Calculate d /Default	Calculated
Source of data	Baseline and Monitoring Methodology (AM00 28 ver05)
Value(s) of monitored parameter	Average: <table><tr><td></td><td>Plant I</td><td>Plant II</td></tr><tr><td>$SE_{N2O, period}$(kgN_2O/tCaprolactam)</td><td>24.97</td><td>17.38</td></tr></table>
Monitoring equipment	Not applicable
Measuring/Reading/ Recording frequency	Not applicable
Calculation method (if applicable)	$SE_{N2O,period} = QI_{N2O,period} / P_{product,period} \times 1000$ Where, $QI_{N2O,y}$ means Quantity of N_2O emissions at the inlet of the destruction facility ($t N_2O$)
QA/QC procedures	Not applicable
Purpose of data	Baseline emission Calculation
Additional comment	Not applicable

Data/Parameter	$OXID_{CH4}$
Unit	%
Description	Oxidation factor of CH_4 in natural gas for re-heating tail gas
Measured/Calculate d /Default	Calculated
Source of data	Not applicable
Value(s) of monitored parameter	Average: <table><tr><td></td><td>Period 1</td><td>Plant II</td></tr><tr><td>$OXID_{CH4}$</td><td>94.61</td><td>97.98</td></tr></table>
Monitoring equipment	Not applicable
Measuring/Reading/ Recording frequency	Not applicable

Calculation method (if applicable)	$OXID_{CH4}=\{ Q_{CH4} - (\sum_{i}^{n} F_{TE,i} \times CO_{CH4,i} \times 10^{-6})\} / Q_{CH4} \times 100$
QA/QC procedures	Not applicable
Purpose of data	Project emission Calculation
Additional comment	Not applicable

Data/Parameter	CO_{CH4}
Unit	ppm (v)
Description	Methane concentration at destruction facility outlet.
Measured/Calculated /Default	Measured
Source of data	Non-dispersion infrared absorption analyzer with dual-channel as a gas path
Value(s) of monitored parameter	Average: CO_{CH4} (ppm) — Period 2 Plant I (CO_{CH4-1}): 26.59 Plant II (CO_{CH4-2}): 15.11
Monitoring equipment	(see table below)
Measuring/Reading/ Recording frequency	•Measuring period : Continuously •Recording frequency : Hourly
Calculation method (if applicable)	Not applicable
QA/QC procedures	Every two years, the measuring instrument is calibrated by the authorized organization providing the calibration service on the basis of the national standard. Otherwise, the measuring instrument is replaced with new instrument calibrated according to the national standard.
Purpose of data	Project emission Calculation
Additional comment	Not applicable

Values of monitored parameter:

CO_{CH4} (ppm)	Period 2
Plant I (CO_{CH4-1})	26.59
Plant II (CO_{CH4-2})	15.11

Monitoring equipment:

	Plant I (CO_{CH4-1})	Plant II(CO_{CH4-2})
Type	NDIR	NDIR
Accuracy class	>95%	>95%
Serial No.	AO-750	AO-751
Calibration frequency	Every 2weeks	Every 2weeks
Date of last calibration	28/12/2011	28/12/2011
Validity	Yes	Yes
Model	ULTRAMAT 6	ULTRAMAT 6

Data/Parameter	Reg_{NOx}
Unit	$tNOx/Nm^3$
Description	National regulation on NOx emissions
Measured/Calculated /Default	Not applicable

Source of data	The "Clean Air Conservation Act", one of the National environmental legislation, Ministry of Environment
Value(s) of monitored parameter	4.10714 x 10^{-7} tNOx/Nm_3 (as a NO_2 concentration)
Monitoring equipment	Not applicable
Measuring/Reading/ Recording frequency	Recording frequency : Date of Regulation
Calculation method (if applicable)	Not applicable
QA/QC procedures	Not applicable
Purpose of data	Baseline emission Calculation
Additional comment	Not applicable

Data/Parameter	$RSE_{N2O,y}$
Unit	tN_2O/tCaprolactam
Description	Regulatory limit of N_2O emissions per unit of outlet of caprolactam (tN_2O/t caprolactam)
Measured/Calculated /Default	Not applicable
Source of data	National legislation in Republic of Korea. (That may be mostly like environmental regulation.)
Value(s) of monitored parameter	Not applicable
Monitoring equipment	Not applicable
Measuring/Reading/ Recording frequency	Recording frequency : Date of Regulation
Calculation method (if applicable)	Not applicable
QA/QC procedures	Not applicable
Purpose of data	Baseline emission Calculation
Additional comment	Not applicable

D.3. Implementation of sampling plan

>>

N/A

SECTION E. Calculation of emission reductions or GHG removals by sinks

E.1. Calculation of baseline emissions or baseline net GHG removals by sinks

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In the case of a nitric acid plant or a caprolactam plant using the Raschig process, baseline emissions are limited to the design capacity of the existing nitric acid or caprolactam production plant. If the actual production of caprolactam ($P_{product}$) exceeds the design capacity ($P_{product,max}$) then emissions related to the production above $P_{product,max}$ will not be claimed for the baseline scenario. Therefore $P_{product,}$ of each plant

should be monitored. However, it is not able to be decided whether the actual production of caprolactam exceeds $P_{product,max}$ or not, because those values($P_{product,max}$ and $P_{product}$) should be compared on the annual values for comparing each other, and only 206 days have been monitored for this project since starting date of crediting period (84 days for first period and 122days for second period). So, in order to simply make rough estimation to the status of production, the actual average daily output for period 2 was compared with the expected average daily output described in PDD, as shown in the Table E.1. As a result, it can be said that actual values are lower for both of plants. (All of the data for the actual daily production of caprolactam were listed in detail in the emission reductions calculation spreadsheet.)

Table E.1 The Daily output of Caprolactam Production

Item		Plant I	Plant II
PDD	Design Capacity , $P_{product,max}$ (ton/yr)	63,307	64,965
	Daily output(ton/day)	174	183
Period (01/09/2011-31/12/2011)	Period total, $P_{product,period}$ (ton/period)	17,035	20,619
	Average value of daily output (ton/day)	153	169

Therefore on the assumption $P_{product,y} < P_{product,\ max}$, baseline emissions ($BE$) for this period are given by following equation :

$$BE_{\ period} = \left(\sum_{i}^{n} F_{TI,i} \times CI_{N2O,i} \times M_i\right) \times GWP_{N2O}$$

Where

M_i	Length of Measuring Interval (hr), (1hr : set value at instrument for this project)
GWP_{N2O}	Global warming potential of the N_2O, (310: default value).
N	Number of intervals during this period
$F_{TI,i}$	Volume flow rate at the inlet of the DF during interval (Nm^3/hr)
$CI_{N2O,i}$	N_2O concentration in the tail gas of the DF inlet during interval ($tN_2O/\ Nm^3$)

If the actual average daily operating temperature and/or pressure in the ammonia oxidation reactor (T_g and P_g) are outside a "permitted range" of operating temperatures and/or pressures ($T_{g,hist}$ and $P_{g,hist}$), the baseline emission is integrated of the daily baseline emission($BE_{,daily,\ out\ of\ permit\ range}$) for the respective day in which AOR operation conditions were outside of "permitted range". The daily baseline emission is calculated for the respective time period as follows:

$$BE_{daily,\ out\ of\ permit\ range} = P_{product,\ day} \times EF_{N2O} \times GWP_{N2O} / 1000$$

Where

$BE_{daily,\ out\ of\ permit\ range}$: The daily daseline emission for the respective day in which AOR operation conditions were outside of "permitted range"(tonCO_2/day)

$P_{product,\ day}$: The daily output of caprolactam for the respective day in which AOR operation conditions were outside of permitted range (ton caprolactam/day)

EF_{N2O} : N_2O Emission factor to the process of caprolactam production (kgN_2O/ton caprolactam)

Emission factor of N_2O(EF_{N2O}) is the lowest value among (a) $EF_{N2O,IPCC}$, (b) $SE_{N2O,y}$ and (c) any related value as a result of legal regulation(e.g. $RSE_{N2O,y}$). In Republic of Korea, there is no mandatory regulation for N_2O emission. Therefore, actually *EF of* N_2O is the lower value between (a) $EF_{N2O,IPCC}$ and (b) $SE_{N2O,y}$. $F_{N2O,IPCC}$ means Conservative IPCC default value of the latest IPCC GHG Inventory Guidelines accepted by the IPCC for the equivalent N_2O emission process. At this time, $EF_{N2O,IPCC}$ is 5.4kgN_2O/tonne of caprolactam.

$SE_{N2O,y}$ is the specific N_2O emission per unit of output of caprolactam defined as :

$$SE_{N2O,y} = QI_{N2O,y} / P_{product,y} \times 1000$$

Where, $QI_{N2O,y}$ means Quantity of N_2O emissions at the inlet of the destruction facility in year, y (t N_2O) given by :

$$QI_{N2O,y} = \sum_{i}^{n} F_{TI,i} \times CI_{N2O,i} \times M_i$$

For this period, $SE_{N2O,y}$ should be converted as $SE_{N2O,period}$ as follows :

$$SE_{N2O,period}. = QI_{N2O,\ period} / P_{product,period}$$

On condition of that the actual daily ammonia flow rate exceeds the (upper) limit on maximum historical daily permitted ammonia flow rate, the baseline N_2O emissions for this operating day are capped at conservative IPCC default values. Where, the upper limit on ammonia flow should be determined based on "the historical operating data on maximum daily average ammonia flow".

1. **Plant I**

<u>BE in Plant I with AOR operation conditions within "permitted range"</u>

In order to calculate the hourly BE ($BE_{,hr-1}$), the hourly integrated measured values of $F_{TI,i\ -1}$and $CI_{N2O,-1i}$ except the data to the to the day in which AOR was operated outside of permit range, are input. These hourly BE ($BE_{,hr-1}$) are aggregated to the daily BE($BE_{,day-1}$), and total BE on the period for plant I ($BE_{,period-1}$), 131,842.47 tonCO_2/period , are estimate as sum of $BE_{,day-1}$. 111days are considered for calculating among the number of operating days of period 2 (122days), because it is exclude that the respective day in which AOR operation conditions were outside of "permitted range.

BE calculated on hourly input data is explained in detail on the emission reductions calculation spreadsheet.

BE in case of AOR operation conditions outside of "permitted range".

Quantity of N_2O emissions at the inlet of the destruction facility in period 2($QI_{N2O,\ period\text{-}2}$) was 425.30 ton/period. The total production of caprolactam for period 2 was 17,035ton/period. Therefore $SE_{N2O,period}$ is calculated to be 24.97 kgN_2O/t Caprolactam. Between $EF_{N2O,IPCC}$ and $SE_{N2O,period}$ (5.4 and 24.97 kgN_2O/t Caprolactam respectively), the lower value should be taken as the EF_{N2O} for calculating $BE_{,\ day\text{-}1}$ in which AOR was operated outside of permit range. So, the value of EF_{N2O} is 5.4 kgN_2O/t Caprolactam.

Table E.2 EF_{N2O} of period 2 of Plant I

parameter		Values	Unit	Note
$QI_{N2O,period.}$		425.30	ton N_2O/period	$QI_{N2O,y} = \sum_{i}^{n} F_{TI,i} \times CI_{N2O,i} \times M_i$
$P_{product,\ period,}$		17,035	ton/period	/
EF_{N2O}	$EF_{N2O,IPCC}$	5.4	kgN_2O/tCaprolactam	Lower value should be taken
	$SE_{N2O,period}$	24.97		

All of the daily caprolactam productions for the respective days in which AOR operation conditions were outside of permitted range were zero, because AOR operation conditions are deviated from the permit ranges definite in PDD for 11days (09/10/2011~19/10/2011) for which regular complete overhaul was performed. Therefore each of the daily baseline emission ($BE_{daily,\ out\ of\ permit\ range}$) is estimated as zero also.

As a result, the baseline emission in which AOR operation conditions were outside of permitted range for period 2 ($BE_{period,\ out\ of\ permit\ range}$) is zero.

2. **Plant II**

BE by Plant 2 with AOR operation conditions within "permitted range"

Hourly BE ($BE_{,hr\text{-}2}$) calculated on hourly integrated measured values of $F_{T\ i\text{-}2}$ and $CI_{N2O,i\text{-}2}$ are aggregated to the daily BE($BE_{,day\text{-}2}$), and total BE on the period ($BE_{,period\text{-}2}$) are estimate as sum of $BE_{,day\text{-}2}$. The total BE on the period 2 for Plant 2 ($BE_{,period\text{-}2}$) is 111,056.93 $tonCO_2$/period. All of daily average values of the AOR operation condition parameters have been kept within permit range.

BE calculated on hourly input data is explained in detail on the emission reductions calculation spreadsheet.

BE in case of AOR operation conditions outside of "permitted range".

In case of Plant II, permit range of AOR operation condition has been kept for period 2. Therefore it is not necessary that the baseline emission calculation for period 2 depending on IPCC default values or ($SE_{N2O,y}$)the specific N_2O emission per unit of output of caprolactam.

3. The total BE of Period 2

Eventually, Total BE in this period is 242,899.40 ton CO_2 as shown below table.

Table E.3 Summary of BE for period 2

Item		$BE_{period\text{-}2}$ (ton CO_2/period)	
		$BE_{period\text{-}2}$ in Plant I	$BE_{period\text{-}2}$ in Plant II
BE_{period} on AOR condition	within "permitted range	131,842.47	111,056.93
	Outside "permitted range	0	0
BE_{period} total	BE_{period} for each plant	131,842.47	111,056.93
	$BE_{period\text{-}total}$	242,899.40	

E.2. Calculation of project emissions or actual net GHG removals by sinks

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The emission due to the project activity are composed of (a) the emissions of not destroyed N_2O, (b) on-site emissions due to the hydrocarbons (; Natural Gas) use as input to the N_2O destruction facility, and (c) the emissions from the operation of the destruction facility.

Hydrocarbons can be used as reducing agent and/or re-heating the tail gas to enhance the catalytic N_2O reduction efficiency. In this project, natural gas is used for re-heating the tail gas to enhance the catalytic N_2O reduction efficiency

$$PE_{period} = \left(\sum_{i}^{n} F_{TE,i} \times CO_{N2O,i} \times M_i\right) \times GWP_{N2O}$$
$$+ \left[(\rho_{HC} \times Q_{HC,y} \times EF_{HC} \times OXID_{HC}/100) + (\rho_{CH4} \times Q_{CH4,y} \times EF_{CH4} \times OXID_{CH4}/100) \right]$$
$$+ \left[\rho_{CH4} \times Q_{CH4,y} \times GWP_{CH4} \times (1-OXID_{CH4}/100) \right]$$

n	: Number of intervals during the year ($period^{-1}$)
M_i	: Length of Measuring Interval (hr), (1hr : set value at instrument for this project)
$F_{TE,i}$	: Volume flow rate at the exit of the DF during interval i (Nm^3/hr)
$CO_{N2O,i}$	: N_2O concentration in the tail gas of the DF exit during interval i (tN_2O/m^3)
GWP_{CH4}	: Global warming potential of CH_4, 21 (: default value)
GWP_{N2O}	: Global warming potential of the nitrous oxide, 310 (: default value)
ρ_{CH4}	: Density of methane (tCH_4/m^3) , 0.000716
ρ_{HC}	: Density of HC (tHC/m^3)
EF_{CH4}	: CO_2 emission factor of CH_4 (tCO_2e/tCH_4), 2.75
EF_{HC}	: CO_2 emission factor of HC with two or more carbon molecule in natural gas (tCO_2e/tHC)
$Q_{CH4,y}$	: Methane used in period (Nm^3/period)
$Q_{HC,y}$	: HC with two or more carbon molecule in natural gas used in period (Nm^3/period)

$OXID_{CH4}$: Oxidation factor of methane (%)

$OXID_{HC}$: Oxidation factor of HC(%), 100% (Fixed value)

Hourly calculated PE ($PE_{,hr}$) are aggregated into the daily PE($PE_{,day}$), and total PE on the period ($PE_{,period}$) are estimated as sum of $PE_{,day}$. ER calculation sheet for each plant which daily measured and calculated results were integrated into is in detail on the mission reductions calculation spreadsheet

1. **Plant 1**

In order to calculate the hourly PE ($PE_{,hr-1}$) for Plant I, the hourly integrated measured values of $F_{TE,i\ -1}$and $CO_{N2O,i-I}$ are input. These hourly PE ($PE_{,hr-1}$) are aggregated to the daily PE($PE_{,day-1}$), and total PE on the period2 for plant I ($PE_{,period-1}$) is 14,112.46 tonCO_2/period .

PE on the period2 for plant I calculated on hourly input data is explained in detail on the emission reductions calculation *spreadsheet.*

2. **Plant II**

The hourly integrated measured values of $F_{TE,i\ -2}$ and $CO_{N2O,i-2}$ are input for calculating hourly PE for Plant II($PE_{,hr-2}$) , and then these hourly PE ($PE_{,hr-2}$) are aggregated to the daily PE($PE_{,day-2}$). The total PE on the period for plant II ($PE_{,period-2}$) is 12,249.16 tonCO_2/period .

PE on the period2 for plant II calculated on hourly input data is explained in detail on the emission reductions calculation spreadsheet.

3. **The total PE of Period 2**

Total PE in this period is 26,361.62 ton CO_2 as shown below table.

Item	Plant I	Plant II
PE for each Plant (ton CO_2/period)	14,112.46	12,249.16
PE for Period total, PE_{period} (ton CO_2/period)	26,361.62	

E.3. Calculation of leakage
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The installation of the N_2O destruction facility doesn't result in significant additional energy consumption at the caprolactam production plant. In conclusion, no leakage is expected at this project as per the registered PDD. The emission by leakage is accounted as zero ($LE_y = 0$)

E.4. Summary of calculation of emission reductions or net anthropogenic GHG removals by sinks

The emission reduction ER_{period} by the project activity during a given year y is the difference between the baseline emissions (BE_{period}) and project emissions (PE_{period}), as follows:

$$ER_{period} = BE_{period} - PE_{period} - LE_{period}$$

Therefore ER_{period} can be estimated upon the values of BE_{period} PE_{period} and LE_{period} those are calculated as mentioned above.

Table E.4 Summary of ER for period 2

Time Period (01/09/2011-31/12/2011)	**Baseline emissions or baseline net GHG removals by sinks (tCO_2e)**	**Project emissions or actual net GHG removals by sinks (tCO_{2e})**	**Leakage (tCO_2e)**	**Emission reductions or net anthropogenic GHG removals by sinks (tCO_2e)**
Plant I	131,842.47	14,112.46	0	117,730.01
Plant II	110,056.93	12,249.16	0	98,807.76
Total	242,899.40	26,361.62	0	216,537

E.5. Comparison of actual emission reductions or net anthropogenic GHG removals by sinks with estimates in registered PDD

Below table is to show comparison of actual values of the emission reductions achieved during the monitoring period with the estimations in the registered CDM-PDD.

Table E.5 Comparison of actual emission reductions with estimates in the CDM-PDD

Item	Values applied in ex-ante calculation of the registered PDD	Actual values reached during the monitoring period
Emission reductions (tCO_2e)	660,995	216,537
Days	365	122
Daily average(tCO_2e/day)	1,811	1,775

The actual value is lower than the ex-ante calculated value of the registered CDM-PDD.

E.6. Remarks on difference from estimated value in registered PDD

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Not applicable

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History of the document

Version	Date	Nature of revision
02.0	EB 66 13 March 2012	Revision required to ensure consistency with the "Guidelines for completing the monitoring report form" (EB 66, Annex 20).
01	EB 54, Annex 34 28 May 2010	Initial adoption.
Decision Class: Regulatory **Document Type**: Form **Business Function**: Issuance		