



**Monitoring report form**  
**(Version 05.1)**

*Complete this form in accordance with the Attachment "Instructions for filling out the monitoring report form" at the end of this form.*

**MONITORING REPORT**

<b>Title of the project activity</b>	N <sub>2</sub> O Abatement Project of Capro Corporation	
<b>UNFCCC reference number of the project activity</b>	4665	
<b>Version number of the monitoring report</b>	v.2.1	
<b>Completion date of the monitoring report</b>	10/02/2016	
<b>Monitoring period number and duration of this monitoring period</b>	Period Number : 5 Duration : 01/01/2013 –15/11/2013 (first and last days included)	
<b>Project participant(s)</b>	Capro Corporation Hyosung Ebara Engineering Co., Ltd. Hyosung Corporation	
<b>Host Party</b>	The Republic of Korea	
<b>Sectoral scope(s)</b>	Scope No. 5, Chemical industries	
<b>Selected methodology(ies)</b>	AM0028(Version 05) Catalytic N <sub>2</sub> O destruction in the tail gas of Nitric Acid Plants or Caprolactam Production	
<b>Selected standardized baseline(s)</b>	None	
<b>Estimated amount of GHG emission reductions or net GHG removals by sinks for this monitoring period in the registered PDD</b>	577,691 tCO <sub>2</sub> e/period (Year total amount in PDD : 660,995 tCO <sub>2</sub> e/y)	
<b>Total amount of GHG emission reductions or net GHG removals by sinks achieved in this monitoring period</b>	GHG emission reductions or net GHG removals by sinks reported up to 31 December 2012	GHG emission reductions or net GHG removals by sinks reported from 1 January 2013 onwards
	N/A	472,010 tCO <sub>2</sub> e

## 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<sub>2</sub>O emissions of the tail gas emitted from Caprolactam production process in Capro Corporation (hereinafter "Capro") by installing catalytic N<sub>2</sub>O destruction system.
- (b) Brief description of the installed technology and equipments;  
N<sub>2</sub>O treatment system for this project is CRI N<sub>2</sub>O abatement system, which is N<sub>2</sub>O 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<sub>2</sub>O 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 <sub>2</sub> O abatement system
20/04/2011	Commissioning start(Plant 1)
27/04/2011	Commissioning start(Plant 2)
02/05/2011	Completing Construction of N <sub>2</sub> O abatement system and the N <sub>2</sub> O 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 this project, which means the starting date of the crediting period of this project.
26/09/2011 ~29/09/2011	Additional Field Test for Quality Assurance (QAL2) of installation and calibration of AMS
14/05/2012 ~17/05/2012	Taking Annual surveillance test (AST) for Quality Assurance of AMS
23/05/2013 ~ 25/05/2013	Taking Annual surveillance test (AST) for Quality Assurance of AMS for Plant 1
22/05/2013 ~ 23/05/2013	Taking Annual surveillance test (AST) for Quality Assurance of AMS for Plant 2

- (d) Total emission reductions achieved in this monitoring period: 472,010 tonCO<sub>2</sub>e

### 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 whether the Party involved wishes to be considered as project participant (yes/no)
The Republic of Korea(host)	Private entity • Capro Corporation • Hyosung Ebara Engineering Co., Ltd. • Hyosung Corporation	No

**A.4. Reference of applied methodology and standardized baseline**

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1. The reference of :

(a) The applied methodology :

AM0028 "Catalytic N<sub>2</sub>O destruction in the tail gas of Nitric Acid Plants or Caprolactam Production" (Version 05.1.0)

(b) Any tools to which the applied methodology refers :

"Tool for the demonstration and assessment of additionality"(Version 05.2)

2. UNFCCC CDM website for :

(a) The applied methodology : <http://cdm.unfccc.int/methodologies/index.html>

(b) Any tools to which the applied methodology refers :

<http://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-01-v5.2.pdf>**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	Year	Period No.	period	No. of days
	1 <sup>st</sup> year	1 <sup>st</sup>	09/06/2011 ~ 31/08/2011	84
		2 <sup>nd</sup>	01/09/2011 ~ 31/12/2011	122
		Accumulated no. of operating days for the year		<b>206</b>
	2 <sup>nd</sup> year	3 <sup>rd</sup>	01/01/2012 ~ 08/06/2012	160
		4 <sup>th</sup>	09/06/2012 ~ 31/12/2012	205
		Accumulated no. of operating days for the year		<b>365</b>
	3 <sup>rd</sup> year	5 <sup>th</sup> (This period)	01/01/2013 ~15/11/2013	319
Accumulated number of days				<b>890</b>

**A.6. Contact information of responsible persons/entities**

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Information of the person responsible for completing the CDM-MR-FORM is as follows:

<b>Organization name</b>	Hyosung Corporation
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Street/P.O. Box	450 Gongduk-Dong, Mapo-Gu
Building	Hyosung Building
City	Seoul
State/region	-
Postcode	121-720
Country	Republic of Korea
Telephone	+8227077586
Fax	+8227077664
E-mail	memories37@hyosung.com
Website	<a href="http://www.hyosung.com">www.hyosung.com</a>
Contact person	YungYul Choi
Title	Associate
Salutation	Mr.
Last name	Choi
Middle name	
First name	YungYul
Department	Green Management Team in Corporate Strategy Center
Mobile	+821029372463
Direct fax	
Direct tel.	+8227077586
Personal e-mail	memories37@gmail.com

The person is a project participant in Appendix 1.

## SECTION B. Implementation of project activity

### B.1. Description of implemented registered project activity

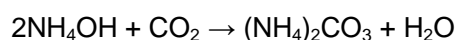
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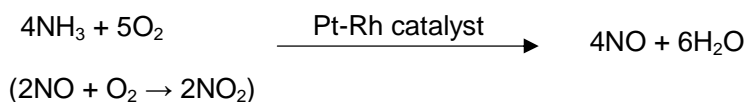
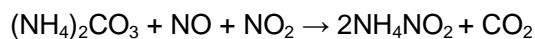
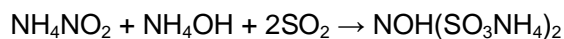
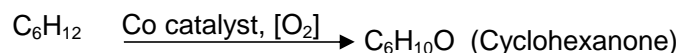
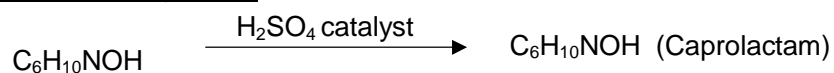
#### (a) General Introduction

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:

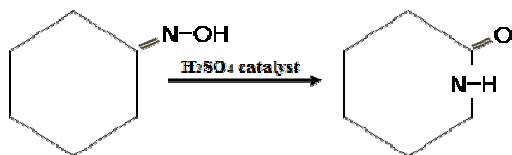
Hydroxylamine sulfate preparation :

Ammonium carbonate preparation



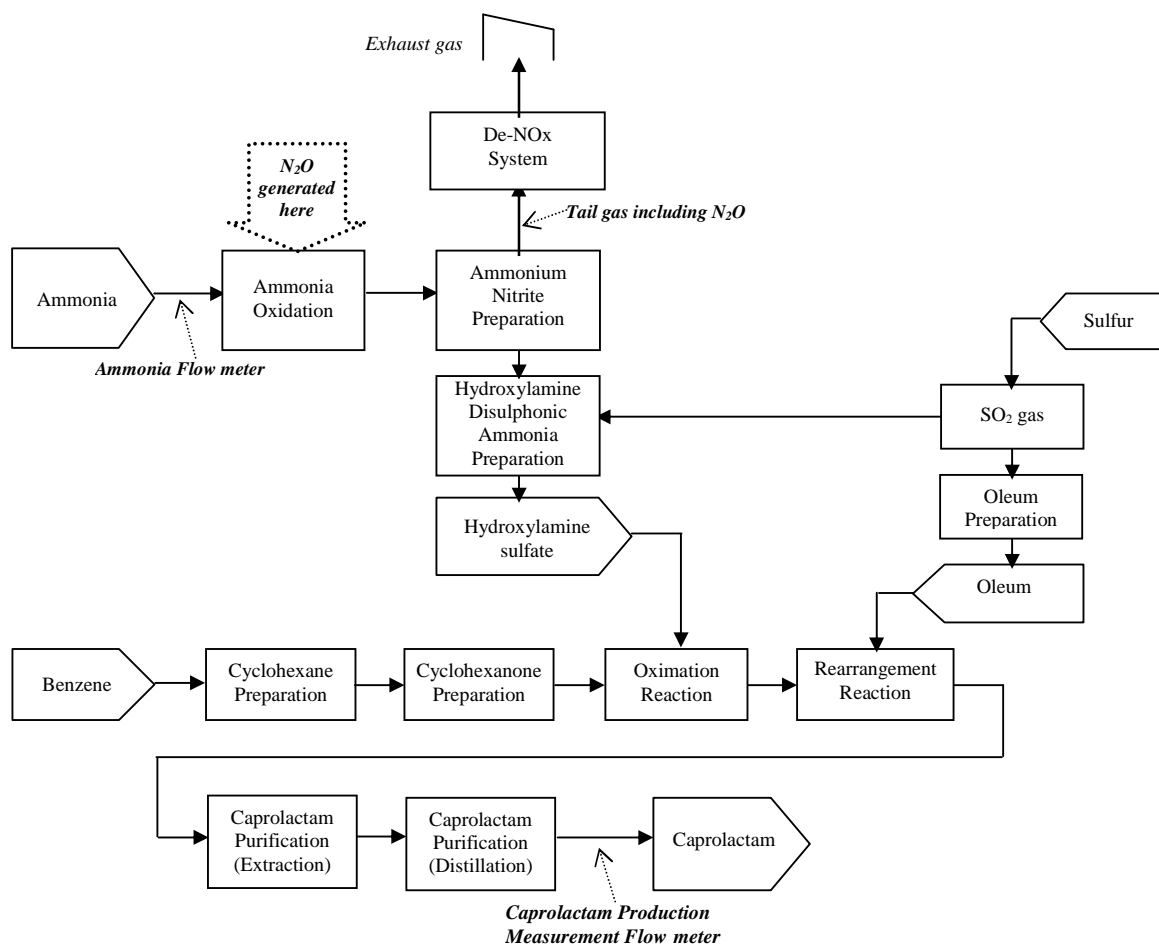
Ammonia oxidationAmmonium Nitrite Preparation:Hydroxylamine disulfonic ammonia Preparation:Hydroxylamine Sulfate Preparation:Cyclohexanone preparationOximation Reaction:Beckmann rearrangement:

Cyclohexanone oxime reacts with sulfuric acid catalyst to caprolactam as final product. The structural formula of Beckmann rearrangement is shown in Figure B1-1.



**Figure B1-1.** Structural formula of Beckmann rearrangement

The block flow diagram for existed caprolactam production process of Capro is shown in Figure B1-2.



**Figure B1-2.** Block flow diagram for caprolactam production process

Ammonia oxidation reaction is necessary to generate NO and NO<sub>2</sub>, 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<sub>2</sub>O) is generated as an undesired by-product through the side reaction of Ammonia oxidation as follows:



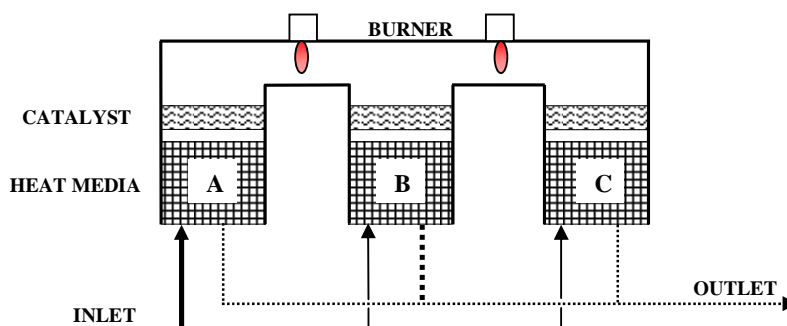
In this project, two plants (Plant I, Plant II) are included. In each plant, there are two of the Ammonium Oxidation Reactors (AORs), the ammonia gas is equally fed to the both of AORs through the one line with one flow meter. Input ammonia is oxidized by passing through the Pt-Rh Catalyst gauze located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

**(b) Description of the installed technology, technical processes and equipments:**

De-N<sub>2</sub>O system for this project is to destruct the N<sub>2</sub>O included in tail gas by catalyst without any reducing agent.

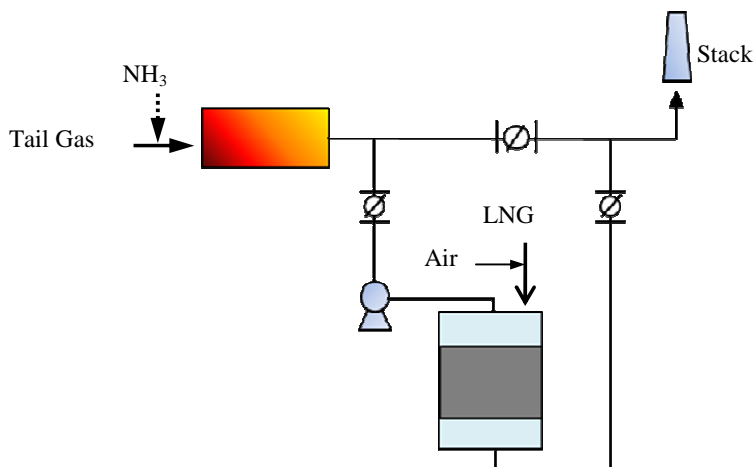


The catalytic reactor designed by Hyosung Ebara Engineering Co. was derived from RTO (Regenerative Thermal Oxidizer), to save the energy required for catalytic reaction to decompose N<sub>2</sub>O, and this N<sub>2</sub>O destruction facility is the so-called "Regenerative Catalytic System". Where, liquefied 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<sub>2</sub>O catalytic reaction. Catalyst is provided by CRI.



**Figure B1-3.** Overview of Regenerative Catalytic System

The principle of performance can be step-wisely described with Figure B1-3 as follows: At the inlet of De-N<sub>2</sub>O system, in-flowed tail-gas is heated up to 550°C by going to heat media A (previously heated), before N<sub>2</sub>O 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<sub>2</sub>O in the once treated tail gas is decomposed again by the next catalytic 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<sub>2</sub>O processes have been applied to Plant I and II.



**Figure B1-4.** Overview of the De-N<sub>2</sub>O process in Plant I and II

**(c) Information on the implementation and actual operation of the project activity**

The information on the implementation and actual operation of the project activity including relevant dates is summarized as following table

**Table B1-1** The information on the implementation and actual operation of the project activity

The information on the implementation and actual operation of the project activity	Relevant dates (dd/mm/yyyy)	
	Plant I	Plant II
Starting Construction of N <sub>2</sub> O abatement system	16/11/2010	16/11/2010
Commissioning start	20/04/2011	27/04/2011
Starting continued normal operation	02/05/2011	02/05/2011
Regular overhaul (period 2)	08/10/2011 ~ 20/10/2011	None
Regular overhaul (period 4)	11/10/2012 ~ 24/10/2012	11/10/2012 ~ 29/10/2012
Regular overhaul (period 5)	10/10/2013 ~ 15/11/2013	10/10/2013 ~ 31/10/2012

In order to avoid that the operation of the caprolactam production plant is manipulated in a way to increase the N<sub>2</sub>O generation, thereby increasing the CERs, the operating temperature and pressure of the ammonia oxidation reactor (AOR), and NH<sub>3</sub> input to the AOR, have been monitored every working day. During the monitoring period 5, the actual average daily AOR operation conditions are monitored as below Table B1-2.

**Table B1-2** Summary of the AOR operation data

Plant I	Item	$T_{a,a}$ (°C)	$T_{a,b}$ (°C)	$P_{a-1}$ ( Pa )	$A_{OR,d-1}$ (tonNH <sub>3</sub> /d)
	Permit range in PDD	656.57~731.66	662.08~743.92	43,320~98,564	42.250 (Upper limit)
	Actual average in period 5	719.53	730.87	79,372	36.456
	The number of days outside permit range	40	40	40	0
Plant II	Item	$T_{a,c}$ (°C)	$T_{a,d}$ (°C)	$P_{g-2}$ ( Pa )	$A_{OR,d-2}$ (tonNH <sub>3</sub> /d)
	Permit range in PDD	738.95~774.85	734.53~770.57	79,317~96,381	44.557 (Upper limit)
	Actual average in period 5	747.08	742.05	83,476	39.643
	The number of days outside permit range	27	27	37	0

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

**Table B1-3** The status of ammonia oxidation catalysts installed in AOR

Item		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 4	The composition ( $G_{com}$ )	Pt(90%): Rh(10%)	Pt(90%): Rh(10%)
	Supplier ( $G_{sup}$ )	Johnson Matthey	Johnson Matthey



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 ( $P_{\text{product}}$ ) exceeds the design capacity ( $P_{\text{product,max}}$ ) then emissions related to the production above  $P_{\text{product,max}}$  will not be claimed for the baseline scenario. Therefore  $P_{\text{product}}$  of each plant should be monitored. All of the data for production of caprolactam for this period were listed in detail in the emission reductions calculation spreadsheet.

**Table B1-4** The information of Caprolactam production

Item		Plant I	Plant II
PDD	$P_{\text{product,max}}$ (tCaprolactam/yr)	63,307	64,965
	Maximum operating day(day/yr)	363	355
	Average daily output(ton/day)	174	183
Period 5	Sub-total output for period(tCaprolactam/period)	40,384	48,744
	No. of operating days(day/period)	319	319
	Average daily output(ton/day)	126.60	152.80

The actual production of caprolactam ( $P_{\text{product}}$ ) did not exceed the design capacity ( $P_{\text{product,max}}$ )

**(d) Events or situations occurred during the monitoring**

(1) Events of Plant I

Events information

**Table B1-5** The list of operating events of Plant 1

Sites	No.	Date (dd/mm/yy) & Time		description
		from	to	
N <sub>2</sub> O Abatement System (NAS)	1	11/01/2013, 11:46	11/01/2013, 18:08	Replacing the damaged shaft (:XV-1521A limit S/W shaft).
	2	25/06/2013, 16:00	25/06/2013, 17:00	Data signal out because of communications disruption
	3	27/06/2013, 14:00	27/06/2013, 16:00	
	4	27/06/2013, 18:00	27/06/2013, 19:00	
	5	27/06/2013, 20:00	27/06/2013, 21:00	
	6	28/06/2013, 12:00	28/06/2013, 13:00	
	7	28/06/2013, 16:00	28/06/2013, 17:00	
	8	29/06/2013, 16:00	29/06/2013, 17:00	
	9	30/06/2013, 05:00	30/06/2013, 06:00	
	10	30/06/2013, 10:00	30/06/2013, 13:00	
	11	30/06/2013, 14:00	30/06/2013, 17:00	
	12	30/06/2013, 19:00	30/06/2013, 24:00	
	13	01/07/2013, 00:00	01/07/2013, 03:00	Because of regular inspection, the digital signal for $F_{T1}$ was out
	14	01/07/2013, 11:00	01/07/2013, 12:00	
	15	01/07/2013, 21:00	01/07/2013, 22:00	Data signal out because of communications disruption
	16	02/07/2013, 03:00	02/07/2013, 04:00	
	17	10/07/2013, 12:54	10/07/2013, 18:30	
	18	11/07/2013, 13:00	11/07/2013, 14:00	
	19	12/07/2013, 00:00	12/07/2013, 01:00	
	20	12/07/2013, 03:00	12/07/2013, 07:00	
	21	12/07/2013, 09:00	12/07/2013, 10:00	
	22	12/07/2013, 18:00	12/07/2013, 19:00	
	23	14/07/2013, 02:00	14/07/2013, 03:00	
	24	15/07/2013, 02:00	15/07/2013, 03:00	
	25	17/07/2013, 11:00	17/07/2013, 12:00	

Sites	No.	Date (dd/mm/yy) & Time		description
		from	to	
	26	17/07/2013, 13:00	17/07/2013, 14:00	
	27	17/07/2013, 21:00	17/07/2013, 22:00	
	28	19/07/2013, 12:00	19/07/2013, 13:00	
	29	19/07/2013, 16:00	19/07/2013, 17:00	
	30	19/07/2013, 19:00	19/07/2013, 20:00	
	31	20/07/2013, 10:00	20/07/2013, 11:00	
	32	21/07/2013, 03:00	21/07/2013, 04:00	
	33	22/07/2013, 10:00	22/07/2013, 12:00	
	34	23/07/2013, 07:00	23/07/2013, 08:00	
	35	25/07/2013, 20:00	25/07/2013, 21:00	
	36	26/07/2013, 12:00	26/07/2013, 13:00	
	37	27/07/2013, 13:00	27/07/2013, 14:00	
	38	28/07/2013, 19:00	28/07/2013, 20:00	
	39	29/07/2013, 01:00	29/07/2013, 02:00	
	40	29/07/2013, 05:00	29/07/2013, 07:00	
	41	30/07/2013, 03:00	30/07/2013, 04:00	
	42	30/07/2013, 10:00	30/07/2013, 11:00	
	43	31/07/2013, 03:00	31/07/2013, 05:00	
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	45	31/07/2013, 08:00	31/07/2013, 09:00	
	46	02/08/2013, 09:00	02/08/2013, 10:00	
	47	12/08/2013, 13:00	12/08/2013, 14:00	
	48	12/08/2013, 17:00	12/08/2013, 18:00	
	49	12/08/2013, 19:00	12/08/2013, 20:00	
	50	13/08/2013, 10:00	13/08/2013, 11:00	
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	55	16/08/2013, 14:00	16/08/2013, 15:00	
	56	16/08/2013, 20:00	16/08/2013, 21:00	
	57	19/08/2013, 13:00	19/08/2013, 14:00	
	58	26/08/2013, 14:00	26/08/2013, 15:00	
	59	26/08/2013, 20:00	26/08/2013, 22:00	
	60	24/09/2013, 15:00	24/09/2013, 16:00	
	61	28/09/2013, 14:00	28/09/2013, 15:00	
Product Facility	62	08/02/2013, 01:02	09/02/2013, 13:37	By-pass valve was opened because of I.A Pressure dropped.
	63	25/02/2013, 16:59	27/02/2013, 18:09	Unstable process operating by the damaged motor (: 3K-2002)
	64	03/03/2013, 06:55	04/03/2013, 21:24	Unstable process operating by the leaked tube (: 3E-2006).
	65	06/03/2013, 10:25	07/03/2013, 13:25	Vent flange (: E-1302) was leaked.
	66	14/03/2013, 08:45	15/03/2013, 19:40	Coupling Membrane was damaged.
	67	16/03/2013, 10:57	16/03/2013, 20:06	Unstable process operating
	68	18/03/2013, 01:24	19/03/2013, 10:58	Repairing the damaged motor (: 3K-2002)
	69	21/05/2013, 16:48	22/05/2013, 10:14	Repairing the damaged coupling Membrane (: 3K-2001)
	70	24/05/2013, 02:34	27/05/2013, 08:02	Replacing the leaked tube (: 3E-2006).
	71	18/06/2013, 08:27	18/06/2013, 22:00	Replacing the leaked gas inlet flange (R-1101)
	72	18/09/2013, 10:22	19/09/2013, 09:48	Repairing the tube (: 3E-2006).
	73	19/09/2013, 20:02	20/09/2013, 12:00	Repairing the indicator for temperature for ammonia oxidation reactor, $T_{q-b}$ (TI-1206)
	74	25/09/2013, 07:11	27/09/2013, 00:58	Replacing the leaked tube (: E-1301A).
	75	10/10/2013, 06:00	15/11/2013, 24:00	Overhaul

Action to the events

For the events related N<sub>2</sub>O Abatement System (NAS), the data on N<sub>2</sub>O concentration ( $C_{I_{N2O-1}}$ ,  $CO_{N2O-1}$ ) 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<sub>4</sub> 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<sub>2</sub>O concentration ( $C_{I_{N2O-1}}$ ,  $CO_{N2O-1}$ ) and volume flow rate ( $F_{TI-1}$ ,  $F_{TE-1}$ ) which are measured in N<sub>2</sub>O Abatement System (NAS) in plant I.

**Table B1-6** The action to the events of Plant 1

Sites	No.	Relevant Time to Data cancelling		Parameters of the cancelled data
		from	to	
N <sub>2</sub> O Abatement System (NAS)	1	11/01/2013, 11:00	11/01/2013, 19:00	<ul style="list-style-type: none"> <li>N<sub>2</sub>O concentrations (<math>C_{I_{N2O-1}}</math>, <math>CO_{N2O-1}</math>)</li> <li>volume flow rate (<math>F_{TI-1}</math>, <math>F_{TE-1}</math>)</li> </ul>
	2	25/06/2013, 16:00	25/06/2013, 17:00	
	3	27/06/2013, 14:00	27/06/2013, 16:00	
	4	27/06/2013, 18:00	27/06/2013, 19:00	
	5	27/06/2013, 20:00	27/06/2013, 21:00	
	6	28/06/2013, 12:00	28/06/2013, 13:00	
	7	28/06/2013, 16:00	28/06/2013, 17:00	
	8	29/06/2013, 16:00	29/06/2013, 17:00	
	9	30/06/2013, 05:00	30/06/2013, 06:00	
	10	30/06/2013, 10:00	30/06/2013, 13:00	
	11	30/06/2013, 14:00	30/06/2013, 17:00	
	12	30/06/2013, 19:00	30/06/2013, 24:00	
	13	01/07/2013, 00:00	01/07/2013, 03:00	
	14	01/07/2013, 11:00	01/07/2013, 12:00	
	15	01/07/2013, 21:00	01/07/2013, 22:00	
	16	02/07/2013, 03:00	02/07/2013, 04:00	
	17	10/07/2013, 12:00	10/07/2013, 19:00	
	18	11/07/2013, 13:00	11/07/2013, 14:00	
	19	12/07/2013, 00:00	12/07/2013, 01:00	
	20	12/07/2013, 03:00	12/07/2013, 07:00	
	21	12/07/2013, 09:00	12/07/2013, 10:00	
	22	12/07/2013, 18:00	12/07/2013, 19:00	
	23	14/07/2013, 02:00	14/07/2013, 03:00	
	24	15/07/2013, 02:00	15/07/2013, 03:00	
	25	17/07/2013, 11:00	17/07/2013, 12:00	
	26	17/07/2013, 13:00	17/07/2013, 14:00	
	27	17/07/2013, 21:00	17/07/2013, 22:00	
	28	19/07/2013, 12:00	19/07/2013, 13:00	
	29	19/07/2013, 16:00	19/07/2013, 17:00	
	30	19/07/2013, 19:00	19/07/2013, 20:00	
	31	20/07/2013, 10:00	20/07/2013, 11:00	
	32	21/07/2013, 03:00	21/07/2013, 04:00	
	33	22/07/2013, 10:00	22/07/2013, 12:00	
	34	23/07/2013, 07:00	23/07/2013, 08:00	
	35	25/07/2013, 20:00	25/07/2013, 21:00	
	36	26/07/2013, 12:00	26/07/2013, 13:00	
	37	27/07/2013, 13:00	27/07/2013, 14:00	
	38	28/07/2013, 19:00	28/07/2013, 20:00	
	39	29/07/2013, 01:00	29/07/2013, 02:00	

Sites	No.	Relevant Time to Data cancelling		Parameters of the cancelled data
		from	to	
	40	29/07/2013, 05:00	29/07/2013, 07:00	
	41	30/07/2013, 03:00	30/07/2013, 04:00	
	42	30/07/2013, 10:00	30/07/2013, 11:00	
	43	31/07/2013, 03:00	31/07/2013, 05:00	
	44	31/07/2013, 06:00	31/07/2013, 07:00	
	45	31/07/2013, 08:00	31/07/2013, 09:00	
	46	02/08/2013, 09:00	02/08/2013, 10:00	
	47	12/08/2013, 13:00	12/08/2013, 14:00	
	48	12/08/2013, 17:00	12/08/2013, 18:00	
	49	12/08/2013, 19:00	12/08/2013, 20:00	
	50	13/08/2013, 10:00	13/08/2013, 11:00	
	51	13/08/2013, 13:00	13/08/2013, 15:00	
	52	13/08/2013, 18:00	13/08/2013, 19:00	
	53	14/08/2013, 11:00	14/08/2013, 12:00	
	54	14/08/2013, 18:00	14/08/2013, 20:00	
	55	16/08/2013, 14:00	16/08/2013, 15:00	
	56	16/08/2013, 20:00	16/08/2013, 21:00	
	57	19/08/2013, 13:00	19/08/2013, 14:00	
	58	26/08/2013, 14:00	26/08/2013, 15:00	
	59	26/08/2013, 20:00	26/08/2013, 22:00	
	60	24/09/2013, 15:00	24/09/2013, 16:00	
	61	28/09/2013, 14:00	28/09/2013, 15:00	
Product Facility	62	08/02/2013, 01:00	08/02/2013, 14:00	<ul style="list-style-type: none"> <li>• N<sub>2</sub>O concentrations (<math>CI_{N2O-1}</math>, <math>CO_{N2O-1}</math>)</li> <li>• volume flow rate (<math>F_{TI-1}</math>, <math>F_{TE-1}</math>)</li> <li>• AOR operation conditions (<math>A_{OR,d-1}</math>, <math>P_{g-1}</math>, <math>T_{g-a}</math>, <math>T_{g-b}</math>)</li> <li>Plant output of caprolactam (<math>P_{product-1}</math>)</li> </ul>
	63	25/02/2013, 16:00	27/02/2013, 19:00	
	64	03/03/2013, 06:00	04/03/2013, 22:00	
	65	06/03/2013, 10:00	07/03/2013, 14:00	
	66	14/03/2013, 08:00	15/03/2013, 20:00	
	67	16/03/2013, 10:00	16/03/2013, 21:00	
	68	18/03/2013, 01:00	19/03/2013, 11:00	
	69	21/05/2013, 16:00	22/05/2013, 11:00	
	70	24/05/2013, 02:00	27/05/2013, 09:00	
	71	18/06/2013, 08:00	18/06/2013, 22:00	
	72	18/09/2013, 10:00	19/09/2013, 10:00	
	73	19/09/2013, 20:00	20/09/2013, 12:00	
	74	25/09/2013, 07:00	27/09/2013, 01:00	
	75	10/10/2013, 06:00	15/11/2013, 24:00	

## (2)Events of Plant II

Events information**Table B1-7** The list of operating events of Plant 2

Sites	No	Date (dd/mm/yy) & Time		description
		from	to	
N <sub>2</sub> O Abatement System (NAS)	1	23/07/2013, 10:00	23/07/2013, 11:00	Data signal out because of communications disruption
	2	24/07/2013, 11:22	24/07/2013, 14:14	Replacing the solenoid valve (: 2XV-1523'B')
	3	08/08/2013, 12:00	08/08/2013, 13:00	Data signal out because of communications disruption
	4	09/08/2013, 08:00	09/08/2013, 13:00	Data signal out because of communications disruption
	5	14/08/2013, 06:09	14/08/2013, 16:20	Replacing the limit switch box(: 2XV-1521'A')

Sites	No	Date (dd/mm/yy) & Time		description
		from	to	
	6	17/08/2013, 00:00	17/08/2013, 06:00	Data signal out because of communications disruption
	7	08/09/2013, 17:00	08/09/2013, 20:00	
	8	08/09/2013, 22:00	09/09/2013, 07:00	
	9	13/09/2013, 13:00	13/09/2013, 14:00	
	10	13/09/2013, 18:00	13/09/2013, 23:00	
	11	19/09/2013, 18:00	19/09/2013, 19:00	
	12	20/09/2013, 03:00	20/09/2013, 07:00	
	13	22/09/2013, 03:00	22/09/2013, 07:00	
	14	23/09/2013, 14:00	23/09/2013, 23:59	
	15	01/10/2013, 03:00	01/10/2013, 14:00	
	16	06/10/2013, 04:00	06/10/2013, 07:00	
Product Facility	17	15/11/2013, 16:23	15/11/2013, 23:59	
	18	11/06/2013, 08:48	11/06/2013, 13:52	Fixing the oil pump(: EK-13-1 P1 B)
	19	10/07/2013, 05:52	15/07/2013, 01:05	Fin tube(2E-2011) jet cleaning
	20	25/08/2013, 04:55	27/08/2013, 08:33	Replacing the pump (2P-1302'B')
	21	10/10/2013, 05:29	31/10/2013, 23:18	Overhaul

### Action to the events

For the events related N<sub>2</sub>O Abatement System (NAS), the data on N<sub>2</sub>O 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 1 are cancelled. However, the data of the natural gas input ( $Q_{NG-2}$ ) and CH<sub>4</sub> 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<sub>2</sub>O concentration ( $CI_{N2O-2}$ ,  $CO_{N2O-2}$ ) and volume flow rate ( $F_{TI-2}$ ,  $F_{TE-2}$ ) which are measured in N<sub>2</sub>O Abatement System (NAS) in plant II.

**Table B1-8** The action to the events of Plant 2

Sites	No.	Relevant Time to Data cancelling		Parameters of the cancelled data
		from	to	
N <sub>2</sub> O Abatement System (NAS)	1	23/07/2013, 10:00	23/07/2013, 11:00	<ul style="list-style-type: none"> <li>N<sub>2</sub>O concentrations (<math>CI_{N2O-2}</math>, <math>CO_{N2O-2}</math>)</li> <li>volume flow rate (<math>F_{TI-2}</math>, <math>F_{TE-2}</math>)</li> </ul>
	2	24/07/2013, 11:00	24/07/2013, 15:00	
	3	08/08/2013, 12:00	08/08/2013, 13:00	
	4	09/08/2013, 08:00	09/08/2013, 13:00	
	5	14/08/2013, 06:00	14/08/2013, 17:00	
	6	17/08/2013, 00:00	17/08/2013, 06:00	
	7	08/09/2013, 17:00	08/09/2013, 20:00	
	8	08/09/2013, 22:00	09/09/2013, 07:00	
	9	13/09/2013, 13:00	13/09/2013, 14:00	
	10	13/09/2013, 18:00	13/09/2013, 23:00	
	11	19/09/2013, 18:00	19/09/2013, 19:00	
	12	20/09/2013, 03:00	20/09/2013, 07:00	
	13	22/09/2013, 03:00	22/09/2013, 07:00	
	14	23/09/2013, 14:00	23/09/2013, 24:00	
	15	01/10/2013, 03:00	01/10/2013, 14:00	
	16	06/10/2013, 04:00	06/10/2013, 07:00	
	17	15/11/2013, 16:00	15/11/2013, 24:00	
Product	18	11/06/2013, 08:00	11/06/2013, 14:00	<ul style="list-style-type: none"> <li>N<sub>2</sub>O concentrations (<math>CI_{N2O-2}</math>, <math>CO_{N2O-2}</math>)</li> </ul>

Sites	No.	Relevant Time to Data cancelling		Parameters of the cancelled data
		from	to	
Facility	19	10/07/2013, 05:00	15/07/2013, 02:00	<ul style="list-style-type: none"> <li>• volume flow rate (<math>F_{TI-2}</math>, <math>F_{TE-2}</math>)</li> <li>• AOR operation conditions (<math>A_{OR,d-2}</math>, <math>P_{g-2}</math>, <math>T_{g-c}</math>, <math>T_{g-d}</math>)</li> <li>• Plant output of caprolactam (<math>P_{product-2}</math>)</li> </ul>
	20	25/08/2013, 04:00	27/08/2013, 09:00	
	21	10/10/2013, 05:00	31/10/2013, 24:00	

**B.2. Post-registration changes****B.2.1. Temporary deviations from registered monitoring plan, applied methodology or applied standardized baseline**

>>  
None

**B.2.2. Corrections**

>>  
None

**B.2.3. Changes to start date of crediting period**

>>  
None

**B.2.4. Inclusion of a monitoring plan to the registered PDD that was not included at registration**

>>  
None

**B.2.5. Permanent changes from registered monitoring plan, applied methodology or applied standardized baseline**

>>  
None

**B.2.6. Changes to project design of registered project activity**

>>  
None

**B.2.7. Types of changes specific to afforestation or reforestation project activity**

>>  
Not applicable

## SECTION C. Description of monitoring system

&gt;&gt;

### (a) Monitoring points to be measured

#### (1) Monitoring Points in Plant I

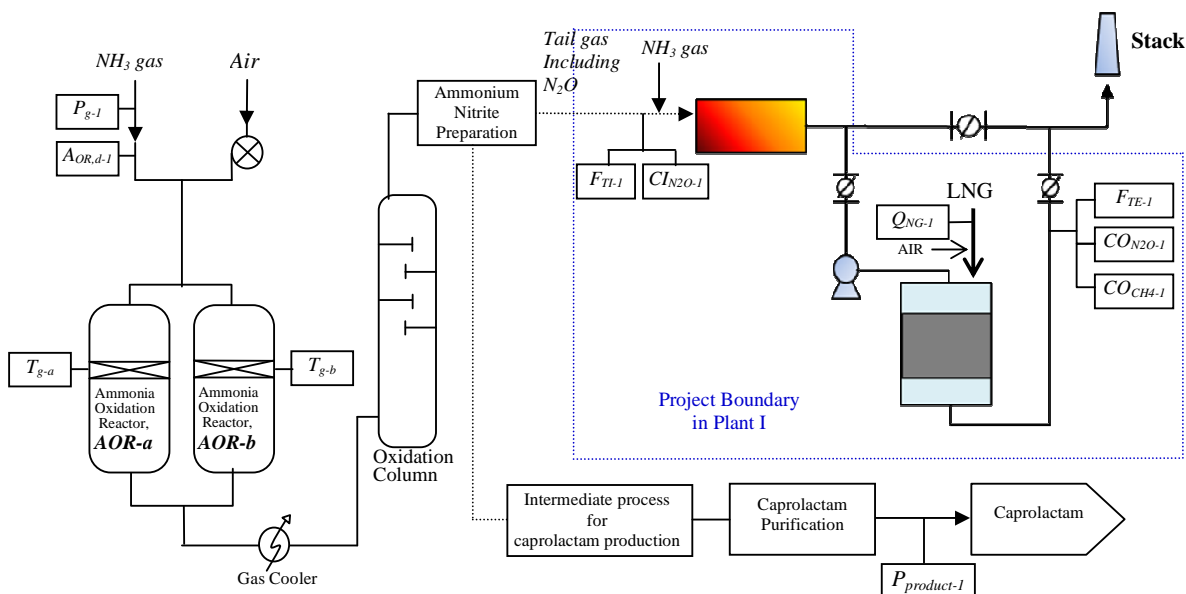


Figure C1. Monitoring Points in Plant I

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:

Plant I	Parameters	Tag No. in PDD	Actual Tag No. in Period 5
	$CO_{N2O-1}$	AI-1522	AI-1522(a)
	$CO_{CH4-1}$	AI-1522	AI-1522(b)

## (2) Monitoring Points in Plant II

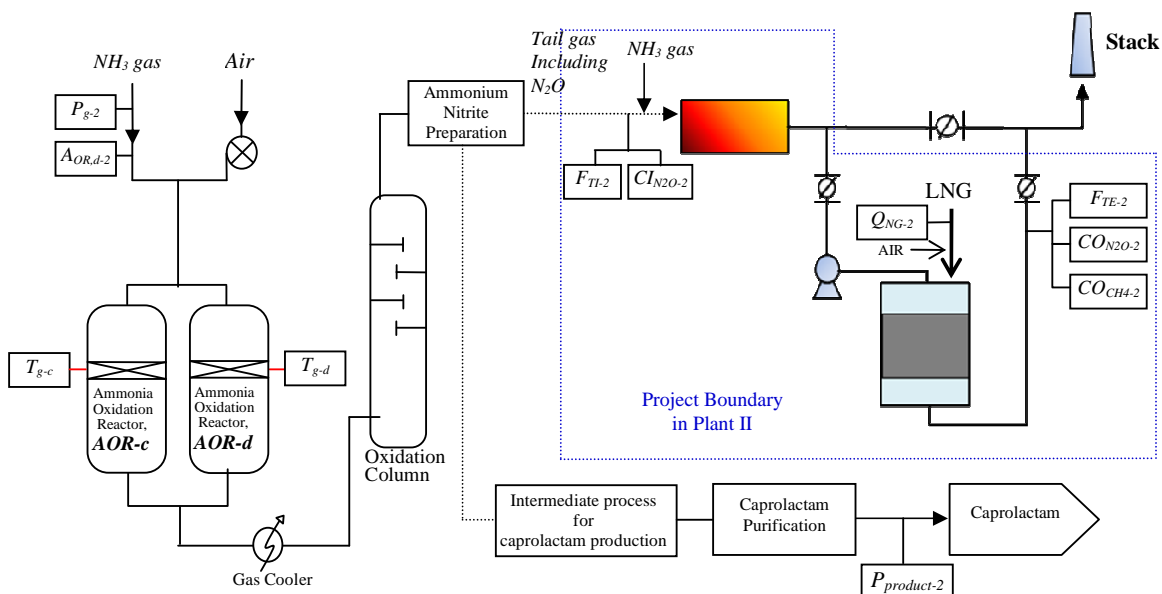


Figure C2. Monitoring Points in Plant II

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
$C_{I,N2O-2}$	$N_2O$ concentration at destruction facility inlet in Plant II	2AI-1521
$C_{O,N2O-2}$	$N_2O$ 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
$C_{O,CH4-2}$	$CH_4$ 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 5
Plant II	$CO_{N2O-2}$	2AI-1522	2AI-1522(a)
	$CO_{CH4-2}$	2AI-1522	2AI-1522(b)



**(b) 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 respectively, and then transmitted to EEU.  $Q_{NG}$  is measured by Flow meter separately installed from AMS and  $CO_{CH_4}$  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 C1.** The information of the data collection and storage devices except DCS

Item		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.

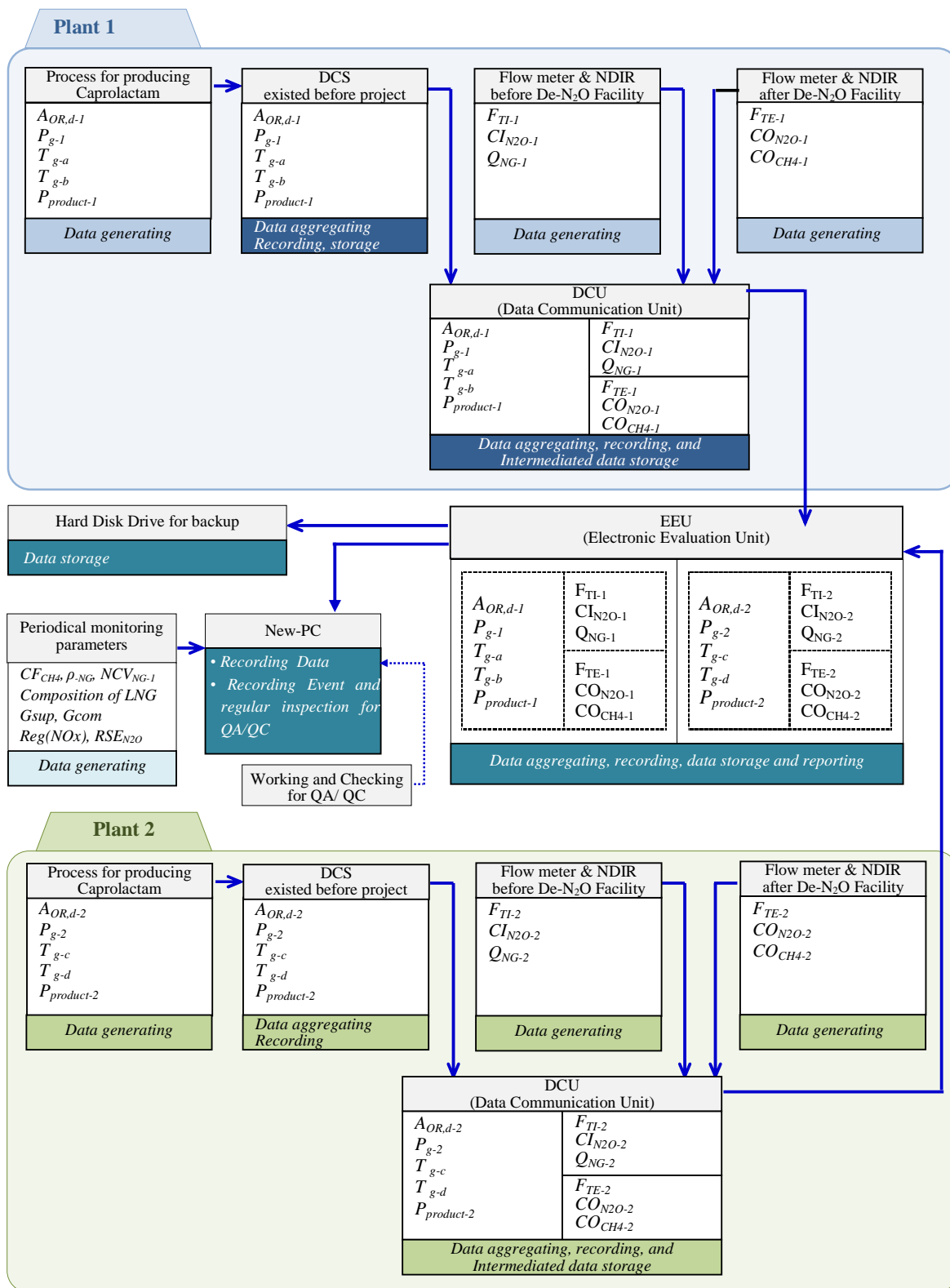
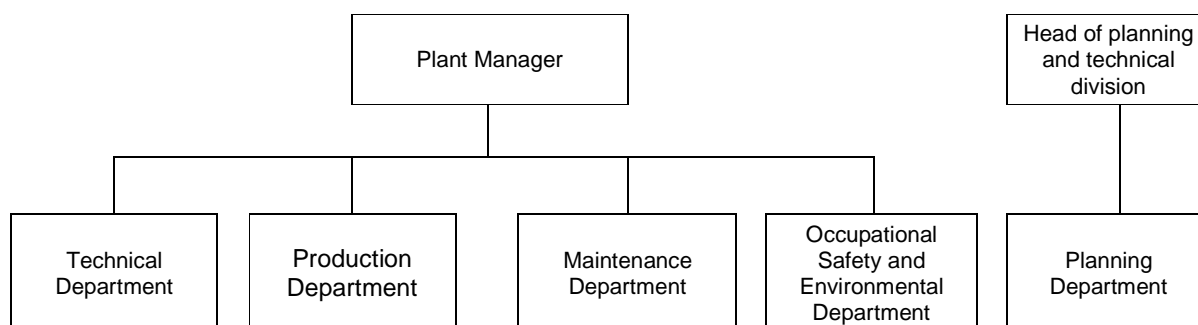


Figure C.3 Data Collecting Flow

**(c) Organizational structure, roles and responsibilities of personnel****(1) Organization Structure****Figure C.4** The scheme of the operational and management structure**(2) Roles and responsibilities of personnel****Plant Manager**

The Plant Manager takes overall responsibility for the operation and maintenance of the N<sub>2</sub>O 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<sub>2</sub>O 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<sub>2</sub>O monitoring system periodically.

**(d) 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 analyzers.

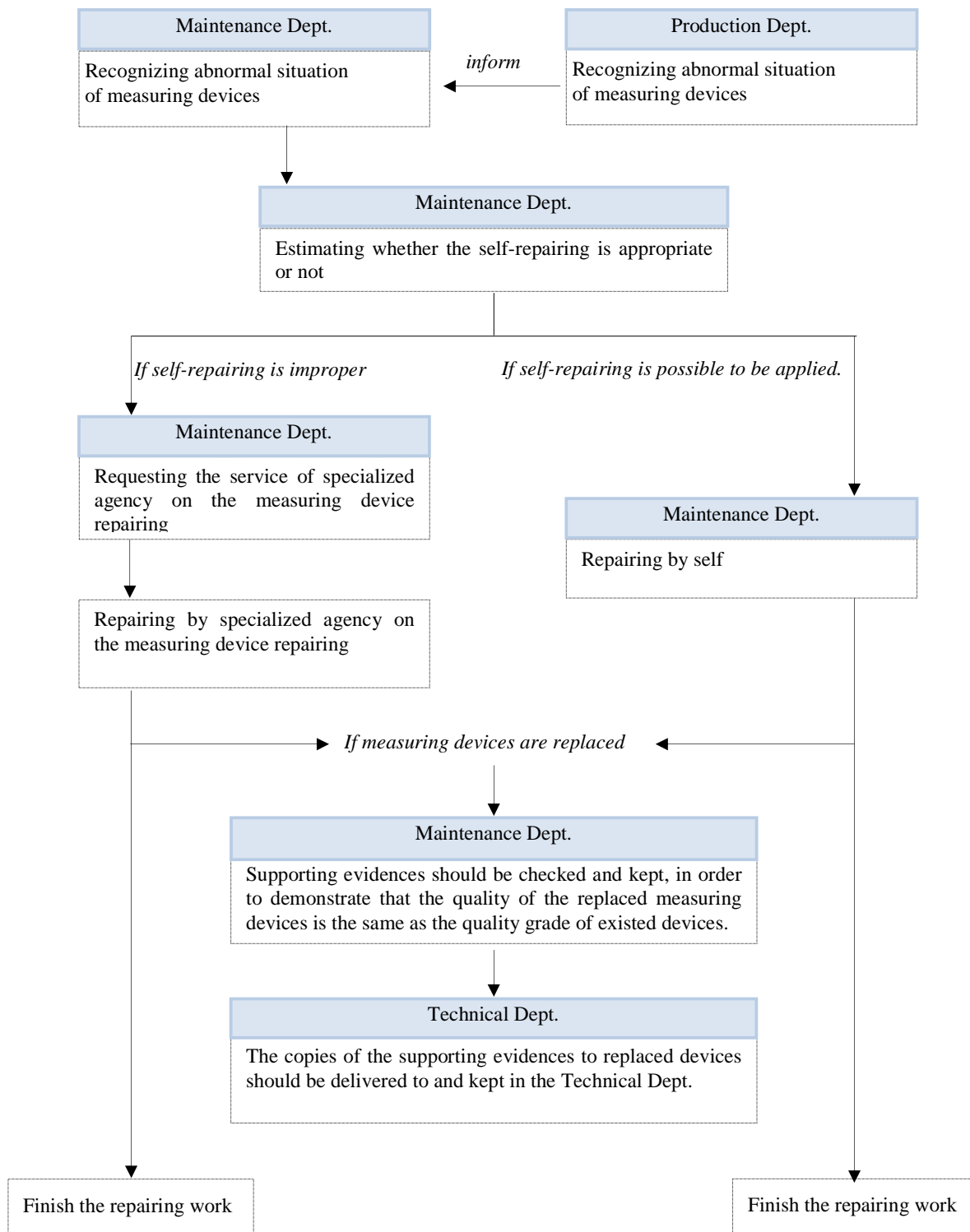
If the data deviation is not covered by procedures above, Technical Department makes the decision to correct figures or to abandon the data. In addition, any data correction is in compliance with the applied methodology and done in a conservative bias

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<sub>2</sub>O concentration or flow rate at the monitoring points of inlet and outlet of N<sub>2</sub>O 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<sub>2</sub>O 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

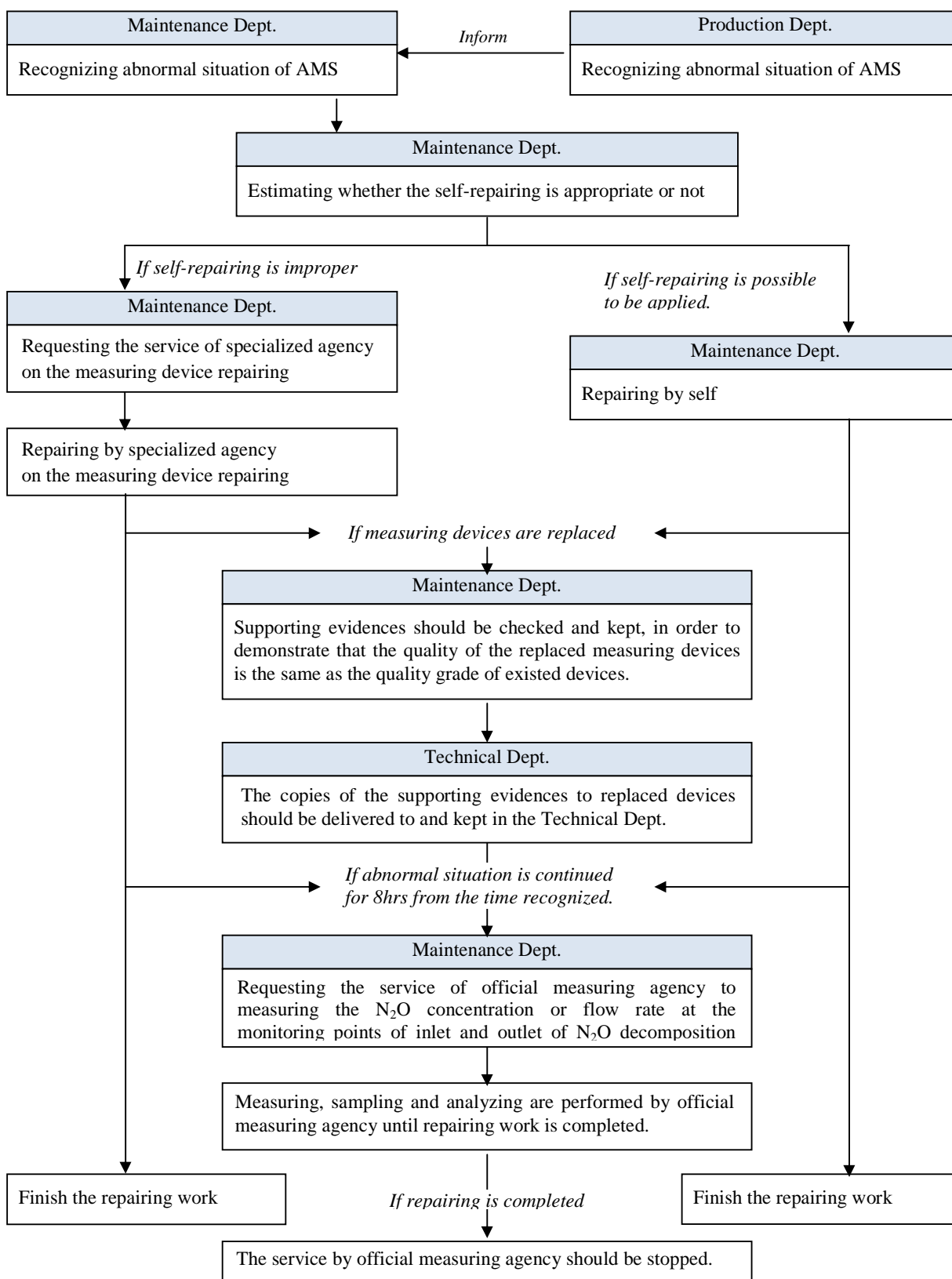
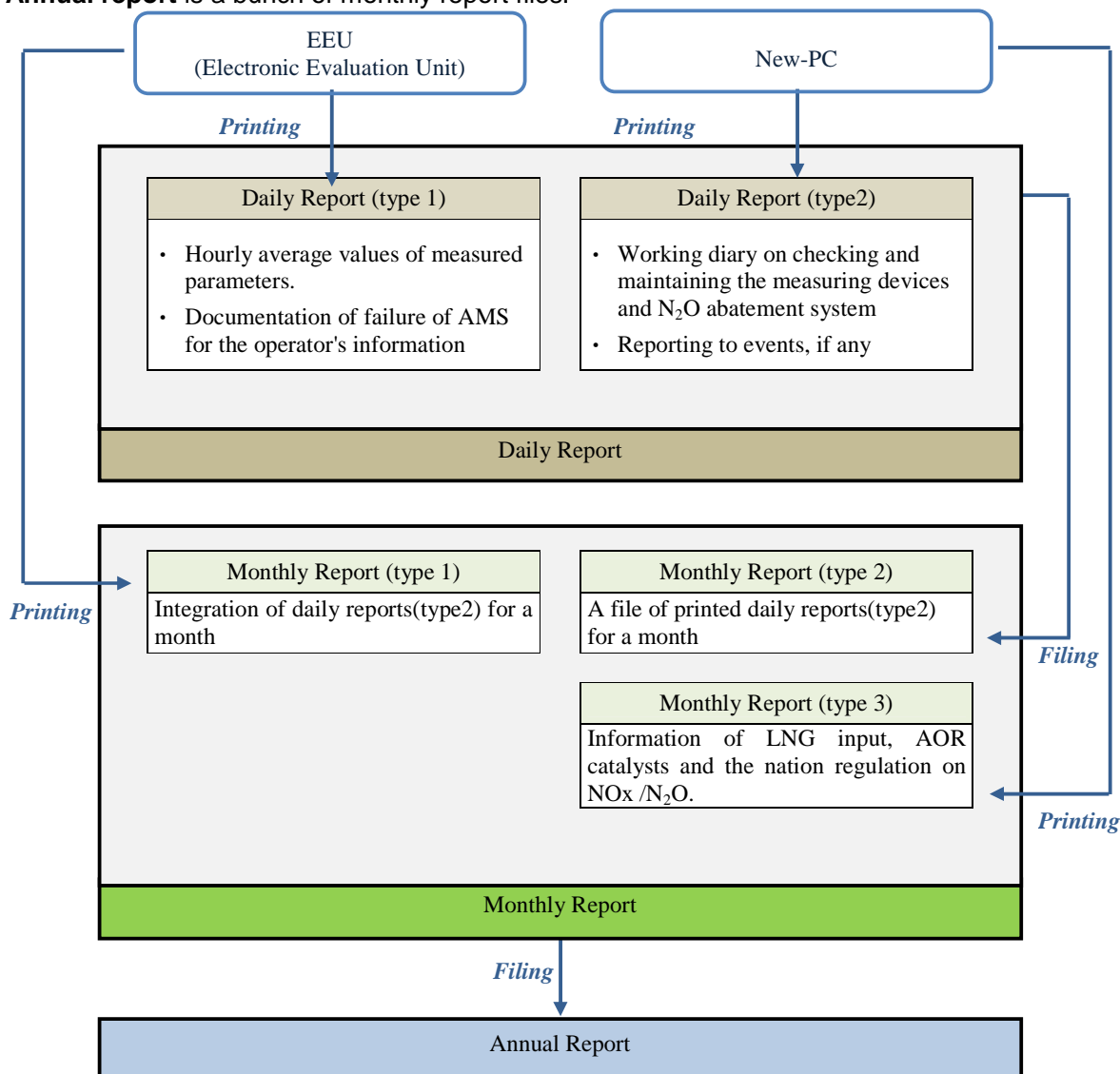


Figure C.6 Emergency Procedures for malfunction of AMS

**(e) 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<sub>2</sub>O 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 NO<sub>x</sub> and N<sub>2</sub>O are checked by monthly report too.
- **Annual report** is a bunch of monthly report files.

**Figure C.7** The consists of the periodical reports

**(f) Quality Assurance of AMS(Automated measuring system)**

AMS(Automated measuring system) has been applied to measure the amount of N<sub>2</sub>O emission at the two monitoring points of the inlet and outlet of N<sub>2</sub>O destruction facility of each plant involved in this project. By AMS, the concentration of N<sub>2</sub>O and the volume flow rate of tail gas are measured simultaneously(F<sub>TI</sub>, Cl<sub>N2O</sub>, and F<sub>TE</sub>, CO<sub>N2O</sub>) 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<sub>2</sub>O gas analyzers having the performance certificate with calculation uncertainty were selected as summarized in following tables.

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

Para-meters	Type	model	serial number	Standard for Performance certification	Certificate No.	The date of Certificate Issued (dd/mm/yyyy)	Approved Methods to calculate of uncertainty
<b>F<sub>TI-1</sub></b>	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	
<b>Cl<sub>N2O-1</sub></b>	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 explosion protection of GB Chemie (GRG 104)
				FM Approvals	3016050	15/07/2003	
				CSA INTERNATIONAL	1431560	17/04/2003	
<b>F<sub>TE-1</sub></b>	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	
<b>CO<sub>N2O-1</sub></b>	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 explosion 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

Para-meters	Type	model	serial number	Standard for Performance certification	Certificate No.	The date of Certificate Issued (dd/mm/yyyy)	Approved Methods to calculate of uncertainty
<b>F<sub>TI-2</sub></b>	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	
<b>Cl<sub>N2O-2</sub></b>	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 explosion protection of GB Chemie (GRG 104)
				FM Approvals	3016050	15/07/2003	
				CSA INTERNATIONAL	1431560	17/04/2003	
<b>F<sub>TE-2</sub></b>	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	
<b>CO<sub>N2O-2</sub></b>	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 explosion protection of GB Chemie (GRG 104)
				FM Approvals	3016050	15/07/2003	
				CSA INTERNATIONAL	1431560	17/04/2003	

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:

- Section of the location of measurement
- Duly installation of the monitoring equipment
- Correct choice of measurement range
- Calibration of AMS using the standard-Reference-Method(SRM) as guidance
- Calibration curve either as linear regression or as straight line from absolute zero to centre of a scatter-plot
- 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 been carried out in May of 2012 (14/05/2012~17/05/2012) and May of 2013 (23/05/2013~ 25/05/2013 for Plant 1 and 22/05/2013 ~ 23/05/2013 for Plant 2).

**(g) 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.

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

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 ( $Nm^3/h$ )
$Q_{NG \text{ combustion gas}}$	: Combustion gas of natural gas ( $Nm^3/h$ )
VEF	: Volumetric Expansion Factor

For monitoring, the gas generated by combusting natural gas ( $Q_{NG \text{ combustion gas}}$ ) 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- $NO_x$  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.

**(h) 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

<b>Data/parameter:</b>	<b><math>GWP_{N_2O}</math></b>
Unit	Not applicable
Description	Global warming potential of the nitrous oxide
Source of data	IPCC, The Second Assessment Report
Value(s) applied	298
Choice of data or measurement methods and procedures	As per EB 69 Report, Annex 3 the GWP of $N_2O$ is defined in the 2 <sup>nd</sup> commitment period (starting 1/1/2013) as 298 tCO <sub>2</sub> /tN <sub>2</sub> O.
Purpose of data	Baseline Emission / Project Emission Calculation
Additional comments	Not applicable

<b>Data/parameter:</b>	<b><math>GWP_{CH_4}</math></b>
Unit	Not applicable
Description	Global warming potential of the nitrous oxide
Source of data	IPCC, The Second Assessment Report
Value(s) applied	25
Choice of data or measurement methods and procedures	As per EB 69 Report, Annex 3 the GWP of $CH_4$ is defined in the 2 <sup>nd</sup> commitment period (starting 1/1/2013) as 25 tCO <sub>2</sub> /tCH <sub>4</sub> .
Purpose of data	Project Emission Calculation
Additional comments	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.		
Choice of data or measurement methods and procedures	Specified in the methodology		
	All of ammonia oxidation reactors of these plants are keeping with the same as they were installed at the beginning.		
	Each plant of Capro's design capacity is established upon the maximum daily production and maximum operating days till 31 December 2005.		
	Item	Plant I	Plant II
	Maximum Daily production (ton/day)	174.4	183
	Maximum operating day (day/yr)	363	355
	Design Capacity for each plant (ton/yr)	63,307	64,965
Purpose of data	Baseline Emission / Project Emission Calculation		
Additional comments	Not applicable		

<b>Data/parameter:</b>	<b><math>A_{OR,hist}</math></b>
Unit	tNH <sub>3</sub> /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 <sub>3</sub> /d (total flow rate for AOR-a and AOR-b in Plant I) $A_{OR,hist-2}$ : 44.557tNH <sub>3</sub> /d (total flow rate for AOR-c and AOR-d in Plant II)
Choice of data or measurement methods and procedures	These values are set based on maximum values of historical daily data within latest 3 years (1 <sup>st</sup> Jan.2007 – 31 <sup>st</sup> Dec.2009). Since, the historical operating data on maximum daily average ammonia flow is existed in each plant on Capro, the upper limit on ammonia flow is determined on this historical data.
Purpose of data	Baseline Emission Calculation
Additional comments	Not applicable

<b>Data/parameter:</b>	<b><math>T_{g,hist}</math></b>
Unit	°C
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°C (for AOR-a in Plant I) $T_{g,hist-b}$ : 662.08–743.92 °C (for AOR-b in Plant I) $T_{g,hist-c}$ : 738.95– 774.85°C (for AOR-c in Plant II) $T_{g,hist-d}$ : 734.53– 770.57°C (for AOR-d in Plant II)
Choice of data or measurement methods and procedures	The permitted range of operating temperatures is set based on historical data within latest 3 years (1 <sup>st</sup> Jan.2007 – 31 <sup>st</sup> Dec.2009).
Purpose of data	Baseline Emission Calculation
Additional comments	Not applicable

<b>Data/parameter:</b>	<b><math>P_{g,hist}</math></b>
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)
Choice of data or measurement methods and procedures	The permitted range of operating pressure is set based on historical data within latest 3 years (1 <sup>st</sup> Jan.2007 – 31 <sup>st</sup> Dec.2009).
Purpose of data	Baseline Emission Calculation
Additional comments	Not applicable

<b>Data/parameter:</b>	<b><math>G_{sup,hist}</math></b>
Unit	Not applicable
Description	Historical supplier of the ammonia oxidation catalyst
Source of data	PDD
Value(s) applied	Name of the supplier: Johnson Matthey

Choice of data or measurement methods and procedures	Specified in the methodology.
Purpose of data	Baseline Emission Calculation
Additional comments	Not applicable

<b>Data/parameter:</b>	<b><math>G_{com,hist}</math></b>
Unit	%
Description	Historical composition of the ammonia oxidation catalyst
Source of data	PDD
Value(s) applied	Pt (90%): Rh (10%)
Choice of data or measurement methods and procedures	Specified in the methodology.
Purpose of data	Baseline Emission Calculation
Additional comments	Not applicable

<b>Data/parameter:</b>	<b><math>OXID_{HC}</math></b>
Unit	%
Description	Oxidation factor of natural gas, with two or more molecules of carbon
Source of data	PDD
Value(s) applied	100%
Choice of data or measurement methods and procedures	Specified in the methodology.
Purpose of data	Project Emission Calculation
Additional comments	Not applicable

<b>Data/parameter:</b>	<b><math>EF_{CH_4}</math></b>
Unit	tCO <sub>2</sub> /tCH <sub>4</sub>
Description	Emission factor of methane
Source of data	PDD
Value(s) applied	2.75(tCO <sub>2</sub> /tCH <sub>4</sub> )
Choice of data or measurement methods and procedures	This value is theoretically calculated as follows; 44 gCO <sub>2</sub> /16gCH <sub>4</sub>
Purpose of data	Project Emission Calculation
Additional comments	Not applicable

<b>Data/parameter:</b>	<b><math>\rho_{CH_4}</math></b>
Unit	t/m <sup>3</sup>
Description	Density of methane
Source of data	Tool to determine project emissions from flaring gases containing methane
Value(s) applied	0.000716 t/m <sup>3</sup> (0°C, 1atm)

Choice of data or measurement methods and procedures	The value converted into the normal condition is applied as this parameter. In case of the normal condition, this parameter can be given by theoretical value.
Purpose of data	Project Emission Calculation
Additional comments	Not applicable

<b>ata/parameter:</b>	<b><math>M_i</math></b>
Unit	hour
Description	Length of measuring interval
Source of data	AMS
Value(s) applied	1 hour (to be measured continuously for 24 hours)
Choice of data or measurement methods and procedures	Specified in the methodology. This parameter is set based on recording frequencies for volume flow rates and N <sub>2</sub> O concentrations at N <sub>2</sub> O destruction facility inlet and outlet.
Purpose of data	Baseline Emission Calculation / Project Emission Calculation
Additional comments	Not applicable

<b>Data/parameter:</b>	<b><math>Reg_{NOx}</math></b>
Unit	tNO <sub>x</sub> /Nm <sup>3</sup>
Description	National regulation on NO <sub>x</sub> emissions
Source of data	The "Clean Air Conservation Act", one of the National environmental legislation, Ministry of Environment
Value(s) applied	4.10714×10 <sup>-7</sup> tNO <sub>x</sub> /Nm <sup>3</sup> (as a NO <sub>2</sub> concentration)
Choice of data or measurement methods and procedures	Calculated. According to Article 15 of the Enforcement Regulation Of The Clean Air Conservation Act, the highest permit limit for NO <sub>x</sub> emission is 200 ppm(v) as a NO <sub>2</sub> concentration level.  The unit of (tNO <sub>x</sub> /Nm <sup>3</sup> ) is adjusted from the ppm(v) unit by following equation : $4.10714 \times 10^{-7} [tNO_x/Nm^3] = 200 \text{ ppm(v)} \times 10^{-6} \times 46/22.4/1,000$
Purpose of data	Not applicable
Additional comments	Not applicable

**D.2. Data and parameters monitored**

<b>Data/parameter:</b>	$F_{Ti,i}$																					
Unit	Nm <sup>3</sup> /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 $F_{Ti}$ <table border="1"> <tr> <th>Average values</th><th>Plant I (<math>F_{Ti,1}</math>)</th><th>Plant II (<math>F_{Ti,2}</math>)</th></tr> <tr> <td><math>F_{Ti}</math> as Nm<sup>3</sup>/hr</td><td>38,696</td><td>38,476</td></tr> </table>	Average values	Plant I ( $F_{Ti,1}$ )	Plant II ( $F_{Ti,2}$ )	$F_{Ti}$ as Nm <sup>3</sup> /hr	38,696	38,476															
Average values	Plant I ( $F_{Ti,1}$ )	Plant II ( $F_{Ti,2}$ )																				
$F_{Ti}$ as Nm <sup>3</sup> /hr	38,696	38,476																				
Monitoring equipment	<table border="1"> <tr> <th>Item</th><th>Plant I (<math>F_{Ti,1}</math>)</th><th>Plant II (<math>F_{Ti,2}</math>)</th></tr> <tr> <td>Type</td><td>Ultrasonic flow meter</td><td>Ultrasonic flow meter</td></tr> <tr> <td>Accuracy class</td><td>&lt; 2%</td><td>&lt; 2%</td></tr> <tr> <td>Serial No.</td><td> <ul style="list-style-type: none"> <li>• HEAD A: 1217007</li> <li>• HEAD B: 1217008</li> <li>• Evaluation Unit :1216861</li> <li>• Case of Evaluation : 1216999</li> </ul> </td><td> <ul style="list-style-type: none"> <li>• HEAD A: 1217011</li> <li>• HEAD B: 1217012</li> <li>• Evaluation Unit :1216866</li> <li>• Case of Evaluation : 1217002</li> </ul> </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<sup>1)</sup></td><td>09/10/2013</td><td>14/11/2013</td></tr> <tr> <td>Validity</td><td>Yes</td><td>Yes</td></tr> </table>	Item	Plant I ( $F_{Ti,1}$ )	Plant II ( $F_{Ti,2}$ )	Type	Ultrasonic flow meter	Ultrasonic flow meter	Accuracy class	< 2%	< 2%	Serial No.	<ul style="list-style-type: none"> <li>• HEAD A: 1217007</li> <li>• HEAD B: 1217008</li> <li>• Evaluation Unit :1216861</li> <li>• Case of Evaluation : 1216999</li> </ul>	<ul style="list-style-type: none"> <li>• HEAD A: 1217011</li> <li>• HEAD B: 1217012</li> <li>• Evaluation Unit :1216866</li> <li>• Case of Evaluation : 1217002</li> </ul>	Calibration frequency	Every day by Auto calibration manner	Every day by Auto calibration manner	Date of last Calibration <sup>1)</sup>	09/10/2013	14/11/2013	Validity	Yes	Yes
Item	Plant I ( $F_{Ti,1}$ )	Plant II ( $F_{Ti,2}$ )																				
Type	Ultrasonic flow meter	Ultrasonic flow meter																				
Accuracy class	< 2%	< 2%																				
Serial No.	<ul style="list-style-type: none"> <li>• HEAD A: 1217007</li> <li>• HEAD B: 1217008</li> <li>• Evaluation Unit :1216861</li> <li>• Case of Evaluation : 1216999</li> </ul>	<ul style="list-style-type: none"> <li>• HEAD A: 1217011</li> <li>• HEAD B: 1217012</li> <li>• Evaluation Unit :1216866</li> <li>• Case of Evaluation : 1217002</li> </ul>																				
Calibration frequency	Every day by Auto calibration manner	Every day by Auto calibration manner																				
Date of last Calibration <sup>1)</sup>	09/10/2013	14/11/2013																				
Validity	Yes	Yes																				
Measuring/reading/recording frequency:	<ul style="list-style-type: none"> <li>•Measuring period : Continuously</li> <li>•Recording frequency : Hourly</li> </ul>																					
Calculation method (if applicable):	Not applicable																					
QA/QC procedures:	QAL 1, 2,3 and AST for AMS																					
Purpose of data:	Baseline Emission Calculation																					
Additional comments:	Not applicable																					

<b>Data/parameter:</b>	$F_{TE,i}$						
Unit	Nm <sup>3</sup> /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 border="1"> <tr> <th>Average values</th><th>Plant I (<math>F_{TE,1}</math>)</th><th>Plant II (<math>F_{TE,2}</math>)</th></tr> <tr> <td><math>F_{TE}</math> as Nm<sup>3</sup>/hr</td><td>40,801</td><td>45,759</td></tr> </table>	Average values	Plant I ( $F_{TE,1}$ )	Plant II ( $F_{TE,2}$ )	$F_{TE}$ as Nm <sup>3</sup> /hr	40,801	45,759
Average values	Plant I ( $F_{TE,1}$ )	Plant II ( $F_{TE,2}$ )					
$F_{TE}$ as Nm <sup>3</sup> /hr	40,801	45,759					

<sup>1)</sup> Flow meter is automatically calibrated at 24 o'clock every day. Plant I was shut down after 6am. on 10 October 2013. Therefore the auto calibration for flow meter at inlet of the destruction facility of plant 1 was done on 9 October 2013 lastly. Also in the case of plant 2, 14 November 2013 is actually last date of auto calibration because plant was shut down after 5pm on 15 November 2013.

Monitoring equipment	Item	Plant I ( $F_{TE,1}$ )	Plant II ( $F_{TE,2}$ )
	Type	Ultrasonic flow meter	Ultrasonic flow meter
	Accuracy class	< 2%	< 2%
	Serial No.	<ul style="list-style-type: none"> <li>•HEAD A: 1217009</li> <li>•HEAD B: 1217010</li> <li>• Evaluation Unit : 1216862</li> <li>• Case of Evaluation : 1217001</li> </ul>	<ul style="list-style-type: none"> <li>•HEAD A: 1217013</li> <li>•HEAD B: 1217014</li> <li>• Evaluation Unit : 1216867</li> <li>• Case of Evaluation : 1217003</li> </ul>
	Calibration frequency	Every day by Auto calibration manner	Every day by Auto calibration manner
	Date of last calibration <sup>2)</sup>	09/10/2013	14/11/2013
	Validity	Yes	Yes
Measuring/reading/recording frequency:	<ul style="list-style-type: none"> <li>•Measuring period : Continuously</li> <li>•Recording frequency : Hourly</li> </ul>		
Calculation method (if applicable):	Not applicable		
QA/QC procedures:	QAL 1, 2,3 and AST for AMS		
Purpose of data:	Project Emission Calculation		
Additional comments:	Not applicable		

Data/parameter:	$CI_{N2O,i}$		
Unit	tN <sub>2</sub> O/Nm <sup>3</sup>		
Description	N <sub>2</sub> O 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 $CI_{N2O}$		
	Average values	Plant I ( $CI_{N2O-1}$ )	Plant II ( $CI_{N2O-2}$ )
	$CI_{N2O,i}$ as tN <sub>2</sub> O/Nm <sup>3</sup>	3.8107×10 <sup>-6</sup>	3.3850×10 <sup>-6</sup>
Monitoring equipment	Item	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 <sup>3)</sup>	27/09/2013	31/10/2013
	Validity	Yes	Yes
Measuring/reading/recording frequency:	<ul style="list-style-type: none"> <li>•Measuring period : Continuously</li> <li>•Recording frequency : Hourly</li> </ul>		

<sup>2)</sup> Flow meter is automatically calibrated at 24 o'clock every day. Plant I was shut down after 6am. on 10 October 2013. Therefore the auto calibration for flow meter at exit of the destruction facility of plant 1 was done on 9 October 2013 lastly. Also in the case of plant 2, 14 November 2013 is actually last date of auto calibration because plant was shut down after 4pm on 15 November 2013.

<sup>3)</sup> NDIR is calibrated every 2 weeks. On the date of next turn to the last calibration for NDIR of each plant, both of plants were shut down.



Calculation method (if applicable):	Not applicable
QA/QC procedures:	QAL 1, 2,3 and AST for AMS
Purpose of data:	Baseline Emission Calculation
Additional comments:	Not applicable

Data/parameter:	CO <sub>N2O,i</sub>		
Unit	tN <sub>2</sub> O/Nm <sup>3</sup>		
Description	N <sub>2</sub> O 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 <sub>N2O</sub>		
	Average values	Plant I(CO <sub>N2O-1</sub> )	Plant II(CO <sub>N2O-2</sub> )
	CO <sub>N2O,i</sub> as tN <sub>2</sub> O/Nm <sup>3</sup>	4.0195×10 <sup>-7</sup>	3.3017×10 <sup>-7</sup>
Monitoring equipment			
	Item	Plant I(CO <sub>N2O-1</sub> )	Plant II(CO <sub>N2O-2</sub> )
	Type	NDIR	NDIR
	Accuracy class (repeatability)	>95%	>95%
	Serial No.	AO-750	AO-751
	Calibration frequency	Every 2weeks	Every 2weeks
	Date of last calibration <sup>4)</sup>	27/09/2013	31/10/2013
	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 comments:	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			
	Average values	Plant I ( $P_{product-1}$ )	Plant II( $P_{product-2}$ )
	$P_{product, period}$ (ton/period)	40,384	48,744

<sup>4)</sup> NDIR is calibrated every 2 week. On the date of next turn to the last calibration for NDIR of each plant, both of plants were shut down.

Monitoring equipment	Item	Plant I ( $P_{product-1}$ )	Plant II ( $P_{product-2}$ )
	Type	Mass flow meter	Mass flow meter
	Accuracy class	Within $\pm 0.1\%$	$\pm 0.15\%$
	Serial No.	F1013202000	28 529138
	Calibration frequency	Every 2years	Every 2years
	Date of last calibration	20/01/2012	16/10/2012
	Validity	Yes	Yes
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 comments:	Not applicable		

Data/parameter:	$A_{OR,d}$		
Unit	tNH <sub>3</sub> /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 <sub>3</sub> /day) of AOR in this period		
	Average values	Plant I ( $A_{OR,d-1}$ )	Plant II ( $A_{OR,d-2}$ )
	$A_{OR,d}$ (tNH <sub>3</sub> /day)	36.46	39.64
Monitoring equipment	The measuring instruments for $A_{OR,d}$ indicated in the registered PDD were replaced on 12 <sup>th</sup> October 2012. Therefore all of the information of measuring instrument for $A_{OR,d}$ in this period is the same with that in previous period.		
	Plant I ( $A_{OR,d-1}$ )	Before replacement	After replacement
	Type	Differential Pressure	Differential Pressure
	Accuracy class	Within $\pm 0.1\%$	Within $\pm 0.1\%$
	Serial No.	10530360038	1210 80055040028
	Calibration frequency	Every 2 years	Every 2 years
	Date of last calibration	11/01/2010	18/04/2012
	Validity	Yes	Yes
	Plant II ( $A_{OR,d-2}$ )	Before replacement	After replacement
	Type	Differential Pressure	Differential Pressure
	Accuracy class	Within $\pm 0.1\%$	Within $\pm 0.1\%$
	Serial No.	10530360080	1210 80055040029
	Calibration frequency	Every 2 years	Every 2 years
	Date of last calibration	11/03/2010	18/04/2012
	Validity	Yes	Yes
	•Measuring period : Continuously •Recording frequency : Hourly		
	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 comments:	Not applicable

Data/parameter:	$T_{g,d}$			
Unit	°C			
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 (°C) of AOR in this period			
	Plant I		Plant II	
	$T_{g,a}$ (°C)	$T_{g,b}$ (°C)	$T_{g,c}$ (°C)	$T_{g,d}$ (°C)
	719.53	730.87	747.08	742.05
	The measuring instrument for $T_{g-b}$ which is indicated in the registered PDD was replaced on October 2011. Even though the model number and Maker of the new measuring equipment are different from past one described in PDD, the type and the accuracy class of the equipment are the same.			

Monitoring equipment	The measuring instruments for $T_{g,d}$ indicated in the registered PDD were replaced . The relevant dates are summarized on following table.				
	Period	Date on instruments replaced			
		$T_{g-a}$	$T_{g-b}$	$T_{g-c}$	$T_{g-d}$
	Period 1	None	None	None	None
	Period 2	None	17/10/2011	None	None
	Period 3	None	None	None	None
	Period 4	19/10/2012	19/10/2012	21/10/2012	21/10/2012
	Period 5	None	None	None	None
	Therefore all of the information of measuring instrument for $T_{g,d}$ in this period is the same with that in previous period.				
	The information of the measuring instrument for $T_{g,d}$ is as follows:				
	$T_{g-a}$	Before Replacement		After Replacement	
	Type	Thermocouple K		Thermocouple K	
	Accuracy class (Maximum error)	300°C	+0.00°C	300°C	-0.7°C
		500°C	+0.35°C	500°C	-0.1°C
		700°C	+0.98°C	700°C	-0.7°C
	Serial No.	2170447		124011	
	Calibration frequency	Every 2 years		Every 2 years	
	Date of last calibration	13/05/2011		18/04/2012	
	Validity	Yes		Yes	
	$T_{g-b}$	After 1 <sup>st</sup> Replacement		After 2 <sup>nd</sup> Replacement	
	Type	Thermocouple K		Thermocouple K	
	Accuracy class (Maximum error)	300°C	+0.00°C	300°C	-0.7°C
		500°C	+0.35°C	500°C	-0.1°C
		700°C	+0.98°C	700°C	-0.7°C
	Serial No.	2170445		124012	
	Calibration frequency	Every 2 years		Every 2 years	
	Date of last calibration	17/10/2011		18/04/2012	
	Validity	Yes		Yes	
	$T_{g-c}$	Before Replacement		After Replacement (21/10/2012)	
	Type	Thermocouple K		Thermocouple K	
	Accuracy class (Maximum error)	300°C	-0.7°C	300°C	-0.7°C
		500°C	-0.1°C	500°C	-0.1°C
		700°C	-0.7°C	700°C	-0.7°C
	Serial No.	24001		124008	
	Calibration frequency	Every 2 years		Every 2 years	
	Date of last calibration	23/05/2011		18/04/2012	
	Validity	Yes		Yes	
	$T_{g-d}$	Before Replacement		After Replacement (21/10/2012)	
	Type	Thermocouple K		Thermocouple K	
	Accuracy class (Maximum error)	300°C	-0.7°C	300°C	-0.7°C
		500°C	-0.1°C	500°C	-0.1°C
		700°C	-0.7°C	700°C	-0.7°C
	Serial No.	24002		124007	
	Calibration frequency	Every 2 years		Every 2 years	
	Date of last calibration	23/05/2011		18/04/2012	
	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 comments:	Not applicable

<b>Data/parameter:</b>	<b><math>P_{g,d}</math></b>																																																										
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 this period																																																										
	Average values	Plant I ( $P_{g-1}$ )	Plant II ( $P_{g-2}$ )																																																								
	$P_{g,d}$ (Pa/day)	79,372	83,476																																																								
Monitoring equipment	<p>The measuring instruments for <math>P_{g-1}</math> and <math>P_{g-2}</math> indicated in the registered PDD were replaced on 21<sup>th</sup> October 2012 and 12<sup>th</sup> October 2012 respectively. Therefore all of the information of measuring instrument for <math>P_{g,d}</math> in this period is the same with that in previous period.</p> <p>The information of the measuring instrument for <math>P_{g,d}</math> is as follows:</p> <table> <tr> <th colspan="2">Plant I (<math>P_{g-1}</math>)</th><th>Before replacement</th><th>After replacement</th></tr> <tr> <td>Type</td><td></td><td>Gauge Pressure</td><td>Gauge Pressure</td></tr> <tr> <td>Accuracy class</td><td></td><td>Within <math>\pm 0.1\%</math></td><td>Within <math>\pm 0.1\%</math></td></tr> <tr> <td>Serial No.</td><td></td><td>10530360183</td><td>1211 80055040030</td></tr> <tr> <td>Calibration frequency</td><td></td><td>Every 2 years</td><td>Every 2 years</td></tr> <tr> <td>Date of last calibration</td><td></td><td>11/01/2010</td><td>18/04/2012</td></tr> <tr> <td>Validity</td><td></td><td>Yes</td><td>Yes</td></tr> </table> <table> <tr> <th colspan="2">Plant II (<math>P_{g-2}</math>)</th><th>Before replacement</th><th>After replacement</th></tr> <tr> <td>Type</td><td></td><td>Gauge Pressure</td><td>Gauge Pressure</td></tr> <tr> <td>Accuracy class</td><td></td><td><math>\pm 0.1\%</math></td><td>Within <math>\pm 0.1\%</math></td></tr> <tr> <td>Serial No.</td><td></td><td>10530360212</td><td>1211 80055040031</td></tr> <tr> <td>Calibration frequency</td><td></td><td>Every 2 years</td><td>Every 2 years</td></tr> <tr> <td>Date of last calibration</td><td></td><td>11/03/2010</td><td>18/04/2012</td></tr> <tr> <td>Validity</td><td></td><td>Yes</td><td>Yes</td></tr> </table>			Plant I ( $P_{g-1}$ )		Before replacement	After replacement	Type		Gauge Pressure	Gauge Pressure	Accuracy class		Within $\pm 0.1\%$	Within $\pm 0.1\%$	Serial No.		10530360183	1211 80055040030	Calibration frequency		Every 2 years	Every 2 years	Date of last calibration		11/01/2010	18/04/2012	Validity		Yes	Yes	Plant II ( $P_{g-2}$ )		Before replacement	After replacement	Type		Gauge Pressure	Gauge Pressure	Accuracy class		$\pm 0.1\%$	Within $\pm 0.1\%$	Serial No.		10530360212	1211 80055040031	Calibration frequency		Every 2 years	Every 2 years	Date of last calibration		11/03/2010	18/04/2012	Validity		Yes	Yes
Plant I ( $P_{g-1}$ )		Before replacement	After replacement																																																								
Type		Gauge Pressure	Gauge Pressure																																																								
Accuracy class		Within $\pm 0.1\%$	Within $\pm 0.1\%$																																																								
Serial No.		10530360183	1211 80055040030																																																								
Calibration frequency		Every 2 years	Every 2 years																																																								
Date of last calibration		11/01/2010	18/04/2012																																																								
Validity		Yes	Yes																																																								
Plant II ( $P_{g-2}$ )		Before replacement	After replacement																																																								
Type		Gauge Pressure	Gauge Pressure																																																								
Accuracy class		$\pm 0.1\%$	Within $\pm 0.1\%$																																																								
Serial No.		10530360212	1211 80055040031																																																								
Calibration frequency		Every 2 years	Every 2 years																																																								
Date of last calibration		11/03/2010	18/04/2012																																																								
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 comments:	Not applicable																																																										

<b>Data/parameter:</b>	<b><math>G_{sup}</math></b>
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 comments:	Not applicable

<b>Data/parameter:</b>	<b><math>G_{com}</math></b>
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 comments:	Not applicable

<b>Data/parameter:</b>	<b><math>Type_{HC}</math></b>
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 comments:	Not applicable

Data/parameter:	CF <sub>CH4</sub>		
Unit	-		
Description	Methane content of hydrocarbon, natural gas		
Measured/calculated/default	Not applicable		
Source of data	Information provided by the natural gas supplier		
Value(s) of monitored parameter	The same kinds of natural gas are supplied to the Plant I and Plant II.		
	Month	Plant I	Plant II
	January	0.9239	0.9239
	February	0.9222	0.9222
	March	0.9222	0.9222
	April	0.9205	0.9205
	May	0.9164	0.9164
	June	0.9192	0.9192
	July	0.9137	0.9137
	August	0.9178	0.9178
	September	0.9192	0.9192
	October	0.9187	0.9187
	November	0.9193	0.9193
Period 5	0.9194	0.9194	
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 comments:	Not applicable		

Data/parameter:	$Q_{NG,y}$		
Unit	Nm <sup>3</sup>		
Description	Natural gas input for re-heating the tail gas		
Measured/calculated/default	Measured		
Source of data	Flow meter with normalizing functions		
Value(s) of monitored parameter	Average daily value of $Q_{NG}$ (Nm <sup>3</sup> /day) in this period		
	Average values	Plant I ( $Q_{NG,1}$ )	Plant II( $Q_{NG,2}$ )
	$Q_{NG}$ (Nm <sup>3</sup> /day)	541.14	736.59

Monitoring equipment	Item	Plant I ( $Q_{NG,1}$ )	Plant II ( $Q_{NG,2}$ )
	Type	Orifice	Orifice
	Accuracy class	$\pm 0.90\%$	$\pm 0.90\%$
	Serial No.	02319622	02319623
	Calibration frequency	Every 2 years	Every 2 years
	Date of last calibration	08/03/2012	08/03/2012
	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:	Project emission Calculation		
Additional comments:	Not applicable		

Data/parameter:	$Q_{CH4,y}$		
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 ( $Q_{CH4,d}$ ) in this period		
	Average values	Plant I	Plant II
	$Q_{CH4,d}$ ( $Nm^3/day$ )	408.88	630.70
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 comments:	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 ( $Q_{HC,d}$ ) for this period		
	Average values	Plant I	Plant II
	$Q_{HC,d}$ ( $Nm^3/day$ )	35.79	55.19



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 comments:	Not applicable

Data/parameter:	$\rho_{NG}$		
Unit	t/Nm <sup>3</sup>		
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	The same kinds of natural gas are supplied to the Plant I and Plant II.		
	Month	Plant I	Plant II
	January	0.7861×10 <sup>-3</sup>	0.7861×10 <sup>-3</sup>
	February	0.7877×10 <sup>-3</sup>	0.7877×10 <sup>-3</sup>
	March	0.7877×10 <sup>-3</sup>	0.7877×10 <sup>-3</sup>
	April	0.7854×10 <sup>-3</sup>	0.7854×10 <sup>-3</sup>
	May	0.7883×10 <sup>-3</sup>	0.7883×10 <sup>-3</sup>
	June	0.7856×10 <sup>-3</sup>	0.7856×10 <sup>-3</sup>
	July	0.7921×10 <sup>-3</sup>	0.7921×10 <sup>-3</sup>
	August	0.7887×10 <sup>-3</sup>	0.7887×10 <sup>-3</sup>
	September	0.7876×10 <sup>-3</sup>	0.7876×10 <sup>-3</sup>
	October	0.7885×10 <sup>-3</sup>	0.7885×10 <sup>-3</sup>
	November	0.7897×10 <sup>-3</sup>	0.7897×10 <sup>-3</sup>
Period 5	0.7879×10 <sup>-3</sup>	0.7879×10 <sup>-3</sup>	
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 comments:	Not applicable		

<b>Data/parameter:</b>	$\rho_{HC}$
Unit	t/m <sup>3</sup>
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	The same kinds of natural gas are supplied to the Plant I and Plant II.		
	Month	Plant I	Plant II
	January	1.6372×10 <sup>-3</sup>	1.6372×10 <sup>-3</sup>
	February	1.6376×10 <sup>-3</sup>	1.6376×10 <sup>-3</sup>
	March	1.6376×10 <sup>-3</sup>	1.6376×10 <sup>-3</sup>
	April	1.5890×10 <sup>-3</sup>	1.5890×10 <sup>-3</sup>
	May	1.5808×10 <sup>-3</sup>	1.5808×10 <sup>-3</sup>
	June	1.5777×10 <sup>-3</sup>	1.5777×10 <sup>-3</sup>
	July	1.5978×10 <sup>-3</sup>	1.5978×10 <sup>-3</sup>
	August	1.6002×10 <sup>-3</sup>	1.6002×10 <sup>-3</sup>
	September	1.6021×10 <sup>-3</sup>	1.6021×10 <sup>-3</sup>
	October	1.6078×10 <sup>-3</sup>	1.6078×10 <sup>-3</sup>
	November	1.6293×10 <sup>-3</sup>	1.6293×10 <sup>-3</sup>
Period 5	1.6088×10 <sup>-3</sup>	1.6088×10 <sup>-3</sup>	
Monitoring equipment	Not applicable		
Measuring/reading/recording frequency:	Not applicable		
Calculation method (if applicable):	$\rho_{HC} = (\rho_{NG} - \rho_{CH_4} \times CF_{CH_4}) / (1 - CF_{CH_4})$		
QA/QC procedures:	Not applicable		
Purpose of data:	Project emission Calculation		
Additional comments:	Not applicable		

Data/parameter:	EF <sub>NG</sub>		
Unit	tCO <sub>2</sub> /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	The same kinds of natural gas are supplied to the Plant I and Plant II.		
	Month	Plant I	Plant II
	January	2.7760	2.7760
	February	2.7746	2.7746
	March	2.7746	2.7746
	April	2.7712	2.7712
	May	2.7725	2.7725
	June	2.7716	2.7716
	July	2.7684	2.7684
	August	2.7707	2.7707
	September	2.7714	2.7714
	October	2.7720	2.7720
	November	2.7728	2.7728
Period 5	2.7724	2.7724	
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 <sup>3</sup> ] For this project, $NCV_{NG}$ is offered by KOGAS. $\rho_{NG}$ : Density of the natural gas[t/Nm <sup>3</sup> ] For this project, based on data source by natural gas supplier.
QA/QC procedures:	Not applicable
Purpose of data:	Project emission Calculation
Additional comments:	Not applicable

Data/parameter:	EF <sub>HC</sub>																																									
Unit	tCO <sub>2</sub> /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	<div>The same kinds of natural gas are supplied to the Plant I and Plant II.</div> <table><tr><th>Month</th><th>Plant I</th><th>Plant II</th></tr><tr><td>January</td><td>2.9141</td><td>2.9141</td></tr><tr><td>February</td><td>2.9023</td><td>2.9023</td></tr><tr><td>March</td><td>2.9023</td><td>2.9023</td></tr><tr><td>April</td><td>2.8821</td><td>2.8821</td></tr><tr><td>May</td><td>2.8843</td><td>2.8843</td></tr><tr><td>June</td><td>2.8834</td><td>2.8834</td></tr><tr><td>July</td><td>2.8558</td><td>2.8558</td></tr><tr><td>August</td><td>2.8742</td><td>2.8742</td></tr><tr><td>September</td><td>2.8800</td><td>2.8800</td></tr><tr><td>October</td><td>2.8829</td><td>2.8829</td></tr><tr><td>November</td><td>2.8868</td><td>2.8868</td></tr><tr><td>Period 5</td><td>2.8862</td><td>2.8862</td></tr></table>			Month	Plant I	Plant II	January	2.9141	2.9141	February	2.9023	2.9023	March	2.9023	2.9023	April	2.8821	2.8821	May	2.8843	2.8843	June	2.8834	2.8834	July	2.8558	2.8558	August	2.8742	2.8742	September	2.8800	2.8800	October	2.8829	2.8829	November	2.8868	2.8868	Period 5	2.8862	2.8862
Month	Plant I	Plant II																																								
January	2.9141	2.9141																																								
February	2.9023	2.9023																																								
March	2.9023	2.9023																																								
April	2.8821	2.8821																																								
May	2.8843	2.8843																																								
June	2.8834	2.8834																																								
July	2.8558	2.8558																																								
August	2.8742	2.8742																																								
September	2.8800	2.8800																																								
October	2.8829	2.8829																																								
November	2.8868	2.8868																																								
Period 5	2.8862	2.8862																																								
Monitoring equipment	Not applicable																																									
Measuring/reading/recording frequency:	Not applicable																																									
Calculation method (if applicable):	<div>EF<sub>HC</sub> = (EF<sub>NG</sub>×ρ<sub>NG</sub> -EF<sub>CH4</sub>×ρ<sub>CH4</sub> ×CF<sub>CH4</sub>)/ (1-CF<sub>CH4</sub>)/ ρ<sub>HC</sub></div> <div>Where</div> <div>EF<sub>NG</sub> : CO<sub>2</sub> emission factor of NG[tCO<sub>2</sub>/tNG</div> <div>ρ<sub>NG</sub> : Density of natural gas (tNG/m<sup>3</sup>)</div> <div>EF<sub>CH4</sub> : CO<sub>2</sub> emission factor of CH<sub>4</sub>(tCO<sub>2</sub>/tCH<sub>4</sub>).</div> <div>ρ<sub>CH4</sub> : Density of methane (tCH<sub>4</sub>/ m<sup>3</sup>).</div> <div>CF<sub>CH4</sub> : Methane fraction in the natural gas</div>																																									
QA/QC procedures:	Not applicable																																									
Purpose of data:	Project emission Calculation																																									
Additional comments:	Not applicable																																									

Data/parameter:	SE <sub>N2O</sub>								
Unit	kgN <sub>2</sub> O/tCaprolactam								
Description	N <sub>2</sub> O emission rate per ton of caprolactam								
Measured/calculated/default	Calculated								
Source of data	Baseline and Monitoring Methodology (AM0028 ver05)								
Value(s) of monitored parameter	<div>SE<sub>N2O</sub> is for this period.<table><tr><td>Average values</td><td>Plant I</td><td>Plant II</td></tr><tr><td>SE<sub>N2O,period</sub>(kgN<sub>2</sub>O/tCaprolactam)</td><td>22.83</td><td>18.37</td></tr></table></div>			Average values	Plant I	Plant II	SE <sub>N2O,period</sub> (kgN <sub>2</sub> O/tCaprolactam)	22.83	18.37
Average values	Plant I	Plant II							
SE <sub>N2O,period</sub> (kgN <sub>2</sub> O/tCaprolactam)	22.83	18.37							
Monitoring equipment	Not applicable								
Measuring/reading/recording frequency:	Not applicable								
Calculation method (if applicable):	SE <sub>N2O,period</sub> = QI <sub>N2O,period</sub> / P <sub>product,period</sub> × 1000 Where, QI <sub>N2O,period</sub> means the monitored quantity of N <sub>2</sub> O emissions at the inlet of the destruction facility (t N <sub>2</sub> O), and P <sub>product,period</sub> is the actual output of caprolactam for this period.								
QA/QC procedures:	Not applicable								
Purpose of data:	Baseline emission Calculation								
Additional comments:	Not applicable								

Data/parameter:	OXIDCH4								
Unit	%								
Description	Oxidation factor of CH4 in natural gas for re-heating tail gas								
Measured/calculated/default	Calculated								
Source of data	Not applicable								
Value(s) of monitored parameter	Average value in this period <table><tr><td>Average values</td><td>Plant I</td><td>Plant II</td></tr><tr><td>OXIDCH4</td><td>97.24</td><td>98.35</td></tr></table>			Average values	Plant I	Plant II	OXIDCH4	97.24	98.35
Average values	Plant I	Plant II							
OXIDCH4	97.24	98.35							
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 comments:	Not applicable								

Data/parameter:	CO <sub>CH4</sub>		
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 value in this period		
	Average values	Plant I	Plant II
	CO <sub>CH4</sub>	13.68	10.51

Monitoring equipment	Item	Plant I (CO <sub>CH4-1</sub> )	Plant II(CO <sub>CH4-2</sub> )
	Type	NDIR	NDIR
	Accuracy class	>95%	>95%
	Serial No.	AO-750	AO-751
	Calibration frequency	Every 2weeks	Every 2weeks
	Date of last calibration <sup>5)</sup>	27/09/2013	31/10/2013
	Validity	Yes	Yes
	Model	ULTRAMAT 6	ULTRAMAT 6
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 comments:	Not applicable		

<b>Data/parameter:</b>	<b>Reg<sub>NOx</sub></b>
Unit	tNOX/Nm <sup>3</sup>
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 <sup>-7</sup> tNOx/Nm <sup>3</sup> (as a NO <sub>2</sub> 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 comments:	Not applicable

<b>Data/parameter:</b>	<b>RSE<sub>N2O,v</sub></b>
Unit	tN <sub>2</sub> O/tCaprolactam
Description	Regulatory limit of N <sub>2</sub> O emissions per unit of outlet of caprolactam (tN <sub>2</sub> O/t caprolactam)
Measured/calculated/default	Not applicable
Source of data	National legislation in Republic of Korea. (That may be mostly like environmental regulation.)

<sup>5</sup> NDIR is calibrated every 2 week. On the date of next turn to the last calibration for NDIR of each plant, both of plants were shut down.

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 comments:	Not applicable

### D.3. Implementation of sampling plan

&gt;&gt;

Not applicable

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

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

&gt;&gt;

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 ( $P_{\text{product,actual}}$ ) exceeds the design capacity ( $P_{\text{product,max}}$ ), the emissions related to the production above  $P_{\text{product,max}}$  will not be claimed for the baseline scenario. Therefore  $P_{\text{product,actual}}$  of each plant should be monitored. However, it is not able to be decided whether the actual production of caprolactam exceeds  $P_{\text{product,max}}$ , or not, because those values ( $P_{\text{product,max}}$  and  $P_{\text{product,actual}}$ ) should be compared on the annual values for comparing each other, and only 319 days have been monitored for this period, so in order to simply make rough estimation to the status of production, the actual average daily output for this period was compared with the expected average daily output described in PDD, as shown in the Table E.1-1. (All of the data for the actual daily production of caprolactam were listed in detail in the emission reductions calculation spreadsheet.)

**Table E.1-1** The actual value of Caprolactam Production for this period and the expected value of that on PDD

Item	Yearly expected in PDD			For this period		
	Design Capacity , $P_{\text{product,max}}$ (ton/yr)	No. of Operating days In PDD	Daily output (ton/day)	Period total output $P_{\text{product,period}}$ (ton/period)	No. of Operating days	Daily output (ton/day)
Plant I	63,307	363	174.40	40,384	319	126.60
Plant II	64,965	355	183.00	48,744	319	152.80

As a result, it can be said that actual production of caprolactam ( $P_{\text{product}}$ ) did not exceed the design capacity ( $P_{\text{product,max}}$ ). Therefore on the condition of  $P_{\text{product,y}} < P_{\text{product,max}}$ , baseline emissions ( $BE$ ) for the period are given by following equation :

$$BE_{\text{period, within permit range}} = \left( \sum_i^n F_{TI,i} \times CI_{N_2O,i} \times M_i \right) \times GWP_{N_2O}$$

Where

- $M_i$  : Length of Measuring Interval (hr),  
(1hr is set value at instrument for this project )
- $GWP_{N_2O}$  : Global warming potential of the  $N_2O$ , (298: default value).
- $n$  : Number of intervals during this period
- $F_{TI,i}$  : Volume flow rate at the inlet of the DF during interval ( $Nm^3/hr$ )
- $CI_{N_2O,i}$  :  $N_2O$  concentration in the tail gas of the DF inlet during interval ( $tN_2O/ Nm^3$ )

However, if the actual average daily operating temperature and/or pressure in the ammonia oxidation reactor ( $T_g$  and  $P_g$ ) are outside the bounds of the “permitted range” of AOR operation conditions (:  $T_{g,hist}$  and/or  $P_{g,hist}$ ), the calculation of baseline emission is the integration of the daily baseline emission( $BE_{\text{daily, out of permit range}}$ ) for the respective day. The daily baseline emission is calculated for the respective time period as follows:

$$BE_{\text{daily, out of permit range}} = P_{\text{product, day}} \times EF_{N_2O} \times GWP_{N_2O} / 1000$$

$$BE_{\text{period, out of permit range}} = \sum BE_{\text{daily, out of permit range}}$$

Where

- $BE_{\text{daily, out of permit range}}$  : The daily baseline emission for the respective day in which AOR operation conditions were outside of “permitted range”(tonCO<sub>2</sub>/day)
- $P_{\text{product, day}}$  : The daily output of caprolactam for the respective day in which AOR operation conditions were outside of permitted range (ton caprolactam/day)
- $EF_{N_2O}$  :  $N_2O$  Emission factor to the process of caprolactam production (kgN<sub>2</sub>O/ton caprolactam)

Emission factor of  $N_2O$ ( $EF_{N_2O}$ ) is the lowest value among (a)  $EF_{N_2O,IPCC}$ , (b)  $SE_{N_2O,y}$  and (c) any related value as a result of legal regulation(e.g.  $RSE_{N_2O,y}$ ). In Republic of Korea, there is no mandatory regulation for  $N_2O$  emission. Therefore, actually  $EF_{N_2O}$  is the lower value between (a)  $EF_{N_2O,IPCC}$  and (b)  $SE_{N_2O,y}$ .

$EF_{N_2O,IPCC}$  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,  $EF_{N_2O,IPCC}$  is 5.4kgN<sub>2</sub>O/tonne of caprolactam.

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

$$SE_{N_2O,y} = QI_{N_2O,y} / P_{\text{product,y}} \times 1000$$

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

$$QI_{N_2O,y} = \sum_i^n F_{TI,i} \times CI_{N_2O,i} \times M_i$$

For this period,  $SE_{N_2O,y}$  and  $QI_{N_2O,y}$  should be converted as  $SE_{N_2O,period}$  and  $QI_{N_2O,period}$  as follows :

$$SE_{N_2O, period} = QI_{N_2O, period} / P_{product, period} \times 1000$$

The both of  $SE_{N_2O, y}$  values for plants are calculated as higher than  $EF_{N_2O, IPCC}$  (22.83 for plant 1 and 18.37 for plant 2), and thus the values of  $EF_{N_2O}$  are decided as 5.4kgN<sub>2</sub>O/tonne of caprolactam in order to calculate  $BE_{period, out of permit range}$ .

**Table E1-2**  $SE_{N_2O, y}$  for this period (period 5)

Item	Unit	Plant 1	Plant 2
$QI_{N_2O-Plant1}$	ton N <sub>2</sub> O/period	921.99	895.27
$P_{product-Plant1}$	ton Caprolactam/period	40,384.15	48,744.30
$SE_{N_2O, period}$	kgN <sub>2</sub> O/tCaprolactam	22.83	18.37

If the actual daily ammonia flow rate exceeds the (upper) limit on maximum historical daily permitted ammonia flow rate, the baseline N<sub>2</sub>O 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”.

Consequently, on condition of  $P_{product, y} < P_{product, max}$ , baseline emissions ( $BE$ ) for the period can be calculated as follows for this period.

$$BE_{period} = BE_{period, within permit range} + BE_{period, out of permit range}$$

#### (a) Baseline emission of Plant 1

##### In Case of AOR operation conditions within “permitted range”

In order to calculate the hourly BE ( $BE_{hr-i}$ ), the hourly integrated measured values of  $F_{Ti, i-1}$  and  $CI_{N_2O, -1}$  except the data to the day in which AOR was operated outside of permit range, are input. These hourly BE ( $BE_{hr-i}$ ) are aggregated to the daily BE ( $BE_{day}$ ), and total BE on this period for plant I ( $BE_{period-1}$ ), 274,753 tonCO<sub>2</sub>/period. BE calculated on hourly input data is explained in detail on the emission reductions calculation spreadsheet.

##### In case of AOR operation conditions outside of “permitted range”

For this period, the number of days on which the condition of AOR deviated from permitted range is 40 (Refer to Table B.1-2). All of those days showed zero values of caprolactam products. The baseline emission calculation for period 5 depends on following equation.

$$BE_{period, out of permit range} = \sum BE_{daily, out of permit range} = P_{product, day} \times EE_{N_2O, period} \times GWP_{N_2O} / 1000$$

**Table E.1-3** The date and  $BE$  on the condition of AOR deviated from permitted range in Plant 1

No.	Date (dd/mm/yyyy)	Product (ton/day)	$BE_{daily, out of permit range}$ (ton CO <sub>2</sub> /day)
1	26/02/2013	0	0
2	25/05/2013	0	0
3	26/05/2013	0	0
4	26/09/2013	0	0
5	11/10/2013	0	0
6	12/10/2013	0	0
7	13/10/2013	0	0
8	14/10/2013	0	0



No.	Date (dd/mm/yyyy)	Product (ton/day)	$BE_{daily, out of permit range}$ (ton CO <sub>2</sub> /day)
9	15/10/2013	0	0
10	16/10/2013	0	0
11	17/10/2013	0	0
12	18/10/2013	0	0
13	19/10/2013	0	0
14	20/10/2013	0	0
15	21/10/2013	0	0
16	22/10/2013	0	0
17	23/10/2013	0	0
18	24/10/2013	0	0
19	25/10/2013	0	0
20	26/10/2013	0	0
21	27/10/2013	0	0
22	28/10/2013	0	0
23	29/10/2013	0	0
24	30/10/2013	0	0
25	31/10/2013	0	0
26	01/11/2013	0	0
27	02/11/2013	0	0
28	03/11/2013	0	0
29	04/11/2013	0	0
30	05/11/2013	0	0
31	06/11/2013	0	0
32	07/11/2013	0	0
33	08/11/2013	0	0
34	09/11/2013	0	0
35	10/11/2013	0	0
36	11/11/2013	0	0
37	12/11/2013	0	0
38	13/11/2013	0	0
39	14/11/2013	0	0
40	15/11/2013	0	0
Total		0	0

The baseline emission in which AOR operation conditions of Plant 1 were outside of permitted range for this period ( $BE_{period, out of permit range}$ ) is zero.

**(b) Baseline emission of Plant II**

*In Case of AOR operation conditions within “permitted range”*

Hourly BE ( $BE_{hr-2}$ ) calculated on hourly integrated measured values of  $F_{T\ i-2}$  and  $CI_{N2O,i-2}$  are aggregated to the daily BE ( $BE_{day-2}$ ), and total BE on the period ( $BE_{period-2}$ ) are estimate as sum of  $BE_{day-2}$ . The total BE on the period 5 for Plant 2 ( $BE_{period-2}$ ) is 259,912tonCO<sub>2</sub>/period. BE calculated on hourly input data is explained in detail on the emission reductions calculation spreadsheet.

*In case of AOR operation conditions outside of “permitted range”.*

For this period, the number of days on which the condition of AOR deviated from permitted range is 38 (Refer to Table B.1). Among them, 26days showed zero values of caprolactam products, except 12days.

The baseline emission in which AOR operation conditions of Plant 2 were outside of permitted range for this period ( $BE_{\text{period, out of permit range}}$ ) is calculated as 3,268tonCO<sub>2</sub> /period depends on following equation.

$$BE_{\text{period, out of permit range}} = \sum BE_{\text{daily, out of permit range}} = P_{\text{product, day}} \times EE_{N_2O, \text{period}} \times GWP_{N_2O} / 1000$$

**Table .E1-4** The date and BE on the condition of AOR deviated from permitted range in Plant 2

No.	Date (dd/mm/yyyy)	Product (ton/day)	$BE_{\text{daily, out of permit range}}$ (ton CO <sub>2</sub> /day)
1	05/01/2013	169.96	273.50
2	06/01/2013	169.49	272.74
3	07/01/2013	169.72	273.11
4	08/01/2013	172.64	277.81
5	01/02/2013	167.76	269.96
6	18/06/2013	174.16	280.26
7	04/07/2013	167.17	269.01
8	05/07/2013	167.83	270.07
9	06/07/2013	167.91	270.20
10	11/07/2013	0.00	0.00
11	12/07/2013	0.00	0.00
12	13/07/2013	0.00	0.00
13	14/07/2013	0.00	0.00
14	29/07/2013	166.66	268.19
15	07/08/2013	162.06	260.79
16	26/08/2013	0.00	0.00
17	11/10/2013	0.00	0.00
18	12/10/2013	0.00	0.00
19	13/10/2013	0.00	0.00
20	14/10/2013	0.00	0.00
21	15/10/2013	0.00	0.00
22	16/10/2013	0.00	0.00
23	17/10/2013	0.00	0.00
24	18/10/2013	0.00	0.00
25	19/10/2013	0.00	0.00
26	20/10/2013	0.00	0.00
27	21/10/2013	0.00	0.00
28	22/10/2013	0.00	0.00
29	23/10/2013	0.00	0.00
30	24/10/2013	0.00	0.00
31	25/10/2013	0.00	0.00
32	26/10/2013	0.00	0.00
33	27/10/2013	0.00	0.00
34	28/10/2013	0.00	0.00
35	29/10/2013	0.00	0.00
36	30/10/2013	0.00	0.00
37	31/10/2013	0.00	0.00

No.	Date (dd/mm/yyyy)	Product (ton/day)	BE <sub>daily, out of permit range</sub> (ton CO <sub>2</sub> /day)
38	14/11/2013	175.73	282.78
Total		2031.09	3268.43

**(c) The total BE of Period 5**

Eventually, Total BE in this period is about 534,665tonCO<sub>2</sub> /period as shown below table.

**Table E1-5** Summary of BE for this period

Item		BE <sub>period-5</sub> (ton CO <sub>2</sub> /period)	
		BE <sub>period-5</sub> in Plant I	BE <sub>period-5</sub> in Plant II
BE <sub>period</sub> on AOR condition	within "permitted range"	274,753	256,643
	Outside "permitted range"	0	3,268
BE <sub>period</sub> total	BE <sub>period</sub> for each plant	274,753	259,912
	BE <sub>period-total</sub>		534,665

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

>>

The emission due to the project activity are composed of (a) the emissions of not destroyed N<sub>2</sub>O, (b) on-site emissions due to the hydrocarbons (; Natural Gas) use as input to the N<sub>2</sub>O 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<sub>2</sub>O reduction efficiency. In this project, natural gas is used for re-heating the tail gas to enhance the catalytic N<sub>2</sub>O reduction efficiency.

$$\begin{aligned}
 PE_{period} = & \left( \sum_i^n F_{TE,i} \times CO_{N_2O,i} \times M_i \right) \times GWP_{N_2O} \\
 & + [ (\rho_{HC} \times Q_{HC,y} \times EF_{HC} \times OXID_{HC}/100) + (\rho_{CH_4} \times Q_{CH_4,y} \times EF_{CH_4} \times OXID_{CH_4}/100) ] \\
 & + [ \rho_{CH_4} \times Q_{CH_4,y} \times GWP_{CH_4} \times (1-OXID_{CH_4}/100) ]
 \end{aligned}$$

Where

- $n$  : Number of intervals during the year (period<sup>-1</sup>)
- $M_i$  : 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<sup>3</sup>/hr)
- $CO_{N_2O,i}$  : N<sub>2</sub>O concentration in the tail gas of the DF exit during interval  $i$  (tN<sub>2</sub>O/m<sup>3</sup>)
- $GWP_{CH_4}$  : Global warming potential of CH<sub>4</sub>, 21 (: default value)
- $GWP_{N_2O}$  : Global warming potential of the nitrous oxide, 310 (: default value)
- $\rho_{CH_4}$  : Density of methane (tCH<sub>4</sub>/m<sup>3</sup>), 0.000716
- $\rho_{HC}$  : Density of HC (tHC/m<sup>3</sup>)
- $EF_{CH_4}$  : CO<sub>2</sub> emission factor of CH<sub>4</sub> (tCO<sub>2</sub>e/tCH<sub>4</sub>), 2.75
- $EF_{HC}$  : CO<sub>2</sub> emission factor of HC with two or more carbon molecule in natural gas (tCO<sub>2</sub>e/tHC)
- $Q_{CH_4,y}$  : Methane used in period (Nm<sup>3</sup>/period)
- $Q_{HC,y}$  : HC with two or more carbon molecule in natural gas used in period (Nm<sup>3</sup>/period)
- $OXID_{CH_4}$  : 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.

#### **(a) Project emission of Plant I**

In order to calculate the hourly PE ( $PE_{hr-1}$ ) for Plant I, the hourly integrated measured values of  $F_{TE,i-1}$  and  $CO_{N2O,i-1}$  are input. These hourly PE ( $PE_{hr-1}$ ) are aggregated to the daily PE( $PE_{day-1}$ ). The total PE on the period 5 for plant I ( $PE_{period-1}$ ) is 31,186tonCO<sub>2</sub>/period. PE on this period for plant I calculated on hourly input data is explained in detail on the emission reductions calculation spreadsheet.

#### **(b) Project emission of 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 this period for plant II ( $PE_{period-2}$ ) is 31,469tonCO<sub>2</sub>/period. PE on the period 5 for plant II calculated on hourly input data is explained in detail on the emission reductions calculation spreadsheet.

#### **(c) The total PE of Period 5**

Total PE in this period is 62,655 ton CO<sub>2</sub> as shown below table.

**Table E.2** Summary of PE for this period

Item	Plant I	Plant II
PE for each Plant (ton CO <sub>2</sub> /period)	31,186	31,469
PE for Period total, PE <sub>period-5</sub> (ton CO <sub>2</sub> /period)	62,655	

### **E.3. Calculation of leakage**

>>

The installation of the N<sub>2</sub>O 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 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.

Item	Baseline emissions or baseline net GHG removals by sinks (t CO <sub>2</sub> e)	Project emissions or actual net GHG removals by sinks (t CO <sub>2</sub> e)	Leakage (t CO <sub>2</sub> e)	GHG emission reductions or net GHG removals by sinks		
				Up to 31/12/2012	From 01/01/2013	Total amount
<b>Total</b>	534,665	62,655	0	N/A	472,010	472,010

**E.5. Comparison of actual emission reductions or net 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 Ex-ante values with Actual values in ER

Item	Values estimated in ex ante calculation of registered PDD	Actual values achieved during this monitoring period
Emission reductions or GHG removals by sinks (t CO <sub>2</sub> e)	577,691 <sup>6</sup>	472,010

As a conclusion, the actual emission reduction during this monitoring period is lower than the ex-ante value of the registered CDM-PDD. The data for period and calculated results are in detail on calculation spreadsheet for this period (period 5).

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

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Not applicable

<sup>6</sup> 577,691=660,995 \* 319 days / 365 days

## Appendix 1. Contact information of project participants and responsible persons/entities

<b>Project participant and/or responsible person/ entity</b>	<input checked="" type="checkbox"/> Project participant <input checked="" type="checkbox"/> Person/entity responsible for completing the CDM-MR-FORM
<b>Organization name</b>	Hyosung Corporation
<b>Street/P.O. Box</b>	450 Gongduk-Dong, Mapo-Gu
<b>Building</b>	Hyosung Building
<b>City</b>	Seoul
<b>State/region</b>	
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<b>Country</b>	Republic of Korea
<b>Telephone</b>	+8227077586
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<b>E-mail</b>	memories37@hyosung.com
<b>Website</b>	<a href="http://www.hyosung.com">www.hyosung.com</a>
<b>Contact person</b>	YungYul Choi
<b>Title</b>	Associate
<b>Salutation</b>	Mr.
<b>Last name</b>	Choi
<b>Middle name</b>	
<b>First name</b>	YungYul
<b>Department</b>	Green Management Team in Corporate Strategy Center
<b>Mobile</b>	+821029372463
<b>Direct fax</b>	
<b>Direct tel.</b>	+8227077586
<b>Personal e-mail</b>	memories37@gmail.com

<b>Project participant and/or responsible person/ entity</b>	<input checked="" type="checkbox"/> Project participant <input type="checkbox"/> Person/entity responsible for completing the CDM-MR-FORM
<b>Organization name</b>	Capro Corporation
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