# THIRD MONITORING REPORT

**PROJECT:** **ACHEMA UKL-7 plant $N_2O$ abatement project**

**Prepared by:**

VERTIS

VERTIS FINANCE

**November 10, 2011**

## Monitoring periods

**Line 2**

Project campaign 3

| | |
|---|---|
| FROM: | 13/10/2009 |
| TO: | 21/10/2010 |
| ERUs | 200,666 |

**Line 3**

Project campaign 3

| | |
|---|---|
| FROM: | 17/06/2009 |
| TO: | 16/11/2010 |
| ERUs | 49,142 |

**Line 4**

Project campaign 3

| | |
|---|---|
| FROM: | 03/08/2010 |
| TO: | 09/03/2011 |
| ERUs | 98,976 |

**Line 5**

Project campaign 3

| | |
|---|---|
| FROM: | 12/08/2010 |
| TO: | 17/03/2011 |
| ERUs | 103,817 |

**Line 7**

Project campaign 3

| | |
|---|---|
| FROM: | 03/11/2009 |
| TO: | 08/12/2010 |
| ERUs | 150,615 |

**Line 8**

Project campaign 3

| | |
|---|---|
| FROM: | 21/11/2009 |
| TO: | 25/10/2010 |
| ERUs | 91,448 |

**Line 2**

Project campaign 4

| | |
|---|---|
| FROM: | 22/10/2010 |
| TO: | 12/05/2011 |
| ERUs | 160,448 |

Third monitoring period start and end: **June 17, 2009 – May 12, 2011**

Third monitoring period ERUs in total: **855,112**

# MONITORING REPORT

**PROJECT:** ACHEMA UKL nitric acid plant $N_2O$ abatement project
**LINE:** Line 2
**MONITORING PERIOD:**
**FROM:** 13/10/2009

**TO:** 21/10/2010

**Prepared by:**

VERTIS

**VERTIS FINANCE**

www.vertisfinance.com

# Table of Contents

# 1. EXECUTIVE SUMMARY

This monitoring report determines baseline emission factor for the Line 2 of ACHEMA UKL nitric acid plant and quantity of emission reduction generated during the third project campaign on Line 2.

The first project campaign on Line 2 started on 30/05/2008. Secondary catalyst was installed on 07/11/2008. Total quantity of emission reductions generated during the third project period from 13/10/2009 through 21/10/2010 on Line 2 is **200 666 ERUs**.

### T 1 Emission reduction calculations

| EMISSION REDUCTION | | | |
|---|---|---|---|
| Baseline Emission Factor | EF_BL | 9.51 | kgN2O/tHNO3 |
| Project Campaign Emission Factor | EF_P | 1.99 | kgN2O/tHNO3 |
| Nitric Acid Produced in the Baseline Campaign | NAP_BL | 60 767 | tHNO3 |
| Nitric Acid Produced in the NCSG Baseline Campaign | NAP_BL_NCSG | 60 767 | tHNO3 |
| Nitric Acid Produced in the Project Campaign | NAP_P | 86 079 | tHNO3 |
| GWP | GWP | 310 | tCO2e/tN2O |
| **Emission Reduction** | **ER** | **200 666** | **tCOe** |
| *ER=(EF_BL-EF_P)*NAP_P*GWP/1000* | | | |
| **Abatement Ratio** | | **79.0%** | |

| EMISSION REDUCTION PER YEAR | | | |
|---|---|---|---|
| Year | 2008 | 2009 | 2010 |
| Date From | | 13 Oct 2009 | 01 Jan 2010 |
| Date To | | 31 Dec 2009 | 21 Oct 2010 |
| Nitric Acid Production | | 17 444 | 68 634 |
| **Emission Reduction** | | **40 666** | **160 000** |
| *ER_YR = ER * NAP_P_YR / NAP_P* | | | |

Baseline emission factor established for the Line 2 during baseline measurement carried from 09/11/2007 through 20/05/2008 is 9.51 $kgN_2O/tHNO_3$.

Project emission factor during the third project campaign after installation of secondary catalysts on Line 2, which started on 13/10/2009 and went through 21/10/2010 with secondary catalyst installed and commissioned on 07/11/2008, is 1.99 $kgN_2O/tHNO_3$.

During the project campaign 86 079 tonnes of nitric acid was produced.

# 2. DESCRIPTION OF THE PROJECT ACTIVITY

Purpose of the Project (the “Project”) is the reduction of nitrous oxide ($N_2O$) emissions from nitric acid production Lines at the UKL-7 nitric acid plant of AB Achema (“Achema” or “the Company”). The Company is situated in Jonava, Lithuania.

Achema has installed and operates secondary $N_2O$ reduction catalysts underneath the primary catalyst precious metal catching and catalytic gauzes package in the ammonium burners of the UKL-7 nitric acid plant.

This monitoring report contains information on Line 2 emission reductions including information on baseline emission factor setting for the Line 2.

The separate treatment of nitric acid lines and overlapping of the monitoring periods are allowed by the clarification issued Joint Implementation Supervisory Committee: “CLARIFICATION REGARDING OVERLAPPING MONITORING PERIODS UNDER THE VERIFICATION PROCEDURE UNDER THE JOINT IMPLEMENTATION SUPERVISORY COMMITTEE”. The Project meets all the requirements set out by the clarification:

1. The Project is composed of clearly identifiable components for which emission reductions or enhancements of removals are calculated independently; and

2. Monitoring is performed independently for each of these components, i.e. the data/parameters monitored for one component are not dependent on/effect data/parameters (to be) monitored for another component; and

3. The monitoring plan ensures that monitoring is performed for all components and that in these cases all the requirements of the JI guidelines and further guidance by the JISC regarding monitoring are met.

# 3. BASELINE SETTING

Baseline emission factor for line 2 has been established on the Line-specific basis. Campaign used for baseline measurements on the line 2 has been carried out from 09/11/2007 through 20/05/2008.

$N_2O$ concentration and gas volume flow are monitored by monitoring system complying with requirements of the European Norm 14181.

Monitoring system provides separate readings for $N_2O$ concentration and gas flow volume for every hour of operation as an average of the measured values for the previous 60 minutes.

Measurement results can be distorted before and after periods of downtime or malfunction of the monitoring system and can lead to mavericks. To eliminate such extremes and to ensure a conservative approach, the following statistical evaluation is applied to the complete data series of $N_2O$ concentration as well as to the data series for gas volume flow. The statistical procedure is applied to data obtained after eliminating data measured for periods where the plant operated outside the permitted ranges:

a) Calculate the sample mean (x)
b) Calculate the sample standard deviation (s)
c) Calculate the 95% confidence interval (equal to 1.96 times the standard deviation)
d) Eliminate all data that lie outside the 95% confidence interval
e) Calculate the new sample mean from the remaining values (volume of stack gas (VSG) and $N_2O$ concentration of stack gas (NCSG))

The average mass of $N_2O$ emissions per hour is estimated as product of the NCSG and VSG. The $N_2O$ emissions per campaign are estimates product of $N_2O$ emission per hour and the total number of complete hours of operation of the campaign using the following equation:

$$BE_{BC} = VSG_{BC} * NCSG_{BC} * 10^{-9} * OH_{BC} \ (tN_2O)$$

The Line specific baseline emissions factor representing the average $N_2O$ emissions per tonne of nitric acid over one full campaign is derived by dividing the total mass of $N_2O$ emissions by the total output of 100% concentrated nitric acid during baseline campaign.

The overall uncertainty of the monitoring system has been determined by the QAL2 report and the measurement error is expressed as a percentage (UNC). The $N_2O$ emission factor per tonne of nitric acid produced in the baseline period (EFBL) has been then be reduced by the percentage error as follows:

$$EF_{BL} = (BE_{BC} / NAP_{BC}) \ (1 – UNC/100) \ (tN_2O/tHNO_3)$$

where:

| Variable | Definition |
|---|---|
| $EF_{BL}$ | Baseline $N_2O$ emissions factor ($tN_2O/tHNO_3$) |
| $BE_{BC}$ | Total $N_2O$ emissions during the baseline campaign ($tN_2O$) |
| $NCSG_{BC}$ | Mean concentration of $N_2O$ in the stack gas during the baseline campaign ($mgN_2O/m^3$) |
| $OH_{BC}$ | Operating hours of the baseline campaign (h) |
| $VSG_{BC}$ | Mean gas volume flow rate at the stack in the baseline measurement period ($m^3/h$) |
| $NAP_{BC}$ | Nitric acid production during the baseline campaign ($tHNO_3$) |
| UNC | Overall uncertainty of the monitoring system (%), calculated as the combined uncertainty of the applied monitoring equipment. |

## 3.1 Measurement procedure for $N_2O$ concentration and tail gas volume flow

### 3.1.1 Tail gas $N_2O$ concentration

$N_2O$ concentration is measured by extractive measurement system. Tail gas samples are taken from the Line 2 tail gas duct at sampling point located after expansion turbine and transported by sample Line to the Monitoring room A, where the analyzer is located.

Tail gas samples are filtered and conditioned in the condensation dryer (4°C), so $N_2O$ concentration is measured on a dry basis.

$N_2O$ concentration is measured by concentration infrared absorption principle meters Xentra 4900 using GFX monitoring technology.

Recently there are 8 production lines. $N_2O$ concentration is measured by 3 concentration meters on a switched basis.

$N_2O$ concentration measured data are sent from the analyzer on a 2 sec basis in a form of 4-20mA signal to the datalogger and processed further.

### 3.1.2 Tail gas flow rate, pressure and temperature

Tail gas flow, pressure and temperature is measured by ultrasonic Durag DF-L 200 flowmeters based on ultrasonic pulse fly time across the entire duct cross-section. Tail gas flow, pressure and temperature measured data are sent from the flow meter on a 2 sec basis in a form of 4-20mA signal to the datalogger and processed further.

## 3.2 Permitted range of operating conditions of the nitric acid plant

Under certain circumstances, the operating conditions during the measurement period used to determine baseline $N_2O$ emission factor may be outside the permitted range or limit corresponding to normal operating conditions. $N_2O$ baseline data measured during hours

where the operating conditions were outside the permitted range have been eliminated from the calculation of the baseline emissions factor.

Normal ranges for operating conditions have been determined for the following parameters:

oxidation temperature;
oxidation pressure;
ammonia gas flow rate,
air input flow rate.

The permitted range for these parameters has been established using the plant operation manual, as described in the PDD..

## 3.3 Historic Campaign Length

The average historic campaign length ($CL_{normal}$) defined as the average campaign length for the historic campaigns used to define operating condition (the previous five campaigns), has not been used as a cap on the length of the baseline campaign because of shorter project campaign.

# 4. PROJECT EMISSIONS

During the first project campaign on line 2 the tail gas volume flow in the stack of the nitric acid plant as well as $N_2O$ concentration have been measured on the continuous basis.

### 4.1.1 Estimation of campaign-specific project emissions factor

The monitoring system was installed using the guidance document EN 14181 and provides separate readings for $N_2O$ concentration and gas flow volume for every hour of operation. Same statistical evaluation that was applied to the baseline data series has been applied to the project data series:

a) Calculate the sample mean (x)
b) Calculate the sample standard deviation (s)
c) Calculate the 95% confidence interval (equal to 1.96 times the standard deviation)
d) Eliminate all data that lie outside the 95% confidence interval
e) Calculate the new sample mean from the remaining values

$$PE_n = VSG * NCSG * 10^{-9} * OH \ (tN_2O)$$

where:

| **Variable** | **Definition** |
|---|---|
| VSG | Mean stack gas volume flow rate for the project campaign ($m^3/h$) |
| NCSG | Mean concentration of $N_2O$ in the stack gas for the project campaign ($mgN_2O/m^3$) |
| $PE_n$ | Total $N_2O$ emissions of the $n^{th}$ project campaign ($tN_2O$) |
| OH | Is the number of hours of operation in the specific monitoring period (h) |

### 4.1.2 Derivation of a moving average emission factor

Because the project emission factor measured was higher than the moving average EF of the campaigns on this line so far, we have used the actual project EF for the calculation of the quantity of emission reductions generated during this campaign.

## 4.2 Minimum project emission factor

The minimum average emission factor established factor will be established after 10th project campaign.

## 4.3 Project Campaign Length

Project campaign production of nitric acid has been below defined nameplate capacity and thus all NAP produced from date of installation of secondary catalysts has been used for calculation of emission reductions.

## 4.4 Leakage

No leakage calculation is required.

## 4.5 Emission reductions

The emission reductions for the project activity during this campaign have been determined by deducting the campaign-specific emission factor from the baseline emission factor and multiplying the result by the production output of 100% concentrated nitric acid over the campaign period and the GWP of $N_2O$:

$$ER = (EFBL - EFP) * NAP * GWPN_2O \ (tCO_2e)$$

Where:

| Variable | Definition |
|---|---|
| ER | Emission reductions of the project for the specific campaign ($tCO_2e$) |
| NAP | Nitric acid production for the project campaign ($tHNO_3$). The maximum value of NAP shall not exceed the design capacity. |
| EFBL | Baseline emissions factor ($tN_2O/tHNO_3$ ) |
| EFP | Emissions factor used to calculate the emissions from this particular campaign (i.e. the higher of $EF_{ma,n}$ and $EF_n$) |

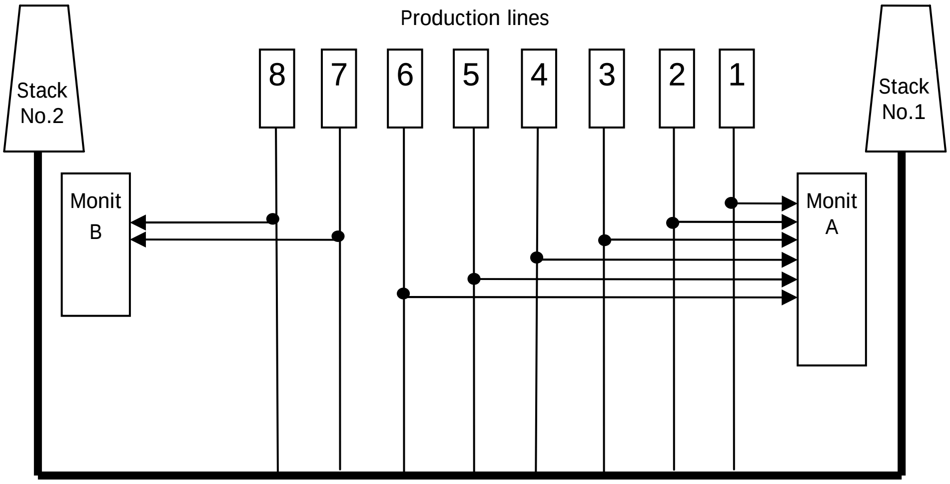
# 5. MONITORING PLAN

### Purpose of the monitoring plan

The purpose of the monitoring plan is to describe the system used to monitor emissions of $N_2O$ from the plant in such a way that is compliant with the prescriptions of the AM0034/Version 02.

### Plant description

The UKL-7 nitric acid plant comprises 8 production Lines numbered from 1 through 8, each with its own burner, absorption column and expansion turbine. Each production Line represents a separate nitric acid production unit independent from each other. The tail gasses from each Line are after expansion turbines led to a common stack bus and vented through two interconnected stacks.



Primary catalyst is changed at different times thus it is necessary to measure the emissions from each Line individually. This means that eight separate sets of monitoring equipment are installed to measure tail gas flow, nitric acid production, nitric acid concentration, and the operating conditions. $N_2O$ concentration in the tail gas is measured by 3 switched concentration meters.

### Monitoring System architecture

Methodology AM0034/Version 02 requires installation of an $N_2O$ monitoring system that includes both a gas volume flow meter to determine the tail gas mass volume flow and an infrared gas analyser to determine the concentration of $N_2O$.

But tail gas $N_2O$ concentration meter and tail gas volume flow meter alone are not sufficient for a JI project purposes. In order of being able to calculate the baseline emission factor expressed as tonnage of $N_2O$ in t $CO_2e$ per 1 tonne of $HNO_3$ (100%), it is necessary to include also $HNO_3$ measurement, and in order of being able to document normal operating conditions it is necessary to include also operating conditions measurement.

Because of this we use the term Monitoring System (MS) to describe entire monitoring system directly and indirectly used for the JI purposes, while Automated Measurement System (AMS) covers only $N_2O$ emissions and tail gas mass volume part of the MS.

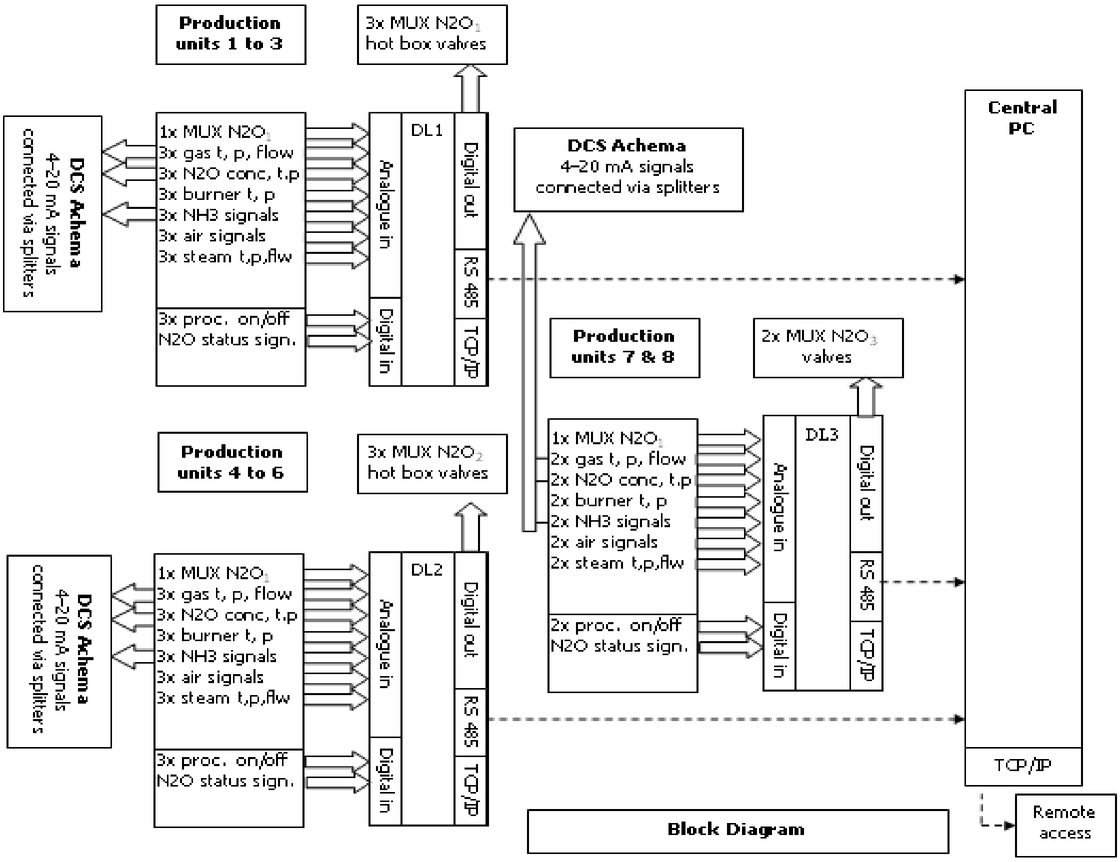
Monitoring System (MS) for purpose of this monitoring plan means:

**monitoring system measuring operational conditions;**
Ammonia volume flow
Ammonia temperature
Ammonia pressure
Primary air volume flow
Primary air temperature
Primary air pressure
Oxidation temperature
Oxidation pressure

**nitric acid 100% concentrate production;**
Nitric acid concentration
Nitric acid flow
Nitric acid temperature

**and newly installed measurement devices for measurement of N2O concentration and tail gas flow, temperature and pressure (AMS)**
$N_2O$ concentration in the stack
Stack volume flow rate
Stack gas temperature
Stack gas pressure

Incorporation of the AMS into the MS by interfacing already existing and newly installed measurement devices is documented by the diagram below.



### $N_2O$ automated measurement system

Main purpose of the $N_2O$ automated measurement system (AMS) is to measure total mass of $N_2O$ emitted during particular campaigns (both baseline and project). In order of calculation of total mass of $N_2O$ emitted during particular campaign it is necessary to measure on an extractive basis the $N_2O$ concentration in a tail gas and on a non-extractive basis tail gas flow, pressure and temperature.

### $N_2O$ concentration

$N_2O$ concentration is measured by extractive measurement system. Tail gas samples are taken from respective tail gas ducts at sampling points located after expansion turbines and transported by heated sample lines to the Monitoring room A located next to the main production hall. This applies to 2 concentration meters measuring lines 1-3 and lines 4-6. lines 7-8 are measured by third concentration meter located at the other side of the production hall (Monitoring room B) physically closer to respective production lines 7 and 8.

Tail gas samples are filtered and conditioned in the condensation dryer (4°C), so $N_2O$ concentration is measured on a dry basis. Correction of dry basis ppmV value to real wet tail

gas conditions based on steam flow injected into the system is part of both - the project emissions calculations and baseline emission factor calculations.

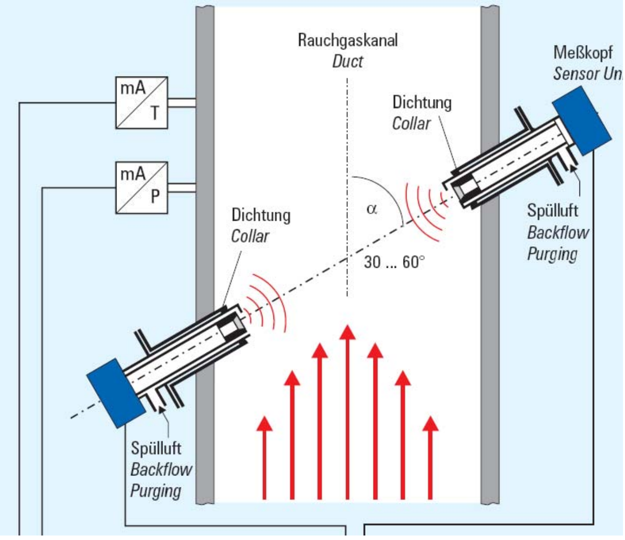
$N_2O$ concentration is measured by concentration infrared absorption principle meters Xentra 4900 using GFX monitoring technology.

Recently there are 8 production Lines. $N_2O$ concentration is measured by 3 concentration meters on a switched basis. Tail gas samples are automatically switched. Under-sampling uncertainty is part of both - the project emissions calculations and baseline emission factor calculations.

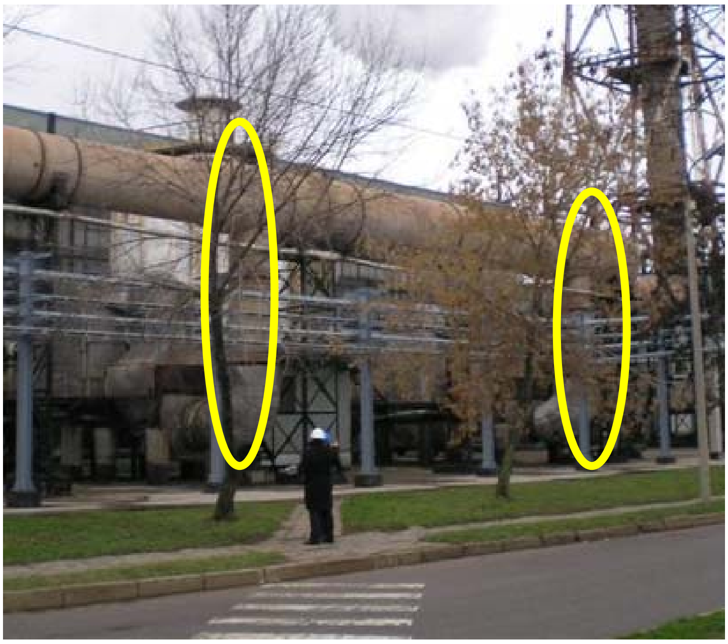
$N_2O$ concentration measured data are sent from the concentration meter on a 2 sec basis in a form of 4-20mA signal to the datalogger and processed further.

**Tail gas flow, pressure and temperature**

Tail gas flow is measured by ultrasonic Durag DF-L 200 flowmeters based on ultrasonic pulse fly time across the entire duct cross-section.



The tail gas ducts do not allow any optimum location to perform the flow monitoring. The only possible location is the quite short vertical tube behind the 90° “knee”.



Since the flow is not really laminar, a classical Pitot tube one point solution wouldn't allow good results. The ultrasonic system is under these conditions superior to differential pressure. Cross duct monitoring is more accurate than a couple of discrete point averaged pressure.

Tail gas flow, pressure and temperature measured data are sent from the flow meter on a 2 sec basis in a form of 4-20mA signal to the datalogger and processed further.

**Tail gas steam injection elimination**

Steam injected into the Achema UKL-7 tail gas for purpose of increasing the turbine output is eliminated from the tail gas mass flow calculation by following formulae:

flow - STVF=L1_Flow_N2O*(273.15/(273.15+L1_Temp))*(L1_Press/101.325)*((100-L1_Humi)/100)

where Humi (water content)=

(L1_Flow_steam*1.2436)/(L1_Flow_N2O*(273.15/(273.15+L1_Temp))*(L1_Press/101.325))*100+0.6

where 1.2436 is the conversion factor from kg/h to Nm3/h and 0.6% is a value of humidity present in a flue gas permanently without steam injection

The Flow_steam parameter necessary for calculation of the water content in the dataloggers is provided in the kg/h unit.

Achema measures steam flow in kg/h using formula Q=C*sqrt(dp) , where C is flow constant which is already integrated using an orifice plate sizing program. The orifice plate calculation for injection steam has been done for temperature 250˚C and pressure 6 bar.

Flow steam in kg/h measured by using the constant steam T and P values is then recalculated to actual steam T and P values valid for relevant hours and as result the STVF value cleaned of the steam injected is used for further emission reductions calculations.

### EN14181 compliance

As required by the AM0034/Version 02 methodology the $N_2O$ automated measurement system (AMS) complies with requirements of the technical norm EN14181. $N_2O$ AMS consists from the $N_2O$ concentration meter and integrated flowmeter (F, T, P). Both measurement devices are QAL1 certified (concentration meter for the $N_2O$ measurand specifically) and after full commissioning of the monitoring system there was the QAL2 test carried out by an independent laboratory certified according to ISO17025.

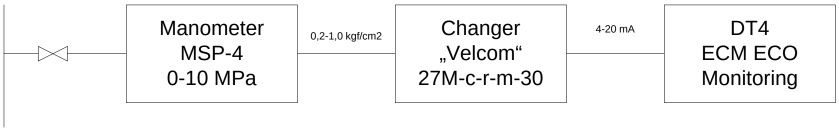
### Operating conditions

For purpose of the baseline emissions factor setting it is necessary to monitor and report operating conditions in all 8 burners. Namely:

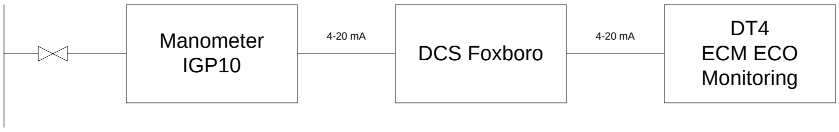
Ammonia flow
Ammonia temperature
Ammonia pressure
Primary air flow
Primary air temperature
Primary air pressure
Oxidation temperature
Oxidation pressure

All these parameters are measured by the plant monitoring system as presented on diagrams below:

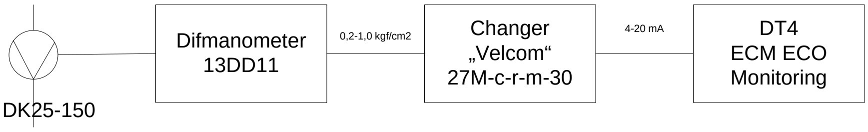
P in mixer 1-6 line



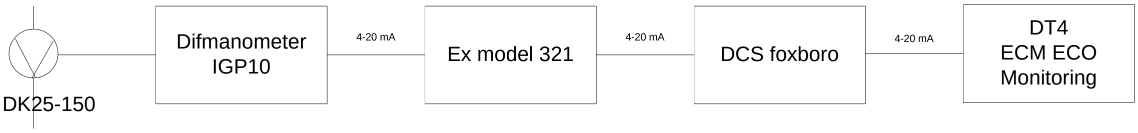
P in mixer 7-8 line



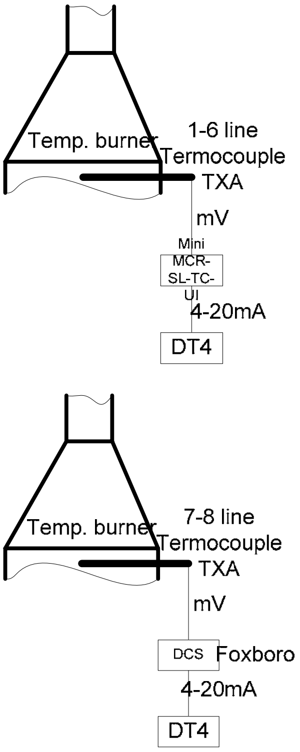
NH3 to mixer 1-6 line



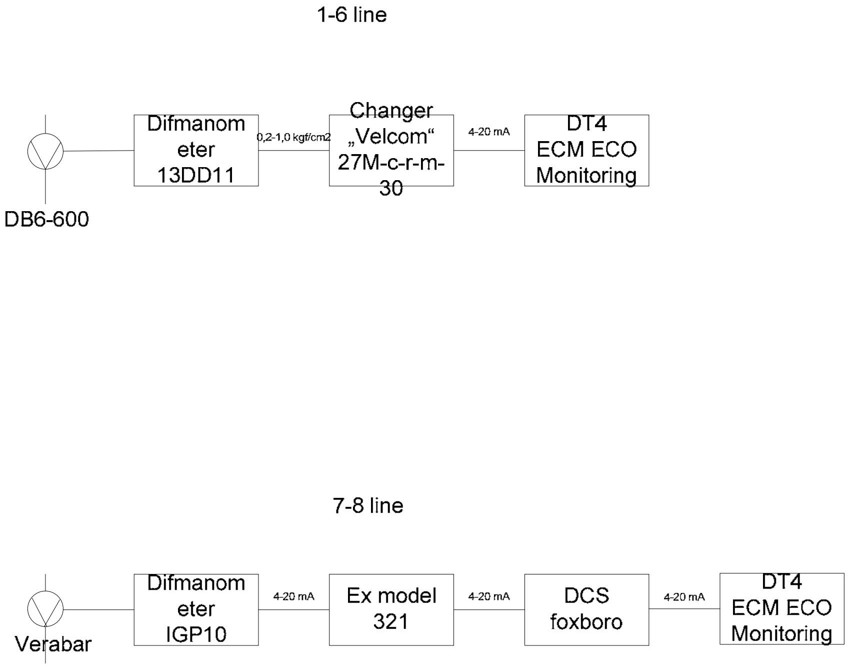
NH3 to mixer 7-8 line



T in burner



Air to mixer

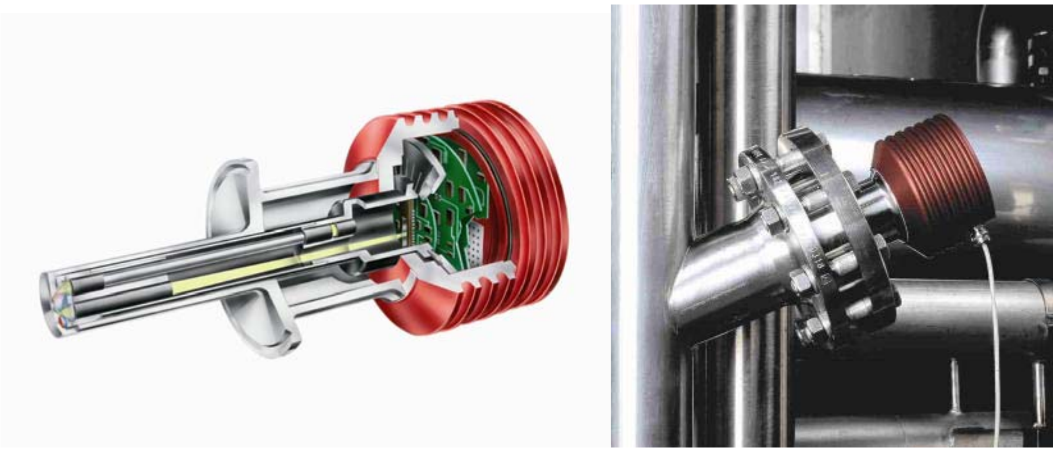


Signals obtained from these measurement devices from production Lines 1-6 are converted from pneumatic to 4-20mA analog signals. Operating conditions measurement devices installed in production Lines 7-8 provide the 4-20mA signals which are digitalized and provided to the monitoring system dataloggers, which process them further. Maintenance procedures for the ammonia oxidation parameters follow the existing procedures for the operation of the nitric acid plant.

### Nitric acid production

Nitric acid concentration is based on two components: nitric acid and water. Standard monitoring method is on-Line refractometry. Measurement of nitric acid (100%) mass volume production per campaign is necessary for calculation of the baseline emissions factor. Nitric acid concentration on all 8 Lines is measured by K-Patents PR-23-GP refractometers.

This analyzer is applying a prism to "return" a generated optical beam back to an LCD detector.



The detector is measuring refraction of monitored liquid based on known refraction of water and nitric acid. The instrument is calibrated for percent concentration of nitric acid. The analyzer is mounted on DIN-flange 2656, PN25 DN80. The optical prism does not require cleaning.

PR-23-GP characteristics:

- Measuring RI is a direct concentration measurement principle. No need to rely or convert magnitudes.
- Digital instrument – no calibration drift
- As it is a robust instrument it is maintenance free
- Dual connectivity if the installation positions allow.
- On-Line data logging, through Ethernet, on whichever web browser.
- No influence by bubbles or particles. It is very common that air enters the process pipeline and still the refractometer measures accurately.

Nitric acid concentration data are in an analog 4-20mA format provided to dataloggers which process these signals further.

In order of being able to calculate total mass volume of nitric acid 100% concentrate produced during the baseline campaign it is necessary to monitor also nitric acid flow and temperature. Measurement of pressure is not necessary for determination of the nitric acid mass volume flow, because nitric acid is in form of liquid and as such it has stabile pressure characteristic.

Signals obtained from the nitric acid flow and temperature measurement devices from production Lines 1-6 are converted from pneumatic to 4-20mA analog signals. Nitric acid flow and temperature measurement devices installed in production Lines 7-8 provide the 4-20mA signals which are digitalized and provided to the monitoring system dataloggers, which process them further.

After installation of refractometers there have been occurrences of their failure and following repair service by the manufacturer. For this period starting from 08/11/2007 and ending on 29/07/2008 project uses $HNO_3$ concentration data provided by the laboratory measurements.

# 6. QAL 2 CALIBRATION ADJUSTMENTS

## 6.1 Applied principle

As required in the applicable norm EN14181: “The relation between the instrument readings of the recording measuring procedure and the quantity of the measuring objects has to be described by using a suitable convention method. The results have to be expressed by a regression analysis.”

As it is described in the Calibration Report issued by Airtec laboratory, the measurement results derived from the analog signals (4 mA to 20 mA) provided the installed instruments have been compared to the comparative measurements.

Linearity check of the instruments characteristics is stated in the QAL2 Calibration Report issued by the laboratory. The valid ranges of Linearity are determined by statistical analysis according to the guideline and the Linearity assumptions are further used in the Calibration Report establishing Linear regression Lines.

The general formula of the regression Line, established in the EN14181 and used in the Calibration Report is:

$$Y= a + bX$$

where:

X is the measured value of the instrument in mA
Y is the value of the parameter being objective of the measurement
a is a constant of the regression Line
b is the slope of the regression Line

After a comparative test the laboratory issued the old and new regression Lines properties, namely “a” and “b” applying for all of the measured parameters that are subject to calibration as stated in the Calibration Report.

The QAL2 corrections are based on the fact that the actual analog current outputs (in mA) of the measurement instruments are relevant for both, the old and new regression Lines:

$$X_o=X_n=X$$

where:

$X_n$: X new
$Y_o$: Y old

This allows us to derive a calibrating formula that gives us the corrected value of the measured physical parameters. The applied calibrating equation is:

$$Yn=An + (Bn/Bo)*(Yo-Ao)$$

In order to take into account the properties of the AMS and their implication to the QAL 2 implementation in the model, we will further introduce several remarks to the conversion and normalization of the data.

The units returned by the AMS “nm3/h” stand for normalized cubic meters of the gas volume at normal gas conditions (0° C, 1 atm.).

## 6.2 Stack gas volume flow

Based on the real conditions measured and applied by the AMS for normalization (TSG in °C and PSG in hPa), the stack gas volume flow values are converted to real conditions before the regression analysis using the ideal gas law. The actual gas volume flow rates are derived from gas velocity measurements, therefore, before applying the regression analysis the gas speed is calculated from the volume flow and the duct cross-section and is fed into the calibrating equation. The calibrated values derived from the calibrating equation then converted back to normalized units using the calibrated real conditions (calibrated TSG and PSG). The normalized calibrated stack gas flow rates are further fed into the emission calculation model for further processing as set out by the Approved Baseline and Monitoring Methodology AM_0034.

## 6.3 Nitric acid concentration in stack gas

The nitric acid concentration in the raw data set from the AMS is in $mgN_2O/m_3$. The concentration was converted to ppmv to make it compatible with the regression Lines parameters. The nitrous gas concentration values are then calibrated using the provided regression Lines parameters and are input in the model.

## 6.4 Stack gas Temperature

The stack gas temperature was calibrated by the regression conversion formula

## 6.5 Stack gas Pressure

The calibration report provides us with a regression Line for the stack gas pressure. We calibrate the readings of the measurements system using the regression formula and applying the values (in kPa).

# 7. EMISSION REDUCTION CALCULATIONS

Table T 2 illustrates the establishment of historic campaign length based on 5 previous campaigns. Average production in 5 campaigns preceding the baseline campaign was 62 710 $tHNO_3$ and time duration was on average 239 days. Table contains also information on suppliers of primary catalysts for the line 2.

### T 2 Historic campaigns

| Line | ACHEMA UKL-2 | Production | Start | End | Days | Production per day | Primary Catalyst | Composition |
|---|---|---|---|---|---|---|---|---|
| **Historic Campaigns** | **1** t HNO3 | 63 318 | 07 Jun 2004 | 26 Jan 2005 | 233 | 272 | Heraeus | 90/5/5 |
| | **2** t HNO3 | 65 490 | 27 Jan 2005 | 21 Sep 2005 | 237 | 276 | Umicore | 95/5 |
| | **3** t HNO3 | 51 101 | 22 Sep 2005 | 10 Apr 2006 | 200 | 256 | Heraeus | 62/4/34 |
| | **4** t HNO3 | 63 008 | 11 Apr 2006 | 24 Jan 2007 | 288 | 219 | Heraeus | 63/4/33 |
| | **5** t HNO3 | 70 635 | 14 Mar 2007 | 08 Nov 2007 | 239 | 296 | Johnson Matthey | n.a. |
| **Average HNO3 production** | t HNO3 | **62 710** | | | **239** | **262** | | |
| **Project Campaigns** | **BL** t HNO3 | 60 767 | 09 Nov 2007 | 20 May 2008 | 193 | 315 | Johnson Matthey | n.a. |
| | **PL** t HNO3 | 86 079 | 13 Oct 2009 | 21 Oct 2010 | 373 | 231 | Johnson Matthey | n.a. |

It is business as usual scenario in Achema UKL-7 plant to keep using primary catalysts from several suppliers and with several compositions. Selection of primary catalysts is determined by technical parameters of their use and price levels offered by suppliers in specific time. Primary catalysts used during the baseline campaign, if other than used in previous campaign/s, did not increase emissions of N2O as confirmed by relevant statements provided to the verifier.

T 3 and Chart C 1 define the length of the baseline campaign. Baseline campaign measurements for this project campaign started on 09/11/2007 and continued through 20/05/2008 when the 60 767 $tHNO_3$ nitric acid production was reached. The measurement of baseline Nitrous Acid Concentration (NCSG) was carried out until production reached - $tHNO_3$ .

### T 3 Baseline campaign length

| ACHEMA UKL-2 | Historic Campaings End | Start of Baseline Measurement | End of Baseline Measurement NCSG | End of Baseline Measurement | End of Baseline Campaign |
|---|---|---|---|---|---|
| **Dates** | 2007 Nov 08 | 2007 Nov 09 | 2008 May 20 | 2008 May 20 | 2008 May 21 |
| **Baseline Factor kgN2O/tHNO3** | - | - | 9.52 | 9.52 | 9.52 |
| **Production tHNO3** | | - | 60 767 | 60 767 | - |
| **Per Day Production tHNO3** | 261.9 | | | | |
| **Baseline less Historic Production** | **(1 943.4)** | | | | |
| **Baseline less Historic Days** | **(7.4)** | | | | |
| | | | | | |

## C 1 Baseline campaign length

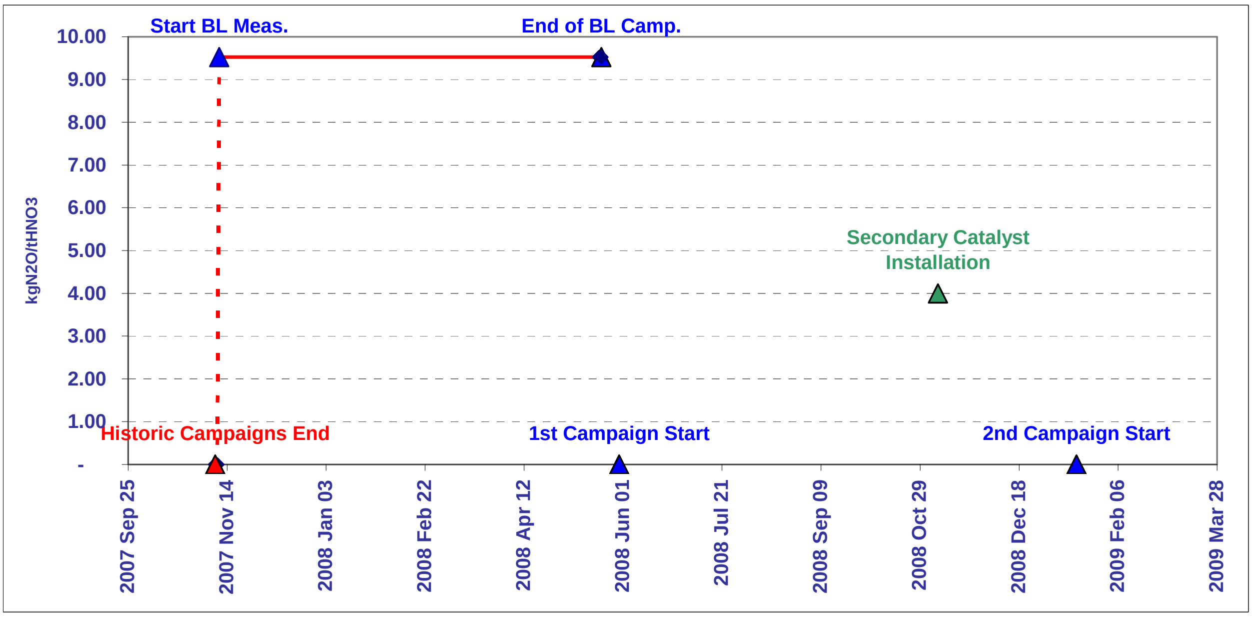


Table T 4 illustrates the calculation of the baseline emission factor on Line 2 using the method as defined in the CDM methodology AM0034 and in the PDD. We have not used overlapping approach allowed by the PDD. Baseline emission factor was determined based on raw data measured from 09/11/2007 through 20/05/2008.

Extreme values and data measured during hours when one or more of operating conditions were outside of the permitted range have been eliminated from the calculations. As a next step we have eliminated data beyond 95% confidence interval and calculated new mean values of $N_2O$ concentration and stack gas volume flow using following method:

a) Calculate the sample mean (x)
b) Calculate the sample standard deviation (s)
c) Calculate the 95% confidence interval (equal to 1.96 times the standard deviation)
d) Eliminate all data that lie outside the 95% confidence interval
e) Calculate the new sample mean from the remaining values (volume of stack gas (VSG) and $N_2O$ concentration of stack gas (NCSG))

Using the means values we have calculated the baseline emissions as set out in the PDD.

$$BE_{BC} = VSG_{BC} * NCSG_{BC} * 10^{-9} * OH_{BC}\ (tN_2O)$$

Operating hours defined as hours, when nitric acid production at least 0.1 tHNO3 and oxidation temperature at least 600°C occurred. Calculated baseline N2O emissions were 618 $tN_2O$.

$$EF_{BL} = (BE_{BC} / NAP_{BC})\ (1 – UNC/100)\ (tN_2O/tHNO_3)$$

The UNC factor defined by the QAL2 report is 6.460%, which is further modified by an uncertainty of 0.087% due to under-sampling. As a result we have arrived to the baseline emission factor of 9.51 $kgN_2O/tHNO_3$.

Table T 5 shows the calculation of the project emission factor on Line 2 during the project campaign. Project campaign started on 13/10/2009 and went through 21/10/2010.

We have eliminated extreme values and data beyond the 95% confidence interval as prescribed by the PDD.

a) Calculate the sample mean (x)
b) Calculate the sample standard deviation (s)
c) Calculate the 95% confidence interval (equal to 1.96 times the standard deviation)
d) Eliminate all data that lie outside the 95% confidence interval
e) Calculate the new sample mean from the remaining values

Using the mean values we have calculated total mass of $N_2O$ emissions ($PE_n$) as follows:

$$PE_n = VSG * NCSG * 10\text{-}9 * OH\ (tN2O)$$

Operating hours (OH) defined as hours, when nitric acid production at least 0.1 tHNO3 and oxidation temperature at least 600˚C occurred.

By dividing total mass of $N_2O$ emissions by the nitric acid production (capped by nameplate capacity 350 tHNO3/day) we have determined the project campaign specific emission factor at value of 1.99 kgN2O/tHNO3.

$$EF_n = PE_n / NAP_n\ (tN_2O/tHNO_3)$$

Because the project emission factor measured was higher than the moving average EF of the campaigns on this line so far, we have used the actual project EF for the calculation of the quantity of emission reductions generated during this campaign.

# T 4 Baseline emission factor

| BASELINE EMISSION FACTOR | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Parameter* | **Operating Hours** | **Nitric Acid Production** | **N2O Concentration** | **Gas Volume Flow** | **Ammonia Flow Rate** | **Ammonia to Air Ratio** | **Oxidation Temperature** | **Oxidation Pressure** | **AMS in Operation** | **Nitric Acid Production NCSG** |
| ***Code*** | **OH** | **NAP** | **NCSG** | **VSG** | **AFR** | **AIFR** | **OT** | **OP** | | **NAP** |
| ***Unit*** | **h** | **t/h** | **mg N2O/Nm3** | **Nm3/h** | **Nm3/h** | **%** | **°C** | **kPa** | **h** | **t/h** |
| **Elimination of extreme values** | | | | | | | | | | |
| Lower limit | | 0 | 0 | 0 | 0 | 0 | - 50 | 0 | | 0 |
| Upper Limit | | 50.00 | 3 000 | 120 000 | 10 000 | 20.00 | 1 200 | 1 000 | | 50 |
| **Raw Data Measured Range** | | | | | | | | | | |
| Count | **4 254** | 4 633 | 4 353 | 4 216 | 4 296 | 4 277 | 4 606 | 4 576 | 3 828 | 4 633 |
| *as % of Dataset* | *92%* | *100%* | *94%* | *91%* | *93%* | *92%* | *99%* | *99%* | *83%* | *100%* |
| Minimum | | - | 0 | 140 | 2 069 | - | 42 | 5 | | - |
| Maximum | | 15.73 | 2 356 | 106 649 | 6 243 | 18.13 | 1 100 | 679 | | 16 |
| Mean | | 13.12 | 1 576 | 83 679 | 5 815 | 9.78 | 843 | 604 | | 13 |
| Standard Deviation | | 3.81 | 323 | 18 036 | 263 | 1.67 | 207 | 45 | | 4 |
| Total | | 60 767 | | | | | | | | 60 767 |
| N2O Emissions ( VSG * NCSG * OH) | 561 | t N2O | | | | | | | | |
| Emission Factor | 8.64 | kgN2O / tHNO3 | | | | | | | | |
| **Permitted Range** | | | | | | | | | | |
| Minimum | | | | | 4 500 | 0 | 880 | 0 | | |
| Maximum | | | | | 7 500 | 11.70 | 910 | 800 | | |
| **Data within the permitted range** | | | | | | | | | | |
| Count | **3 710** | | 3 710 | 3 710 | | | | | 3 828 | |
| *as % of Operating Hours* | ***87%*** | | *87%* | *87%* | | | | | *90%* | |
| Minimum | | | 465 | 10 197 | | | | | | |
| Maximum | | | 2 356 | 105 388 | | | | | | |
| Mean | | | 1 588 | 85 591 | | | | | | |
| Standard Deviation | | | 293 | 14 825 | | | | | | |
| N2O Emissions ( VSG * NCSG * OH) | 578 | t N2O | | | | | | | | |
| Emission Factor | 8.90 | kgN2O / tHNO3 | | | | | | | | |
| **Data within the confidence interval** | | | | | | | | | | |
| 95% Confidence interval | | | | | | | | | | |
| Lower bound | | | 1 014 | 56 534 | | | | | | |
| Upper bound | | | 2 162 | 114 648 | | | | | | |
| Count | | | 3 430 | 3 604 | | | | | | |
| *as % of Operating Hours* | | | *81%* | *85%* | | | | | | |
| Minimum | | | 1 118 | 77 416 | | | | | | |
| Maximum | | | 2 156 | 105 388 | | | | | | |
| Mean | | | 1 654 | 87 784 | | | | | | |
| Standard Deviation | | | 173 | 7 591 | | | | | | |
| **N2O Emissions ( VSG * NCSG * OH)** | **618** | **t N2O** | | | | | | | | |
| **Emission Factor (EF_BL)** | **9.51** | **kgN2O / tHNO3** | | | | | | | | |

# T 5 Project emission factor

**PROJECT EMISSION FACTOR**

| *Parameter* | **Operating Hours** | **Nitric Acid Production** | **N2O Concentration** | **Gas Volume Flow** | **Ammonia Flow Rate** | **Ammonia to Air Ratio** | **Oxidation Temperature** | **Oxidation Pressure** |
|---|---|---|---|---|---|---|---|---|
| ***Code*** | **OH** | **NAP** | **NCSG** | **VSG** | **AFR** | **AIFR** | **OT** | **OP** |
| ***Unit*** | **h** | **t/h** | **mg N2O/Nm3** | **Nm3/h** | **Nm3/h** | **%** | **°C** | **kPa** |
| **Elimination of extreme values** | | | | | | | | |
| Lower limit | | 0 | 0 | 0 | 0 | 0 | - 50 | 0 |
| Upper Limit | | 50.00 | 3 000 | 120 000 | 10 000 | 20.00 | 1 200 | 1 000 |
| **Raw Data Measured Range** | | | | | | | | |
| Count | **5 920** | 5 895 | 5 768 | 5 880 | 7 351 | 6 207 | 8 949 | 8 935 |
| *as % of Dataset* | *66%* | *66%* | *64%* | *66%* | *82%* | *69%* | *100%* | *100%* |
| Minimum | | 0.95 | 3 | 50 032 | 293 | 4 | 6 | 1 |
| Maximum | | 18.90 | 633 | 98 491 | 7 902 | 19.56 | 1 100 | 712 |
| Mean | | 14.60 | 359 | 82 917 | 5 574 | 10.74 | 646 | 523 |
| Standard Deviation | | 1.37 | 67 | 4 044 | 1 296 | 0.79 | 394 | 180 |
| Total | | 86 079 | | | | | | |

| | | |
|---|---|---|
| N2O Emissions ( VSG * NCSG * OH) | 176 | t N2O |
| Emission Factor | 2.05 | kgN2O / tHNO3 |

| **Data within the confidence interval** | | |
|---|---|---|
| 95% Confidence interval | | |
| Lower bound | 227 | 74 990 |
| Upper bound | 491 | 90 843 |
| Count | 5 062 | 5 453 |
| *as % of Operating Hours* | *86%* | *92%* |
| Minimum | 228 | 75 154 |
| Maximum | 491 | 90 838 |
| Mean | 353 | 82 072 |
| Standard Deviation | 56 | 3 239 |

| | | |
|---|---|---|
| **N2O Emissions ( VSG * NCSG * OH)** | **172** | **t N2O** |
| **Actual Project Emission Factor (EF_PActual)** | **1.99** | **kgN2O / tHNO3** |
| **Abatement Ratio** | **79.0%** | |

| **Moving Average Emission Factor Correction** | **Actual Factors** | **Moving Average Rule** |
|---|---|---|
| **1** | 1.80 | 1.80 |
| **2** | 1.84 | 1.84 |
| **3** | 1.99 | 1.99 |
| **4** | - | |

| | | |
|---|---|---|
| **Project Emission Factor (EF_P)** | **1.99** | **kgN2O / tHNO3** |
| **Abatement Ratio** | **79.0%** | |

# MONITORING REPORT

**PROJECT:** ACHEMA UKL nitric acid plant $N_2O$ abatement project
**LINE:** Line 2
**MONITORING PERIOD:**
**FROM:** 22/10/2010

**TO:** 12/05/2011

**Prepared by:**

VERTIS

**VERTIS FINANCE**

www.vertisfinance.com

# Table of Contents

# 1. EXECUTIVE SUMMARY

This monitoring report determines baseline emission factor for the Line 2 of ACHEMA UKL nitric acid plant and quantity of emission reduction generated during the fourth project campaign on Line 2.

The first project campaign on Line 2 started on 30/05/2008. Secondary catalyst was installed on 07/11/2008. Total quantity of emission reductions generated during the fourth project period from 22/10/2010 through 12/05/2011 on Line 2 is **160 448 ERUs**.

### T 1 Emission reduction calculations

| EMISSION REDUCTION | | | |
|---|---|---|---|
| Baseline Emission Factor | EF_BL | 9.51 | kgN2O/tHNO3 |
| Project Campaign Emission Factor | EF_P | 1.83 | kgN2O/tHNO3 |
| Nitric Acid Produced in the Baseline Campaign | NAP_BL | 60 767 | tHNO3 |
| Nitric Acid Produced in the NCSG Baseline Campaign | NAP_BL_NCSG | 60 767 | tHNO3 |
| Nitric Acid Produced in the Project Campaign | NAP_P | 67 392 | tHNO3 |
| GWP | GWP | 310 | tCO2e/tN2O |
| **Emission Reduction** | **ER** | **160 448** | **tCOe** |
| *ER=(EF_BL-EF_P)*NAP_P*GWP/1000* | | | |
| **Abatement Ratio** | | **82.4%** | |

| EMISSION REDUCTION PER YEAR | | | |
|---|---|---|---|
| Year | 2099 | 2010 | 2011 |
| Date From | | 22 Oct 2010 | 01 Jan 2011 |
| Date To | | 31 Dec 2010 | 12 May 2011 |
| Nitric Acid Production | | 25 426 | 41 966 |
| **Emission Reduction** | | **60 535** | **99 913** |
| *ER_YR = ER * NAP_P_YR / NAP_P* | | | |

Baseline emission factor established for the Line 2 during baseline measurement carried from 09/11/2007 through 20/05/2008 is 9.51 kg$N_2O$/t$HNO_3$.

Project emission factor during the fourth project campaign after installation of secondary catalysts on Line 2, which started on 22/10/2010 and went through 12/05/2011 with secondary catalyst installed and commissioned on 07/11/2008, is 1.83 kg$N_2O$/t$HNO_3$.

During the project campaign 67 392 tonnes of nitric acid was produced.

# 2. DESCRIPTION OF THE PROJECT ACTIVITY

Purpose of the Project (the “Project”) is the reduction of nitrous oxide ($N_2O$) emissions from nitric acid production Lines at the UKL-7 nitric acid plant of AB Achema (“Achema” or “the Company”). The Company is situated in Jonava, Lithuania.

Achema has installed and operates secondary $N_2O$ reduction catalysts underneath the primary catalyst precious metal catching and catalytic gauzes package in the ammonium burners of the UKL-7 nitric acid plant.

This monitoring report contains information on Line 2 emission reductions including information on baseline emission factor setting for the Line 2.

The separate treatment of nitric acid lines and overlapping of the monitoring periods are allowed by the clarification issued Joint Implementation Supervisory Committee: “CLARIFICATION REGARDING OVERLAPPING MONITORING PERIODS UNDER THE VERIFICATION PROCEDURE UNDER THE JOINT IMPLEMENTATION SUPERVISORY COMMITTEE”. The Project meets all the requirements set out by the clarification:

1. The Project is composed of clearly identifiable components for which emission reductions or enhancements of removals are calculated independently; and

2. Monitoring is performed independently for each of these components, i.e. the data/parameters monitored for one component are not dependent on/effect data/parameters (to be) monitored for another component; and

3. The monitoring plan ensures that monitoring is performed for all components and that in these cases all the requirements of the JI guidelines and further guidance by the JISC regarding monitoring are met.

# 3. BASELINE SETTING

Baseline emission factor for line 2 has been established on the Line-specific basis. Campaign used for baseline measurements on the line 2 has been carried out from 09/11/2007 through 20/05/2008.

$N_2O$ concentration and gas volume flow are monitored by monitoring system complying with requirements of the European Norm 14181.

Monitoring system provides separate readings for $N_2O$ concentration and gas flow volume for every hour of operation as an average of the measured values for the previous 60 minutes.

Measurement results can be distorted before and after periods of downtime or malfunction of the monitoring system and can lead to mavericks. To eliminate such extremes and to ensure a conservative approach, the following statistical evaluation is applied to the complete data series of $N_2O$ concentration as well as to the data series for gas volume flow. The statistical procedure is applied to data obtained after eliminating data measured for periods where the plant operated outside the permitted ranges:

a) Calculate the sample mean (x)
b) Calculate the sample standard deviation (s)
c) Calculate the 95% confidence interval (equal to 1.96 times the standard deviation)
d) Eliminate all data that lie outside the 95% confidence interval
e) Calculate the new sample mean from the remaining values (volume of stack gas (VSG) and $N_2O$ concentration of stack gas (NCSG))

The average mass of $N_2O$ emissions per hour is estimated as product of the NCSG and VSG. The $N_2O$ emissions per campaign are estimates product of $N_2O$ emission per hour and the total number of complete hours of operation of the campaign using the following equation:

$$BE_{BC} = VSG_{BC} * NCSG_{BC} * 10^{-9} * OH_{BC}\ (tN_2O)$$

The Line specific baseline emissions factor representing the average $N_2O$ emissions per tonne of nitric acid over one full campaign is derived by dividing the total mass of $N_2O$ emissions by the total output of 100% concentrated nitric acid during baseline campaign.

The overall uncertainty of the monitoring system has been determined by the QAL2 report and the measurement error is expressed as a percentage (UNC). The $N_2O$ emission factor per tonne of nitric acid produced in the baseline period (EFBL) has been then be reduced by the percentage error as follows:

$$EF_{BL} = (BE_{BC} / NAP_{BC})\ (1 – UNC/100)\ (tN_2O/tHNO_3)$$

where:

| Variable | Definition |
|---|---|
| $EF_{BL}$ | Baseline $N_2O$ emissions factor ($tN_2O/tHNO_3$) |
| $BE_{BC}$ | Total $N_2O$ emissions during the baseline campaign ($tN_2O$) |
| $NCSG_{BC}$ | Mean concentration of $N_2O$ in the stack gas during the baseline campaign ($mgN_2O/m^3$) |
| $OH_{BC}$ | Operating hours of the baseline campaign (h) |
| $VSG_{BC}$ | Mean gas volume flow rate at the stack in the baseline measurement period ($m^3/h$) |
| $NAP_{BC}$ | Nitric acid production during the baseline campaign ($tHNO_3$) |
| UNC | Overall uncertainty of the monitoring system (%), calculated as the combined uncertainty of the applied monitoring equipment. |

## 3.1 Measurement procedure for $N_2O$ concentration and tail gas volume flow

### 3.1.1 Tail gas $N_2O$ concentration

$N_2O$ concentration is measured by extractive measurement system. Tail gas samples are taken from the Line 2 tail gas duct at sampling point located after expansion turbine and transported by sample Line to the Monitoring room A, where the analyzer is located.

Tail gas samples are filtered and conditioned in the condensation dryer (4°C), so $N_2O$ concentration is measured on a dry basis.

$N_2O$ concentration is measured by concentration infrared absorption principle meters Xentra 4900 using GFX monitoring technology.

Recently there are 8 production lines. $N_2O$ concentration is measured by 3 concentration meters on a switched basis.

$N_2O$ concentration measured data are sent from the analyzer on a 2 sec basis in a form of 4-20mA signal to the datalogger and processed further.

### 3.1.2 Tail gas flow rate, pressure and temperature

Tail gas flow, pressure and temperature is measured by ultrasonic Durag DF-L 200 flowmeters based on ultrasonic pulse fly time across the entire duct cross-section. Tail gas flow, pressure and temperature measured data are sent from the flow meter on a 2 sec basis in a form of 4-20mA signal to the datalogger and processed further.

## 3.2 Permitted range of operating conditions of the nitric acid plant

Under certain circumstances, the operating conditions during the measurement period used to determine baseline $N_2O$ emission factor may be outside the permitted range or limit corresponding to normal operating conditions. $N_2O$ baseline data measured during hours

where the operating conditions were outside the permitted range have been eliminated from the calculation of the baseline emissions factor.

Normal ranges for operating conditions have been determined for the following parameters:

oxidation temperature;
oxidation pressure;
ammonia gas flow rate,
air input flow rate.

The permitted range for these parameters has been established using the plant operation manual, as described in the PDD..

## 3.3 Historic Campaign Length

The average historic campaign length ($CL_{normal}$) defined as the average campaign length for the historic campaigns used to define operating condition (the previous five campaigns), has not been used as a cap on the length of the baseline campaign because of shorter project campaign.

# 4. PROJECT EMISSIONS

During the first project campaign on line 2 the tail gas volume flow in the stack of the nitric acid plant as well as $N_2O$ concentration have been measured on the continuous basis.

### 4.1.1 Estimation of campaign-specific project emissions factor

The monitoring system was installed using the guidance document EN 14181 and provides separate readings for $N_2O$ concentration and gas flow volume for every hour of operation. Same statistical evaluation that was applied to the baseline data series has been applied to the project data series:

a) Calculate the sample mean (x)
b) Calculate the sample standard deviation (s)
c) Calculate the 95% confidence interval (equal to 1.96 times the standard deviation)
d) Eliminate all data that lie outside the 95% confidence interval
e) Calculate the new sample mean from the remaining values

$$PE_n = VSG * NCSG * 10^{-9} * OH \ (tN_2O)$$

where:

| **Variable** | **Definition** |
|---|---|
| VSG | Mean stack gas volume flow rate for the project campaign ($m^3/h$) |
| NCSG | Mean concentration of $N_2O$ in the stack gas for the project campaign ($mgN_2O/m^3$) |
| $PE_n$ | Total $N_2O$ emissions of the $n^{th}$ project campaign ($tN_2O$) |
| OH | Is the number of hours of operation in the specific monitoring period (h) |

### 4.1.2 Derivation of a moving average emission factor

Because the project emission factor measured was lower than the moving average EF of the campaigns on this line so far, we have used the average EF for the calculation of the quantity of emission reductions generated during this campaign.

## 4.2 Minimum project emission factor

The minimum average emission factor established factor will be established after 10th project campaign.

## 4.3 Project Campaign Length

Project campaign production of nitric acid has been below defined nameplate capacity and thus all NAP produced from date of installation of secondary catalysts has been used for calculation of emission reductions.

## 4.4 Leakage

No leakage calculation is required.

## 4.5 Emission reductions

The emission reductions for the project activity during this campaign have been determined by deducting the campaign-specific emission factor from the baseline emission factor and multiplying the result by the production output of 100% concentrated nitric acid over the campaign period and the GWP of $N_2O$:

$$ER = (EFBL – EFP) * NAP *GWPN_2O \ (tCO_2e)$$

Where:

| **Variable** | **Definition** |
|---|---|
| ER | Emission reductions of the project for the specific campaign ($tCO_2e$) |
| NAP | Nitric acid production for the project campaign ($tHNO_3$). The maximum value of NAP shall not exceed the design capacity. |
| EFBL | Baseline emissions factor ($tN_2O/tHNO_3$ ) |
| EFP | Emissions factor used to calculate the emissions from this particular campaign (i.e. the higher of $EF_{ma,n}$ and $EF_n$) |

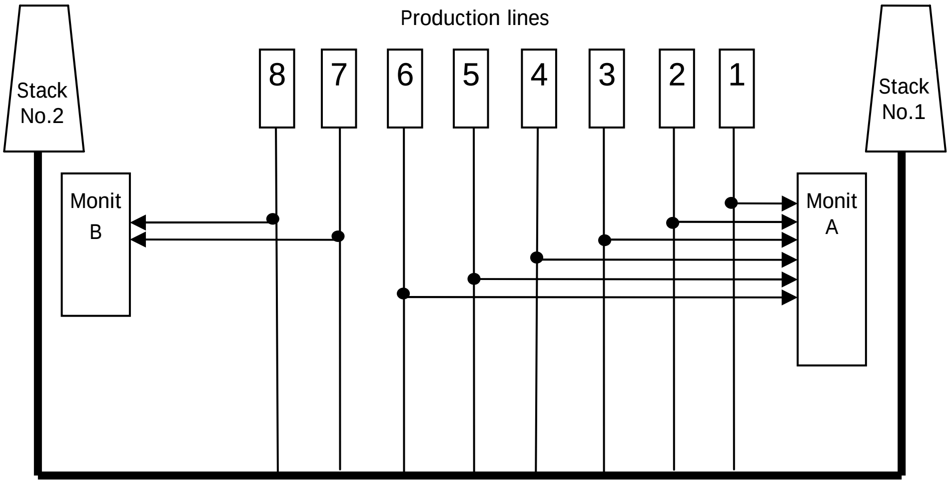
# 5. MONITORING PLAN

## Purpose of the monitoring plan

The purpose of the monitoring plan is to describe the system used to monitor emissions of $N_2O$ from the plant in such a way that is compliant with the prescriptions of the AM0034/Version 02.

## Plant description

The UKL-7 nitric acid plant comprises 8 production Lines numbered from 1 through 8, each with its own burner, absorption column and expansion turbine. Each production Line represents a separate nitric acid production unit independent from each other. The tail gasses from each Line are after expansion turbines led to a common stack bus and vented through two interconnected stacks.



Primary catalyst is changed at different times thus it is necessary to measure the emissions from each Line individually. This means that eight separate sets of monitoring equipment are installed to measure tail gas flow, nitric acid production, nitric acid concentration, and the operating conditions. $N_2O$ concentration in the tail gas is measured by 3 switched concentration meters.

## Monitoring System architecture

Methodology AM0034/Version 02 requires installation of an $N_2O$ monitoring system that includes both a gas volume flow meter to determine the tail gas mass volume flow and an infrared gas analyser to determine the concentration of $N_2O$.

But tail gas $N_2O$ concentration meter and tail gas volume flow meter alone are not sufficient for a JI project purposes. In order of being able to calculate the baseline emission factor expressed as tonnage of $N_2O$ in t $CO_2e$ per 1 tonne of $HNO_3$ (100%), it is necessary to include also $HNO_3$ measurement, and in order of being able to document normal operating conditions it is necessary to include also operating conditions measurement.

Because of this we use the term Monitoring System (MS) to describe entire monitoring system directly and indirectly used for the JI purposes, while Automated Measurement System (AMS) covers only $N_2O$ emissions and tail gas mass volume part of the MS.

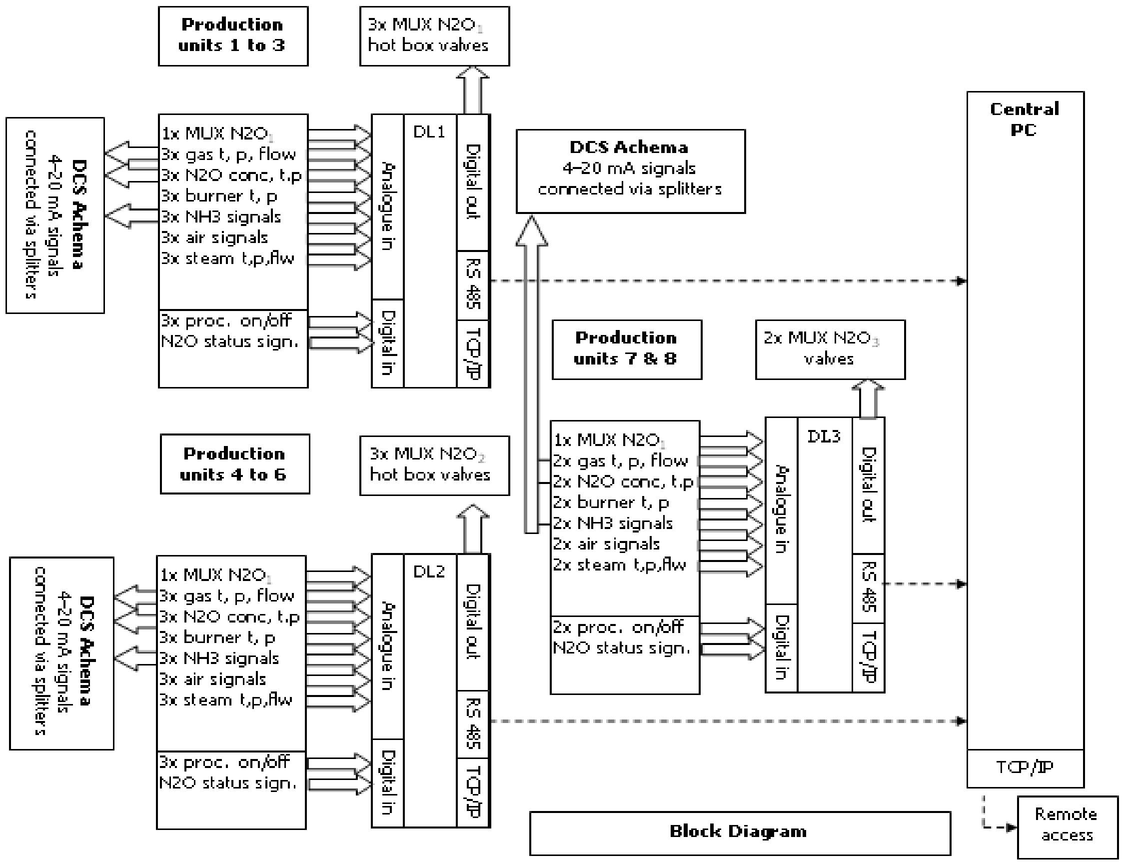
Monitoring System (MS) for purpose of this monitoring plan means:

**monitoring system measuring operational conditions;**
Ammonia volume flow
Ammonia temperature
Ammonia pressure
Primary air volume flow
Primary air temperature
Primary air pressure
Oxidation temperature
Oxidation pressure

**nitric acid 100% concentrate production;**
Nitric acid concentration
Nitric acid flow
Nitric acid temperature

**and newly installed measurement devices for measurement of N2O concentration and tail gas flow, temperature and pressure (AMS)**
$N_2O$ concentration in the stack
Stack volume flow rate
Stack gas temperature
Stack gas pressure

Incorporation of the AMS into the MS by interfacing already existing and newly installed measurement devices is documented by the diagram below.



## $N_2O$ automated measurement system

Main purpose of the $N_2O$ automated measurement system (AMS) is to measure total mass of $N_2O$ emitted during particular campaigns (both baseline and project). In order of calculation of total mass of $N_2O$ emitted during particular campaign it is necessary to measure on an extractive basis the $N_2O$ concentration in a tail gas and on a non-extractive basis tail gas flow, pressure and temperature.

## $N_2O$ concentration

$N_2O$ concentration is measured by extractive measurement system. Tail gas samples are taken from respective tail gas ducts at sampling points located after expansion turbines and transported by heated sample lines to the Monitoring room A located next to the main production hall. This applies to 2 concentration meters measuring lines 1-3 and lines 4-6. lines 7-8 are measured by third concentration meter located at the other side of the production hall (Monitoring room B) physically closer to respective production lines 7 and 8.

Tail gas samples are filtered and conditioned in the condensation dryer (4°C), so $N_2O$ concentration is measured on a dry basis. Correction of dry basis ppmV value to real wet tail

gas conditions based on steam flow injected into the system is part of both - the project emissions calculations and baseline emission factor calculations.

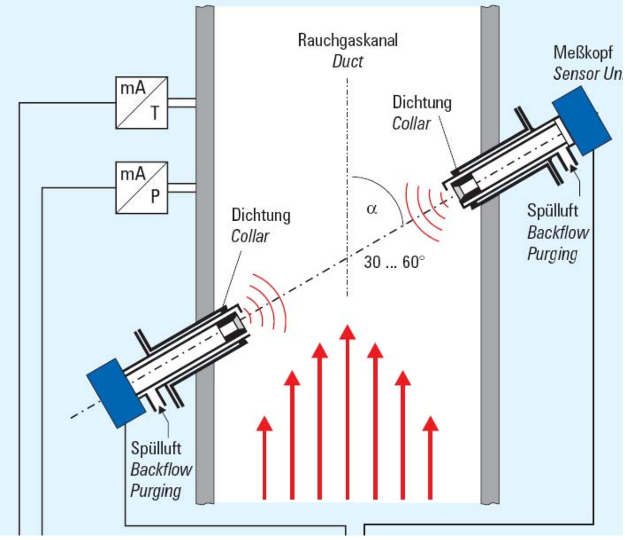
$N_2O$ concentration is measured by concentration infrared absorption principle meters Xentra 4900 using GFX monitoring technology.

Recently there are 8 production Lines. $N_2O$ concentration is measured by 3 concentration meters on a switched basis. Tail gas samples are automatically switched. Under-sampling uncertainty is part of both - the project emissions calculations and baseline emission factor calculations.

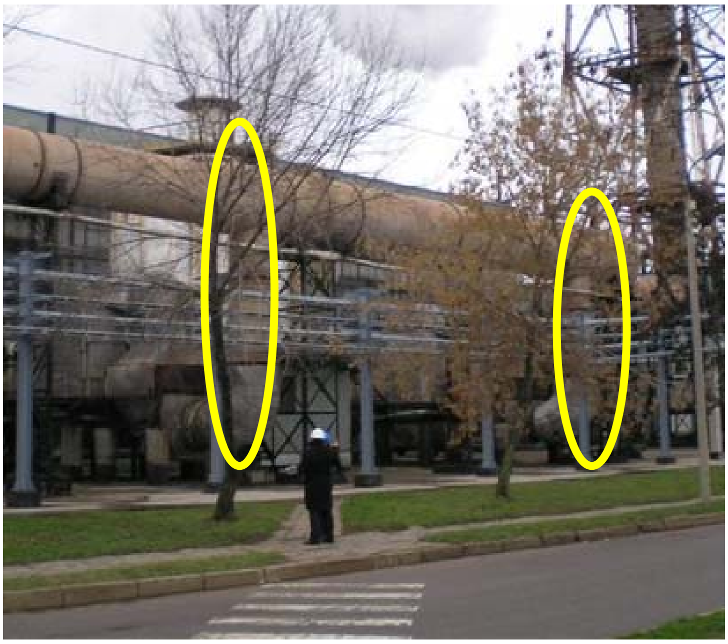
$N_2O$ concentration measured data are sent from the concentration meter on a 2 sec basis in a form of 4-20mA signal to the datalogger and processed further.

**Tail gas flow, pressure and temperature**

Tail gas flow is measured by ultrasonic Durag DF-L 200 flowmeters based on ultrasonic pulse fly time across the entire duct cross-section.



The tail gas ducts do not allow any optimum location to perform the flow monitoring. The only possible location is the quite short vertical tube behind the 90° “knee”.



Since the flow is not really laminar, a classical Pitot tube one point solution wouldn't allow good results. The ultrasonic system is under these conditions superior to differential pressure. Cross duct monitoring is more accurate than a couple of discrete point averaged pressure.

Tail gas flow, pressure and temperature measured data are sent from the flow meter on a 2 sec basis in a form of 4-20mA signal to the datalogger and processed further.

**Tail gas steam injection elimination**

Steam injected into the Achema UKL-7 tail gas for purpose of increasing the turbine output is eliminated from the tail gas mass flow calculation by following formulae:

flow - STVF=L1_Flow_N2O*(273.15/(273.15+L1_Temp))*(L1_Press/101.325)*((100-L1_Humi)/100)

where Humi (water content)=

(L1_Flow_steam*1.2436)/(L1_Flow_N2O*(273.15/(273.15+L1_Temp))*(L1_Press/101.325))*100+0.6

where 1.2436 is the conversion factor from kg/h to Nm3/h and 0.6% is a value of humidity present in a flue gas permanently without steam injection

The Flow_steam parameter necessary for calculation of the water content in the dataloggers is provided in the kg/h unit.

Achema measures steam flow in kg/h using formula Q=C*sqrt(dp) , where C is flow constant which is already integrated using an orifice plate sizing program. The orifice plate calculation for injection steam has been done for temperature 250˚C and pressure 6 bar.

Flow steam in kg/h measured by using the constant steam T and P values is then recalculated to actual steam T and P values valid for relevant hours and as result the STVF value cleaned of the steam injected is used for further emission reductions calculations.

### EN14181 compliance

As required by the AM0034/Version 02 methodology the $N_2O$ automated measurement system (AMS) complies with requirements of the technical norm EN14181. $N_2O$ AMS consists from the $N_2O$ concentration meter and integrated flowmeter (F, T, P). Both measurement devices are QAL1 certified (concentration meter for the $N_2O$ measurand specifically) and after full commissioning of the monitoring system there was the QAL2 test carried out by an independent laboratory certified according to ISO17025.

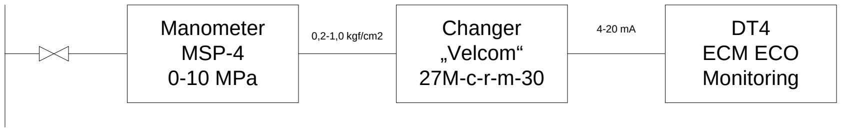
### Operating conditions

For purpose of the baseline emissions factor setting it is necessary to monitor and report operating conditions in all 8 burners. Namely:

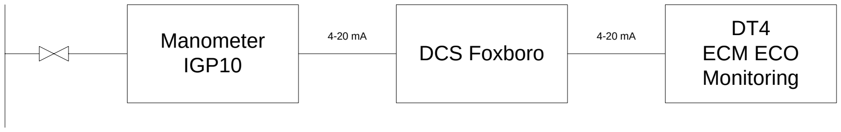
Ammonia flow
Ammonia temperature
Ammonia pressure
Primary air flow
Primary air temperature
Primary air pressure
Oxidation temperature
Oxidation pressure

All these parameters are measured by the plant monitoring system as presented on diagrams below:

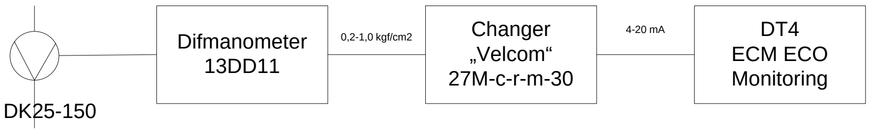
P in mixer 1-6 line



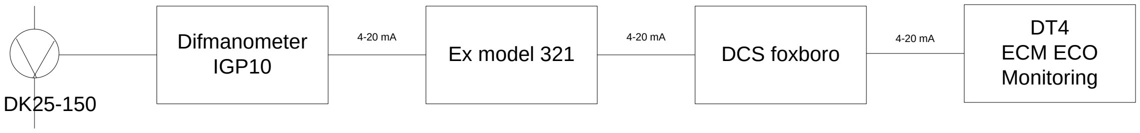
P in mixer 7-8 line

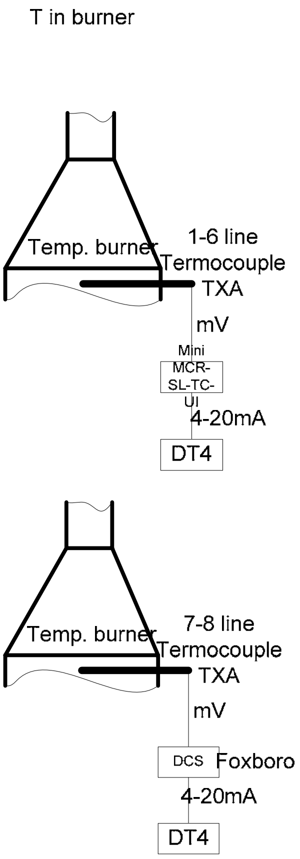


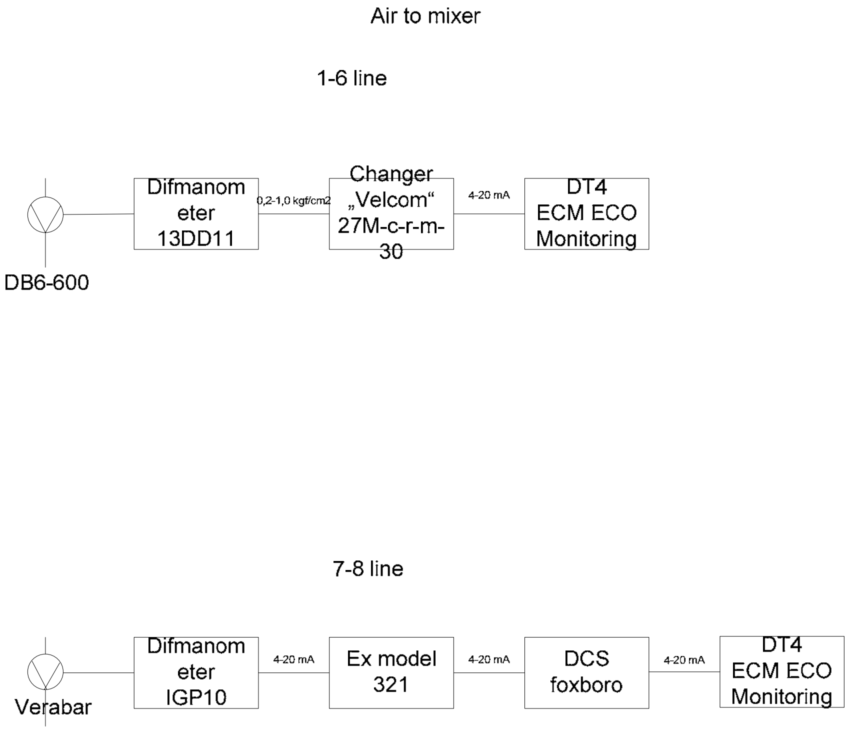
NH3 to mixer 1-6 line



NH3 to mixer 7-8 line







Signals obtained from these measurement devices from production Lines 1-6 are converted from pneumatic to 4-20mA analog signals. Operating conditions measurement devices installed in production Lines 7-8 provide the 4-20mA signals which are digitalized and provided to the monitoring system dataloggers, which process them further. Maintenance procedures for the ammonia oxidation parameters follow the existing procedures for the operation of the nitric acid plant.

### Nitric acid production

Nitric acid concentration is based on two components: nitric acid and water. Standard monitoring method is on-Line refractometry. Measurement of nitric acid (100%) mass volume production per campaign is necessary for calculation of the baseline emissions factor. Nitric acid concentration on all 8 Lines is measured by K-Patents PR-23-GP refractometers.

This analyzer is applying a prism to “return” a generated optical beam back to an LCD detector.

The detector is measuring refraction of monitored liquid based on known refraction of water and nitric acid. The instrument is calibrated for percent concentration of nitric acid. The analyzer is mounted on DIN-flange 2656, PN25 DN80. The optical prism does not require cleaning.

PR-23-GP characteristics:

- Measuring RI is a direct concentration measurement principle. No need to rely or convert magnitudes.
- Digital instrument – no calibration drift
- As it is a robust instrument it is maintenance free
- Dual connectivity if the installation positions allow.
- On-Line data logging, through Ethernet, on whichever web browser.
- No influence by bubbles or particles. It is very common that air enters the process pipeline and still the refractometer measures accurately.

Nitric acid concentration data are in an analog 4-20mA format provided to dataloggers which process these signals further.

In order of being able to calculate total mass volume of nitric acid 100% concentrate produced during the baseline campaign it is necessary to monitor also nitric acid flow and temperature. Measurement of pressure is not necessary for determination of the nitric acid mass volume flow, because nitric acid is in form of liquid and as such it has stabile pressure characteristic.

Signals obtained from the nitric acid flow and temperature measurement devices from production Lines 1-6 are converted from pneumatic to 4-20mA analog signals. Nitric acid flow and temperature measurement devices installed in production Lines 7-8 provide the 4-20mA signals which are digitalized and provided to the monitoring system dataloggers, which process them further.

After installation of refractometers there have been occurrences of their failure and following repair service by the manufacturer. For this period starting from 08/11/2007 and ending on 29/07/2008 project uses $HNO_3$ concentration data provided by the laboratory measurements.

# 6. QAL 2 CALIBRATION ADJUSTMENTS

## 6.1 Applied principle

As required in the applicable norm EN14181: “The relation between the instrument readings of the recording measuring procedure and the quantity of the measuring objects has to be described by using a suitable convention method. The results have to be expressed by a regression analysis.”

As it is described in the Calibration Report issued by Airtec laboratory, the measurement results derived from the analog signals (4 mA to 20 mA) provided the installed instruments have been compared to the comparative measurements.

Linearity check of the instruments characteristics is stated in the QAL2 Calibration Report issued by the laboratory. The valid ranges of Linearity are determined by statistical analysis according to the guideline and the Linearity assumptions are further used in the Calibration Report establishing Linear regression Lines.

The general formula of the regression Line, established in the EN14181 and used in the Calibration Report is:

$$Y= a + bX$$

where:

X is the measured value of the instrument in mA
Y is the value of the parameter being objective of the measurement
a is a constant of the regression Line
b is the slope of the regression Line

After a comparative test the laboratory issued the old and new regression Lines properties, namely “a” and “b” applying for all of the measured parameters that are subject to calibration as stated in the Calibration Report.

The QAL2 corrections are based on the fact that the actual analog current outputs (in mA) of the measurement instruments are relevant for both, the old and new regression Lines:

$$Xo=Xn=X$$

where:

Xn: X new
Yo: Y old

This allows us to derive a calibrating formula that gives us the corrected value of the measured physical parameters. The applied calibrating equation is:

$$Yn=An + (Bn/Bo)*(Yo-Ao)$$

In order to take into account the properties of the AMS and their implication to the QAL 2 implementation in the model, we will further introduce several remarks to the conversion and normalization of the data.

The units returned by the AMS “nm3/h” stand for normalized cubic meters of the gas volume at normal gas conditions (0° C, 1 atm.).

## 6.2 Stack gas volume flow

Based on the real conditions measured and applied by the AMS for normalization (TSG in °C and PSG in hPa), the stack gas volume flow values are converted to real conditions before the regression analysis using the ideal gas law. The actual gas volume flow rates are derived from gas velocity measurements, therefore, before applying the regression analysis the gas speed is calculated from the volume flow and the duct cross-section and is fed into the calibrating equation. The calibrated values derived from the calibrating equation then converted back to normalized units using the calibrated real conditions (calibrated TSG and PSG). The normalized calibrated stack gas flow rates are further fed into the emission calculation model for further processing as set out by the Approved Baseline and Monitoring Methodology AM_0034.

## 6.3 Nitric acid concentration in stack gas

The nitric acid concentration in the raw data set from the AMS is in $mgN_2O/m_3$. The concentration was converted to ppmv to make it compatible with the regression Lines parameters. The nitrous gas concentration values are then calibrated using the provided regression Lines parameters and are input in the model.

## 6.4 Stack gas Temperature

The stack gas temperature was calibrated by the regression conversion formula

## 6.5 Stack gas Pressure

The calibration report provides us with a regression Line for the stack gas pressure. We calibrate the readings of the measurements system using the regression formula and applying the values (in kPa).

# 7. EMISSION REDUCTION CALCULATIONS

Table T 2 illustrates the establishment of historic campaign length based on 5 previous campaigns. Average production in 5 campaigns preceding the baseline campaign was 62 710 $tHNO_3$ and time duration was on average 239 days. Table contains also information on suppliers of primary catalysts for the line 2.

### T 2 Historic campaigns

| Line | ACHEMA UKL-2 | Production | Start | End | Days | Production per day | Primary Catalyst | Composition |
|---|---|---|---|---|---|---|---|---|
| **Historic Campaigns** | **1** t HNO3 | 63 318 | 07 Jun 2004 | 26 Jan 2005 | 233 | 272 | Heraeus | 90/5/5 |
| | **2** t HNO3 | 65 490 | 27 Jan 2005 | 21 Sep 2005 | 237 | 276 | Umicore | 95/5 |
| | **3** t HNO3 | 51 101 | 22 Sep 2005 | 10 Apr 2006 | 200 | 256 | Heraeus | 62/4/34 |
| | **4** t HNO3 | 63 008 | 11 Apr 2006 | 24 Jan 2007 | 288 | 219 | Heraeus | 63/4/33 |
| | **5** t HNO3 | 70 635 | 14 Mar 2007 | 08 Nov 2007 | 239 | 296 | Johnson Matthey | n.a. |
| **Average HNO3 production** | t HNO3 | **62 710** | | | **239** | **262** | | |
| **Project Campaigns** | **BL** t HNO3 | 60 767 | 09 Nov 2007 | 20 May 2008 | 193 | 315 | Johnson Matthey | n.a. |
| | **PL** t HNO3 | 67 392 | 22 Oct 2010 | 12 May 2011 | 202 | 334 | Johnson Matthey | n.a. |

It is business as usual scenario in Achema UKL-7 plant to keep using primary catalysts from several suppliers and with several compositions. Selection of primary catalysts is determined by technical parameters of their use and price levels offered by suppliers in specific time. Primary catalysts used during the baseline campaign, if other than used in previous campaign/s, did not increase emissions of N2O as confirmed by relevant statements provided to the verifier.

T 3 and Chart C 1 define the length of the baseline campaign. Baseline campaign measurements for this project campaign started on 09/11/2007 and continued through 20/05/2008 when the 60 767 $tHNO_3$ nitric acid production was reached. The measurement of baseline Nitrous Acid Concentration (NCSG) was carried out until production reached - $tHNO_3$ .

### T 3 Baseline campaign length

| ACHEMA UKL-2 | Historic Campaings End | Start of Baseline Measurement | End of Baseline Measurement NCSG | End of Baseline Measurement | End of Baseline Campaign |
|---|---|---|---|---|---|
| **Dates** | 2007 Nov 08 | 2007 Nov 09 | 2008 May 20 | 2008 May 20 | 2008 May 21 |
| **Baseline Factor kgN2O/tHNO3** | - | - | 9.51 | 9.51 | 9.51 |
| **Production tHNO3** | | - | 60 767 | 60 767 | - |
| **Per Day Production tHNO3** | 261.9 | | | | |
| **Baseline less Historic Production** | **(1 943.4)** | | | | |
| **Baseline less Historic Days** | **(7.4)** | | | | |

## C 1 Baseline campaign length

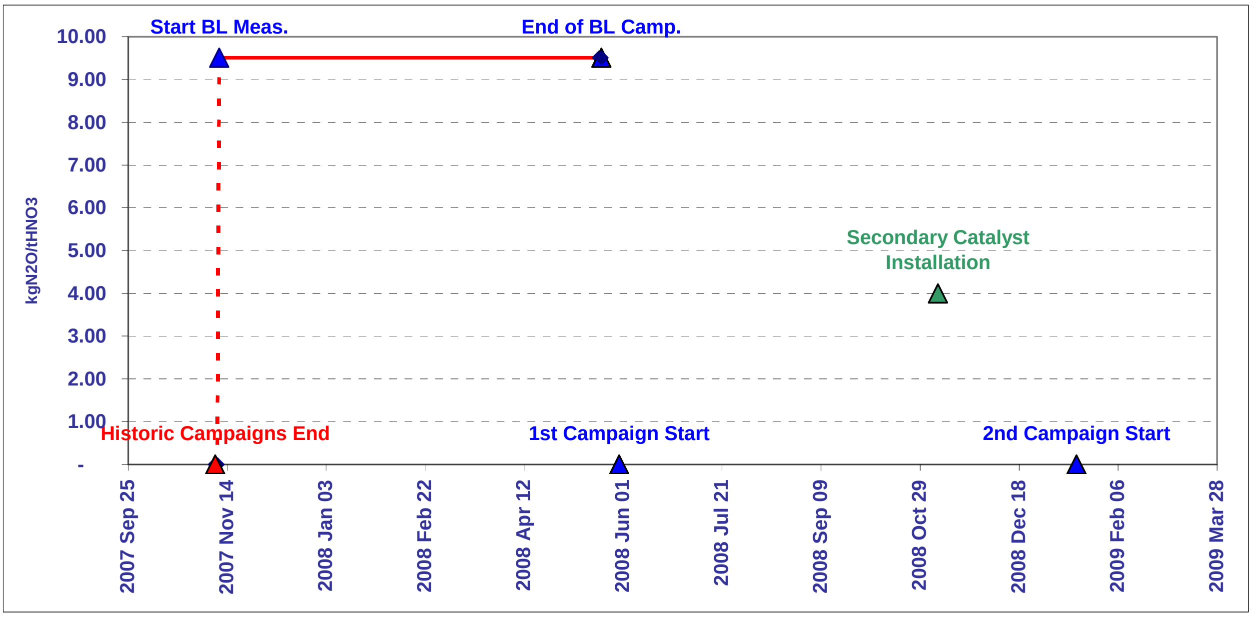


Table T 4 illustrates the calculation of the baseline emission factor on Line 2 using the method as defined in the CDM methodology AM0034 and in the PDD. We have not used overlapping approach allowed by the PDD. Baseline emission factor was determined based on raw data measured from 09/11/2007 through 20/05/2008.

Extreme values and data measured during hours when one or more of operating conditions were outside of the permitted range have been eliminated from the calculations. As a next step we have eliminated data beyond 95% confidence interval and calculated new mean values of $N_2O$ concentration and stack gas volume flow using following method:

a) Calculate the sample mean (x)
b) Calculate the sample standard deviation (s)
c) Calculate the 95% confidence interval (equal to 1.96 times the standard deviation)
d) Eliminate all data that lie outside the 95% confidence interval
e) Calculate the new sample mean from the remaining values (volume of stack gas (VSG) and $N_2O$ concentration of stack gas (NCSG))

Using the means values we have calculated the baseline emissions as set out in the PDD.

$$BE_{BC} = VSG_{BC} * NCSG_{BC} * 10^{-9} * OH_{BC} \ (tN_2O)$$

Operating hours defined as hours, when nitric acid production at least 0.1 tHNO3 and oxidation temperature at least 600°C occurred. Calculated baseline N2O emissions were 618 $tN_2O$.

$$EF_{BL} = (BE_{BC} / NAP_{BC}) \ (1 – UNC/100) \ (tN_2O/tHNO_3)$$

The UNC factor defined by the QAL2 report is 6.460%, which is further modified by an uncertainty of 0.087% due to under-sampling. As a result we have arrived to the baseline emission factor of 9.51 $kgN_2O/tHNO_3$.

Table T 5 shows the calculation of the project emission factor on Line 2 during the project campaign. Project campaign started on 22/10/2010 and went through 12/05/2011.

We have eliminated extreme values and data beyond the 95% confidence interval as prescribed by the PDD.

a) Calculate the sample mean (x)
b) Calculate the sample standard deviation (s)
c) Calculate the 95% confidence interval (equal to 1.96 times the standard deviation)
d) Eliminate all data that lie outside the 95% confidence interval
e) Calculate the new sample mean from the remaining values

Using the mean values we have calculated total mass of $N_2O$ emissions ($PE_n$) as follows:

$$PE_n = VSG * NCSG * 10\text{-}9 * OH\ (tN2O)$$

Operating hours (OH) defined as hours, when nitric acid production at least 0.1 tHNO3 and oxidation temperature at least 600˚C occurred.

By dividing total mass of $N_2O$ emissions by the nitric acid production (capped by nameplate capacity 350 tHNO3/day) we have determined the project campaign specific emission factor at value of  1.83 kgN2O/tHNO3.

$$EF_n = PE_n / NAP_n\ (tN_2O/tHNO_3)$$

Because the project emission factor measured was lower than the moving average EF of the campaigns on this line so far, we have used the average EF for the calculation of the quantity of emission reductions generated during this campaign.

# T 4 Baseline emission factor

**BASELINE EMISSION FACTOR**

| *Parameter* | Operating Hours | Nitric Acid Production | N2O Concentration | Gas Volume Flow | Ammonia Flow Rate | Ammonia to Air Ratio | Oxidation Temperature | Oxidation Pressure | AMS in Operation | Nitric Acid Production NCSG |
|---|---|---|---|---|---|---|---|---|---|---|
| *Code* | OH | NAP | NCSG | VSG | AFR | AIFR | OT | OP | | NAP |
| *Unit* | h | t/h | mg N2O/Nm3 | Nm3/h | Nm3/h | % | °C | kPa | h | t/h |
| **Elimination of extreme values** | | | | | | | | | | |
| Lower limit | | 0 | 0 | 0 | 0 | 0 | - 50 | 0 | | 0 |
| Upper Limit | | 50.00 | 3 000 | 120 000 | 10 000 | 20.00 | 1 200 | 1 000 | | 50 |
| **Raw Data Measured Range** | | | | | | | | | | |
| Count | **4 254** | 4 633 | 4 353 | 4 216 | 4 296 | 4 277 | 4 606 | 4 576 | 3 828 | 4 633 |
| *as % of Dataset* | *92%* | *100%* | *94%* | *91%* | *93%* | *92%* | *99%* | *99%* | *83%* | *100%* |
| Minimum | | - | 0 | 140 | 2 069 | - | 42 | 5 | | - |
| Maximum | | 15.73 | 2 356 | 106 649 | 6 243 | 18.13 | 1 100 | 679 | | 16 |
| Mean | | 13.12 | 1 576 | 83 679 | 5 815 | 9.78 | 843 | 604 | | 13 |
| Standard Deviation | | 3.81 | 323 | 18 036 | 263 | 1.67 | 207 | 45 | | 4 |
| Total | | 60 767 | | | | | | | | 60 767 |
| N2O Emissions ( VSG * NCSG * OH) | 561 | t N2O | | | | | | | | |
| Emission Factor | 8.64 | kgN2O / tHNO3 | | | | | | | | |
| **Permitted Range** | | | | | | | | | | |
| Minimum | | | | | 4 500 | 0 | 880 | 0 | | |
| Maximum | | | | | 7 500 | 11.70 | 910 | 800 | | |
| **Data within the permitted range** | | | | | | | | | | |
| Count | **3 710** | | 3 710 | 3 710 | | | | | 3 828 | |
| *as % of Operating Hours* | ***87%*** | | *87%* | *87%* | | | | | *90%* | |
| Minimum | | | 465 | 10 197 | | | | | | |
| Maximum | | | 2 356 | 105 388 | | | | | | |
| Mean | | | 1 588 | 85 591 | | | | | | |
| Standard Deviation | | | 293 | 14 825 | | | | | | |
| N2O Emissions ( VSG * NCSG * OH) | 578 | t N2O | | | | | | | | |
| Emission Factor | 8.90 | kgN2O / tHNO3 | | | | | | | | |
| **Data within the confidence interval** | | | | | | | | | | |
| 95% Confidence interval | | | | | | | | | | |
| Lower bound | | | 1 014 | 56 534 | | | | | | |
| Upper bound | | | 2 162 | 114 648 | | | | | | |
| Count | | | 3 430 | 3 604 | | | | | | |
| *as % of Operating Hours* | | | *81%* | *85%* | | | | | | |
| Minimum | | | 1 118 | 77 416 | | | | | | |
| Maximum | | | 2 156 | 105 388 | | | | | | |
| Mean | | | 1 654 | 87 784 | | | | | | |
| Standard Deviation | | | 173 | 7 591 | | | | | | |
| **N2O Emissions ( VSG * NCSG * OH)** | **618** | **t N2O** | | | | | | | | |
| **Emission Factor (EF_BL)** | **9.51** | **kgN2O / tHNO3** | | | | | | | | |

# T 5 Project emission factor

**PROJECT EMISSION FACTOR**

| ***Parameter***<br>***Code***<br>***Unit*** | **Operating Hours**<br>**OH**<br>**h** | **Nitric Acid Production**<br>**NAP**<br>**t/h** | **N2O Concentration**<br>**NCSG**<br>**mg N2O/Nm3** | **Gas Volume Flow**<br>**VSG**<br>**Nm3/h** | **Ammonia Flow Rate**<br>**AFR**<br>**Nm3/h** | **Ammonia to Air Ratio**<br>**AIFR**<br>**%** | **Oxidation Temperature**<br>**OT**<br>**°C** | **Oxidation Pressure**<br>**OP**<br>**kPa** |
|---|---|---|---|---|---|---|---|---|
| **Elimination of extreme values** | | | | | | | | |
| Lower limit | | 0 | 0 | 0 | 0 | 0 | - 50 | 0 |
| Upper Limit | | 50.00 | 3 000 | 120 000 | 10 000 | 20.00 | 1 200 | 1 000 |
| **Raw Data Measured Range** | | | | | | | | |
| Count | **4 520** | 4 543 | 4 442 | 4 485 | 4 828 | 4 548 | 4 845 | 4 824 |
| *as % of Dataset* | *93%* | *94%* | *92%* | *93%* | *100%* | *94%* | *100%* | *100%* |
| Minimum | | 0.67 | 151 | 37 339 | 316 | 2 | 5 | 0 |
| Maximum | | 18.63 | 591 | 94 149 | 7 678 | 14.86 | 1 100 | 711 |
| Mean | | 14.83 | 349 | 72 365 | 6 088 | 10.44 | 846 | 614 |
| Standard Deviation | | 1.37 | 68 | 3 529 | 456 | 0.27 | 195 | 87 |
| Total | | 67 392 | | | | | | |

| | | |
|---|---|---|
| N2O Emissions ( VSG * NCSG * OH) | 114 | t N2O |
| Emission Factor | 1.69 | kgN2O / tHNO3 |

| **Data within the confidence interval** | | |
|---|---|---|
| 95% Confidence interval | | |
| Lower bound | 215 | 65 447 |
| Upper bound | 482 | 79 283 |
| | | |
| Count | 4 083 | 4 368 |
| *as % of Operating Hours* | *90%* | *97%* |
| Minimum | 215 | 65 727 |
| Maximum | 482 | 79 275 |
| Mean | 346 | 72 021 |
| Standard Deviation | 58 | 2 589 |

| | | |
|---|---|---|
| **N2O Emissions ( VSG * NCSG * OH)** | **113** | **t N2O** |
| **Actual Project Emission Factor (EF_PActual)** | **1.67** | **kgN2O / tHNO3** |
| **Abatement Ratio** | **82.4%** | |

| **Moving Average Emission Factor Correction** | **Actual Factors** | **Moving Average Rule** |
|---|---|---|
| **1** | 1.80 | 1.80 |
| **2** | 1.84 | 1.84 |
| **3** | 1.99 | 1.99 |
| **4** | 1.67 | 1.83 |

| | | |
|---|---|---|
| **Project Emission Factor (EF_P)** | **1.83** | **kgN2O / tHNO3** |
| **Abatement Ratio** | **80.8%** | |

# MONITORING REPORT

**PROJECT:** ACHEMA UKL nitric acid plant $N_2O$ abatement project
**LINE:** Line 3
**MONITORING PERIOD:**
**FROM:** 17/06/2009

**TO:** 16/11/2010

**Prepared by:**

**VERTIS FINANCE**

www.vertisfinance.com

# Table of Contents

# 1. EXECUTIVE SUMMARY

This monitoring report determines baseline emission factor for the Line 3 of ACHEMA UKLnitric acid plant and quantity of emission reduction generated during the third project campaign on Line 3.

The first campaign on Line 3 started on 27/08/2008. Secondary catalyst was installed on 04/07/2008. Total quantity of emission reductions generated during the third project period from 17/06/2009 through 16/11/2010 on Line 3 is **49 142 ERUs**.

### T 1 Emission reduction calculations

| EMISSION REDUCTION | | | |
|---|---|---|---|
| Baseline Emission Factor | EF_BL | 5.45 | kgN2O/tHNO3 |
| Project Campaign Emission Factor | EF_P | 3.57 | kgN2O/tHNO3 |
| Nitric Acid Produced in the Baseline Campaign | NAP_BL | 59 042 | tHNO3 |
| Nitric Acid Produced in the NCSG Baseline Campaign | NAP_BL_NCSG | 56 309 | tHNO3 |
| Nitric Acid Produced in the Project Campaign | NAP_P | 84 321 | tHNO3 |
| GWP | GWP | 310 | tCO2e/tN2O |
| **Emission Reduction** | **ER** | **49 142** | **tCOe** |
| *ER=(EF_BL-EF_P)*NAP_P*GWP/1000* | | | |
| **Abatement Ratio** | | **34.5%** | |

| EMISSION REDUCTION PER YEAR | | | |
|---|---|---|---|
| Year | 2008 | 2009 | 2010 |
| Date From | | 17 Jun 2009 | 01 Jan 2010 |
| Date To | | 31 Dec 2009 | 16 Nov 2010 |
| Nitric Acid Production | | 35 016 | 49 304 |
| **Emission Reduction** | | **20 408** | **28 735** |
| *ER_YR = ER * NAP_P_YR / NAP_P* | | | |

Baseline emission factor established for the Line 3 during baseline measurement carried using overlapping approach from 01/02/2008 to 04/07/2008 and from 01/09/2007 through 03/11/2007 is 5.45 kg$N_2O$/t$HNO_3$.

Project emission factor during third project campaign after installation of secondary catalysts on Line 3, which started on 17/06/2009 and went through 16/11/2010 with secondary catalyst installed and commissioned on 04/07/2008, is 3.57 kg$N_2O$/t$HNO_3$.

During the project campaign 84 321 tonnes of nitric acid was produced.

# 2. DESCRIPTION OF THE PROJECT ACTIVITY

Purpose of the Project (the “Project”) is the reduction of nitrous oxide ($N_2O$) emissions from nitric acid production Lines at the UKL-7 nitric acid plant of AB Achema (“Achema” or “the Company”). The Company is situated in Jonava, Lithuania.

Achema has installed and operates secondary $N_2O$ reduction catalysts underneath the primary catalyst precious metal catching and catalytic gauzes package in the ammonium burners of the UKL-7 nitric acid plant.

This monitoring report contains information on Line 3 emission reductions including information on baseline emission factor setting for the Line 3.

The separate treatment of nitric acid lines and overlapping of the monitoring periods are allowed by the clarification issued Joint Implementation Supervisory Committee: “CLARIFICATION REGARDING OVERLAPPING MONITORING PERIODS UNDER THE VERIFICATION PROCEDURE UNDER THE JOINT IMPLEMENTATION SUPERVISORY COMMITTEE”. The Project meets all the requirements set out by the clarification:

1. The Project is composed of clearly identifiable components for which emission reductions or enhancements of removals are calculated independently; and

2. Monitoring is performed independently for each of these components, i.e. the data/parameters monitored for one component are not dependent on/effect data/parameters (to be) monitored for another component; and

3. The monitoring plan ensures that monitoring is performed for all components and that in these cases all the requirements of the JI guidelines and further guidance by the JISC regarding monitoring are met.

# 3. BASELINE SETTING

Baseline emission factor for line 3 has been established on the Line-specific basis. Campaign used for baseline measurements on the line 3 has been carried out using overlapping approach from 01/02/2008 to 04/07/2008 and from 01/09/2007 through 03/11/2007.

$N_2O$ concentration and gas volume flow are monitored by monitoring system complying with requirements of the European Norm 14181.

Monitoring system provides separate readings for $N_2O$ concentration and gas flow volume for every hour of operation as an average of the measured values for the previous 60 minutes.

Measurement results can be distorted before and after periods of downtime or malfunction of the monitoring system and can lead to mavericks. To eliminate such extremes and to ensure a conservative approach, the following statistical evaluation is applied to the complete data series of $N_2O$ concentration as well as to the data series for gas volume flow. The statistical procedure is applied to data obtained after eliminating data measured for periods where the plant operated outside the permitted ranges:

a) Calculate the sample mean (x)
b) Calculate the sample standard deviation (s)
c) Calculate the 95% confidence interval (equal to 1.96 times the standard deviation)
d) Eliminate all data that lie outside the 95% confidence interval
e) Calculate the new sample mean from the remaining values (volume of stack gas (VSG) and $N_2O$ concentration of stack gas (NCSG))

The average mass of $N_2O$ emissions per hour is estimated as product of the NCSG and VSG. The $N_2O$ emissions per campaign are estimates product of $N_2O$ emission per hour and the total number of complete hours of operation of the campaign using the following equation:

$$BE_{BC} = VSG_{BC} * NCSG_{BC} * 10^{-9} * OH_{BC} \ (tN_2O)$$

The Line specific baseline emissions factor representing the average $N_2O$ emissions per tonne of nitric acid over one full campaign is derived by dividing the total mass of $N_2O$ emissions by the total output of 100% concentrated nitric acid during baseline campaign.

The overall uncertainty of the monitoring system has been determined by the QAL2 report and the measurement error is expressed as a percentage (UNC). The $N_2O$ emission factor per tonne of nitric acid produced in the baseline period (EFBL) has been then be reduced by the percentage error as follows:

$$EF_{BL} = (BE_{BC} / NAP_{BC}) (1 – UNC/100) \ (tN_2O/tHNO_3)$$

where:

| Variable | Definition |
|---|---|
| $EF_{BL}$ | Baseline $N_2O$ emissions factor ($tN_2O/tHNO_3$) |
| $BE_{BC}$ | Total $N_2O$ emissions during the baseline campaign ($tN_2O$) |
| $NCSG_{BC}$ | Mean concentration of $N_2O$ in the stack gas during the baseline campaign ($mgN_2O/m^3$) |
| $OH_{BC}$ | Operating hours of the baseline campaign (h) |
| $VSG_{BC}$ | Mean gas volume flow rate at the stack in the baseline measurement period ($m^3/h$) |
| $NAP_{BC}$ | Nitric acid production during the baseline campaign ($tHNO_3$) |
| UNC | Overall uncertainty of the monitoring system (%), calculated as the combined uncertainty of the applied monitoring equipment. |

## 3.1 Measurement procedure for $N_2O$ concentration and tail gas volume flow

### 3.1.1 Tail gas $N_2O$ concentration

$N_2O$ concentration is measured by extractive measurement system. Tail gas samples are taken from the Line 3 tail gas duct at sampling point located after expansion turbine and transported by sample Line to the Monitoring room B, where the analyzer is located.

Tail gas samples are filtered and conditioned in the condensation dryer (4°C), so $N_2O$ concentration is measured on a dry basis.

$N_2O$ concentration is measured by concentration infrared absorption principle meters Xentra 4900 using GFX monitoring technology.

Recently there are 8 production lines. $N_2O$ concentration is measured by 3 concentration meters on a switched basis.

$N_2O$ concentration measured data are sent from the analyzer on a 2 sec basis in a form of 4-20mA signal to the datalogger and processed further.

### 3.1.2 Tail gas flow rate, pressure and temperature

Tail gas flow, pressure and temperature is measured by ultrasonic Durag DF-L 200 flowmeters based on ultrasonic pulse fly time across the entire duct cross-section. Tail gas flow, pressure and temperature measured data are sent from the flow meter on a 2 sec basis in a form of 4-20mA signal to the datalogger and processed further.

## 3.2 Permitted range of operating conditions of the nitric acid plant

Under certain circumstances, the operating conditions during the measurement period used to determine baseline $N_2O$ emission factor may be outside the permitted range or limit corresponding to normal operating conditions. $N_2O$ baseline data measured during hours

where the operating conditions were outside the permitted range have been eliminated from the calculation of the baseline emissions factor.

Normal ranges for operating conditions have been determined for the following parameters:

oxidation temperature;
oxidation pressure;
ammonia gas flow rate,
air input flow rate.

The permitted range for these parameters has been established using the plant operation manual, as described in the PDD.

## 3.3 Historic Campaign Length

The average historic campaign length ($CL_{normal}$) defined as the average campaign length for the historic campaigns used to define operating condition (the previous five campaigns), has not been used as a cap on the length of the baseline campaign because of shorter project campaign.

# 4. PROJECT EMISSIONS

During the first project campaign on line 3 the tail gas volume flow in the stack of the nitric acid plant as well as $N_2O$ concentration have been measured on the continuous basis.

### 4.1.1 Estimation of campaign-specific project emissions factor

The monitoring system was installed using the guidance document EN 14181 and provides separate readings for $N_2O$ concentration and gas flow volume for every hour of operation. Same statistical evaluation that was applied to the baseline data series has been applied to the project data series:

a) Calculate the sample mean (x)
b) Calculate the sample standard deviation (s)
c) Calculate the 95% confidence interval (equal to 1.96 times the standard deviation)
d) Eliminate all data that lie outside the 95% confidence interval
e) Calculate the new sample mean from the remaining values

$$PEn = VSG * NCSG * 10^{-9} * OH\ (tN_2O)$$

where:

| **Variable** | **Definition** |
|---|---|
| VSG | Mean stack gas volume flow rate for the project campaign ($m^3/h$) |
| NCSG | Mean concentration of $N_2O$ in the stack gas for the project campaign ($mgN_2O/m^3$) |
| $PE_n$ | Total $N_2O$ emissions of the $n^{th}$ project campaign ($tN_2O$) |
| OH | Is the number of hours of operation in the specific monitoring period (h) |

### 4.1.2 Derivation of a moving average emission factor

Because the project emission factor measured was higher than the moving average EF of the campaigns on this line so far, we have used the actual project EF for the calculation of the quantity of emission reductions generated during this campaign.

## 4.2 Minimum project emission factor

Because this campaign was third project campaign on Line 3 there has been no minimum average emission factor established yet for this campaign. This factor will be established after 10th project campaign.

## 4.3 Project Campaign Length

Project campaign production of nitric acid has been below defined nameplate capacity and thus all NAP produced from date of installation of secondary catalysts has been used for calculation of emission reductions.

## 4.4 Leakage

No leakage calculation is required.

## 4.5 Emission reductions

The emission reductions for the project activity during this campaign have been determined by deducting the campaign-specific emission factor from the baseline emission factor and multiplying the result by the production output of 100% concentrated nitric acid over the campaign period and the GWP of $N_2O$:

$$ER = (EFBL – EFP) * NAP *GWPN_2O \ (tCO_2e)$$

Where:

| **Variable** | **Definition** |
|---|---|
| ER | Emission reductions of the project for the specific campaign ($tCO_2e$) |
| NAP | Nitric acid production for the project campaign ($tHNO_3$). The maximum value of NAP shall not exceed the design capacity. |
| EFBL | Baseline emissions factor ($tN_2O/tHNO_3$ ) |
| EFP | Emissions factor used to calculate the emissions from this particular campaign (i.e. the higher of $EF_{ma,n}$ and $EF_n$) |

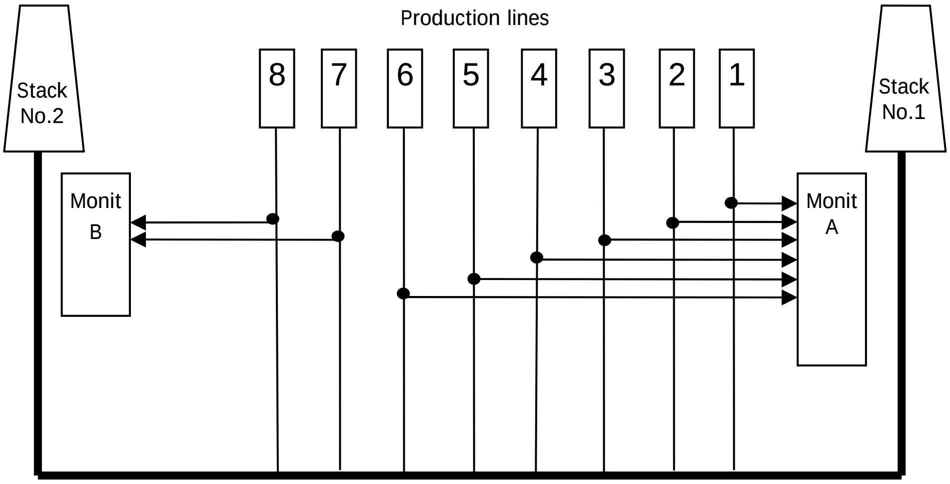
# 5. MONITORING PLAN

### Purpose of the monitoring plan

The purpose of the monitoring plan is to describe the system used to monitor emissions of $N_2O$ from the plant in such a way that is compliant with the prescriptions of the AM0034/Version 02.

### Plant description

The UKL-7 nitric acid plant comprises 8 production Lines numbered from 1 through 8, each with its own burner, absorption column and expansion turbine. Each production Line represents a separate nitric acid production unit independent from each other. The tail gasses from each Line are after expansion turbines led to a common stack bus and vented through two interconnected stacks.



Primary catalyst is changed at different times thus it is necessary to measure the emissions from each Line individually. This means that eight separate sets of monitoring equipment are installed to measure tail gas flow, nitric acid production, nitric acid concentration, and the operating conditions. $N_2O$ concentration in the tail gas is measured by 3 switched concentration meters.

### Monitoring System architecture

Methodology AM0034/Version 02 requires installation of an $N_2O$ monitoring system that includes both a gas volume flow meter to determine the tail gas mass volume flow and an infrared gas analyser to determine the concentration of $N_2O$.

But tail gas $N_2O$ concentration meter and tail gas volume flow meter alone are not sufficient for a JI project purposes. In order of being able to calculate the baseline emission factor expressed as tonnage of $N_2O$ in t $CO_2e$ per 1 tonne of $HNO_3$ (100%), it is necessary to include also $HNO_3$ measurement, and in order of being able to document normal operating conditions it is necessary to include also operating conditions measurement.

Because of this we use the term Monitoring System (MS) to describe entire monitoring system directly and indirectly used for the JI purposes, while Automated Measurement System (AMS) covers only $N_2O$ emissions and tail gas mass volume part of the MS.

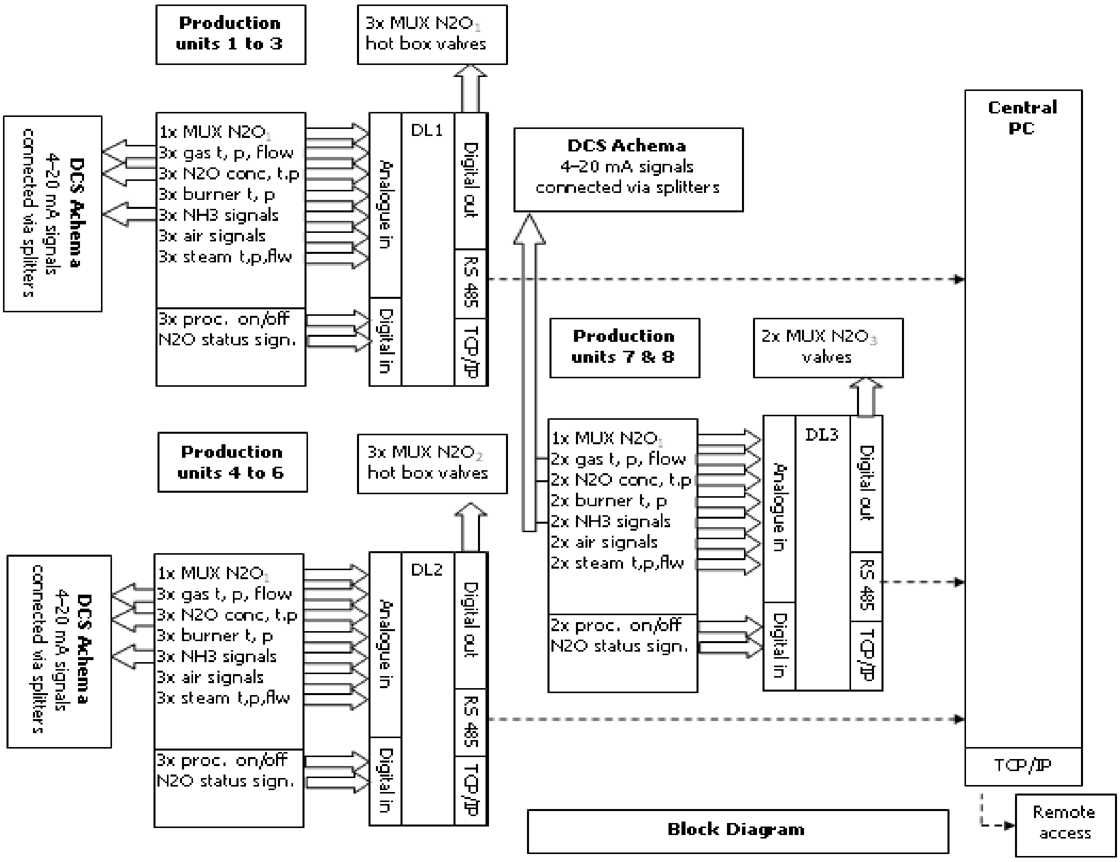
Monitoring System (MS) for purpose of this monitoring plan means:

**monitoring system measuring operational conditions;**
Ammonia volume flow
Ammonia temperature
Ammonia pressure
Primary air volume flow
Primary air temperature
Primary air pressure
Oxidation temperature
Oxidation pressure

**nitric acid 100% concentrate production;**
Nitric acid concentration
Nitric acid flow
Nitric acid temperature

**and newly installed measurement devices for measurement of N2O concentration and tail gas flow, temperature and pressure (AMS)**
$N_2O$ concentration in the stack
Stack volume flow rate
Stack gas temperature
Stack gas pressure

Incorporation of the AMS into the MS by interfacing already existing and newly installed measurement devices is documented by the diagram below.



## $N_2O$ automated measurement system

Main purpose of the $N_2O$ automated measurement system (AMS) is to measure total mass of $N_2O$ emitted during particular campaigns (both baseline and project). In order of calculation of total mass of $N_2O$ emitted during particular campaign it is necessary to measure on an extractive basis the $N_2O$ concentration in a tail gas and on a non-extractive basis tail gas flow, pressure and temperature.

## $N_2O$ concentration

$N_2O$ concentration is measured by extractive measurement system. Tail gas samples are taken from respective tail gas ducts at sampling points located after expansion turbines and transported by heated sample lines to the Monitoring room A located next to the main production hall. This applies to 2 concentration meters measuring lines 1-3 and lines 4-6. lines 7-8 are measured by third concentration meter located at the other side of the production hall (Monitoring room B) physically closer to respective production lines 7 and 8.

Tail gas samples are filtered and conditioned in the condensation dryer (4°C), so $N_2O$ concentration is measured on a dry basis. Correction of dry basis ppmV value to real wet tail

gas conditions based on steam flow injected into the system is part of both - the project emissions calculations and baseline emission factor calculations.

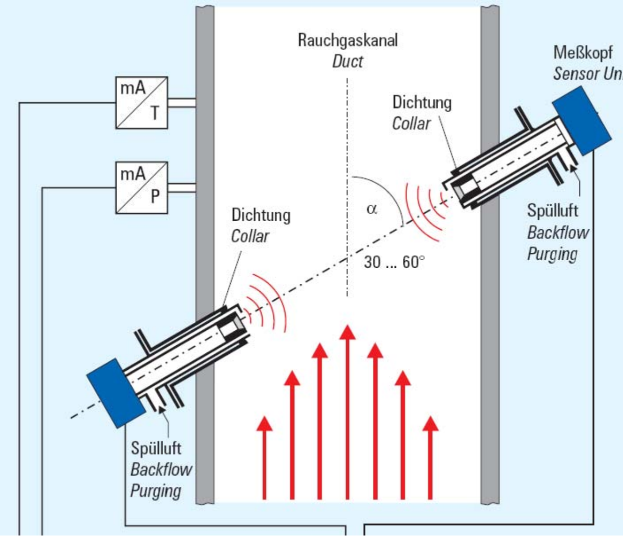
$N_2O$ concentration is measured by concentration infrared absorption principle meters Xentra 4900 using GFX monitoring technology.

Recently there are 8 production Lines. $N_2O$ concentration is measured by 3 concentration meters on a switched basis. Tail gas samples are automatically switched. Under-sampling uncertainty is part of both - the project emissions calculations and baseline emission factor calculations.

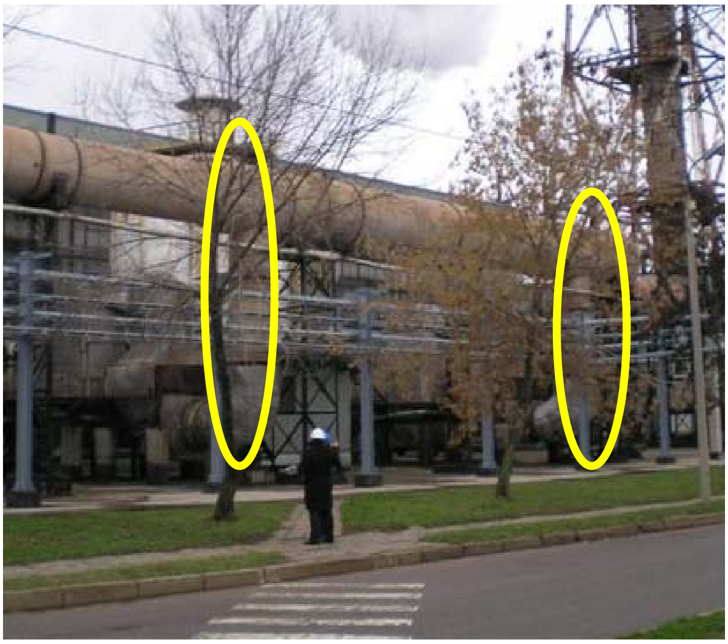
$N_2O$ concentration measured data are sent from the concentration meter on a 2 sec basis in a form of 4-20mA signal to the datalogger and processed further.

**Tail gas flow, pressure and temperature**

Tail gas flow is measured by ultrasonic Durag DF-L 200 flowmeters based on ultrasonic pulse fly time across the entire duct cross-section.



The tail gas ducts do not allow any optimum location to perform the flow monitoring. The only possible location is the quite short vertical tube behind the 90° “knee”.



Since the flow is not really laminar, a classical Pitot tube one point solution wouldn't allow good results. The ultrasonic system is under these conditions superior to differential pressure. Cross duct monitoring is more accurate than a couple of discrete point averaged pressure.

Tail gas flow, pressure and temperature measured data are sent from the flow meter on a 2 sec basis in a form of 4-20mA signal to the datalogger and processed further.

**Tail gas steam injection elimination**

Steam injected into the Achema UKL-7 tail gas for purpose of increasing the turbine output is eliminated from the tail gas mass flow calculation by following formulae:

flow - STVF=L1_Flow_N2O*(273.15/(273.15+L1_Temp))*(L1_Press/101.325)*((100-L1_Humi)/100)

where Humi (water content)=

(L1_Flow_steam*1.2436)/(L1_Flow_N2O*(273.15/(273.15+L1_Temp))*(L1_Press/101.325))*100+0.6

where 1.2436 is the conversion factor from kg/h to Nm3/h and 0.6% is a value of humidity present in a flue gas permanently without steam injection

The Flow_steam parameter necessary for calculation of the water content in the dataloggers is provided in the kg/h unit.

Achema measures steam flow in kg/h using formula Q=C*sqrt(dp) , where C is flow constant which is already integrated using an orifice plate sizing program. The orifice plate calculation for injection steam has been done for temperature 250°C and pressure 6 bar.

Flow steam in kg/h measured by using the constant steam T and P values is then recalculated to actual steam T and P values valid for relevant hours and as result the STVF value cleaned of the steam injected is used for further emission reductions calculations.

### EN14181 compliance

As required by the AM0034/Version 02 methodology the $N_2O$ automated measurement system (AMS) complies with requirements of the technical norm EN14181. $N_2O$ AMS consists from the $N_2O$ concentration meter and integrated flowmeter (F, T, P). Both measurement devices are QAL1 certified (concentration meter for the $N_2O$ measurand specifically) and after full commissioning of the monitoring system there was the QAL2 test carried out by an independent laboratory certified according to ISO17025.

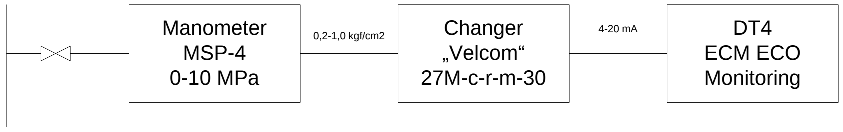
### Operating conditions

For purpose of the baseline emissions factor setting it is necessary to monitor and report operating conditions in all 8 burners. Namely:

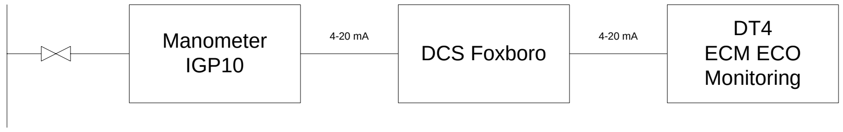
Ammonia flow
Ammonia temperature
Ammonia pressure
Primary air flow
Primary air temperature
Primary air pressure
Oxidation temperature
Oxidation pressure

All these parameters are measured by the plant monitoring system as presented on diagrams below:

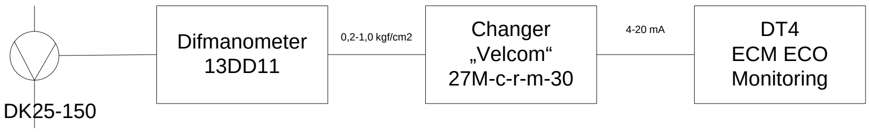
P in mixer 1-6 line



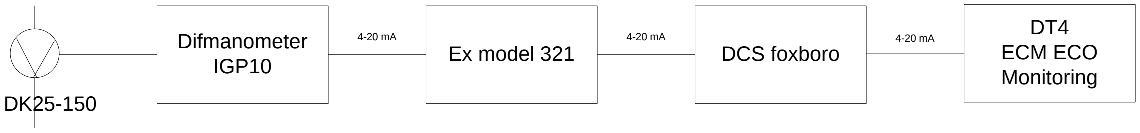
P in mixer 7-8 line



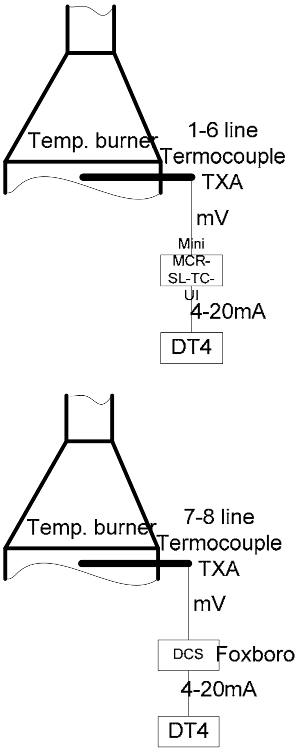
NH3 to mixer 1-6 line



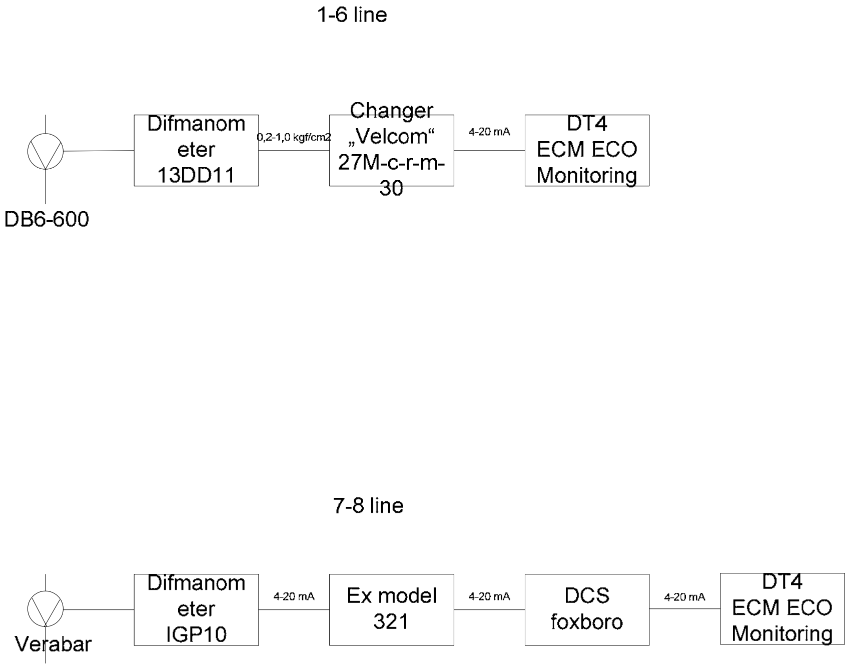
NH3 to mixer 7-8 line



T in burner



Air to mixer

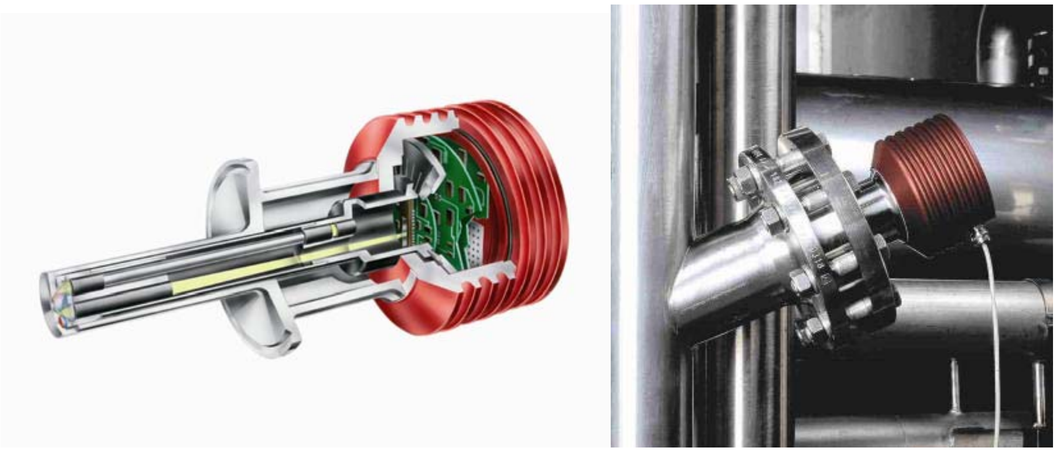


Signals obtained from these measurement devices from production Lines 1-6 are converted from pneumatic to 4-20mA analog signals. Operating conditions measurement devices installed in production Lines 7-8 provide the 4-20mA signals which are digitalized and provided to the monitoring system dataloggers, which process them further. Maintenance procedures for the ammonia oxidation parameters follow the existing procedures for the operation of the nitric acid plant.

**Nitric acid production**

Nitric acid concentration is based on two components: nitric acid and water. Standard monitoring method is on-Line refractometry. Measurement of nitric acid (100%) mass volume production per campaign is necessary for calculation of the baseline emissions factor. Nitric acid concentration on all 8 Lines is measured by K-Patents PR-23-GP refractometers.

This analyzer is applying a prism to “return” a generated optical beam back to an LCD detector.



The detector is measuring refraction of monitored liquid based on known refraction of water and nitric acid. The instrument is calibrated for percent concentration of nitric acid. The analyzer is mounted on DIN-flange 2656, PN25 DN80. The optical prism does not require cleaning.

PR-23-GP characteristics:

- Measuring RI is a direct concentration measurement principle. No need to rely or convert magnitudes.
- Digital instrument – no calibration drift
- As it is a robust instrument it is maintenance free
- Dual connectivity if the installation positions allow.
- On-Line data logging, through Ethernet, on whichever web browser.
- No influence by bubbles or particles. It is very common that air enters the process pipeline and still the refractometer measures accurately.

Nitric acid concentration data are in an analog 4-20mA format provided to dataloggers which process these signals further.

In order of being able to calculate total mass volume of nitric acid 100% concentrate produced during the baseline campaign it is necessary to monitor also nitric acid flow and temperature. Measurement of pressure is not necessary for determination of the nitric acid mass volume flow, because nitric acid is in form of liquid and as such it has stabile pressure characteristic.

Signals obtained from the nitric acid flow and temperature measurement devices from production Lines 1-6 are converted from pneumatic to 4-20mA analog signals. Nitric acid flow and temperature measurement devices installed in production Lines 7-8 provide the 4-20mA signals which are digitalized and provided to the monitoring system dataloggers, which process them further.

After installation of refractometers there have been occurrences of their failure and following repair service by the manufacturer. For this period starting from 09/11/2007 and ending on 30/07/2008 project uses HNO3 concentration data provided by the laboratory measurements.

# 6. QAL 2 CALIBRATION ADJUSTMENTS

## 6.1 Applied principle

As required in the applicable norm EN14181: “The relation between the instrument readings of the recording measuring procedure and the quantity of the measuring objects has to be described by using a suitable convention method. The results have to be expressed by a regression analysis.”

As it is described in the Calibration Report issued by Airtec laboratory, the measurement results derived from the analog signals (4 mA to 20 mA) provided the installed instruments have been compared to the comparative measurements.

Linearity check of the instruments characteristics is stated in the QAL2 Calibration Report issued by the laboratory. The valid ranges of Linearity are determined by statistical analysis according to the guideline and the Linearity assumptions are further used in the Calibration Report establishing Linear regression Lines.

The general formula of the regression Line, established in the EN14181 and used in the Calibration Report is:

$$Y= a + bX$$

where:

X is the measured value of the instrument in mA
Y is the value of the parameter being objective of the measurement
a is a constant of the regression Line
b is the slope of the regression Line

After a comparative test the laboratory issued the old and new regression Lines properties, namely “a” and “b” applying for all of the measured parameters that are subject to calibration as stated in the Calibration Report.

The QAL2 corrections are based on the fact that the actual analog current outputs (in mA) of the measurement instruments are relevant for both, the old and new regression Lines:

$$Xo=Xn=X$$

where:

Xn: X new
Yo: Y old

This allows us to derive a calibrating formula that gives us the corrected value of the measured physical parameters. The applied calibrating equation is:

$$Yn=An + (Bn/Bo)*(Yo-Ao)$$

In order to take into account the properties of the AMS and their implication to the QAL 2 implementation in the model, we will further introduce several remarks to the conversion and normalization of the data.

The units returned by the AMS “nm3/h” stand for normalized cubic meters of the gas volume at normal gas conditions (0° C, 1 atm.).

## 6.2 Stack gas volume flow

Based on the real conditions measured and applied by the AMS for normalization (TSG in °C and PSG in hPa), the stack gas volume flow values are converted to real conditions before the regression analysis using the ideal gas law. The actual gas volume flow rates are derived from gas velocity measurements, therefore, before applying the regression analysis the gas speed is calculated from the volume flow and the duct cross-section and is fed into the calibrating equation. The calibrated values derived from the calibrating equation then converted back to normalized units using the calibrated real conditions (calibrated TSG and PSG). The normalized calibrated stack gas flow rates are further fed into the emission calculation model for further processing as set out by the Approved Baseline and Monitoring Methodology AM_0034.

## 6.3 Nitric acid concentration in stack gas

The nitric acid concentration in the raw data set from the AMS is in $mgN_2O/m_3$. The concentration was converted to ppmv to make it compatible with the regression Lines parameters. The nitrous gas concentration values are then calibrated using the provided regression Lines parameters and are input in the model.

## 6.4 Stack gas Temperature

The stack gas temperature was calibrated by the regression conversion formula

## 6.5 Stack gas Pressure

The calibration report provides us with a regression Line for the stack gas pressure. We calibrate the readings of the measurements system using the regression formula and applying the values (in kPa).

# 7. EMISSION REDUCTION CALCULATIONS

Table T 2 illustrates the establishment of historic campaign length based on 5 previous campaigns. Average production in 5 campaigns preceding the baseline campaign was 59 680 $tHNO_3$ and time duration was on average 316 days. Table contains also information on suppliers of primary catalysts for the line 3. As shown in the table, it is usual practice in Achema to use primary catalysts from various suppliers.

### T 2 Historic campaigns

| **Line** | **ACHEMA UKL-3** | **Production** | **Start** | **End** | **Days** | **Production per day** | **Primary Catalyst** | **Composition** |
|---|---|---|---|---|---|---|---|---|
| **Historic Campaigns** | **1** t HNO3 | 64 017 | 05 Feb 2004 | 09 Oct 2005 | 612 | 105 | Heraeus | 63/4/33 |
| | **2** t HNO3 | 63 115 | 10 Oct 2005 | 28 Jun 2006 | 261 | 242 | Heraeus | 90/5/5 |
| | **3** t HNO3 | 59 912 | 01 Jul 2005 | 24 Jan 2006 | 207 | 289 | Heraeus | 63/4/33 |
| | **4** t HNO3 | 56 702 | 25 Jan 2006 | 23 Nov 2006 | 302 | 188 | Heraeus | 63/4/33 |
| | **5** t HNO3 | 54 654 | 24 Dec 2006 | 09 Jul 2007 | 197 | 277 | Heraeus | 63/4/33 |
| **Average HNO3 production** | t HNO3 | **59 680** | | | **316** | **189** | | |
| **Project Campaigns** | **BL** t HNO3 | 59 042 | 01 Sep 2007 | 04 Jul 2008 | 308 | 192 | Heraeus | 63/4/33 |
| | **PL** t HNO3 | 84 321 | 17 Jun 2009 | 16 Nov 2010 | 517 | 163 | Heraeus | 63/4/33 |

It is business as usual scenario in Achema UKL-7 plant to keep using primary catalysts from several suppliers and with several compositions. Selection of primary catalysts is determined by technical parameters of their use and price levels offered by suppliers in specific time. Primary catalysts used during the baseline campaign, if other than used in previous campaign/s, did not increase emissions of N2O as confirmed by relevant statements provided to the verifier.

T 3 and Chart C 1 define the length of the baseline campaign. Baseline campaign measurements for this project campaign started using overlapping approach from 01/02/2008 to 04/07/2008 then from 01/09/2007 through 03/11/2007 when the 59 042 $tHNO_3$ nitric acid production was reached. The baseline measurement for N2O concentration (NCSG) was carried out until the production of 56 309 $tHNO_3$ was reached.

We have two campaigns available that we can use for the baseline. AMS was installed in the middle of the first campaign, whereas the secondary catalyst was installed in the middle of the consecutive second one. We use these two campaigns to construct the baseline campaign using the overlapping approach as set out by the PDD. To get a clear start, that is, the baseline series has to start with a primary catalyst change, we use the beginning of the second campaign as the basis, until the secondary catalyst installation is reached. If this baseline turns out to be shorter than the project line, we use data available from the first campaign from the AMS installation to overlap the two series, and get a comparable baseline. Since we use the earliest available data from the first campaign, where emissions are generally lower, this is a conservative approach and fully in line with the PDD.

## T 3 Baseline campaign length

| ACHEMA UKL-3 | Historic Campaings End | Start of Baseline Measurement | End of Baseline Measurement NCSG | End of Baseline Measurement | End of Baseline Campaign |
|---|---|---|---|---|---|
| **Dates** | 2007 Jul 09 | 2007 Sep 01 | 2008 Jul 04 | 2008 Jul 04 | 2008 Jul 05 |
| **Baseline Factor kgN2O/tHNO3** | - | - | 5.45 | 5.45 | 5.45 |
| **Production tHNO3** | | - | 56 309 | 59 042 | - |
| **Per Day Production tHNO3** | 189.0 | | | | |
| **Baseline less Historic Production** | **(637.7)** | | | | |
| **Baseline less Historic Days** | **(3.4)** | | | | |

## C 1 Baseline campaign length

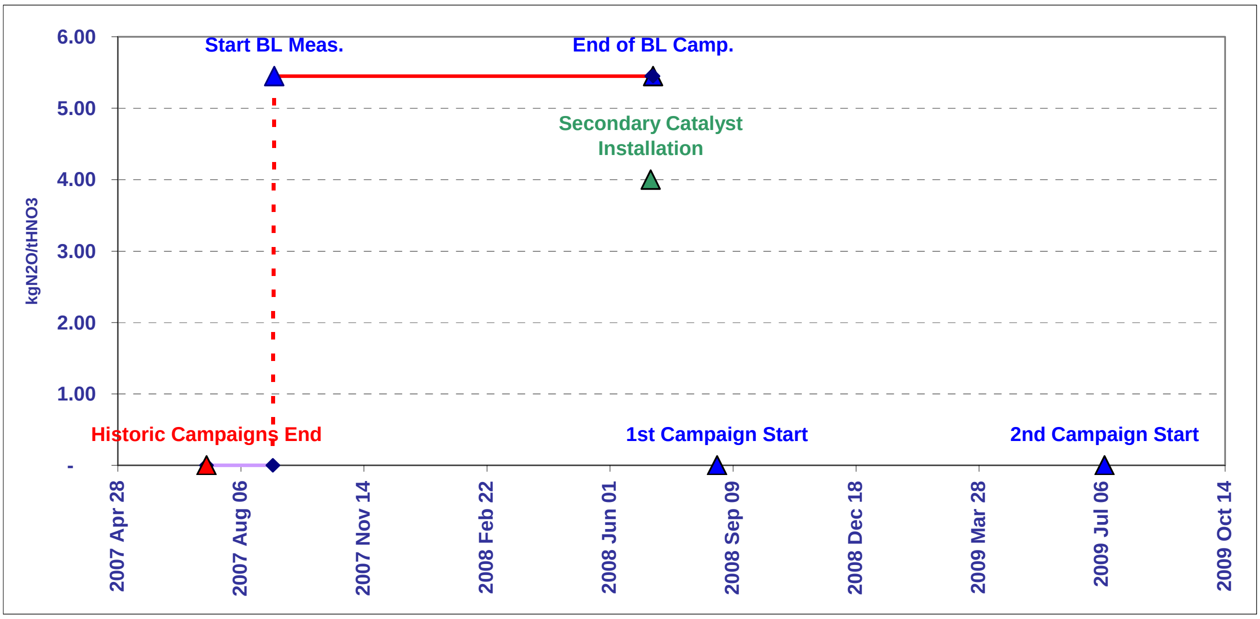


Table T 4 illustrates the calculation of the baseline emission factor on line 3 using the method as defined in the CDM methodology AM0034 and in the PDD.

Extreme values and data measured during hours when one or more of operating conditions were outside of the permitted range have been eliminated from the calculations. As a next step we have eliminated data beyond 95% confidence interval and calculated new mean values of $N_2O$ concentration and stack gas volume flow using following method:

a) Calculate the sample mean (x)
b) Calculate the sample standard deviation (s)
c) Calculate the 95% confidence interval (equal to 1.96 times the standard deviation)
d) Eliminate all data that lie outside the 95% confidence interval
e) Calculate the new sample mean from the remaining values (volume of stack gas (VSG) and $N_2O$ concentration of stack gas (NCSG))

Using the means values we have calculated the baseline emissions as set out in the PDD.

$$BE_{BC} = VSG_{BC} * NCSG_{BC} * 10^{-9} * OH_{BC}\ (tN_2O)$$

Operating hours defined as hours, when nitric acid production at least 0.1 tHNO3 and oxidation temperature at least 600˚C occurred. Calculated baseline N2O emissions were 341 $tN_2O$.

$EF_{BL} = (BE_{BC} / NAP_{BC}) (1 – UNC/100) (tN_2O/tHNO_3)$

The UNC factor defined by the QAL2 report is 5.630%, which was further modified by an uncertainty of 0.094% due to under-sampling. As a result we have arrived to the baseline emission factor of 5.45 $kgN_2O/tHNO_3$.

Table T 5 shows the calculation of the project emission factor on Line 3 during the project campaign. Project campaign started on 17/06/2009 and went through 16/11/2010.

We have eliminated extreme values and data beyond the 95% confidence interval as prescribed by the PDD.

a) Calculate the sample mean (x)
b) Calculate the sample standard deviation (s)
c) Calculate the 95% confidence interval (equal to 1.96 times the standard deviation)
d) Eliminate all data that lie outside the 95% confidence interval
e) Calculate the new sample mean from the remaining values

Using the mean values we have calculated total mass of $N_2O$ emissions (PEn) as follows:

$PEn = VSG * NCSG * 10\text{-}9 * OH (tN_2O)$

Operating hours (OH) defined as hours, when nitric acid production at least 0.1 tHNO3 and oxidation temperature at least 600˚C occurred.

By dividing total mass of $N_2O$ emissions by the nitric acid production (capped by nameplate capacity 350 tHNO3/day) we have determined the project campaign specific emission factor at value of 3.57 kgN2O/tHNO3.

$EF_n = PE_n / NAP_n (tN_2O/tHNO_3)$

Because the project emission factor measured was higher than the moving average EF of the campaigns on this line so far, we have used the actual project EF for the calculation of the quantity of emission reductions generated during this campaign.

# T 4 Baseline emission factor

**BASELINE EMISSION FACTOR**

| *Parameter* | Operating Hours | Nitric Acid Production | N2O Concentration | Gas Volume Flow | Ammonia Flow Rate | Ammonia to Air Ratio | Oxidation Temperature | Oxidation Pressure | AMS in Operation | Nitric Acid Production NCSG |
|---|---|---|---|---|---|---|---|---|---|---|
| *Code* | OH | NAP | NCSG | VSG | AFR | AIFR | OT | OP | | NAP |
| *Unit* | h | t/h | mg N2O/Nm3 | Nm3/h | Nm3/h | % | °C | kPa | h | t/h |
| **Elimination of extreme values** | | | | | | | | | | |
| Lower limit | | 0 | 0 | 0 | 0 | 0 | - 50 | 0 | | 0 |
| Upper Limit | | 50.00 | 3 000 | 120 000 | 10 000 | 20.00 | 1 200 | 1 000 | | 50 |
| **Raw Data Measured Range** | | | | | | | | | | |
| Count | **4 524** | 5 074 | 4 476 | 4 623 | 5 148 | 4 843 | 5 235 | 5 232 | 4 155 | 4 879 |
| *as % of Dataset* | *86%* | *97%* | *85%* | *88%* | *98%* | *92%* | *100%* | *100%* | *79%* | *93%* |
| Minimum | | - | 0 | 10 | 1 | 0 | 0 | 0 | | - |
| Maximum | | 16.63 | 1 864 | 90 517 | 6 221 | 19.99 | 906 | 626 | | 17 |
| Mean | | 11.64 | 1 100 | 67 849 | 4 974 | 10.52 | 794 | 545 | | 12 |
| Standard Deviation | | 5.03 | 298 | 11 542 | 1 802 | 1.62 | 258 | 118 | | 5 |
| Total | | 59 042 | | | | | | | | 56 309 |
| N2O Emissions ( VSG * NCSG * OH) | 338 | t N2O | | | | | | | | |
| Emission Factor | 5.40 | kgN2O / tHNO3 | | | | | | | | |
| **Permitted Range** | | | | | | | | | | |
| Minimum | | | | | 4 500 | 0 | 880 | 0 | | |
| Maximum | | | | | 7 500 | 11.70 | 910 | 800 | | |
| **Data within the permitted range** | | | | | | | | | | |
| Count | **4 087** | | 3 816 | 3 994 | | | | | 4 155 | |
| *as % of Operating Hours* | ***90%*** | | *84%* | *88%* | | | | | *92%* | |
| Minimum | | | 381 | - | | | | | | |
| Maximum | | | 1 864 | 77 232 | | | | | | |
| Mean | | | 1 115 | 64 988 | | | | | | |
| Standard Deviation | | | 148 | 14 287 | | | | | | |
| N2O Emissions ( VSG * NCSG * OH) | 328 | t N2O | | | | | | | | |
| Emission Factor | 5.24 | kgN2O / tHNO3 | | | | | | | | |
| **Data within the confidence interval** | | | | | | | | | | |
| 95% Confidence interval | | | | | | | | | | |
| Lower bound | | | 825 | 36 985 | | | | | | |
| Upper bound | | | 1 406 | 92 991 | | | | | | |
| Count | | | 3 482 | 3 816 | | | | | | |
| *as % of Operating Hours* | | | *77%* | *84%* | | | | | | |
| Minimum | | | 825 | 48 852 | | | | | | |
| Maximum | | | 1 404 | 77 232 | | | | | | |
| Mean | | | 1 108 | 68 019 | | | | | | |
| Standard Deviation | | | 127 | 2 721 | | | | | | |
| **N2O Emissions ( VSG * NCSG * OH)** | **341** | **t N2O** | | | | | | | | |
| **Emission Factor (EF_BL)** | **5.45** | **kgN2O / tHNO3** | | | | | | | | |

# T 5 Project emission factor

| PROJECT EMISSION FACTOR | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *Parameter* | Operating Hours | Nitric Acid Production | N2O Concentration | Gas Volume Flow | Ammonia Flow Rate | Ammonia to Air Ratio | Oxidation Temperature | Oxidation Pressure |
| *Code* | OH | NAP | NCSG | VSG | AFR | AIFR | OT | OP |
| *Unit* | h | t/h | mg N2O/Nm3 | Nm3/h | Nm3/h | % | °C | kPa |
| **Elimination of extreme values** | | | | | | | | |
| Lower limit | | 0 | 0 | 0 | 0 | 0 | - 50 | 0 |
| Upper Limit | | 50.00 | 3 000 | 120 000 | 10 000 | 20.00 | 1 200 | 1 000 |
| **Raw Data Measured Range** | | | | | | | | |
| Count | **6 100** | 8 857 | 5 966 | 6 014 | 12 398 | 6 262 | 12 398 | 12 398 |
| *as % of Dataset* | *49%* | *71%* | *48%* | *48%* | *100%* | *50%* | *100%* | *100%* |
| Minimum | | 0.67 | 21 | 3 043 | 126 | 1 | 14 | 1 |
| Maximum | | 14.70 | 2 188 | 83 576 | 8 000 | 19.99 | 1 100 | 693 |
| Mean | | 9.52 | 708 | 70 624 | 3 654 | 10.43 | 490 | 546 |
| Standard Deviation | | 4.96 | 253 | 4 057 | 2 871 | 1.22 | 400 | 112 |
| Total | | 84 321 | | | | | | |
| N2O Emissions ( VSG * NCSG * OH) | 305 | t N2O | | | | | | |
| Emission Factor | 3.62 | kgN2O / tHNO3 | | | | | | |
| **Data within the confidence interval** | | | | | | | | |
| 95% Confidence interval | | | | | | | | |
| Lower bound | | | 213 | 62 673 | | | | |
| Upper bound | | | 1 204 | 78 575 | | | | |
| Count | | | 5 592 | 5 734 | | | | |
| *as % of Operating Hours* | | | *92%* | *94%* | | | | |
| Minimum | | | 297 | 62 694 | | | | |
| Maximum | | | 1 204 | 78 571 | | | | |
| Mean | | | 700 | 70 511 | | | | |
| Standard Deviation | | | 247 | 2 880 | | | | |
| **N2O Emissions ( VSG * NCSG * OH)** | **301** | **t N2O** | | | | | | |
| **Actual Project Emission Factor (EF_PActual)** | **3.57** | **kgN2O / tHNO3** | | | | | | |
| **Abatement Ratio** | **34.5%** | | | | | | | |
| **Moving Average Emission Factor Correction** | **Actual Factors** | **Moving Average Rule** | | | | | | |
| **1** | 1.92 | 1.92 | | | | | | |
| **2** | 3.01 | 3.01 | | | | | | |
| **3** | 3.57 | 3.57 | | | | | | |
| **4** | - | | | | | | | |
| **Project Emission Factor (EF_P)** | **3.57** | **kgN2O / tHNO3** | | | | | | |
| **Abatement Ratio** | **34.5%** | | | | | | | |

# MONITORING REPORT

**PROJECT:** ACHEMA UKL nitric acid plant $N_2O$ abatement project
**LINE:** Line 4
**MONITORING PERIOD:**
**FROM:** 03/08/2010

**TO:** 09/03/2011

Prepared by:

VERTIS

VERTIS FINANCE

www.vertisfinance.com

# Table of Contents

# 1. EXECUTIVE SUMMARY

This monitoring report determines baseline emission factor for the Line 4 of ACHEMA UKL nitric acid plant and quantity of emission reduction generated during the third project campaign on Line 4.

The first project campaign on Line 4 started on 01/08/2008. Secondary catalyst was installed on 06/10/2008. Total quantity of emission reductions generated during the third project period from 03/08/2010 through 09/03/2011 on Line 4 is **98 976 ERUs**.

**T 1 Emission reduction calculations**

| EMISSION REDUCTION | | | |
|---|---|---|---|
| Baseline Emission Factor | EF_BL | 7.73 | kgN2O/tHNO3 |
| Project Campaign Emission Factor | EF_P | 2.34 | kgN2O/tHNO3 |
| Nitric Acid Produced in the Baseline Campaign | NAP_BL | 58 683 | tHNO3 |
| Nitric Acid Produced in the NCSG Baseline Campaign | NAP_BL_NCSG | 58 683 | tHNO3 |
| Nitric Acid Produced in the Project Campaign | NAP_P | 59 235 | tHNO3 |
| GWP | GWP | 310 | tCO2e/tN2O |
| **Emission Reduction** | **ER** | **98 976** | **tCOe** |
| *ER=(EF_BL-EF_P)*NAP_P*GWP/1000* | | | |
| **Abatement Ratio** | | **75.9%** | |

| EMISSION REDUCTION PER YEAR | | | |
|---|---|---|---|
| Year | 2009 | 2010 | 2011 |
| Date From | | 03 Aug 2010 | 01 Jan 2011 |
| Date To | | 31 Dec 2010 | 09 Mar 2011 |
| Nitric Acid Production | | 38 627 | 20 608 |
| **Emission Reduction** | | **64 542** | **34 434** |
| *ER_YR = ER * NAP_P_YR / NAP_P* | | | |

Baseline emission factor established for the Line 4 during baseline measurement carried from 28/12/2007 through 31/07/2008 is 7.73 $kgN_2O/tHNO_3$.

Project emission factor during the third project campaign after installation of secondary catalysts on Line 4, which started on 03/08/2010 and went through 09/03/2011 with secondary catalyst installed and commissioned on 06/10/2008, is 2.34 $kgN_2O/tHNO_3$.

During the project campaign 59 235 tonnes of nitric acid was produced.

# 2. DESCRIPTION OF THE PROJECT ACTIVITY

Purpose of the Project (the “Project”) is the reduction of nitrous oxide ($N_2O$) emissions from nitric acid production Lines at the UKL-7 nitric acid plant of AB Achema (“Achema” or “the Company”). The Company is situated in Jonava, Lithuania.

Achema has installed and operates secondary $N_2O$ reduction catalysts underneath the primary catalyst precious metal catching and catalytic gauzes package in the ammonium burners of the UKL-7 nitric acid plant.

This monitoring report contains information on Line 4 emission reductions including information on baseline emission factor setting for the Line 4.

The separate treatment of nitric acid lines and overlapping of the monitoring periods are allowed by the clarification issued Joint Implementation Supervisory Committee: “CLARIFICATION REGARDING OVERLAPPING MONITORING PERIODS UNDER THE VERIFICATION PROCEDURE UNDER THE JOINT IMPLEMENTATION SUPERVISORY COMMITTEE”. The Project meets all the requirements set out by the clarification:

1. The Project is composed of clearly identifiable components for which emission reductions or enhancements of removals are calculated independently; and

2. Monitoring is performed independently for each of these components, i.e. the data/parameters monitored for one component are not dependent on/effect data/parameters (to be) monitored for another component; and

3. The monitoring plan ensures that monitoring is performed for all components and that in these cases all the requirements of the JI guidelines and further guidance by the JISC regarding monitoring are met.

# 3. BASELINE SETTING

Baseline emission factor for line 4 has been established on the Line-specific basis. Campaign used for baseline measurements on the line 4 has been carried out from 28/12/2007 through 31/07/2008.

$N_2O$ concentration and gas volume flow are monitored by monitoring system complying with requirements of the European Norm 14181.

Monitoring system provides separate readings for $N_2O$ concentration and gas flow volume for every hour of operation as an average of the measured values for the previous 60 minutes.

Measurement results can be distorted before and after periods of downtime or malfunction of the monitoring system and can lead to mavericks. To eliminate such extremes and to ensure a conservative approach, the following statistical evaluation is applied to the complete data series of $N_2O$ concentration as well as to the data series for gas volume flow. The statistical procedure is applied to data obtained after eliminating data measured for periods where the plant operated outside the permitted ranges:

a) Calculate the sample mean (x)
b) Calculate the sample standard deviation (s)
c) Calculate the 95% confidence interval (equal to 1.96 times the standard deviation)
d) Eliminate all data that lie outside the 95% confidence interval
e) Calculate the new sample mean from the remaining values (volume of stack gas (VSG) and $N_2O$ concentration of stack gas (NCSG))

The average mass of $N_2O$ emissions per hour is estimated as product of the NCSG and VSG. The $N_2O$ emissions per campaign are estimates product of $N_2O$ emission per hour and the total number of complete hours of operation of the campaign using the following equation:

$$BE_{BC} = VSG_{BC} * NCSG_{BC} * 10^{-9} * OH_{BC} \ (tN_2O)$$

The Line specific baseline emissions factor representing the average $N_2O$ emissions per tonne of nitric acid over one full campaign is derived by dividing the total mass of $N_2O$ emissions by the total output of 100% concentrated nitric acid during baseline campaign.

The overall uncertainty of the monitoring system has been determined by the QAL2 report and the measurement error is expressed as a percentage (UNC). The $N_2O$ emission factor per tonne of nitric acid produced in the baseline period (EFBL) has been then be reduced by the percentage error as follows:

$$EF_{BL} = (BE_{BC} / NAP_{BC}) \ (1 – UNC/100) \ (tN_2O/tHNO_3)$$

where:

| Variable | Definition |
|---|---|
| $EF_{BL}$ | Baseline $N_2O$ emissions factor ($tN_2O/tHNO_3$) |
| $BE_{BC}$ | Total $N_2O$ emissions during the baseline campaign ($tN_2O$) |
| $NCSG_{BC}$ | Mean concentration of $N_2O$ in the stack gas during the baseline campaign ($mgN_2O/m^3$) |
| $OH_{BC}$ | Operating hours of the baseline campaign (h) |
| $VSG_{BC}$ | Mean gas volume flow rate at the stack in the baseline measurement period ($m^3/h$) |
| $NAP_{BC}$ | Nitric acid production during the baseline campaign ($tHNO_3$) |
| UNC | Overall uncertainty of the monitoring system (%), calculated as the combined uncertainty of the applied monitoring equipment. |

## 3.1 Measurement procedure for $N_2O$ concentration and tail gas volume flow

### 3.1.1 Tail gas $N_2O$ concentration

$N_2O$ concentration is measured by extractive measurement system. Tail gas samples are taken from the Line 4 tail gas duct at sampling point located after expansion turbine and transported by sample Line to the Monitoring room A, where the analyzer is located.

Tail gas samples are filtered and conditioned in the condensation dryer (4°C), so $N_2O$ concentration is measured on a dry basis.

$N_2O$ concentration is measured by concentration infrared absorption principle meters Xentra 4900 using GFX monitoring technology.

Recently there are 8 production lines. $N_2O$ concentration is measured by 3 concentration meters on a switched basis.

$N_2O$ concentration measured data are sent from the analyzer on a 2 sec basis in a form of 4-20mA signal to the datalogger and processed further.

### 3.1.2 Tail gas flow rate, pressure and temperature

Tail gas flow, pressure and temperature is measured by ultrasonic Durag DF-L 200 flowmeters based on ultrasonic pulse fly time across the entire duct cross-section. Tail gas flow, pressure and temperature measured data are sent from the flow meter on a 2 sec basis in a form of 4-20mA signal to the datalogger and processed further.

## 3.2 Permitted range of operating conditions of the nitric acid plant

Under certain circumstances, the operating conditions during the measurement period used to determine baseline $N_2O$ emission factor may be outside the permitted range or limit corresponding to normal operating conditions. $N_2O$ baseline data measured during hours

where the operating conditions were outside the permitted range have been eliminated from the calculation of the baseline emissions factor.

Normal ranges for operating conditions have been determined for the following parameters:

oxidation temperature;
oxidation pressure;
ammonia gas flow rate,
air input flow rate.

The permitted range for these parameters has been established using the plant operation manual, as described in the PDD..

## 3.3 Historic Campaign Length

The average historic campaign length ($CL_{normal}$) defined as the average campaign length for the historic campaigns used to define operating condition (the previous five campaigns), has not been used as a cap on the length of the baseline campaign because of shorter project campaign.

# 4. PROJECT EMISSIONS

During the first project campaign on line 4 the tail gas volume flow in the stack of the nitric acid plant as well as $N_2O$ concentration have been measured on the continuous basis.

### 4.1.1 Estimation of campaign-specific project emissions factor

The monitoring system was installed using the guidance document EN 14181 and provides separate readings for $N_2O$ concentration and gas flow volume for every hour of operation. Same statistical evaluation that was applied to the baseline data series has been applied to the project data series:

a) Calculate the sample mean (x)
b) Calculate the sample standard deviation (s)
c) Calculate the 95% confidence interval (equal to 1.96 times the standard deviation)
d) Eliminate all data that lie outside the 95% confidence interval
e) Calculate the new sample mean from the remaining values

$$PE_n = VSG * NCSG * 10^{-9} * OH \ (tN_2O)$$

where:

| **Variable** | **Definition** |
|---|---|
| VSG | Mean stack gas volume flow rate for the project campaign ($m^3/h$) |
| NCSG | Mean concentration of $N_2O$ in the stack gas for the project campaign ($mgN_2O/m^3$) |
| $PE_n$ | Total $N_2O$ emissions of the $n^{th}$ project campaign ($tN_2O$) |
| OH | Is the number of hours of operation in the specific monitoring period (h) |

### 4.1.2 Derivation of a moving average emission factor

Because the project emission factor measured was lower than the moving average EF of the campaigns on this line so far, we have used the average EF for the calculation of the quantity of emission reductions generated during this campaign.

## 4.2 Minimum project emission factor

The minimum average emission factor established factor will be established after 10th project campaign.

## 4.3 Project Campaign Length

Project campaign production of nitric acid has been below defined nameplate capacity and thus all NAP produced from date of installation of secondary catalysts has been used for calculation of emission reductions.

## 4.4 Leakage

No leakage calculation is required.

## 4.5 Emission reductions

The emission reductions for the project activity during this campaign have been determined by deducting the campaign-specific emission factor from the baseline emission factor and multiplying the result by the production output of 100% concentrated nitric acid over the campaign period and the GWP of $N_2O$:

$$ER = (EFBL - EFP) * NAP * GWPN_2O \ (tCO_2e)$$

Where:

| **Variable** | **Definition** |
|---|---|
| ER | Emission reductions of the project for the specific campaign ($tCO_2e$) |
| NAP | Nitric acid production for the project campaign ($tHNO_3$). The maximum value of NAP shall not exceed the design capacity. |
| EFBL | Baseline emissions factor ($tN_2O/tHNO_3$ ) |
| EFP | Emissions factor used to calculate the emissions from this particular campaign (i.e. the higher of $EF_{ma,n}$ and $EF_n$) |

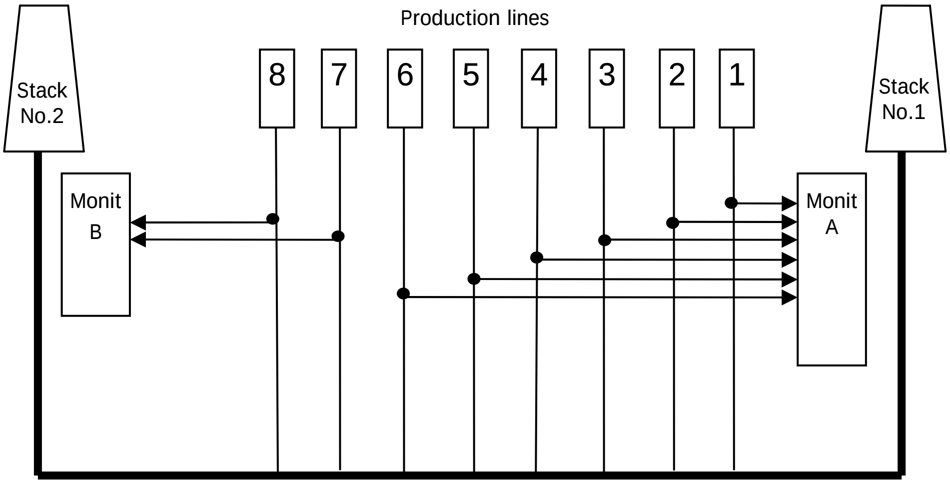
# 5. MONITORING PLAN

### Purpose of the monitoring plan

The purpose of the monitoring plan is to describe the system used to monitor emissions of $N_2O$ from the plant in such a way that is compliant with the prescriptions of the AM0034/Version 02.

### Plant description

The UKL-7 nitric acid plant comprises 8 production Lines numbered from 1 through 8, each with its own burner, absorption column and expansion turbine. Each production Line represents a separate nitric acid production unit independent from each other. The tail gasses from each Line are after expansion turbines led to a common stack bus and vented through two interconnected stacks.



Primary catalyst is changed at different times thus it is necessary to measure the emissions from each Line individually. This means that eight separate sets of monitoring equipment are installed to measure tail gas flow, nitric acid production, nitric acid concentration, and the operating conditions. $N_2O$ concentration in the tail gas is measured by 3 switched concentration meters.

### Monitoring System architecture

Methodology AM0034/Version 02 requires installation of an $N_2O$ monitoring system that includes both a gas volume flow meter to determine the tail gas mass volume flow and an infrared gas analyser to determine the concentration of $N_2O$.

But tail gas $N_2O$ concentration meter and tail gas volume flow meter alone are not sufficient for a JI project purposes. In order of being able to calculate the baseline emission factor expressed as tonnage of $N_2O$ in t $CO_2e$ per 1 tonne of $HNO_3$ (100%), it is necessary to include also $HNO_3$ measurement, and in order of being able to document normal operating conditions it is necessary to include also operating conditions measurement.

Because of this we use the term Monitoring System (MS) to describe entire monitoring system directly and indirectly used for the JI purposes, while Automated Measurement System (AMS) covers only $N_2O$ emissions and tail gas mass volume part of the MS.

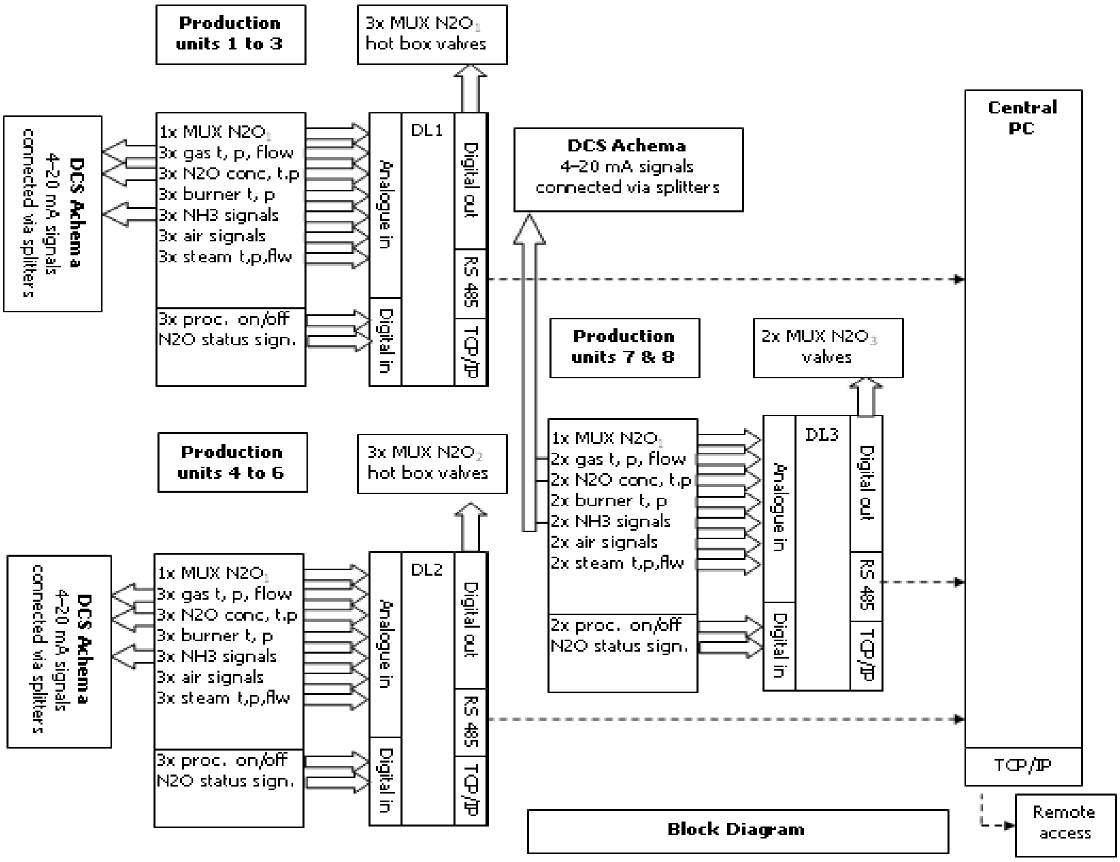
Monitoring System (MS) for purpose of this monitoring plan means:

**monitoring system measuring operational conditions;**
Ammonia volume flow
Ammonia temperature
Ammonia pressure
Primary air volume flow
Primary air temperature
Primary air pressure
Oxidation temperature
Oxidation pressure

**nitric acid 100% concentrate production;**
Nitric acid concentration
Nitric acid flow
Nitric acid temperature

**and newly installed measurement devices for measurement of N2O concentration and tail gas flow, temperature and pressure (AMS)**
$N_2O$ concentration in the stack
Stack volume flow rate
Stack gas temperature
Stack gas pressure

Incorporation of the AMS into the MS by interfacing already existing and newly installed measurement devices is documented by the diagram below.



### $N_2O$ automated measurement system

Main purpose of the $N_2O$ automated measurement system (AMS) is to measure total mass of $N_2O$ emitted during particular campaigns (both baseline and project). In order of calculation of total mass of $N_2O$ emitted during particular campaign it is necessary to measure on an extractive basis the $N_2O$ concentration in a tail gas and on a non-extractive basis tail gas flow, pressure and temperature.

### $N_2O$ concentration

$N_2O$ concentration is measured by extractive measurement system. Tail gas samples are taken from respective tail gas ducts at sampling points located after expansion turbines and transported by heated sample lines to the Monitoring room A located next to the main production hall. This applies to 2 concentration meters measuring lines 1-3 and lines 4-6. lines 7-8 are measured by third concentration meter located at the other side of the production hall (Monitoring room B) physically closer to respective production lines 7 and 8.

Tail gas samples are filtered and conditioned in the condensation dryer (4°C), so $N_2O$ concentration is measured on a dry basis. Correction of dry basis ppmV value to real wet tail

gas conditions based on steam flow injected into the system is part of both - the project emissions calculations and baseline emission factor calculations.

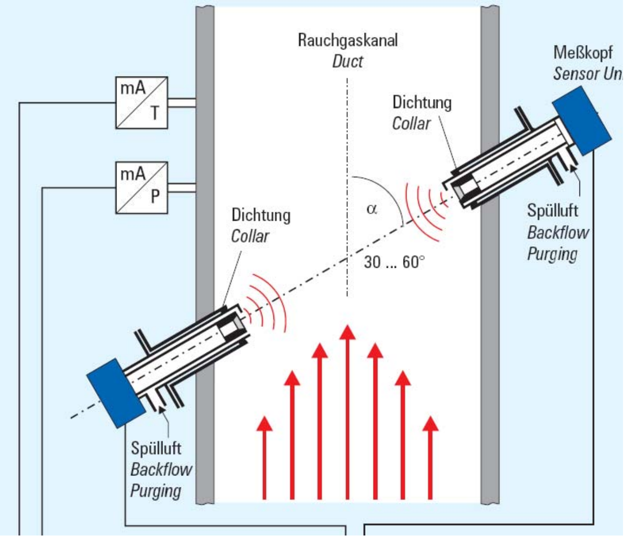
$N_2O$ concentration is measured by concentration infrared absorption principle meters Xentra 4900 using GFX monitoring technology.

Recently there are 8 production Lines. $N_2O$ concentration is measured by 3 concentration meters on a switched basis. Tail gas samples are automatically switched. Under-sampling uncertainty is part of both - the project emissions calculations and baseline emission factor calculations.

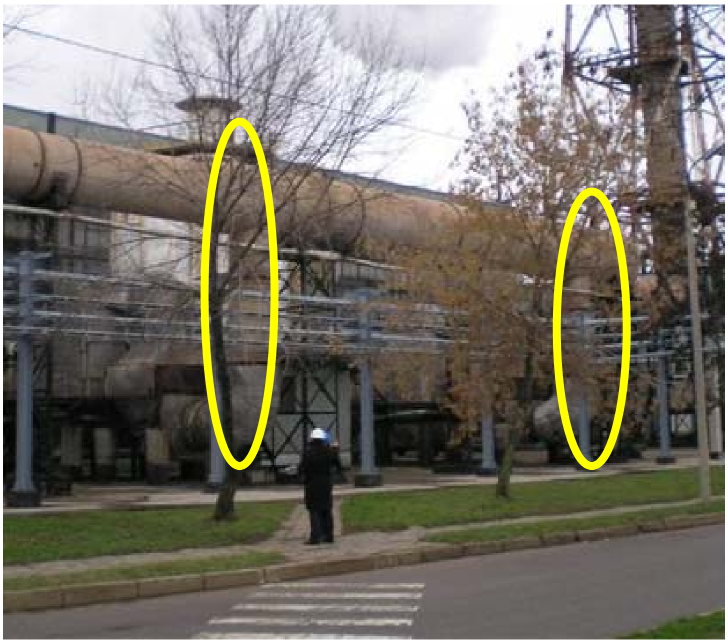
$N_2O$ concentration measured data are sent from the concentration meter on a 2 sec basis in a form of 4-20mA signal to the datalogger and processed further.

## Tail gas flow, pressure and temperature

Tail gas flow is measured by ultrasonic Durag DF-L 200 flowmeters based on ultrasonic pulse fly time across the entire duct cross-section.



The tail gas ducts do not allow any optimum location to perform the flow monitoring. The only possible location is the quite short vertical tube behind the 90° “knee”.



Since the flow is not really laminar, a classical Pitot tube one point solution wouldn't allow good results. The ultrasonic system is under these conditions superior to differential pressure. Cross duct monitoring is more accurate than a couple of discrete point averaged pressure.

Tail gas flow, pressure and temperature measured data are sent from the flow meter on a 2 sec basis in a form of 4-20mA signal to the datalogger and processed further.

**Tail gas steam injection elimination**

Steam injected into the Achema UKL-7 tail gas for purpose of increasing the turbine output is eliminated from the tail gas mass flow calculation by following formulae:

flow - STVF=L1_Flow_N2O*(273.15/(273.15+L1_Temp))*(L1_Press/101.325)*((100-L1_Humi)/100)

where Humi (water content)=

(L1_Flow_steam*1.2436)/(L1_Flow_N2O*(273.15/(273.15+L1_Temp))*(L1_Press/101.325))*100+0.6

where 1.2436 is the conversion factor from kg/h to Nm3/h and 0.6% is a value of humidity present in a flue gas permanently without steam injection

The Flow_steam parameter necessary for calculation of the water content in the dataloggers is provided in the kg/h unit.

Achema measures steam flow in kg/h using formula Q=C*sqrt(dp) , where C is flow constant which is already integrated using an orifice plate sizing program. The orifice plate calculation for injection steam has been done for temperature 250˚C and pressure 6 bar.

Flow steam in kg/h measured by using the constant steam T and P values is then recalculated to actual steam T and P values valid for relevant hours and as result the STVF value cleaned of the steam injected is used for further emission reductions calculations.

### EN14181 compliance

As required by the AM0034/Version 02 methodology the $N_2O$ automated measurement system (AMS) complies with requirements of the technical norm EN14181. $N_2O$ AMS consists from the $N_2O$ concentration meter and integrated flowmeter (F, T, P). Both measurement devices are QAL1 certified (concentration meter for the $N_2O$ measurand specifically) and after full commissioning of the monitoring system there was the QAL2 test carried out by an independent laboratory certified according to ISO17025.

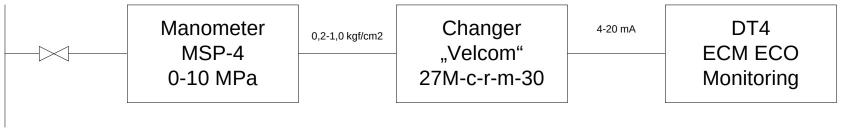
### Operating conditions

For purpose of the baseline emissions factor setting it is necessary to monitor and report operating conditions in all 8 burners. Namely:

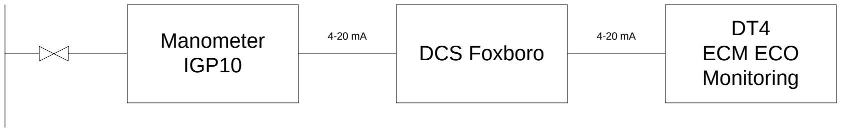
Ammonia flow
Ammonia temperature
Ammonia pressure
Primary air flow
Primary air temperature
Primary air pressure
Oxidation temperature
Oxidation pressure

All these parameters are measured by the plant monitoring system as presented on diagrams below:

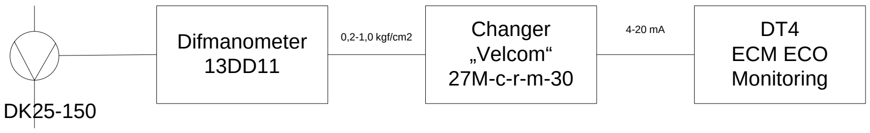
P in mixer 1-6 line



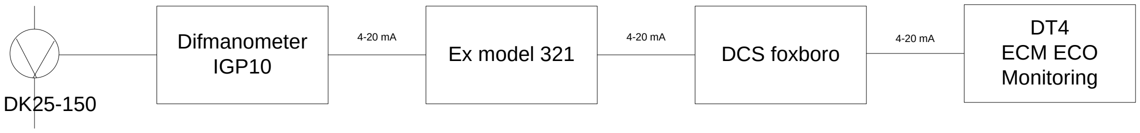
P in mixer 7-8 line



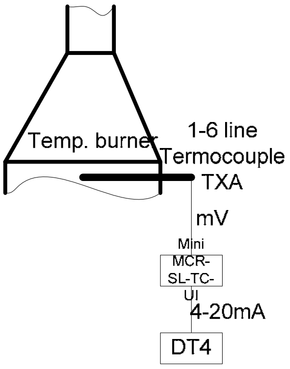
NH3 to mixer 1-6 line

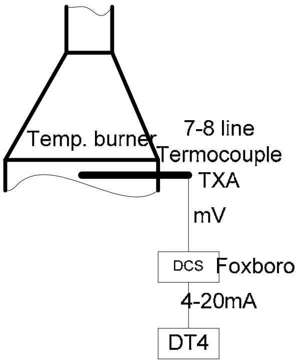


NH3 to mixer 7-8 line



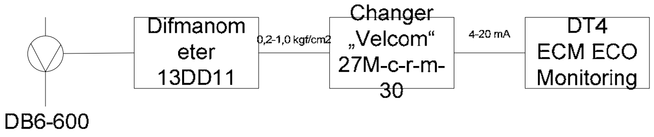
T in burner



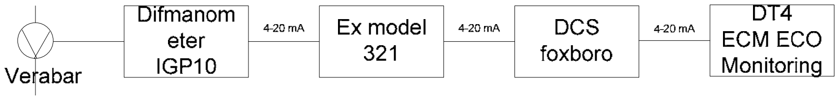


Air to mixer

1-6 line



7-8 line



Signals obtained from these measurement devices from production Lines 1-6 are converted from pneumatic to 4-20mA analog signals. Operating conditions measurement devices installed in production Lines 7-8 provide the 4-20mA signals which are digitalized and provided to the monitoring system dataloggers, which process them further. Maintenance procedures for the ammonia oxidation parameters follow the existing procedures for the operation of the nitric acid plant.

### Nitric acid production

Nitric acid concentration is based on two components: nitric acid and water. Standard monitoring method is on-Line refractometry. Measurement of nitric acid (100%) mass volume production per campaign is necessary for calculation of the baseline emissions factor. Nitric acid concentration on all 8 Lines is measured by K-Patents PR-23-GP refractometers.

This analyzer is applying a prism to “return” a generated optical beam back to an LCD detector.

The detector is measuring refraction of monitored liquid based on known refraction of water and nitric acid. The instrument is calibrated for percent concentration of nitric acid. The analyzer is mounted on DIN-flange 2656, PN25 DN80. The optical prism does not require cleaning.

PR-23-GP characteristics:

Measuring RI is a direct concentration measurement principle. No need to rely or convert magnitudes.
Digital instrument – no calibration drift
As it is a robust instrument it is maintenance free
Dual connectivity if the installation positions allow.
On-Line data logging, through Ethernet, on whichever web browser.
No influence by bubbles or particles. It is very common that air enters the process pipeline and still the refractometer measures accurately.

Nitric acid concentration data are in an analog 4-20mA format provided to dataloggers which process these signals further.

In order of being able to calculate total mass volume of nitric acid 100% concentrate produced during the baseline campaign it is necessary to monitor also nitric acid flow and temperature. Measurement of pressure is not necessary for determination of the nitric acid mass volume flow, because nitric acid is in form of liquid and as such it has stabile pressure characteristic.

Signals obtained from the nitric acid flow and temperature measurement devices from production Lines 1-6 are converted from pneumatic to 4-20mA analog signals. Nitric acid flow and temperature measurement devices installed in production Lines 7-8 provide the 4-20mA signals which are digitalized and provided to the monitoring system dataloggers, which process them further.

After installation of refractometers there have been occurrences of their failure and following repair service by the manufacturer. For this period starting from 31/10/2007 and ending on 10/09/2008 project uses $HNO_3$ concentration data provided by the laboratory measurements.

# 6. QAL 2 CALIBRATION ADJUSTMENTS

## 6.1 Applied principle

As required in the applicable norm EN14181: “The relation between the instrument readings of the recording measuring procedure and the quantity of the measuring objects has to be described by using a suitable convention method. The results have to be expressed by a regression analysis.”

As it is described in the Calibration Report issued by Airtec laboratory, the measurement results derived from the analog signals (4 mA to 20 mA) provided the installed instruments have been compared to the comparative measurements.

Linearity check of the instruments characteristics is stated in the QAL2 Calibration Report issued by the laboratory. The valid ranges of Linearity are determined by statistical analysis according to the guideline and the Linearity assumptions are further used in the Calibration Report establishing Linear regression Lines.

The general formula of the regression Line, established in the EN14181 and used in the Calibration Report is:

$$Y = a + bX$$

where:

X is the measured value of the instrument in mA
Y is the value of the parameter being objective of the measurement
a is a constant of the regression Line
b is the slope of the regression Line

After a comparative test the laboratory issued the old and new regression Lines properties, namely “a” and “b” applying for all of the measured parameters that are subject to calibration as stated in the Calibration Report.

The QAL2 corrections are based on the fact that the actual analog current outputs (in mA) of the measurement instruments are relevant for both, the old and new regression Lines:

$$Xo=Xn=X$$

where:

Xn: X new
Yo: Y old

This allows us to derive a calibrating formula that gives us the corrected value of the measured physical parameters. The applied calibrating equation is:

$$Yn=An + (Bn/Bo)*(Yo-Ao)$$

In order to take into account the properties of the AMS and their implication to the QAL 2 implementation in the model, we will further introduce several remarks to the conversion and normalization of the data.

The units returned by the AMS “nm3/h” stand for normalized cubic meters of the gas volume at normal gas conditions (0° C, 1 atm.).

## 6.2 Stack gas volume flow

Based on the real conditions measured and applied by the AMS for normalization (TSG in °C and PSG in hPa), the stack gas volume flow values are converted to real conditions before the regression analysis using the ideal gas law. The actual gas volume flow rates are derived from gas velocity measurements, therefore, before applying the regression analysis the gas speed is calculated from the volume flow and the duct cross-section and is fed into the calibrating equation. The calibrated values derived from the calibrating equation then converted back to normalized units using the calibrated real conditions (calibrated TSG and PSG). The normalized calibrated stack gas flow rates are further fed into the emission calculation model for further processing as set out by the Approved Baseline and Monitoring Methodology AM_0034.

## 6.3 Nitric acid concentration in stack gas

The nitric acid concentration in the raw data set from the AMS is in $mgN_2O/m_3$. The concentration was converted to ppmv to make it compatible with the regression Lines parameters. The nitrous gas concentration values are then calibrated using the provided regression Lines parameters and are input in the model.

## 6.4 Stack gas Temperature

The stack gas temperature was calibrated by the regression conversion formula

## 6.5 Stack gas Pressure

The calibration report provides us with a regression Line for the stack gas pressure. We calibrate the readings of the measurements system using the regression formula and applying the values (in kPa).

# 7. EMISSION REDUCTION CALCULATIONS

Table T 2 illustrates the establishment of historic campaign length based on 5 previous campaigns. Average production in 5 campaigns preceding the baseline campaign was 65 823 $tHNO_3$ and time duration was on average 275 days. Table contains also information on suppliers of primary catalysts for the line 4.

## T 2 Historic campaigns

| **Line** | **ACHEMA UKL-4** | **Production** | **Start** | **End** | **Days** | **Production per day** | **Primary Catalyst** | **Composition** |
|---|---|---|---|---|---|---|---|---|
| **Historic Campaigns** | **1** t HNO3 | 69 782 | 18 Apr 2003 | 11 Dec 2003 | 237 | 294 | Johnson Matthey | 90/5/5 |
| | **2** t HNO3 | 65 420 | 11 Dec 2003 | 06 Dec 2004 | 361 | 181 | Johnson Matthey | 90/5/5 |
| | **3** t HNO3 | 66 129 | 07 Dec 2004 | 08 Nov 2005 | 336 | 197 | Umicore | 95/5 |
| | **4** t HNO3 | 66 826 | 22 Mar 2006 | 23 Nov 2006 | 246 | 272 | Johnson Matthey | n.a. |
| | **5** t HNO3 | 60 959 | 23 Nov 2006 | 04 Jun 2007 | 193 | 316 | Johnson Matthey | n.a. |
| **Average HNO3 production** | t HNO3 | **65 823** | | | **275** | **240** | | |
| **Project Campaigns** | **BL** t HNO3 | 58 683 | 28 Dec 2007 | 31 Jul 2008 | 216 | 272 | Johnson Matthey | n.a. |
| | **PL** t HNO3 | 59 235 | 03 Aug 2010 | 09 Mar 2011 | 218 | 272 | Johnson Matthey | 90/5/5 |

It is business as usual scenario in Achema UKL-7 plant to keep using primary catalysts from several suppliers and with several compositions. Selection of primary catalysts is determined by technical parameters of their use and price levels offered by suppliers in specific time. Primary catalysts used during the baseline campaign, if other than used in previous campaign/s, did not increase emissions of N2O as confirmed by relevant statements provided to the verifier.

T 3 and Chart C 1 define the length of the baseline campaign. Baseline campaign measurements for this project campaign started on 28/12/2007 and continued through 31/07/2008 when the 58 683 $tHNO_3$ nitric acid production was reached. The measurement of baseline Nitrous Acid Concentration (NCSG) was carried out until production reached - $tHNO_3$ .

## T 3 Baseline campaign length

| **ACHEMA UKL-4** | **Historic Campaings End** | **Start of Baseline Measurement** | **End of Baseline Measurement NCSG** | **End of Baseline Measurement** | **End of Baseline Campaign** |
|---|---|---|---|---|---|
| **Dates** | 2007 Jun 04 | 2007 Dec 28 | 2008 Jul 31 | 2008 Jul 31 | 2008 Aug 01 |
| **Baseline Factor kgN2O/tHNO3** | - | - | 7.73 | 7.73 | 7.73 |
| **Production tHNO3** | | - | 58 683 | 58 683 | - |
| **Per Day Production tHNO3** | 239.7 | | | | |
| **Baseline less Historic Production** | **(7 140.4)** | | | | |
| **Baseline less Historic Days** | **(29.8)** | | | | |

## C 1 Baseline campaign length

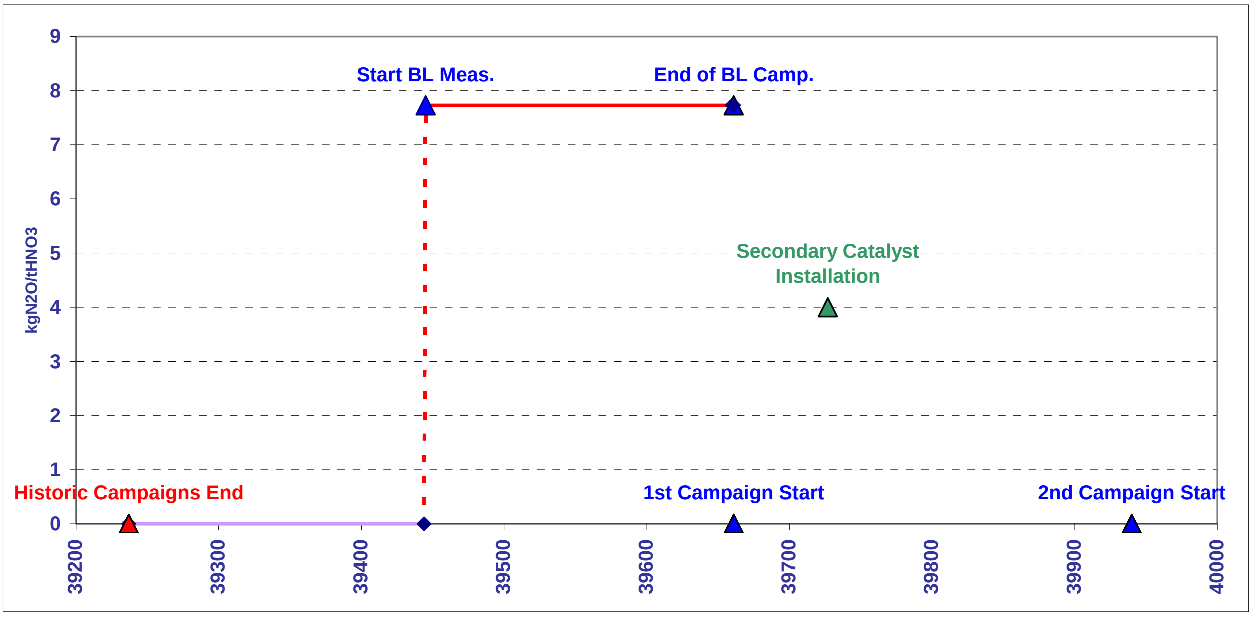


Table T 4 illustrates the calculation of the baseline emission factor on Line 4 using the method as defined in the CDM methodology AM0034 and in the PDD. We have not used overlapping approach allowed by the PDD. Baseline emission factor was determined based on raw data measured from 28/12/2007 through 31/07/2008.

Extreme values and data measured during hours when one or more of operating conditions were outside of the permitted range have been eliminated from the calculations. As a next step we have eliminated data beyond 95% confidence interval and calculated new mean values of $N_2O$ concentration and stack gas volume flow using following method:

a) Calculate the sample mean (x)
b) Calculate the sample standard deviation (s)
c) Calculate the 95% confidence interval (equal to 1.96 times the standard deviation)
d) Eliminate all data that lie outside the 95% confidence interval
e) Calculate the new sample mean from the remaining values (volume of stack gas (VSG) and $N_2O$ concentration of stack gas (NCSG))

Using the means values we have calculated the baseline emissions as set out in the PDD.

$$BE_{BC} = VSG_{BC} * NCSG_{BC} * 10^{-9} * OH_{BC}\ (tN_2O)$$

Operating hours defined as hours, when nitric acid production at least 0.1 tHNO3 and oxidation temperature at least 600˚C occurred. Calculated baseline N2O emissions were 479 $tN_2O$.

$$EF_{BL} = (BE_{BC} / NAP_{BC})\ (1 – UNC/100)\ (tN_2O/tHNO_3)$$

The UNC factor defined by the QAL2 report is 5.450%, which is further modified by an uncertainty of 0.104% due to under-sampling. As a result we have arrived to the baseline emission factor of 7.73 $kgN_2O/tHNO_3$.

Table T 5 shows the calculation of the project emission factor on Line 4 during the project campaign. Project campaign started on 03/08/2010 and went through 09/03/2011.

We have eliminated extreme values and data beyond the 95% confidence interval as prescribed by the PDD.

a) Calculate the sample mean (x)
b) Calculate the sample standard deviation (s)
c) Calculate the 95% confidence interval (equal to 1.96 times the standard deviation)
d) Eliminate all data that lie outside the 95% confidence interval
e) Calculate the new sample mean from the remaining values

Using the mean values we have calculated total mass of $N_2O$ emissions ($PE_n$) as follows:

$$PE_n = VSG * NCSG * 10\text{-}9 * OH \ (tN2O)$$

Operating hours (OH) defined as hours, when nitric acid production at least 0.1 tHNO3 and oxidation temperature at least 600˚C occurred.

By dividing total mass of $N_2O$ emissions by the nitric acid production (capped by nameplate capacity 350 tHNO3/day) we have determined the project campaign specific emission factor at value of 2.34 kgN2O/tHNO3.

$$EF_n = PE_n / NAP_n \ (tN_2O/tHNO_3)$$

Because the project emission factor measured was lower than the moving average EF of the campaigns on this line so far, we have used the average EF for the calculation of the quantity of emission reductions generated during this campaign.

# T 4 Baseline emission factor

| BASELINE EMISSION FACTOR | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Parameter* | Operating Hours | Nitric Acid Production | N2O Concentration | Gas Volume Flow | Ammonia Flow Rate | Ammonia to Air Ratio | Oxidation Temperature | Oxidation Pressure | AMS in Operation | Nitric Acid Production |
| *Code* | **OH** | **NAP** | **NCSG** | **VSG** | **AFR** | **AIFR** | **OT** | **OP** | | **NAP** |
| *Unit* | **h** | **t/h** | **mg N2O/Nm3** | **Nm3/h** | **Nm3/h** | **%** | **°C** | **kPa** | **h** | **t/h** |
| **Elimination of extreme values** | | | | | | | | | | |
| Lower limit | | 0 | 0 | 0 | 0 | 0 | - 50 | 0 | | 0 |
| Upper Limit | | 50.00 | 3 000 | 120 000 | 10 000 | 20.00 | 1 200 | 1 000 | | 50 |
| **Raw Data Measured Range** | | | | | | | | | | |
| Count | **4 564** | 4 906 | 4 891 | 4 467 | 4 733 | 5 086 | 5 161 | 4 755 | 4 028 | 4 906 |
| *as % of Dataset* | *88%* | *95%* | *94%* | *86%* | *91%* | *98%* | *100%* | *92%* | *78%* | *95%* |
| Minimum | | - | 0 | - | 266 | - | 1 | 3 | | - |
| Maximum | | 15.12 | 2 925 | 83 541 | 6 465 | 19.28 | 906 | 634 | | 15 |
| Mean | | 11.96 | 1 485 | 66 846 | 5 718 | 9.71 | 791 | 572 | | 12 |
| Standard Deviation | | 4.35 | 378 | 10 182 | 881 | 2.96 | 272 | 62 | | 4 |
| Total | | 58 683 | | | | | | | | 58 683 |
| N2O Emissions ( VSG * NCSG * OH) | 453 | t N2O | | | | | | | | |
| Emission Factor | 7.30 | kgN2O / tHNO3 | | | | | | | | |
| **Permitted Range** | | | | | | | | | | |
| Minimum | | | | | 4 500 | 0 | 880 | 0 | | |
| Maximum | | | | | 7 500 | 11.70 | 910 | 800 | | |
| **Data within the permitted range** | | | | | | | | | | |
| Count | **4 399** | | 4 152 | 4 210 | | | | | 4 028 | |
| *as % of Operating Hours* | ***96%*** | | *91%* | *92%* | | | | | *88%* | |
| Minimum | | | 511 | - | | | | | | |
| Maximum | | | 2 208 | 75 876 | | | | | | |
| Mean | | | 1 511 | 67 275 | | | | | | |
| Standard Deviation | | | 274 | 8 270 | | | | | | |
| N2O Emissions ( VSG * NCSG * OH) | 464 | t N2O | | | | | | | | |
| Emission Factor | 7.47 | kgN2O / tHNO3 | | | | | | | | |
| **Data within the confidence interval** | | | | | | | | | | |
| 95% Confidence interval | | | | | | | | | | |
| Lower bound | | | 973 | 51 066 | | | | | | |
| Upper bound | | | 2 048 | 83 484 | | | | | | |
| Count | | | 3 735 | 4 149 | | | | | | |
| *as % of Operating Hours* | | | *82%* | *91%* | | | | | | |
| Minimum | | | 1 108 | 59 513 | | | | | | |
| Maximum | | | 2 046 | 75 876 | | | | | | |
| Mean | | | 1 540 | 68 235 | | | | | | |
| Standard Deviation | | | 203 | 2 154 | | | | | | |
| **N2O Emissions ( VSG * NCSG * OH)** | **479** | **t N2O** | | | | | | | | |
| **Emission Factor (EF_BL)** | **7.73** | **kgN2O / tHNO3** | | | | | | | | |

# T 5 Project emission factor

PROJECT EMISSION FACTOR

| *Parameter* | Operating Hours | Nitric Acid Production | N2O Concentration | Gas Volume Flow | Ammonia Flow Rate | Ammonia to Air Ratio | Oxidation Temperature | Oxidation Pressure |
|---|---|---|---|---|---|---|---|---|
| *Code* | OH | NAP | NCSG | VSG | AFR | AIFR | OT | OP |
| *Unit* | h | t/h | mg N2O/Nm3 | Nm3/h | Nm3/h | % | °C | kPa |
| **Elimination of extreme values** | | | | | | | | |
| Lower limit | | 0 | 0 | 0 | 0 | 0 | - 50 | 0 |
| Upper Limit | | 50.00 | 3 000 | 120 000 | 10 000 | 20.00 | 1 200 | 1 000 |
| **Raw Data Measured Range** | | | | | | | | |
| Count | **4 381** | 4 674 | 4 262 | 4 348 | 4 872 | 4 433 | 5 233 | 5 057 |
| *as % of Dataset* | *84%* | *89%* | *81%* | *83%* | *93%* | *85%* | *100%* | *97%* |
| Minimum | | 0.61 | 215 | 33 308 | 367 | 3 | 1 | 1 |
| Maximum | | 16.65 | 989 | 77 286 | 7 622 | 19.59 | 909 | 686 |
| Mean | | 12.67 | 385 | 67 218 | 5 617 | 10.35 | 761 | 593 |
| Standard Deviation | | 2.81 | 87 | 3 837 | 591 | 0.45 | 303 | 86 |
| Total | | 59 235 | | | | | | |

| | | |
|---|---|---|
| N2O Emissions ( VSG * NCSG * OH) | 113 | t N2O |
| Emission Factor | 1.91 | kgN2O / tHNO3 |

| **Data within the confidence interval** | | |
|---|---|---|
| 95% Confidence interval | NCSG | VSG |
| Lower bound | 215 | 59 697 |
| Upper bound | 555 | 74 739 |
| Count | 4 040 | 4 205 |
| *as % of Operating Hours* | *92%* | *96%* |
| Minimum | 236 | 59 701 |
| Maximum | 554 | 74 735 |
| Mean | 375 | 67 236 |
| Standard Deviation | 75 | 3 551 |

| | | |
|---|---|---|
| **N2O Emissions ( VSG * NCSG * OH)** | **110** | **t N2O** |
| **Actual Project Emission Factor (EF_PActual)** | **1.87** | **kgN2O / tHNO3** |
| **Abatement Ratio** | **75.9%** | |

| **Moving Average Emission Factor Correction** | **Actual Factors** | **Moving Average Rule** |
|---|---|---|
| **1** | 2.77 | 2.77 |
| **2** | 2.37 | 2.57 |
| **3** | 1.87 | 2.34 |
| **4** | - | |

| | | |
|---|---|---|
| **Project Emission Factor (EF_P)** | **2.34** | **kgN2O / tHNO3** |
| **Abatement Ratio** | **69.8%** | |

# MONITORING REPORT

**PROJECT:** ACHEMA UKL nitric acid plant $N_2O$ abatement project
**LINE:** Line 5
**MONITORING PERIOD:**
**FROM:** 12/08/2010

**TO:** 17/03/2011

**Prepared by:**

VERTIS

**VERTIS FINANCE**

www.vertisfinance.com

# Table of Contents

# 1. EXECUTIVE SUMMARY

This monitoring report determines baseline emission factor for the Line 5 of ACHEMA UKL nitric acid plant and quantity of emission reduction generated during the third project campaign on Line 5.

The first project campaign on Line 5 started on 02/07/2008. Secondary catalyst was installed on 02/07/2008. Total quantity of emission reductions generated during the third project period from 12/08/2010 through 17/03/2011 on Line 5 is **103 817 ERUs**.

### T 1 Emission reduction calculations

| EMISSION REDUCTION | | | |
|---|---|---|---|
| Baseline Emission Factor | EF_BL | 6.61 | kgN2O/tHNO3 |
| Project Campaign Emission Factor | EF_P | 2.22 | kgN2O/tHNO3 |
| Nitric Acid Produced in the Baseline Campaign | NAP_BL | 55 079 | tHNO3 |
| Nitric Acid Produced in the NCSG Baseline Campaign | NAP_BL_NCSG | 55 079 | tHNO3 |
| Nitric Acid Produced in the Project Campaign | NAP_P | 76 285 | tHNO3 |
| GWP | GWP | 310 | tCO2e/tN2O |
| **Emission Reduction** | **ER** | **103 817** | **tCOe** |
| *ER=(EF_BL-EF_P)*NAP_P*GWP/1000* | | | |
| **Abatement Ratio** | | **68.7%** | |

| EMISSION REDUCTION PER YEAR | | | |
|---|---|---|---|
| Year | 2009 | 2010 | 2011 |
| Date From | | 12 Aug 2010 | 01 Jan 2011 |
| Date To | | 31 Dec 2010 | 17 Mar 2011 |
| Nitric Acid Production | | 48 928 | 27 358 |
| **Emission Reduction** | | **66 585** | **37 231** |
| *ER_YR = ER * NAP_P_YR / NAP_P* | | | |

Baseline emission factor established for the Line 5 during baseline measurement carried from 29/11/2007 through 17/06/2008 is 6.61 kgN$_2$O/tHNO$_3$.

Project emission factor during the third project campaign after installation of secondary catalysts on Line 5, which started on 12/08/2010 and went through 17/03/2011 with secondary catalyst installed and commissioned on 02/07/2008, is 2.22 kgN$_2$O/tHNO$_3$.

During the project campaign 76 285 tonnes of nitric acid was produced.

# 2. DESCRIPTION OF THE PROJECT ACTIVITY

Purpose of the Project (the “Project”) is the reduction of nitrous oxide ($N_2O$) emissions from nitric acid production Lines at the UKL-7 nitric acid plant of AB Achema (“Achema” or “the Company”). The Company is situated in Jonava, Lithuania.

Achema has installed and operates secondary $N_2O$ reduction catalysts underneath the primary catalyst precious metal catching and catalytic gauzes package in the ammonium burners of the UKL-7 nitric acid plant.

This monitoring report contains information on Line 5 emission reductions including information on baseline emission factor setting for the Line 5.

The separate treatment of nitric acid lines and overlapping of the monitoring periods are allowed by the clarification issued Joint Implementation Supervisory Committee: “CLARIFICATION REGARDING OVERLAPPING MONITORING PERIODS UNDER THE VERIFICATION PROCEDURE UNDER THE JOINT IMPLEMENTATION SUPERVISORY COMMITTEE”. The Project meets all the requirements set out by the clarification:

1. The Project is composed of clearly identifiable components for which emission reductions or enhancements of removals are calculated independently; and

2. Monitoring is performed independently for each of these components, i.e. the data/parameters monitored for one component are not dependent on/effect data/parameters (to be) monitored for another component; and

3. The monitoring plan ensures that monitoring is performed for all components and that in these cases all the requirements of the JI guidelines and further guidance by the JISC regarding monitoring are met.

# 3. BASELINE SETTING

Baseline emission factor for line 5 has been established on the Line-specific basis. Campaign used for baseline measurements on the line 5 has been carried out from 29/11/2007 through 17/06/2008.

$N_2O$ concentration and gas volume flow are monitored by monitoring system complying with requirements of the European Norm 14181.

Monitoring system provides separate readings for $N_2O$ concentration and gas flow volume for every hour of operation as an average of the measured values for the previous 60 minutes.

Measurement results can be distorted before and after periods of downtime or malfunction of the monitoring system and can lead to mavericks. To eliminate such extremes and to ensure a conservative approach, the following statistical evaluation is applied to the complete data series of $N_2O$ concentration as well as to the data series for gas volume flow. The statistical procedure is applied to data obtained after eliminating data measured for periods where the plant operated outside the permitted ranges:

a) Calculate the sample mean (x)
b) Calculate the sample standard deviation (s)
c) Calculate the 95% confidence interval (equal to 1.96 times the standard deviation)
d) Eliminate all data that lie outside the 95% confidence interval
e) Calculate the new sample mean from the remaining values (volume of stack gas (VSG) and $N_2O$ concentration of stack gas (NCSG))

The average mass of $N_2O$ emissions per hour is estimated as product of the NCSG and VSG. The $N_2O$ emissions per campaign are estimates product of $N_2O$ emission per hour and the total number of complete hours of operation of the campaign using the following equation:

$$BE_{BC} = VSG_{BC} * NCSG_{BC} * 10^{-9} * OH_{BC} \text{ } (tN_2O)$$

The Line specific baseline emissions factor representing the average $N_2O$ emissions per tonne of nitric acid over one full campaign is derived by dividing the total mass of $N_2O$ emissions by the total output of 100% concentrated nitric acid during baseline campaign.

The overall uncertainty of the monitoring system has been determined by the QAL2 report and the measurement error is expressed as a percentage (UNC). The $N_2O$ emission factor per tonne of nitric acid produced in the baseline period (EFBL) has been then be reduced by the percentage error as follows:

$$EF_{BL} = (BE_{BC} / NAP_{BC}) (1 – UNC/100) \text{ } (tN_2O/tHNO_3)$$

where:

| Variable | Definition |
|---|---|
| $EF_{BL}$ | Baseline $N_2O$ emissions factor ($tN_2O/tHNO_3$) |
| $BE_{BC}$ | Total $N_2O$ emissions during the baseline campaign ($tN_2O$) |
| $NCSG_{BC}$ | Mean concentration of $N_2O$ in the stack gas during the baseline campaign ($mgN_2O/m^3$) |
| $OH_{BC}$ | Operating hours of the baseline campaign (h) |
| $VSG_{BC}$ | Mean gas volume flow rate at the stack in the baseline measurement period ($m^3/h$) |
| $NAP_{BC}$ | Nitric acid production during the baseline campaign ($tHNO_3$) |
| UNC | Overall uncertainty of the monitoring system (%), calculated as the combined uncertainty of the applied monitoring equipment. |

## 3.1 Measurement procedure for $N_2O$ concentration and tail gas volume flow

### 3.1.1 Tail gas $N_2O$ concentration

$N_2O$ concentration is measured by extractive measurement system. Tail gas samples are taken from the Line 5 tail gas duct at sampling point located after expansion turbine and transported by sample Line to the Monitoring room A, where the analyzer is located.

Tail gas samples are filtered and conditioned in the condensation dryer (4°C), so $N_2O$ concentration is measured on a dry basis.

$N_2O$ concentration is measured by concentration infrared absorption principle meters Xentra 4900 using GFX monitoring technology.

Recently there are 8 production lines. $N_2O$ concentration is measured by 3 concentration meters on a switched basis.

$N_2O$ concentration measured data are sent from the analyzer on a 2 sec basis in a form of 4-20mA signal to the datalogger and processed further.

### 3.1.2 Tail gas flow rate, pressure and temperature

Tail gas flow, pressure and temperature is measured by ultrasonic Durag DF-L 200 flowmeters based on ultrasonic pulse fly time across the entire duct cross-section. Tail gas flow, pressure and temperature measured data are sent from the flow meter on a 2 sec basis in a form of 4-20mA signal to the datalogger and processed further.

## 3.2 Permitted range of operating conditions of the nitric acid plant

Under certain circumstances, the operating conditions during the measurement period used to determine baseline $N_2O$ emission factor may be outside the permitted range or limit corresponding to normal operating conditions. $N_2O$ baseline data measured during hours

where the operating conditions were outside the permitted range have been eliminated from the calculation of the baseline emissions factor.

Normal ranges for operating conditions have been determined for the following parameters:

oxidation temperature;
oxidation pressure;
ammonia gas flow rate,
air input flow rate.

The permitted range for these parameters has been established using the plant operation manual, as described in the PDD..

## 3.3 Historic Campaign Length

The average historic campaign length ($CL_{normal}$) defined as the average campaign length for the historic campaigns used to define operating condition (the previous five campaigns), has not been used as a cap on the length of the baseline campaign because of shorter project campaign.

# 4. PROJECT EMISSIONS

During the first project campaign on line 5 the tail gas volume flow in the stack of the nitric acid plant as well as $N_2O$ concentration have been measured on the continuous basis.

### 4.1.1 Estimation of campaign-specific project emissions factor

The monitoring system was installed using the guidance document EN 14181 and provides separate readings for $N_2O$ concentration and gas flow volume for every hour of operation. Same statistical evaluation that was applied to the baseline data series has been applied to the project data series:

a) Calculate the sample mean (x)
b) Calculate the sample standard deviation (s)
c) Calculate the 95% confidence interval (equal to 1.96 times the standard deviation)
d) Eliminate all data that lie outside the 95% confidence interval
e) Calculate the new sample mean from the remaining values

$$PE_n = VSG * NCSG * 10^{-9} * OH \ (tN_2O)$$

where:

| **Variable** | **Definition** |
|---|---|
| VSG | Mean stack gas volume flow rate for the project campaign ($m^3/h$) |
| NCSG | Mean concentration of $N_2O$ in the stack gas for the project campaign ($mgN_2O/m^3$) |
| $PE_n$ | Total $N_2O$ emissions of the $n^{th}$ project campaign ($tN_2O$) |
| OH | Is the number of hours of operation in the specific monitoring period (h) |

### 4.1.2 Derivation of a moving average emission factor

Because the project emission factor measured was lower than the moving average EF of the campaigns on this line so far, we have used the average EF for the calculation of the quantity of emission reductions generated during this campaign.

## 4.2 Minimum project emission factor

The minimum average emission factor established factor will be established after 10th project campaign.

## 4.3 Project Campaign Length

Project campaign production of nitric acid has been below defined nameplate capacity and thus all NAP produced from date of installation of secondary catalysts has been used for calculation of emission reductions.

## 4.4 Leakage

No leakage calculation is required.

## 4.5 Emission reductions

The emission reductions for the project activity during this campaign have been determined by deducting the campaign-specific emission factor from the baseline emission factor and multiplying the result by the production output of 100% concentrated nitric acid over the campaign period and the GWP of $N_2O$:

$$ER = (EFBL - EFP) * NAP * GWPN_2O \ (tCO_2e)$$

Where:

| **Variable** | **Definition** |
|---|---|
| ER | Emission reductions of the project for the specific campaign ($tCO_2e$) |
| NAP | Nitric acid production for the project campaign ($tHNO_3$). The maximum value of NAP shall not exceed the design capacity. |
| EFBL | Baseline emissions factor ($tN_2O/tHNO_3$ ) |
| EFP | Emissions factor used to calculate the emissions from this particular campaign (i.e. the higher of $EF_{ma,n}$ and $EF_n$) |

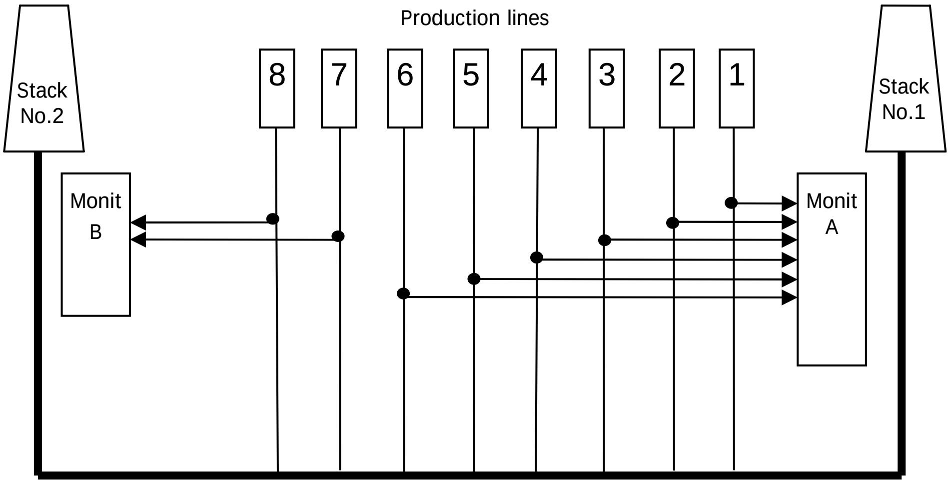
# 5. MONITORING PLAN

### Purpose of the monitoring plan

The purpose of the monitoring plan is to describe the system used to monitor emissions of $N_2O$ from the plant in such a way that is compliant with the prescriptions of the AM0034/Version 02.

### Plant description

The UKL-7 nitric acid plant comprises 8 production Lines numbered from 1 through 8, each with its own burner, absorption column and expansion turbine. Each production Line represents a separate nitric acid production unit independent from each other. The tail gasses from each Line are after expansion turbines led to a common stack bus and vented through two interconnected stacks.



Primary catalyst is changed at different times thus it is necessary to measure the emissions from each Line individually. This means that eight separate sets of monitoring equipment are installed to measure tail gas flow, nitric acid production, nitric acid concentration, and the operating conditions. $N_2O$ concentration in the tail gas is measured by 3 switched concentration meters.

### Monitoring System architecture

Methodology AM0034/Version 02 requires installation of an $N_2O$ monitoring system that includes both a gas volume flow meter to determine the tail gas mass volume flow and an infrared gas analyser to determine the concentration of $N_2O$.

But tail gas $N_2O$ concentration meter and tail gas volume flow meter alone are not sufficient for a JI project purposes. In order of being able to calculate the baseline emission factor expressed as tonnage of $N_2O$ in t $CO_2e$ per 1 tonne of $HNO_3$ (100%), it is necessary to include also $HNO_3$ measurement, and in order of being able to document normal operating conditions it is necessary to include also operating conditions measurement.

Because of this we use the term Monitoring System (MS) to describe entire monitoring system directly and indirectly used for the JI purposes, while Automated Measurement System (AMS) covers only $N_2O$ emissions and tail gas mass volume part of the MS.

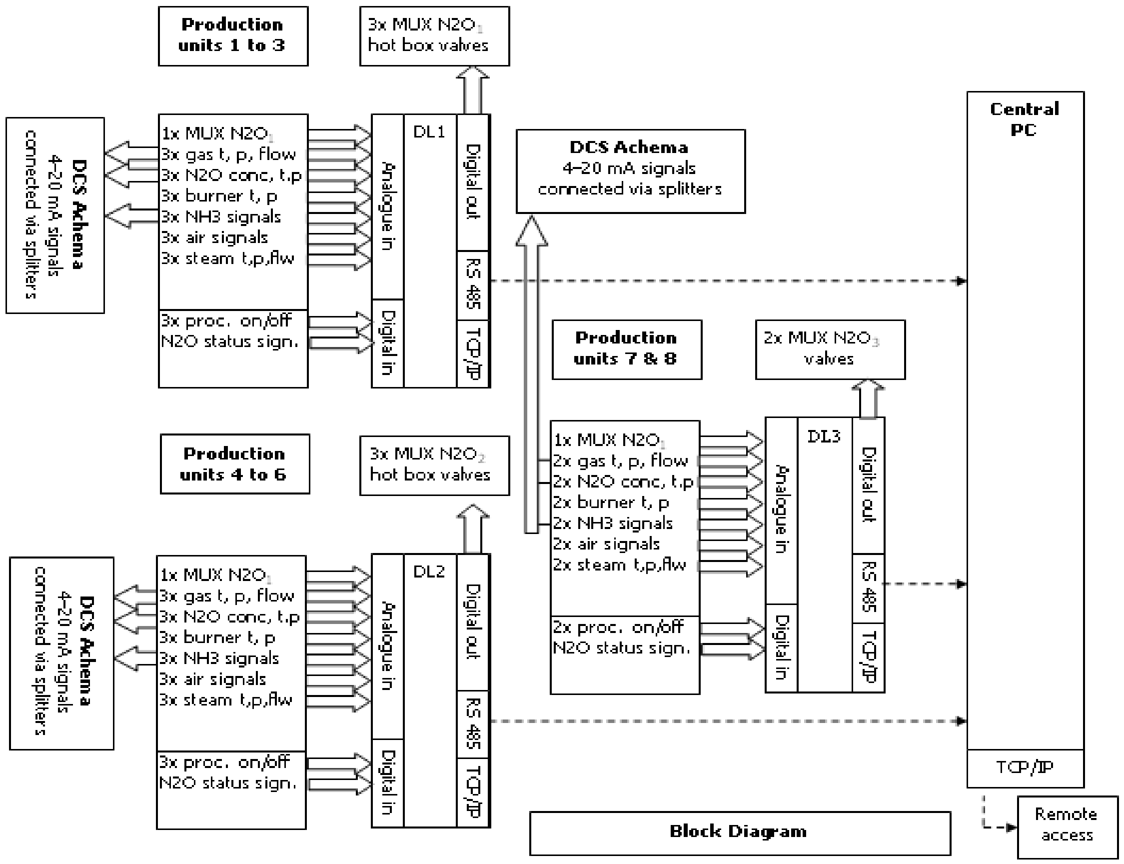
Monitoring System (MS) for purpose of this monitoring plan means:

**monitoring system measuring operational conditions;**
Ammonia volume flow
Ammonia temperature
Ammonia pressure
Primary air volume flow
Primary air temperature
Primary air pressure
Oxidation temperature
Oxidation pressure

**nitric acid 100% concentrate production;**
Nitric acid concentration
Nitric acid flow
Nitric acid temperature

**and newly installed measurement devices for measurement of N2O concentration and tail gas flow, temperature and pressure (AMS)**
$N_2O$ concentration in the stack
Stack volume flow rate
Stack gas temperature
Stack gas pressure

Incorporation of the AMS into the MS by interfacing already existing and newly installed measurement devices is documented by the diagram below.



## $N_2O$ automated measurement system

Main purpose of the $N_2O$ automated measurement system (AMS) is to measure total mass of $N_2O$ emitted during particular campaigns (both baseline and project). In order of calculation of total mass of $N_2O$ emitted during particular campaign it is necessary to measure on an extractive basis the $N_2O$ concentration in a tail gas and on a non-extractive basis tail gas flow, pressure and temperature.

## $N_2O$ concentration

$N_2O$ concentration is measured by extractive measurement system. Tail gas samples are taken from respective tail gas ducts at sampling points located after expansion turbines and transported by heated sample lines to the Monitoring room A located next to the main production hall. This applies to 2 concentration meters measuring lines 1-3 and lines 4-6. lines 7-8 are measured by third concentration meter located at the other side of the production hall (Monitoring room B) physically closer to respective production lines 7 and 8.

Tail gas samples are filtered and conditioned in the condensation dryer (4°C), so $N_2O$ concentration is measured on a dry basis. Correction of dry basis ppmV value to real wet tail

gas conditions based on steam flow injected into the system is part of both - the project emissions calculations and baseline emission factor calculations.

$N_2O$ concentration is measured by concentration infrared absorption principle meters Xentra 4900 using GFX monitoring technology.

There are 8 production lines falling under scope of the JI project (lines 1-8). $N_2O$ concentration is measured by 3 concentration meters on a switched basis.

- 1st analyzer measures 1, 2 and 3 lines.
- 2nd analyzer measures 4, 5 and 6 lines.
- 3rd analyzer measures 7 and 8 lines.

Switching between lines is managed by the AMS software. Switching intervals between lines are 300 seconds (5 minutes). 60 seconds (1 minute) of 300 seconds are for purging, i.e. no measurement during that time. Next 240 seconds (4 minutes) are for measuring, i.e. AMS is registering $N_2O$ concentration values of selected line.

1st analyser complete 15 minutes measuring cycle:

| Lines | Line 1 | | Line 2 | | Line 3 | |
|---|---|---|---|---|---|---|
| process | purging | measuring | purging | measuring | purging | measuring |
| interval | 1 minute | 4 minutes | 1 minute | 4 minutes | 1 minute | 4 minutes |

2nd analyser complete 15 minutes measuring cycle:

| Lines | Line 4 | | Line 5 | | Line 6 | |
|---|---|---|---|---|---|---|
| process | purging | measuring | purging | measuring | purging | measuring |
| interval | 1 minute | 4 minutes | 1 minute | 4 minutes | 1 minute | 4 minutes |

3rd analyser complete 10 minutes measuring cycle:

| Lines | Line 7 | | Line 8 | |
|---|---|---|---|---|
| process | purging | measuring | purging | measuring |
| interval | 1 minute | 4 minutes | 1 minute | 4 minutes |

Emission values are product of

- operating hours
- mean of the hourly measurements $N_2O$ concentration
- mean of the hourly measured VSG

BE = OH * mean(NCSG) * mean(VSG)

The additional uncertainty comes from the additional deviation of mean(NCSG) in the equation, that stems from lower sampling rate. We calculate the deviation of mean(NCSG) under 2 sec sampling intervals, as well as the actual, and take the difference.

The deviation of mean(NCSG) depends on
- deviation of the hourly measurements
- sample size
- number of measurements

stdev(mean("Actual hourly NCSG")) = stdev("Actual hourly NCSG") / sqrt("OH of NCSG measurement")

where OH is the number of hours (or observations) that are taken into account in the calculation of NCSG, that are not eliminated due to various reasons (like short project campaign, etc). Actual means the number we have with under-sampling.

The hourly NCSG values we receive are in fact the averaged values of NCSG readings collected on a 2 seconds interval. Had we sampled every 2 seconds, we would have 1800 samples per hour. In case of two lines on the same device (with 4 minutes measurement, 1 minute of purge time), we have 720 samples per hour (or 480 in case of 3 lines per device).

"sample size" = "logging interval time" / (("measurement time" + "switching time") * "no. of lines") * "measurement time" / "sampling interval time"

We can estimate the deviation of the second level NCSG measured by the device from the deviation of the hourly samples by taking into account the sample size and that they are the average of the second level readings. From this we can calculate what would be the deviation of the hourly NCSG in case we had a full sampling rate.

stdev("Actual hourly NCSG") = stdev("Second level NCSG") / sqrt("Actual sample size")
stdev("Ideal hourly NCSG") = stdev("Second level NCSG") / sqrt("Ideal sample size")

or

stdev("Ideal hourly NCSG") = stdev("Actual hourly NCSG") * sqrt("Actual sample size") / sqrt("Ideal sample size")

Afther that, we take into account the OH of the NCSG measurement to get the ideal deviation of the mean of the hourly values under normal sampling.

stdev(mean("Ideal hourly NCSG")) = stdev("Ideal hourly NCSG") / sqrt("OH of NCSG measurement")

The additional uncertainty is the difference between the ideal and the under-sampled deviation of the mean of the hourly values.

Diff = stdev(mean("Actual hourly NCSG")) - stdev(mean("Ideal hourly NCSG"))

Combined UNC = sqrt( UNC^2 + Diff^2 )

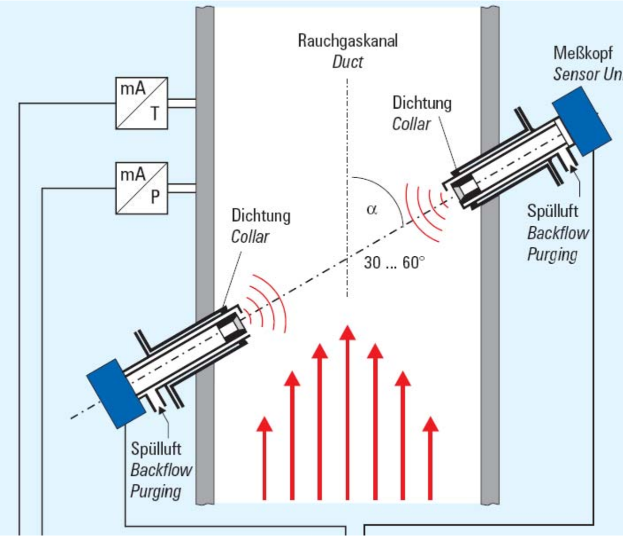
Where UNC is the QAL2 uncertainty.

Under-sampling uncertainty is part of both - the project emissions calculations and baseline emission factor calculations.

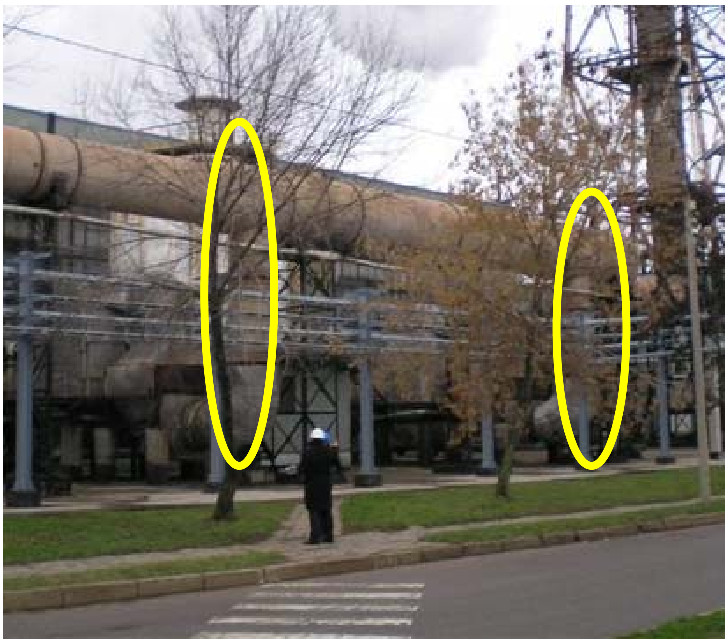
$N_2O$ concentration measured data are sent from the concentration meter on a 2 sec basis in a form of 4-20mA signal to the datalogger and processed further.

**Tail gas flow, pressure and temperature**

Tail gas flow is measured by ultrasonic Durag DF-L 200 flowmeters based on ultrasonic pulse fly time across the entire duct cross-section.



The tail gas ducts do not allow any optimum location to perform the flow monitoring. The only possible location is the quite short vertical tube behind the 90° “knee”.



Since the flow is not really laminar, a classical Pitot tube one point solution wouldn't allow good results. The ultrasonic system is under these conditions superior to differential pressure. Cross duct monitoring is more accurate than a couple of discrete point averaged pressure.

Tail gas flow, pressure and temperature measured data are sent from the flow meter on a 2 sec basis in a form of 4-20mA signal to the datalogger and processed further.

**Tail gas steam injection elimination**

Steam injected into the Achema UKL-7 tail gas for purpose of increasing the turbine output is eliminated from the tail gas mass flow calculation by following formulae:

flow - STVF=L1_Flow_N2O*(273.15/(273.15+L1_Temp))*(L1_Press/101.325)*((100-L1_Humi)/100)

where Humi (water content)=

(L1_Flow_steam*1.2436)/(L1_Flow_N2O*(273.15/(273.15+L1_Temp))*(L1_Press/101.325))*100+0.6

where 1.2436 is the conversion factor from kg/h to Nm3/h and 0.6% is a value of humidity present in a flue gas permanently without steam injection

The Flow_steam parameter necessary for calculation of the water content in the dataloggers is provided in the kg/h unit.

Achema measures steam flow in kg/h using formula Q=C*sqrt(dp) , where C is flow constant which is already integrated using an orifice plate sizing program. The orifice plate calculation for injection steam has been done for temperature 250˚C and pressure 6 bar.

Flow steam in kg/h measured by using the constant steam T and P values is then recalculated to actual steam T and P values valid for relevant hours and as result the STVF value cleaned of the steam injected is used for further emission reductions calculations.

### EN14181 compliance

As required by the AM0034/Version 02 methodology the $N_2O$ automated measurement system (AMS) complies with requirements of the technical norm EN14181. $N_2O$ AMS consists from the $N_2O$ concentration meter and integrated flowmeter (F, T, P). Both measurement devices are QAL1 certified (concentration meter for the $N_2O$ measurand specifically) and after full commissioning of the monitoring system there was the QAL2 test carried out by an independent laboratory certified according to ISO17025.

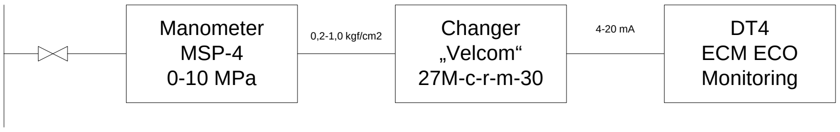
### Operating conditions

For purpose of the baseline emissions factor setting it is necessary to monitor and report operating conditions in all 8 burners. Namely:

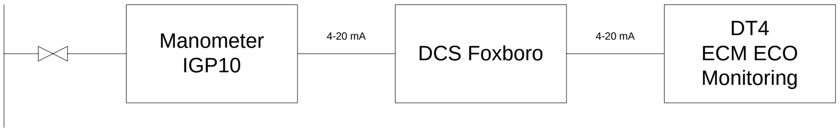
Ammonia flow
Ammonia temperature
Ammonia pressure
Primary air flow
Primary air temperature
Primary air pressure
Oxidation temperature
Oxidation pressure

All these parameters are measured by the plant monitoring system as presented on diagrams below:

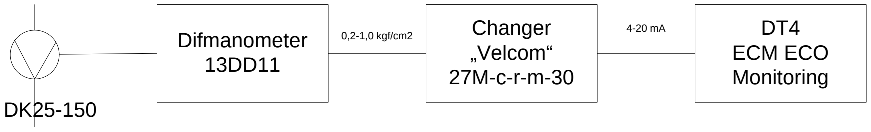
P in mixer 1-6 line



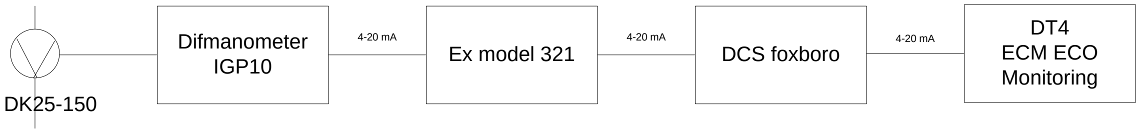
P in mixer 7-8 line



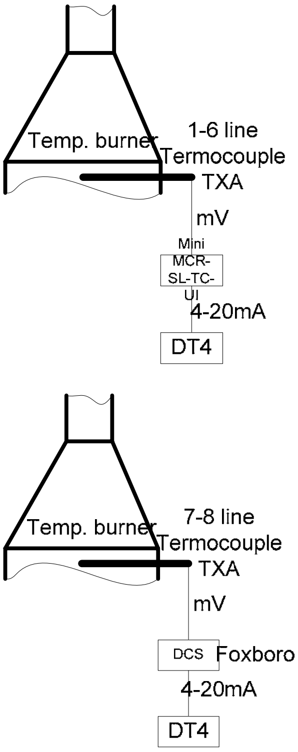
NH3 to mixer 1-6 line



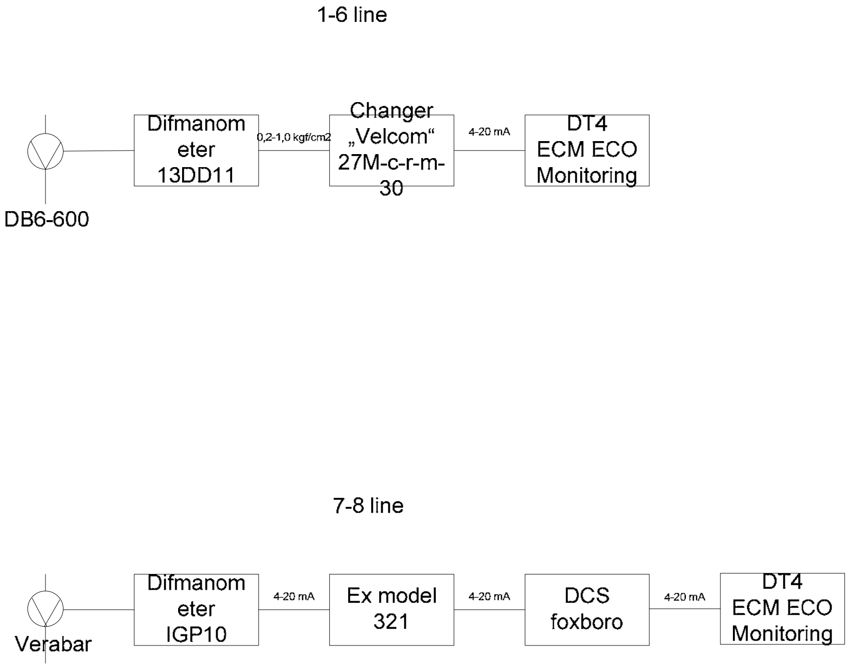
NH3 to mixer 7-8 line



T in burner



Air to mixer



Signals obtained from these measurement devices from production Lines 1-6 are converted from pneumatic to 4-20mA analog signals. Operating conditions measurement devices installed in production Lines 7-8 provide the 4-20mA signals which are digitalized and provided to the monitoring system dataloggers, which process them further. Maintenance procedures for the ammonia oxidation parameters follow the existing procedures for the operation of the nitric acid plant.

## Nitric acid production

Nitric acid concentration is based on two components: nitric acid and water. Standard monitoring method is on-Line refractometry. Measurement of nitric acid (100%) mass volume production per campaign is necessary for calculation of the baseline emissions factor. Nitric acid concentration on all 8 Lines is measured by K-Patents PR-23-GP refractometers.

This analyzer is applying a prism to “return” a generated optical beam back to an LCD detector.

The detector is measuring refraction of monitored liquid based on known refraction of water and nitric acid. The instrument is calibrated for percent concentration of nitric acid. The analyzer is mounted on DIN-flange 2656, PN25 DN80. The optical prism does not require cleaning.

PR-23-GP characteristics:

Measuring RI is a direct concentration measurement principle. No need to rely or convert magnitudes.
Digital instrument – no calibration drift
As it is a robust instrument it is maintenance free
Dual connectivity if the installation positions allow.
On-Line data logging, through Ethernet, on whichever web browser.
No influence by bubbles or particles. It is very common that air enters the process pipeline and still the refractometer measures accurately.

Nitric acid concentration data are in an analog 4-20mA format provided to dataloggers which process these signals further.

In order of being able to calculate total mass volume of nitric acid 100% concentrate produced during the baseline campaign it is necessary to monitor also nitric acid flow and temperature. Measurement of pressure is not necessary for determination of the nitric acid mass volume flow, because nitric acid is in form of liquid and as such it has stabile pressure characteristic.

Signals obtained from the nitric acid flow and temperature measurement devices from production Lines 1-6 are converted from pneumatic to 4-20mA analog signals. Nitric acid flow and temperature measurement devices installed in production Lines 7-8 provide the 4-20mA signals which are digitalized and provided to the monitoring system dataloggers, which process them further.

After installation of refractometers there have been occurrences of their failure and following repair service by the manufacturer. For this period starting from 05/10/2007 and ending on 15/09/2008 project uses $HNO_3$ concentration data provided by the laboratory measurements.

In case of refractometer's malfunction the HNO3 concentration is measured in laboratory.

The sample point of nitric acid production is in the output of the aggregate – in the pipe after the bleaching column. In the laboratory HNO3 concentration is tested by titration method. This method is defined in the company's standard (No.IST 5666739-32:2002 ) of nitric acid production. The laboratory controller, who performs the testing, is trained according "Training program for laboratory assistant performing chemical analysis"," Toxic chemical goods worker training program" and has qualification of chemistry's laboratory assistance.

Until 2010 year the testing frequency was once a week. This periodicity is usual in Achema and it is also the usual industry practice. Since 2010 year the testing frequency is once a day during the period of refractometers eventual malfunction. The laboratory NAC results are recorded in the laboratory registers No.Z42-303-40/303/08 and No.Z14-303-40/303/08. From laboratory registers NAC data are inputted in to Excel sheet manually.

# 6. QAL 2 CALIBRATION ADJUSTMENTS

## 6.1 Applied principle

As required in the applicable norm EN14181: “The relation between the instrument readings of the recording measuring procedure and the quantity of the measuring objects has to be described by using a suitable convention method. The results have to be expressed by a regression analysis.”

As it is described in the Calibration Report issued by Airtec laboratory, the measurement results derived from the analog signals (4 mA to 20 mA) provided the installed instruments have been compared to the comparative measurements.

Linearity check of the instruments characteristics is stated in the QAL2 Calibration Report issued by the laboratory. The valid ranges of Linearity are determined by statistical analysis according to the guideline and the Linearity assumptions are further used in the Calibration Report establishing Linear regression Lines.

The general formula of the regression Line, established in the EN14181 and used in the Calibration Report is:

$$Y= a + bX$$

where:

X is the measured value of the instrument in mA
Y is the value of the parameter being objective of the measurement
a is a constant of the regression Line
b is the slope of the regression Line

After a comparative test the laboratory issued the old and new regression Lines properties, namely “a” and “b” applying for all of the measured parameters that are subject to calibration as stated in the Calibration Report.

The QAL2 corrections are based on the fact that the actual analog current outputs (in mA) of the measurement instruments are relevant for both, the old and new regression Lines:

$$Xo=Xn=X$$

where:

Xn: X new
Yo: Y old

This allows us to derive a calibrating formula that gives us the corrected value of the measured physical parameters. The applied calibrating equation is:

$$Yn=An + (Bn/Bo)*(Yo-Ao)$$

In order to take into account the properties of the AMS and their implication to the QAL 2 implementation in the model, we will further introduce several remarks to the conversion and normalization of the data.

The units returned by the AMS “nm3/h” stand for normalized cubic meters of the gas volume at normal gas conditions (0° C, 1 atm.).

## 6.2 Stack gas volume flow

Based on the real conditions measured and applied by the AMS for normalization (TSG in °C and PSG in hPa), the stack gas volume flow values are converted to real conditions before the regression analysis using the ideal gas law. The actual gas volume flow rates are derived from gas velocity measurements, therefore, before applying the regression analysis the gas speed is calculated from the volume flow and the duct cross-section and is fed into the calibrating equation. The calibrated values derived from the calibrating equation then converted back to normalized units using the calibrated real conditions (calibrated TSG and PSG). The normalized calibrated stack gas flow rates are further fed into the emission calculation model for further processing as set out by the Approved Baseline and Monitoring Methodology AM_0034.

## 6.3 Nitric acid concentration in stack gas

The nitric acid concentration in the raw data set from the AMS is in $mgN_2O/m_3$. The concentration was converted to ppmv to make it compatible with the regression Lines parameters. The nitrous gas concentration values are then calibrated using the provided regression Lines parameters and are input in the model.

## 6.4 Stack gas Temperature

The stack gas temperature was calibrated by the regression conversion formula

## 6.5 Stack gas Pressure

The calibration report provides us with a regression Line for the stack gas pressure. We calibrate the readings of the measurements system using the regression formula and applying the values (in kPa).

# 7. EMISSION REDUCTION CALCULATIONS

Table T 2 illustrates the establishment of historic campaign length based on 5 previous campaigns. Average production in 5 campaigns preceding the baseline campaign was 64 818 $tHNO_3$ and time duration was on average 238 days. Table contains also information on suppliers of primary catalysts for the line 5.

### T 2 Historic campaigns

| Line | ACHEMA UKL-5 | Production | Start | End | Days | Production per day | Primary Catalyst | Composition |
|---|---|---|---|---|---|---|---|---|
| **Historic Campaigns** | **1** t HNO3 | 65 664 | 06 Jun 2003 | 23 Dec 2003 | 200 | 328 | Heraeus | 90/5/5 |
| | **2** t HNO3 | 63 844 | 23 Dec 2003 | 24 Aug 2004 | 245 | 261 | Heraeus | 90/5/5 |
| | **3** t HNO3 | 58 961 | 01 Sep 2004 | 10 May 2005 | 251 | 235 | Johnson Matthey | 90/5/5 |
| | **4** t HNO3 | 66 432 | 12 May 2005 | 06 Mar 2006 | 298 | 223 | Johnson Matthey | 90/5/5 |
| | **5** t HNO3 | 69 189 | 06 Nov 2006 | 23 May 2007 | 198 | 349 | Heraeus | 63/4/33 |
| **Average HNO3 production** | t HNO3 | **64 818** | | | **238** | **272** | | |
| **Project Campaigns** | **BL** t HNO3 | 55 079 | 29 Nov 2007 | 17 Jun 2008 | 201 | 274 | Umicore | 95/5 |
| | **PL** t HNO3 | 76 285 | 12 Aug 2010 | 17 Mar 2011 | 218 | 350 | Umicore | 95/5 |

It is business as usual scenario in Achema UKL-7 plant to keep using primary catalysts from several suppliers and with several compositions. Selection of primary catalysts is determined by technical parameters of their use and price levels offered by suppliers in specific time. Primary catalysts used during the baseline campaign, if other than used in previous campaign/s, did not increase emissions of N2O as confirmed by relevant statements provided to the verifier.

T 3 and Chart C 1 define the length of the baseline campaign. Baseline campaign measurements for this project campaign started on 29/11/2007 and continued through 17/06/2008 when the 55 079 $tHNO_3$ nitric acid production was reached. The measurement of baseline Nitrous Acid Concentration (NCSG) was carried out until production reached - $tHNO_3$ .

### T 3 Baseline campaign length

| ACHEMA UKL-5 | Historic Campaings End | Start of Baseline Measurement | End of Baseline Measurement NCSG | End of Baseline Measurement | End of Baseline Campaign |
|---|---|---|---|---|---|
| **Dates** | 2007 May 23 | 2007 Nov 29 | 2008 Jun 17 | 2008 Jun 17 | 2008 Jun 18 |
| **Baseline Factor kgN2O/tHNO3** | - | - | 6.61 | 6.61 | 6.61 |
| **Production tHNO3** | | - | 55 079 | 55 079 | - |
| **Per Day Production tHNO3** | 271.9 | | | | |
| **Baseline less Historic Production** | **(9 739.2)** | | | | |
| **Baseline less Historic Days** | **(35.8)** | | | | |
| | | | | | |

C 1 Baseline campaign length

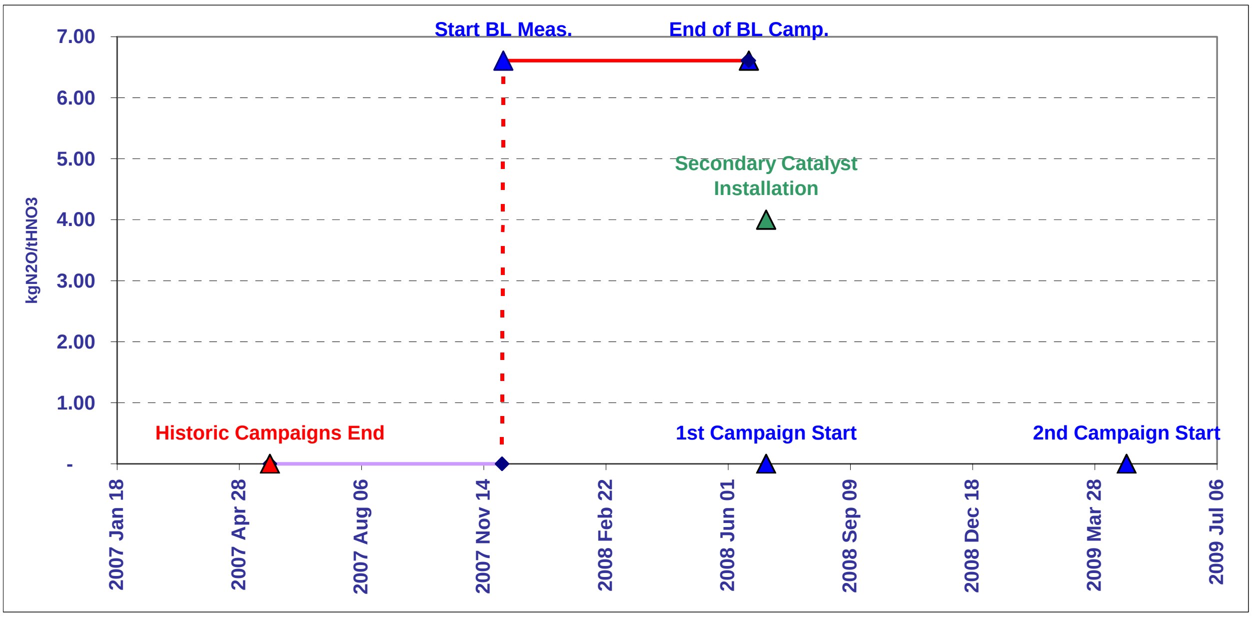


Table T 4 illustrates the calculation of the baseline emission factor on Line 5 using the method as defined in the CDM methodology AM0034 and in the PDD. We have not used overlapping approach allowed by the PDD. Baseline emission factor was determined based on raw data measured from 29/11/2007 through 17/06/2008.

Extreme values and data measured during hours when one or more of operating conditions were outside of the permitted range have been eliminated from the calculations. As a next step we have eliminated data beyond 95% confidence interval and calculated new mean values of $N_2O$ concentration and stack gas volume flow using following method:

a) Calculate the sample mean (x)
b) Calculate the sample standard deviation (s)
c) Calculate the 95% confidence interval (equal to 1.96 times the standard deviation)
d) Eliminate all data that lie outside the 95% confidence interval
e) Calculate the new sample mean from the remaining values (volume of stack gas (VSG) and $N_2O$ concentration of stack gas (NCSG))

Using the means values we have calculated the baseline emissions as set out in the PDD.

$$BE_{BC} = VSG_{BC} * NCSG_{BC} * 10^{-9} * OH_{BC} \ (tN_2O)$$

Operating hours defined as hours, when nitric acid production at least 0.1 tHNO3 and oxidation temperature at least 600˚C occurred. Calculated baseline N2O emissions were 385 $tN_2O$.

$$EF_{BL} = (BE_{BC} / NAP_{BC}) \ (1 – UNC/100) \ (tN_2O/tHNO_3)$$

The UNC factor defined by the QAL2 report is 5.450%, which is further modified by an uncertainty of 0.126% due to under-sampling. As a result we have arrived to the baseline emission factor of 6.61 $kgN_2O/tHNO_3$.

Table T 5 shows the calculation of the project emission factor on Line 5 during the project campaign. Project campaign started on 12/08/2010 and went through 17/03/2011.

We have eliminated extreme values and data beyond the 95% confidence interval as prescribed by the PDD.

a) Calculate the sample mean (x)
b) Calculate the sample standard deviation (s)
c) Calculate the 95% confidence interval (equal to 1.96 times the standard deviation)
d) Eliminate all data that lie outside the 95% confidence interval
e) Calculate the new sample mean from the remaining values

Using the mean values we have calculated total mass of $N_2O$ emissions ($PE_n$) as follows:

$$PE_n = VSG * NCSG * 10\text{-}9 * OH \ (tN2O)$$

Operating hours (OH) defined as hours, when nitric acid production at least 0.1 tHNO3 and oxidation temperature at least 600˚C occurred.

By dividing total mass of $N_2O$ emissions by the nitric acid production (capped by nameplate capacity 350 tHNO3/day) we have determined the project campaign specific emission factor at value of 2.22 kgN2O/tHNO3.

$$EF_n = PE_n / NAP_n \ (tN_2O/tHNO_3)$$

Because the project emission factor measured was lower than the moving average EF of the campaigns on this line so far, we have used the average EF for the calculation of the quantity of emission reductions generated during this campaign.

# T 4 Baseline emission factor

| BASELINE EMISSION FACTOR | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Parameter* | **Operating Hours** | **Nitric Acid Production** | **N2O Concentration** | **Gas Volume Flow** | **Ammonia Flow Rate** | **Ammonia to Air Ratio** | **Oxidation Temperature** | **Oxidation Pressure** | **AMS in Operation** | **Nitric Acid Production NCSG** |
| ***Code*** | **OH** | **NAP** | **NCSG** | **VSG** | **AFR** | **AIFR** | **OT** | **OP** | | **NAP** |
| ***Unit*** | **h** | **t/h** | **mg N2O/Nm3** | **Nm3/h** | **Nm3/h** | **%** | **°C** | **kPa** | **h** | **t/h** |
| **Elimination of extreme values** | | | | | | | | | | |
| Lower limit | | 0 | 0 | 0 | 0 | 0 | - 50 | 0 | | 0 |
| Upper Limit | | 50.00 | 3 000 | 120 000 | 10 000 | 20.00 | 1 200 | 1 000 | | 50 |
| **Raw Data Measured Range** | | | | | | | | | | |
| Count | **4 519** | 4 571 | 4 660 | 4 558 | 4 701 | 4 414 | 4 797 | 4 698 | 4 064 | 4 571 |
| *as % of Dataset* | *94%* | *95%* | *97%* | *94%* | *97%* | *92%* | *99%* | *97%* | *84%* | *95%* |
| Minimum | | - | 0 | - | 315 | - | (0) | 0 | | - |
| Maximum | | 15.02 | 2 289 | 82 389 | 6 482 | 19.73 | 908 | 673 | | 15 |
| Mean | | 12.05 | 1 239 | 65 232 | 5 932 | 10.24 | 844 | 613 | | 12 |
| Standard Deviation | | 3.12 | 268 | 15 041 | 990 | 0.81 | 195 | 46 | | 3 |
| Total | | 55 079 | | | | | | | | 55 079 |
| N2O Emissions ( VSG * NCSG * OH) | 365 | t N2O | | | | | | | | |
| Emission Factor | 6.27 | kgN2O / tHNO3 | | | | | | | | |
| **Permitted Range** | | | | | | | | | | |
| Minimum | | | | | 4 500 | 0 | 880 | 0 | | |
| Maximum | | | | | 7 500 | 11.70 | 910 | 800 | | |
| **Data within the permitted range** | | | | | | | | | | |
| Count | **4 249** | | 4 211 | 4 211 | | | | | 4 064 | |
| *as % of Operating Hours* | ***94%*** | | *93%* | *93%* | | | | | *90%* | |
| Minimum | | | 717 | 6 728 | | | | | | |
| Maximum | | | 2 289 | 78 602 | | | | | | |
| Mean | | | 1 234 | 68 731 | | | | | | |
| Standard Deviation | | | 225 | 2 256 | | | | | | |
| N2O Emissions ( VSG * NCSG * OH) | 383 | t N2O | | | | | | | | |
| Emission Factor | 6.58 | kgN2O / tHNO3 | | | | | | | | |
| **Data within the confidence interval** | | | | | | | | | | |
| 95% Confidence interval | | | | | | | | | | |
| Lower bound | | | 793 | 64 309 | | | | | | |
| Upper bound | | | 1 675 | 73 153 | | | | | | |
| Count | | | 4 009 | 4 063 | | | | | | |
| *as % of Operating Hours* | | | *89%* | *90%* | | | | | | |
| Minimum | | | 796 | 64 317 | | | | | | |
| Maximum | | | 1 674 | 73 152 | | | | | | |
| Mean | | | 1 240 | 68 711 | | | | | | |
| Standard Deviation | | | 204 | 1 796 | | | | | | |
| **N2O Emissions ( VSG * NCSG * OH)** | **385** | **t N2O** | | | | | | | | |
| **Emission Factor (EF_BL)** | **6.61** | **kgN2O / tHNO3** | | | | | | | | |

# T 5 Project emission factor

| PROJECT EMISSION FACTOR | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ***Parameter*** | **Operating Hours** | **Nitric Acid Production** | **N2O Concentration** | **Gas Volume Flow** | **Ammonia Flow Rate** | **Ammonia to Air Ratio** | **Oxidation Temperature** | **Oxidation Pressure** |
| ***Code*** | **OH** | **NAP** | **NCSG** | **VSG** | **AFR** | **AIFR** | **OT** | **OP** |
| ***Unit*** | **h** | **t/h** | **mg N2O/Nm3** | **Nm3/h** | **Nm3/h** | **%** | **°C** | **kPa** |
| **Elimination of extreme values** | | | | | | | | |
| Lower limit | | 0 | 0 | 0 | 0 | 0 | - 50 | 0 |
| Upper Limit | | 50.00 | 3 000 | 120 000 | 10 000 | 20.00 | 1 200 | 1 000 |
| **Raw Data Measured Range** | | | | | | | | |
| Count | **5 118** | 5 143 | 4 999 | 5 064 | 5 209 | 5 142 | 5 230 | 5 179 |
| *as % of Dataset* | *98%* | *98%* | *96%* | *97%* | *100%* | *98%* | *100%* | *99%* |
| Minimum | | 3.95 | 208 | 57 735 | 299 | 7 | (1) | 28 |
| Maximum | | 17.45 | 1 058 | 81 816 | 6 460 | 19.54 | 911 | 716 |
| Mean | | 15.00 | 470 | 67 638 | 6 042 | 10.22 | 882 | 633 |
| Standard Deviation | | 1.43 | 59 | 3 502 | 490 | 0.36 | 116 | 37 |
| Total | | 77 141 | | | | | | |

| | | |
|---|---|---|
| N2O Emissions ( VSG * NCSG * OH) | 163 | t N2O |
| Emission Factor | 2.11 | kgN2O / tHNO3 |

| **Data within the confidence interval** | NCSG | VSG |
|---|---|---|
| 95% Confidence interval | | |
| Lower bound | 355 | 60 775 |
| Upper bound | 585 | 74 501 |
| Count | 4 750 | 4 700 |
| *as % of Operating Hours* | *93%* | *92%* |
| Minimum | 355 | 61 272 |
| Maximum | 585 | 74 495 |
| Mean | 466 | 66 909 |
| Standard Deviation | 50 | 2 486 |

| | | |
|---|---|---|
| **N2O Emissions ( VSG * NCSG * OH)** | **159** | **t N2O** |
| **Actual Project Emission Factor (EF_PActual)** | **2.07** | **kgN2O / tHNO3** |
| **Abatement Ratio** | **68.7%** | |

| **Moving Average Emission Factor Correction** | | **Actual Factors** | **Moving Average Rule** |
|---|---|---|---|
| | **1** | 1.68 | 1.68 |
| | **2** | 2.90 | 2.90 |
| | **3** | 2.07 | 2.22 |

| | | |
|---|---|---|
| **Project Emission Factor (EF_P)** | **2.22** | **kgN2O / tHNO3** |
| **Abatement Ratio** | **66.5%** | |

# MONITORING REPORT

**PROJECT:** ACHEMA UKL nitric acid plant $N_2O$ abatement project
**LINE:** Line 7
**MONITORING PERIOD:**
**FROM:** 03/11/2009

**TO:** 08/12/2010

**Prepared by:**

VERTIS

**VERTIS FINANCE**

www.vertisfinance.com

# Table of Contents

# 1. EXECUTIVE SUMMARY

This monitoring report determines baseline emission factor for the Line 7 of ACHEMA UKL nitric acid plant and quantity of emission reduction generated during the third project campaign on Line 7.

The first project campaign on Line 7 started on 28/03/2008. Secondary catalyst was installed on 03/07/2008. Total quantity of emission reductions generated during the third project period from 03/11/2009 through 08/12/2010 on Line 7 is **150 615 ERUs**.

**T 1 Emission reduction calculations**

| EMISSION REDUCTION | | | |
|---|---|---|---|
| Baseline Emission Factor | EF_BL | 9.09 | kgN2O/tHNO3 |
| Project Campaign Emission Factor | EF_P | 2.31 | kgN2O/tHNO3 |
| Nitric Acid Produced in the Baseline Campaign | NAP_BL | 55 626 | tHNO3 |
| Nitric Acid Produced in the NCSG Baseline Campaign | NAP_BL_NCSG | 55 626 | tHNO3 |
| Nitric Acid Produced in the Project Campaign | NAP_P | 71 660 | tHNO3 |
| GWP | GWP | 310 | tCO2e/tN2O |
| **Emission Reduction** | **ER** | **150 615** | **tCOe** |
| *ER=(EF_BL-EF_P)*NAP_P*GWP/1000* | | | |
| **Abatement Ratio** | | **79.9%** | |

| EMISSION REDUCTION PER YEAR | | | |
|---|---|---|---|
| Year | 2008 | 2009 | 2010 |
| Date From | | 03 Nov 2009 | 01 Jan 2010 |
| Date To | | 31 Dec 2009 | 08 Dec 2010 |
| Nitric Acid Production | | 8 079 | 63 581 |
| **Emission Reduction** | | **16 980** | **133 635** |
| *ER_YR = ER * NAP_P_YR / NAP_P* | | | |

Baseline emission factor established for the Line 7 during baseline measurement carried from 12/09/2007 through 27/03/2008 is 9.09 kg$N_2O$/t$HNO_3$.

Project emission factor during the third project campaign after installation of secondary catalysts on Line 7, which started on 03/11/2009 and went through 08/12/2010 with secondary catalyst installed and commissioned on 03/07/2008, is 2.31 kg$N_2O$/t$HNO_3$.

During the project campaign 71 660 tonnes of nitric acid was produced.

# 2. DESCRIPTION OF THE PROJECT ACTIVITY

Purpose of the Project (the “Project”) is the reduction of nitrous oxide ($N_2O$) emissions from nitric acid production Lines at the UKL-7 nitric acid plant of AB Achema (“Achema” or “the Company”). The Company is situated in Jonava, Lithuania.

Achema has installed and operates secondary $N_2O$ reduction catalysts underneath the primary catalyst precious metal catching and catalytic gauzes package in the ammonium burners of the UKL-7 nitric acid plant.

This monitoring report contains information on Line 7 emission reductions including information on baseline emission factor setting for the Line 7.

The separate treatment of nitric acid lines and overlapping of the monitoring periods are allowed by the clarification issued Joint Implementation Supervisory Committee: “CLARIFICATION REGARDING OVERLAPPING MONITORING PERIODS UNDER THE VERIFICATION PROCEDURE UNDER THE JOINT IMPLEMENTATION SUPERVISORY COMMITTEE”. The Project meets all the requirements set out by the clarification:

1. The Project is composed of clearly identifiable components for which emission reductions or enhancements of removals are calculated independently; and

2. Monitoring is performed independently for each of these components, i.e. the data/parameters monitored for one component are not dependent on/effect data/parameters (to be) monitored for another component; and

3. The monitoring plan ensures that monitoring is performed for all components and that in these cases all the requirements of the JI guidelines and further guidance by the JISC regarding monitoring are met.

# 3. BASELINE SETTING

Baseline emission factor for line 7 has been established on the Line-specific basis. Campaign used for baseline measurements on the line 7 has been carried out from 12/09/2007 through 27/03/2008.

$N_2O$ concentration and gas volume flow are monitored by monitoring system complying with requirements of the European Norm 14181.

Monitoring system provides separate readings for $N_2O$ concentration and gas flow volume for every hour of operation as an average of the measured values for the previous 60 minutes.

Measurement results can be distorted before and after periods of downtime or malfunction of the monitoring system and can lead to mavericks. To eliminate such extremes and to ensure a conservative approach, the following statistical evaluation is applied to the complete data series of $N_2O$ concentration as well as to the data series for gas volume flow. The statistical procedure is applied to data obtained after eliminating data measured for periods where the plant operated outside the permitted ranges:

a) Calculate the sample mean (x)
b) Calculate the sample standard deviation (s)
c) Calculate the 95% confidence interval (equal to 1.96 times the standard deviation)
d) Eliminate all data that lie outside the 95% confidence interval
e) Calculate the new sample mean from the remaining values (volume of stack gas (VSG) and $N_2O$ concentration of stack gas (NCSG))

The average mass of $N_2O$ emissions per hour is estimated as product of the NCSG and VSG. The $N_2O$ emissions per campaign are estimates product of $N_2O$ emission per hour and the total number of complete hours of operation of the campaign using the following equation:

$$BE_{BC} = VSG_{BC} * NCSG_{BC} * 10^{-9} * OH_{BC} \ (tN_2O)$$

The Line specific baseline emissions factor representing the average $N_2O$ emissions per tonne of nitric acid over one full campaign is derived by dividing the total mass of $N_2O$ emissions by the total output of 100% concentrated nitric acid during baseline campaign.

The overall uncertainty of the monitoring system has been determined by the QAL2 report and the measurement error is expressed as a percentage (UNC). The $N_2O$ emission factor per tonne of nitric acid produced in the baseline period (EFBL) has been then be reduced by the percentage error as follows:

$$EF_{BL} = (BE_{BC} / NAP_{BC}) (1 – UNC/100) \ (tN_2O/tHNO_3)$$

where:

| Variable | Definition |
|---|---|
| $EF_{BL}$ | Baseline $N_2O$ emissions factor ($tN_2O/tHNO_3$) |
| $BE_{BC}$ | Total $N_2O$ emissions during the baseline campaign ($tN_2O$) |
| $NCSG_{BC}$ | Mean concentration of $N_2O$ in the stack gas during the baseline campaign ($mgN_2O/m^3$) |
| $OH_{BC}$ | Operating hours of the baseline campaign (h) |
| $VSG_{BC}$ | Mean gas volume flow rate at the stack in the baseline measurement period ($m^3/h$) |
| $NAP_{BC}$ | Nitric acid production during the baseline campaign ($tHNO_3$) |
| UNC | Overall uncertainty of the monitoring system (%), calculated as the combined uncertainty of the applied monitoring equipment. |

## 3.1 Measurement procedure for $N_2O$ concentration and tail gas volume flow

### 3.1.1 Tail gas $N_2O$ concentration

$N_2O$ concentration is measured by extractive measurement system. Tail gas samples are taken from the Line 7 tail gas duct at sampling point located after expansion turbine and transported by sample Line to the Monitoring room B, where the analyzer is located.

Tail gas samples are filtered and conditioned in the condensation dryer (4°C), so $N_2O$ concentration is measured on a dry basis.

$N_2O$ concentration is measured by concentration infrared absorption principle meters Xentra 4900 using GFX monitoring technology.

Recently there are 8 production lines. $N_2O$ concentration is measured by 3 concentration meters on a switched basis.

$N_2O$ concentration measured data are sent from the analyzer on a 2 sec basis in a form of 4-20mA signal to the datalogger and processed further.

### 3.1.2 Tail gas flow rate, pressure and temperature

Tail gas flow, pressure and temperature is measured by ultrasonic Durag DF-L 200 flowmeters based on ultrasonic pulse fly time across the entire duct cross-section. Tail gas flow, pressure and temperature measured data are sent from the flow meter on a 2 sec basis in a form of 4-20mA signal to the datalogger and processed further.

## 3.2 Permitted range of operating conditions of the nitric acid plant

Under certain circumstances, the operating conditions during the measurement period used to determine baseline $N_2O$ emission factor may be outside the permitted range or limit corresponding to normal operating conditions. $N_2O$ baseline data measured during hours

where the operating conditions were outside the permitted range have been eliminated from the calculation of the baseline emissions factor.

Normal ranges for operating conditions have been determined for the following parameters:

oxidation temperature;
oxidation pressure;
ammonia gas flow rate,
air input flow rate.

The permitted range for these parameters has been established using the plant operation manual, as described in the PDD..

## 3.3 Historic Campaign Length

The average historic campaign length ($CL_{normal}$) defined as the average campaign length for the historic campaigns used to define operating condition (the previous five campaigns), has not been used as a cap on the length of the baseline campaign because of shorter project campaign.

# 4. PROJECT EMISSIONS

During the first project campaign on line 7 the tail gas volume flow in the stack of the nitric acid plant as well as $N_2O$ concentration have been measured on the continuous basis.

### 4.1.1 Estimation of campaign-specific project emissions factor

The monitoring system was installed using the guidance document EN 14181 and provides separate readings for $N_2O$ concentration and gas flow volume for every hour of operation. Same statistical evaluation that was applied to the baseline data series has been applied to the project data series:

a) Calculate the sample mean (x)
b) Calculate the sample standard deviation (s)
c) Calculate the 95% confidence interval (equal to 1.96 times the standard deviation)
d) Eliminate all data that lie outside the 95% confidence interval
e) Calculate the new sample mean from the remaining values

$$PE_n = VSG * NCSG * 10^{-9} * OH \ (tN_2O)$$

where:

| **Variable** | **Definition** |
|---|---|
| VSG | Mean stack gas volume flow rate for the project campaign ($m^3/h$) |
| NCSG | Mean concentration of $N_2O$ in the stack gas for the project campaign ($mgN_2O/m^3$) |
| $PE_n$ | Total $N_2O$ emissions of the $n^{th}$ project campaign ($tN_2O$) |
| OH | Is the number of hours of operation in the specific monitoring period (h) |

### 4.1.2 Derivation of a moving average emission factor

Because the project emission factor measured was lower than the moving average EF of the campaigns on this line so far, we have used the average EF for the calculation of the quantity of emission reductions generated during this campaign.

## 4.2 Minimum project emission factor

The minimum average emission factor established factor will be established after 10th project campaign.

## 4.3 Project Campaign Length

Project campaign production of nitric acid has been below defined nameplate capacity and thus all NAP produced from date of installation of secondary catalysts has been used for calculation of emission reductions.

## 4.4 Leakage

No leakage calculation is required.

## 4.5 Emission reductions

The emission reductions for the project activity during this campaign have been determined by deducting the campaign-specific emission factor from the baseline emission factor and multiplying the result by the production output of 100% concentrated nitric acid over the campaign period and the GWP of $N_2O$:

$$ER = (EFBL - EFP) * NAP * GWPN_2O \ (tCO_2e)$$

Where:

| **Variable** | **Definition** |
|---|---|
| ER | Emission reductions of the project for the specific campaign ($tCO_2e$) |
| NAP | Nitric acid production for the project campaign ($tHNO_3$). The maximum value of NAP shall not exceed the design capacity. |
| EFBL | Baseline emissions factor ($tN_2O/tHNO_3$ ) |
| EFP | Emissions factor used to calculate the emissions from this particular campaign (i.e. the higher of $EF_{ma,n}$ and $EF_n$) |

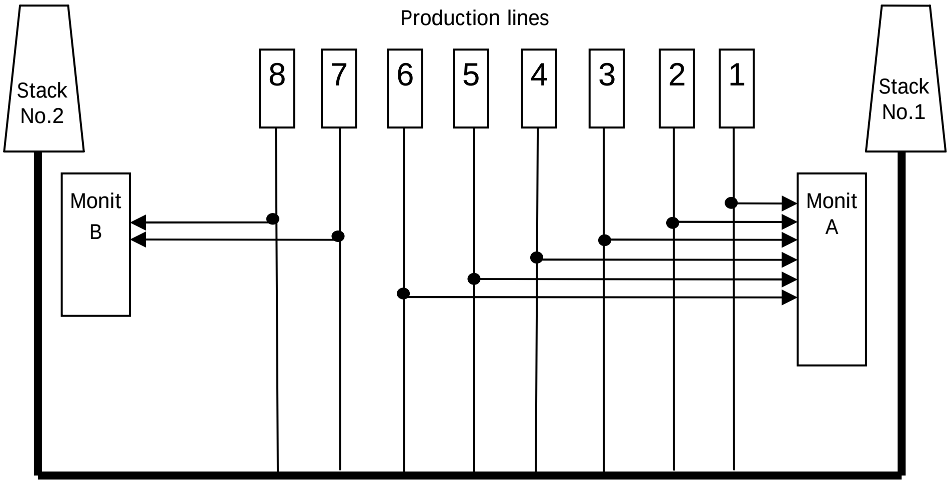
# 5. MONITORING PLAN

### Purpose of the monitoring plan

The purpose of the monitoring plan is to describe the system used to monitor emissions of $N_2O$ from the plant in such a way that is compliant with the prescriptions of the AM0034/Version 02.

### Plant description

The UKL-7 nitric acid plant comprises 8 production Lines numbered from 1 through 8, each with its own burner, absorption column and expansion turbine. Each production Line represents a separate nitric acid production unit independent from each other. The tail gasses from each Line are after expansion turbines led to a common stack bus and vented through two interconnected stacks.



Primary catalyst is changed at different times thus it is necessary to measure the emissions from each Line individually. This means that eight separate sets of monitoring equipment are installed to measure tail gas flow, nitric acid production, nitric acid concentration, and the operating conditions. $N_2O$ concentration in the tail gas is measured by 3 switched concentration meters.

### Monitoring System architecture

Methodology AM0034/Version 02 requires installation of an $N_2O$ monitoring system that includes both a gas volume flow meter to determine the tail gas mass volume flow and an infrared gas analyser to determine the concentration of $N_2O$.

But tail gas $N_2O$ concentration meter and tail gas volume flow meter alone are not sufficient for a JI project purposes. In order of being able to calculate the baseline emission factor expressed as tonnage of $N_2O$ in t $CO_2e$ per 1 tonne of $HNO_3$ (100%), it is necessary to include also $HNO_3$ measurement, and in order of being able to document normal operating conditions it is necessary to include also operating conditions measurement.

Because of this we use the term Monitoring System (MS) to describe entire monitoring system directly and indirectly used for the JI purposes, while Automated Measurement System (AMS) covers only $N_2O$ emissions and tail gas mass volume part of the MS.

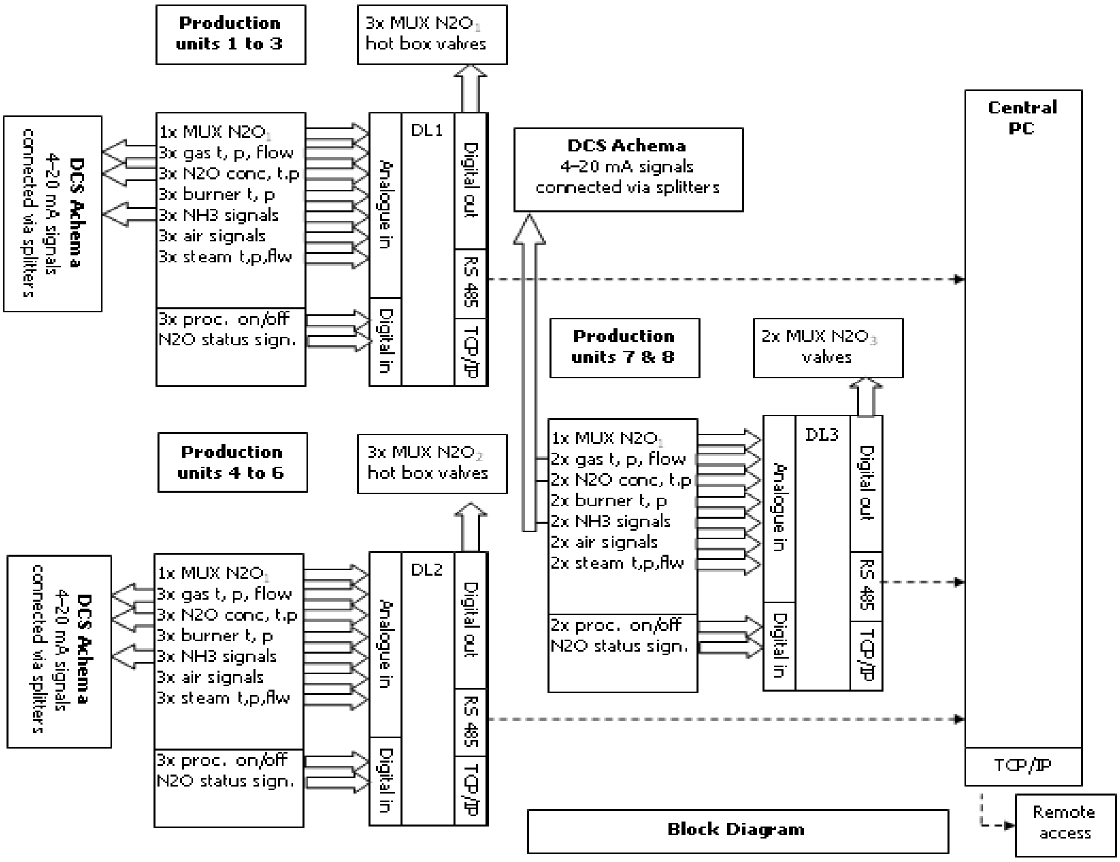
Monitoring System (MS) for purpose of this monitoring plan means:

**monitoring system measuring operational conditions;**
Ammonia volume flow
Ammonia temperature
Ammonia pressure
Primary air volume flow
Primary air temperature
Primary air pressure
Oxidation temperature
Oxidation pressure

**nitric acid 100% concentrate production;**
Nitric acid concentration
Nitric acid flow
Nitric acid temperature

**and newly installed measurement devices for measurement of N2O concentration and tail gas flow, temperature and pressure (AMS)**
$N_2O$ concentration in the stack
Stack volume flow rate
Stack gas temperature
Stack gas pressure

Incorporation of the AMS into the MS by interfacing already existing and newly installed measurement devices is documented by the diagram below.



## $N_2O$ automated measurement system

Main purpose of the $N_2O$ automated measurement system (AMS) is to measure total mass of $N_2O$ emitted during particular campaigns (both baseline and project). In order of calculation of total mass of $N_2O$ emitted during particular campaign it is necessary to measure on an extractive basis the $N_2O$ concentration in a tail gas and on a non-extractive basis tail gas flow, pressure and temperature.

## $N_2O$ concentration

$N_2O$ concentration is measured by extractive measurement system. Tail gas samples are taken from respective tail gas ducts at sampling points located after expansion turbines and transported by heated sample lines to the Monitoring room A located next to the main production hall. This applies to 2 concentration meters measuring lines 1-3 and lines 4-6. lines 7-8 are measured by third concentration meter located at the other side of the production hall (Monitoring room B) physically closer to respective production lines 7 and 8.

Tail gas samples are filtered and conditioned in the condensation dryer (4°C), so $N_2O$ concentration is measured on a dry basis. Correction of dry basis ppmV value to real wet tail

gas conditions based on steam flow injected into the system is part of both - the project emissions calculations and baseline emission factor calculations.

$N_2O$ concentration is measured by concentration infrared absorption principle meters Xentra 4900 using GFX monitoring technology.

There are 8 production lines falling under scope of the JI project (lines 1-8). $N_2O$ concentration is measured by 3 concentration meters on a switched basis.

- 1st analyzer measures 1, 2 and 3 lines.
- 2nd analyzer measures 4, 5 and 6 lines.
- 3rd analyzer measures 7 and 8 lines.

Switching between lines is managed by the AMS software. Switching intervals between lines are 300 seconds (5 minutes). 60 seconds (1 minute) of 300 seconds are for purging, i.e. no measurement during that time. Next 240 seconds (4 minutes) are for measuring, i.e. AMS is registering $N_2O$ concentration values of selected line.

1st analyser complete 15 minutes measuring cycle:

| Lines | Line 1 | | Line 2 | | Line 3 | |
|---|---|---|---|---|---|---|
| process | purging | measuring | purging | measuring | purging | measuring |
| interval | 1 minute | 4 minutes | 1 minute | 4 minutes | 1 minute | 4 minutes |

2nd analyser complete 15 minutes measuring cycle:

| Lines | Line 4 | | Line 5 | | Line 6 | |
|---|---|---|---|---|---|---|
| process | purging | measuring | purging | measuring | purging | measuring |
| interval | 1 minute | 4 minutes | 1 minute | 4 minutes | 1 minute | 4 minutes |

3rd analyser complete 10 minutes measuring cycle:

| Lines | Line 7 | | Line 8 | |
|---|---|---|---|---|
| process | purging | measuring | purging | measuring |
| interval | 1 minute | 4 minutes | 1 minute | 4 minutes |

Emission values are product of

- operating hours
- mean of the hourly measurements $N_2O$ concentration
- mean of the hourly measured VSG

$BE = OH * mean(NCSG) * mean(VSG)$

The additional uncertainty comes from the additional deviation of mean(NCSG) in the equation, that stems from lower sampling rate. We calculate the deviation of mean(NCSG) under 2 sec sampling intervals, as well as the actual, and take the difference.

The deviation of mean(NCSG) depends on

- deviation of the hourly measurements
- sample size
- number of measurements

stdev(mean(“Actual hourly NCSG”)) = stdev(“Actual hourly NCSG”) / sqrt(“OH of NCSG measurement”)

where OH is the number of hours (or observations) that are taken into account in the calculation of NCSG, that are not eliminated due to various reasons (like short project campaign, etc). Actual means the number we have with under-sampling.

The hourly NCSG values we receive are in fact the averaged values of NCSG readings collected on a 2 seconds interval. Had we sampled every 2 seconds, we would have 1800 samples per hour. In case of two lines on the same device (with 4 minutes measurement, 1 minute of purge time), we have 720 samples per hour (or 480 in case of 3 lines per device).

“sample size” = “logging interval time” / ((“measurement time” + “switching time”) * “no. of lines”) * “measurement time” / “sampling interval time”

We can estimate the deviation of the second level NCSG measured by the device from the deviation of the hourly samples by taking into account the sample size and that they are the average of the second level readings. From this we can calculate what would be the deviation of the hourly NCSG in case we had a full sampling rate.

stdev(“Actual hourly NCSG”) = stdev(“Second level NCSG”) / sqrt(“Actual sample size”)
stdev(“Ideal hourly NCSG”) = stdev(“Second level NCSG”) / sqrt(“Ideal sample size”)

or

stdev(“Ideal hourly NCSG”) = stdev(“Actual hourly NCSG”) * sqrt(“Actual sample size”) / sqrt(“Ideal sample size”)

Afther that, we take into account the OH of the NCSG measurement to get the ideal deviation of the mean of the hourly values under normal sampling.

stdev(mean(“Ideal hourly NCSG”)) = stdev(“Ideal hourly NCSG”) / sqrt(“OH of NCSG measurement”)

The additional uncertainty is the difference between the ideal and the under-sampled deviation of the mean of the hourly values.

Diff = stdev(mean(“Actual hourly NCSG”)) - stdev(mean(“Ideal hourly NCSG”))

Combined UNC = sqrt( UNC^2 + Diff^2 )

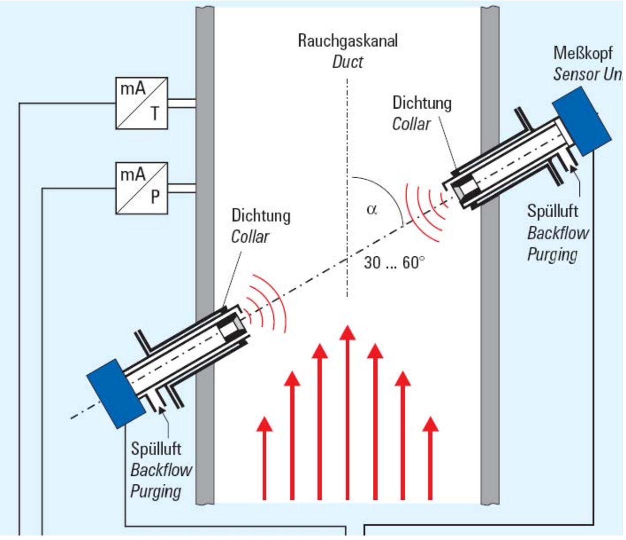
Where UNC is the QAL2 uncertainty.

Under-sampling uncertainty is part of both - the project emissions calculations and baseline emission factor calculations.

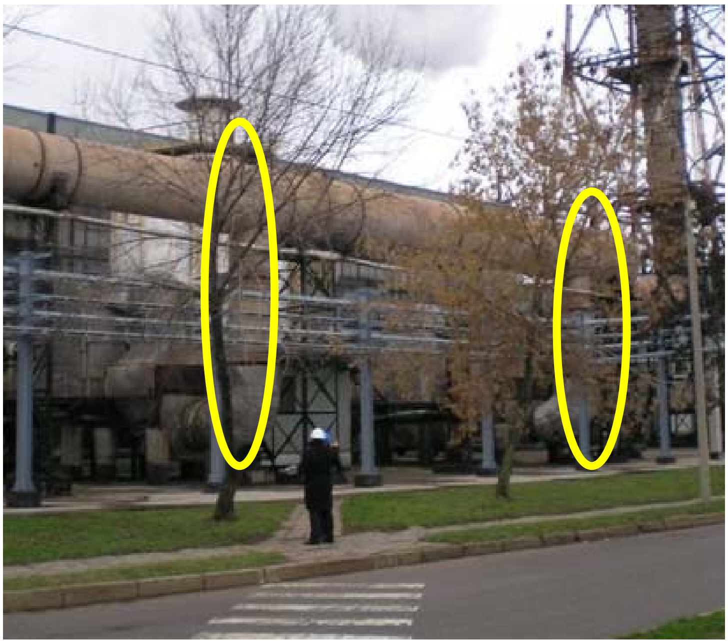
$N_2O$ concentration measured data are sent from the concentration meter on a 2 sec basis in a form of 4-20mA signal to the datalogger and processed further.

**Tail gas flow, pressure and temperature**

Tail gas flow is measured by ultrasonic Durag DF-L 200 flowmeters based on ultrasonic pulse fly time across the entire duct cross-section.



The tail gas ducts do not allow any optimum location to perform the flow monitoring. The only possible location is the quite short vertical tube behind the 90° “knee”.



Since the flow is not really laminar, a classical Pitot tube one point solution wouldn't allow good results. The ultrasonic system is under these conditions superior to differential pressure. Cross duct monitoring is more accurate than a couple of discrete point averaged pressure.

Tail gas flow, pressure and temperature measured data are sent from the flow meter on a 2 sec basis in a form of 4-20mA signal to the datalogger and processed further.

**Tail gas steam injection elimination**

Steam injected into the Achema UKL-7 tail gas for purpose of increasing the turbine output is eliminated from the tail gas mass flow calculation by following formulae:

flow - STVF=L1_Flow_N2O*(273.15/(273.15+L1_Temp))*(L1_Press/101.325)*((100-L1_Humi)/100)

where Humi (water content)=

(L1_Flow_steam*1.2436)/(L1_Flow_N2O*(273.15/(273.15+L1_Temp))*(L1_Press/101.325))*100+0.6

where 1.2436 is the conversion factor from kg/h to Nm3/h and 0.6% is a value of humidity present in a flue gas permanently without steam injection

The Flow_steam parameter necessary for calculation of the water content in the dataloggers is provided in the kg/h unit.

Achema measures steam flow in kg/h using formula Q=C*sqrt(dp) , where C is flow constant which is already integrated using an orifice plate sizing program. The orifice plate calculation for injection steam has been done for temperature 250˚C and pressure 6 bar.

Flow steam in kg/h measured by using the constant steam T and P values is then recalculated to actual steam T and P values valid for relevant hours and as result the STVF value cleaned of the steam injected is used for further emission reductions calculations.

## EN14181 compliance

As required by the AM0034/Version 02 methodology the $N_2O$ automated measurement system (AMS) complies with requirements of the technical norm EN14181. $N_2O$ AMS consists from the $N_2O$ concentration meter and integrated flowmeter (F, T, P). Both measurement devices are QAL1 certified (concentration meter for the $N_2O$ measurand specifically) and after full commissioning of the monitoring system there was the QAL2 test carried out by an independent laboratory certified according to ISO17025.

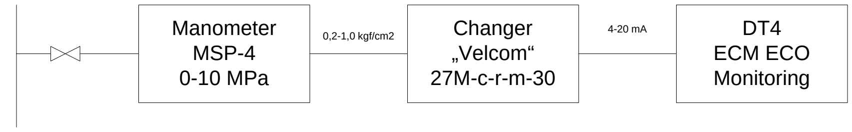
## Operating conditions

For purpose of the baseline emissions factor setting it is necessary to monitor and report operating conditions in all 8 burners. Namely:

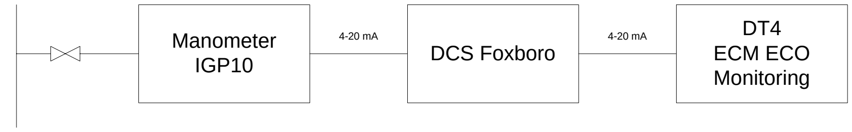
Ammonia flow
Ammonia temperature
Ammonia pressure
Primary air flow
Primary air temperature
Primary air pressure
Oxidation temperature
Oxidation pressure

All these parameters are measured by the plant monitoring system as presented on diagrams below:

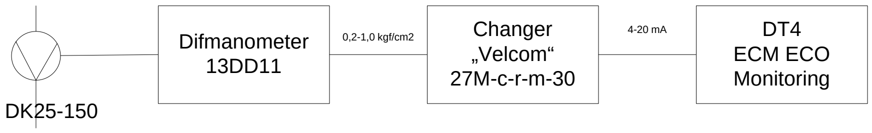
P in mixer 1-6 line



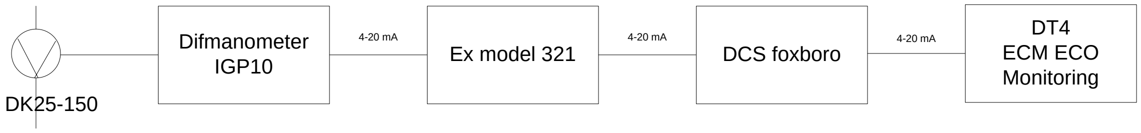
P in mixer 7-8 line



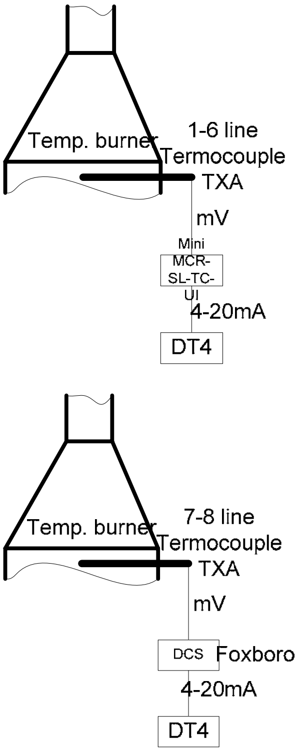
NH3 to mixer 1-6 line



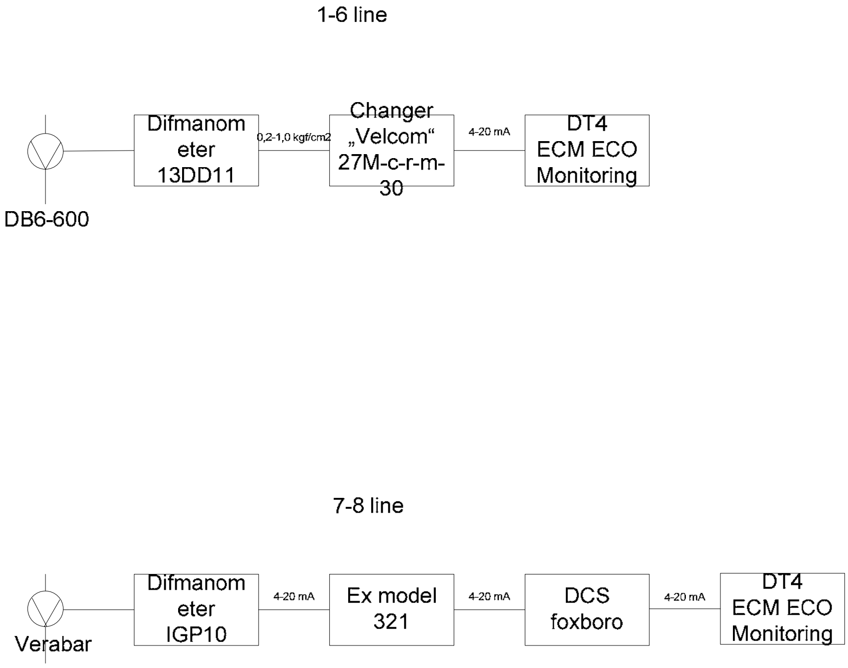
NH3 to mixer 7-8 line



T in burner



Air to mixer



Signals obtained from these measurement devices from production Lines 1-6 are converted from pneumatic to 4-20mA analog signals. Operating conditions measurement devices installed in production Lines 7-8 provide the 4-20mA signals which are digitalized and provided to the monitoring system dataloggers, which process them further. Maintenance procedures for the ammonia oxidation parameters follow the existing procedures for the operation of the nitric acid plant.

## Nitric acid production

Nitric acid concentration is based on two components: nitric acid and water. Standard monitoring method is on-Line refractometry. Measurement of nitric acid (100%) mass volume production per campaign is necessary for calculation of the baseline emissions factor. Nitric acid concentration on all 8 Lines is measured by K-Patents PR-23-GP refractometers.

This analyzer is applying a prism to “return” a generated optical beam back to an LCD detector.

The detector is measuring refraction of monitored liquid based on known refraction of water and nitric acid. The instrument is calibrated for percent concentration of nitric acid. The analyzer is mounted on DIN-flange 2656, PN25 DN80. The optical prism does not require cleaning.

PR-23-GP characteristics:

- Measuring RI is a direct concentration measurement principle. No need to rely or convert magnitudes.
- Digital instrument – no calibration drift
- As it is a robust instrument it is maintenance free
- Dual connectivity if the installation positions allow.
- On-Line data logging, through Ethernet, on whichever web browser.
- No influence by bubbles or particles. It is very common that air enters the process pipeline and still the refractometer measures accurately.

Nitric acid concentration data are in an analog 4-20mA format provided to dataloggers which process these signals further.

In order of being able to calculate total mass volume of nitric acid 100% concentrate produced during the baseline campaign it is necessary to monitor also nitric acid flow and temperature. Measurement of pressure is not necessary for determination of the nitric acid mass volume flow, because nitric acid is in form of liquid and as such it has stabile pressure characteristic.

Signals obtained from the nitric acid flow and temperature measurement devices from production Lines 1-6 are converted from pneumatic to 4-20mA analog signals. Nitric acid flow and temperature measurement devices installed in production Lines 7-8 provide the 4-20mA signals which are digitalized and provided to the monitoring system dataloggers, which process them further.

After installation of refractometers there have been occurrences of their failure and following repair service by the manufacturer. For this period starting from 04/05/2008 and ending on 18/08/2008 project uses $HNO_3$ concentration data provided by the laboratory measurements.

In case of refractometer's malfunction the HNO3 concentration is measured in laboratory.

The sample point of nitric acid production is in the output of the aggregate – in the pipe after the bleaching column. In the laboratory HNO3 concentration is tested by titration method. This method is defined in the company's standard (No.IST 5666739-32:2002 ) of nitric acid production. The laboratory controller, who performs the testing, is trained according "Training program for laboratory assistant performing chemical analysis"," Toxic chemical goods worker training program" and has qualification of chemistry's laboratory assistance.

Until 2010 year the testing frequency was once a week. This periodicity is usual in Achema and it is also the usual industry practice. Since 2010 year the testing frequency is once a day during the period of refractometers eventual malfunction. The laboratory NAC results are recorded in the laboratory registers No.Z42-303-40/303/08 and No.Z14-303-40/303/08. From laboratory registers NAC data are inputted in to Excel sheet manually.

# 6. QAL 2 CALIBRATION ADJUSTMENTS

## 6.1 Applied principle

As required in the applicable norm EN14181: “The relation between the instrument readings of the recording measuring procedure and the quantity of the measuring objects has to be described by using a suitable convention method. The results have to be expressed by a regression analysis.”

As it is described in the Calibration Report issued by Airtec laboratory, the measurement results derived from the analog signals (4 mA to 20 mA) provided the installed instruments have been compared to the comparative measurements.

Linearity check of the instruments characteristics is stated in the QAL2 Calibration Report issued by the laboratory. The valid ranges of Linearity are determined by statistical analysis according to the guideline and the Linearity assumptions are further used in the Calibration Report establishing Linear regression Lines.

The general formula of the regression Line, established in the EN14181 and used in the Calibration Report is:

$$Y= a + bX$$

where:

X is the measured value of the instrument in mA
Y is the value of the parameter being objective of the measurement
a is a constant of the regression Line
b is the slope of the regression Line

After a comparative test the laboratory issued the old and new regression Lines properties, namely “a” and “b” applying for all of the measured parameters that are subject to calibration as stated in the Calibration Report.

The QAL2 corrections are based on the fact that the actual analog current outputs (in mA) of the measurement instruments are relevant for both, the old and new regression Lines:

$$Xo=Xn=X$$

where:

Xn: X new
Yo: Y old

This allows us to derive a calibrating formula that gives us the corrected value of the measured physical parameters. The applied calibrating equation is:

$$Yn=An + (Bn/Bo)*(Yo-Ao)$$

In order to take into account the properties of the AMS and their implication to the QAL 2 implementation in the model, we will further introduce several remarks to the conversion and normalization of the data.

The units returned by the AMS “nm3/h” stand for normalized cubic meters of the gas volume at normal gas conditions (0° C, 1 atm.).

## 6.2 Stack gas volume flow

Based on the real conditions measured and applied by the AMS for normalization (TSG in °C and PSG in hPa), the stack gas volume flow values are converted to real conditions before the regression analysis using the ideal gas law. The actual gas volume flow rates are derived from gas velocity measurements, therefore, before applying the regression analysis the gas speed is calculated from the volume flow and the duct cross-section and is fed into the calibrating equation. The calibrated values derived from the calibrating equation then converted back to normalized units using the calibrated real conditions (calibrated TSG and PSG). The normalized calibrated stack gas flow rates are further fed into the emission calculation model for further processing as set out by the Approved Baseline and Monitoring Methodology AM_0034.

## 6.3 Nitric acid concentration in stack gas

The nitric acid concentration in the raw data set from the AMS is in $mgN_2O/m_3$. The concentration was converted to ppmv to make it compatible with the regression Lines parameters. The nitrous gas concentration values are then calibrated using the provided regression Lines parameters and are input in the model.

## 6.4 Stack gas Temperature

The stack gas temperature was calibrated by the regression conversion formula

## 6.5 Stack gas Pressure

The calibration report provides us with a regression Line for the stack gas pressure. We calibrate the readings of the measurements system using the regression formula and applying the values (in kPa).

# 7. EMISSION REDUCTION CALCULATIONS

Table T 2 illustrates the establishment of historic campaign length based on 5 previous campaigns. Average production in 5 campaigns preceding the baseline campaign was 64 274 $tHNO_3$ and time duration was on average 218 days. Table contains also information on suppliers of primary catalysts for the line 7.

### T 2 Historic campaigns

| **Line** | **ACHEMA UKL-7** | **Production** | **Start** | **End** | **Days** | **Production per day** | **Primary Catalyst** | **Composition** |
|---|---|---|---|---|---|---|---|---|
| **Historic Campaigns** | **1** t HNO3 | 57 671 | 10 Sep 2004 | 16 Mar 2005 | 187 | 308 | Heraeus | 90/5/5 |
| | **2** t HNO3 | 70 015 | 16 Mar 2005 | 07 Nov 2005 | 236 | 297 | Johnson Matthey | 90/5/5 |
| | **3** t HNO3 | 55 426 | 08 Nov 2005 | 20 May 2006 | 193 | 287 | Heraeus | 63/4/33 |
| | **4** t HNO3 | 67 588 | 24 May 2006 | 04 Jan 2007 | 225 | 300 | Johnson Matthey | n.a. |
| | **5** t HNO3 | 70 670 | 04 Jan 2007 | 11 Sep 2007 | 250 | 283 | Umicore | 95/5 |
| **Average HNO3 production** | t HNO3 | **64 274** | | | **218** | **295** | | |
| **Project Campaigns** | **BL** t HNO3 | 55 626 | 12 Sep 2007 | 27 Mar 2008 | 197 | 282 | Heraeus | 63/4/33 |
| | **PL** t HNO3 | 71 660 | 03 Nov 2009 | 08 Dec 2010 | 400 | 179 | Heraeus | 63/4/33 |

It is business as usual scenario in Achema UKL-7 plant to keep using primary catalysts from several suppliers and with several compositions. Selection of primary catalysts is determined by technical parameters of their use and price levels offered by suppliers in specific time. Primary catalysts used during the baseline campaign, if other than used in previous campaign/s, did not increase emissions of N2O as confirmed by relevant statements provided to the verifier.

T 3 and Chart C 1 define the length of the baseline campaign. Baseline campaign measurements for this project campaign started on 12/09/2007 and continued through 27/03/2008 when the 55 626 $tHNO_3$ nitric acid production was reached. The measurement of baseline Nitrous Acid Concentration (NCSG) was carried out until production reached - $tHNO_3$ .

### T 3 Baseline campaign length

| **ACHEMA UKL-7** | **Historic Campaings End** | **Start of Baseline Measurement** | **End of Baseline Measurement NCSG** | **End of Baseline Measurement** | **End of Baseline Campaign** |
|---|---|---|---|---|---|
| **Dates** | 2007 Sep 11 | 2007 Sep 12 | 2008 Mar 27 | 2008 Mar 27 | 2008 Mar 28 |
| **Baseline Factor kgN2O/tHNO3** | - | - | 9.09 | 9.09 | 9.09 |
| **Production tHNO3** | | - | 55 626 | 55 626 | - |
| **Per Day Production tHNO3** | 294.6 | | | | |
| **Baseline less Historic Production** | **(8 647.4)** | | | | |
| **Baseline less Historic Days** | **(29.4)** | | | | |
| | | | | | |

### C 1 Baseline campaign length

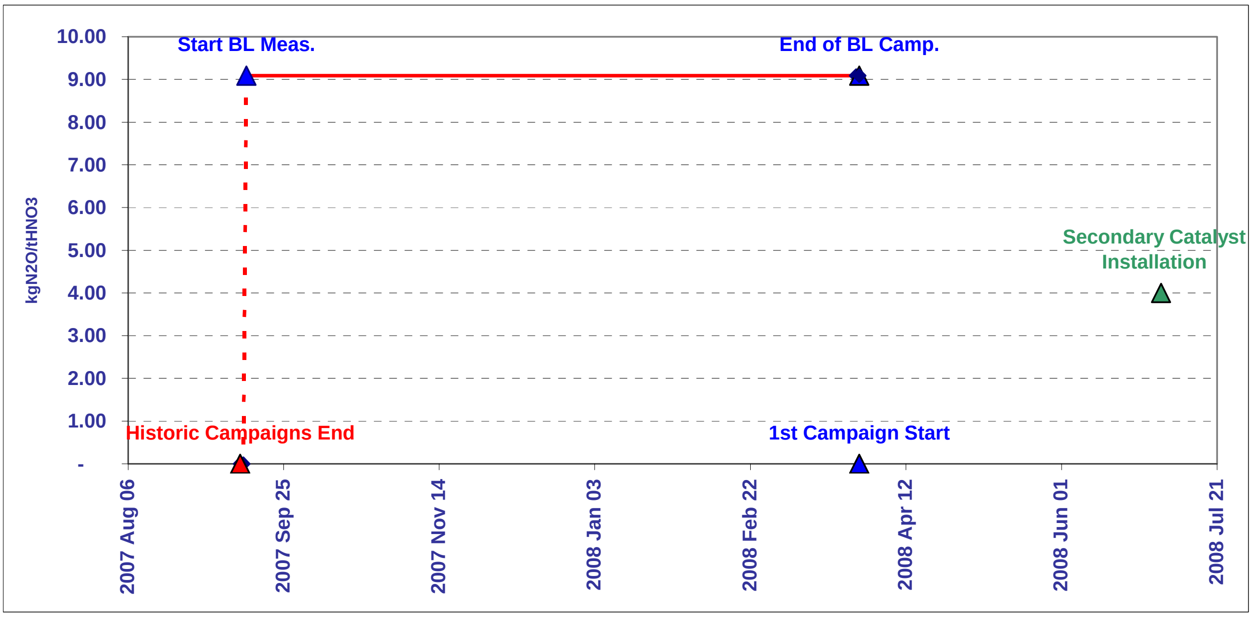


Table T 4 illustrates the calculation of the baseline emission factor on Line 7 using the method as defined in the CDM methodology AM0034 and in the PDD. We have not used overlapping approach allowed by the PDD. Baseline emission factor was determined based on raw data measured from 12/09/2007 through 27/03/2008.

Extreme values and data measured during hours when one or more of operating conditions were outside of the permitted range have been eliminated from the calculations. As a next step we have eliminated data beyond 95% confidence interval and calculated new mean values of $N_2O$ concentration and stack gas volume flow using following method:

a) Calculate the sample mean (x)
b) Calculate the sample standard deviation (s)
c) Calculate the 95% confidence interval (equal to 1.96 times the standard deviation)
d) Eliminate all data that lie outside the 95% confidence interval
e) Calculate the new sample mean from the remaining values (volume of stack gas (VSG) and $N_2O$ concentration of stack gas (NCSG))

Using the means values we have calculated the baseline emissions as set out in the PDD.

$$BE_{BC} = VSG_{BC} * NCSG_{BC} * 10^{-9} * OH_{BC}\ (tN_2O)$$

Operating hours defined as hours, when nitric acid production at least 0.1 tHNO3 and oxidation temperature at least 600°C occurred. Calculated baseline N2O emissions were 536 $tN_2O$.

$$EF_{BL} = (BE_{BC} / NAP_{BC})\ (1 – UNC/100)\ (tN_2O/tHNO_3)$$

The UNC factor defined by the QAL2 report is 5.640%, which is further modified by an uncertainty of 0.124% due to under-sampling. As a result we have arrived to the baseline emission factor of 9.09 $kgN_2O/tHNO_3$.

Table T 5 shows the calculation of the project emission factor on Line 7 during the project campaign. Project campaign started on 03/11/2009 and went through 08/12/2010.

We have eliminated extreme values and data beyond the 95% confidence interval as prescribed by the PDD.

a) Calculate the sample mean (x)
b) Calculate the sample standard deviation (s)
c) Calculate the 95% confidence interval (equal to 1.96 times the standard deviation)
d) Eliminate all data that lie outside the 95% confidence interval
e) Calculate the new sample mean from the remaining values

Using the mean values we have calculated total mass of $N_2O$ emissions ($PE_n$) as follows:

$$PE_n = VSG * NCSG * 10\text{-}9 * OH \ (tN2O)$$

Operating hours (OH) defined as hours, when nitric acid production at least 0.1 tHNO3 and oxidation temperature at least 600˚C occurred.

By dividing total mass of $N_2O$ emissions by the nitric acid production (capped by nameplate capacity 350 tHNO3/day) we have determined the project campaign specific emission factor at value of 2.31 kgN2O/tHNO3.

$$EF_n = PE_n / NAP_n \ (tN_2O/tHNO_3)$$

Because the project emission factor measured was lower than the moving average EF of the campaigns on this line so far, we have used the average EF for the calculation of the quantity of emission reductions generated during this campaign.

# T 4 Baseline emission factor

| BASELINE EMISSION FACTOR | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Parameter* | Operating Hours | Nitric Acid Production | N2O Concentration | Gas Volume Flow | Ammonia Flow Rate | Ammonia to Air Ratio | Oxidation Temperature | Oxidation Pressure | AMS in Operation | Nitric Acid Production NCSG |
| *Code* | OH | NAP | NCSG | VSG | AFR | AIFR | OT | OP | | NAP |
| *Unit* | h | t/h | mg N2O/Nm3 | Nm3/h | Nm3/h | % | °C | kPa | h | t/h |
| **Elimination of extreme values** | | | | | | | | | | |
| Lower limit | | 0 | 0 | 0 | 0 | 0 | - 50 | 0 | | 0 |
| Upper Limit | | 50.00 | 3 000 | 150 000 | 10 000 | 20.00 | 1 200 | 1 000 | | 50 |
| **Raw Data Measured Range** | | | | | | | | | | |
| Count | **4 097** | 4 238 | 4 385 | 4 238 | 4 708 | 4 485 | 4 708 | 4 708 | 3 890 | 4 238 |
| *as % of Dataset* | *87%* | *90%* | *93%* | *90%* | *100%* | *95%* | *100%* | *100%* | *82%* | *90%* |
| Minimum | | 0.00 | 0 | 1 728 | 0 | 0 | 33 | 3 | | 0 |
| Maximum | | 16.41 | 1 933 | 112 864 | 6 476 | 18.83 | 915 | 667 | | 16 |
| Mean | | 13.13 | 1 250 | 81 347 | 5 394 | 9.92 | 811 | 590 | | 13 |
| Standard Deviation | | 4.69 | 448 | 24 945 | 1 806 | 1.37 | 228 | 112 | | 5 |
| Total | | 55 626 | | | | | | | | 55 626 |
| N2O Emissions ( VSG * NCSG * OH) | 417 | t N2O | | | | | | | | |
| Emission Factor | 7.07 | kgN2O / tHNO3 | | | | | | | | |
| **Permitted Range** | | | | | | | | | | |
| Minimum | | | | | - | 0 | 880 | 550 | | |
| Maximum | | | | | 7 500 | 11.20 | 910 | 800 | | |
| **Data within the permitted range** | | | | | | | | | | |
| Count | **3 145** | | 2 856 | 2 856 | | | | | 3 890 | |
| *as % of Operating Hours* | ***77%*** | | *70%* | *70%* | | | | | *95%* | |
| Minimum | | | 722 | 57 328 | | | | | | |
| Maximum | | | 1 933 | 99 189 | | | | | | |
| Mean | | | 1 433 | 89 644 | | | | | | |
| Standard Deviation | | | 281 | 5 811 | | | | | | |
| N2O Emissions ( VSG * NCSG * OH) | 526 | t N2O | | | | | | | | |
| Emission Factor | 8.93 | kgN2O / tHNO3 | | | | | | | | |
| **Data within the confidence interval** | | | | | | | | | | |
| 95% Confidence interval | | | | | | | | | | |
| Lower bound | | | 882 | 78 254 | | | | | | |
| Upper bound | | | 1 984 | 101 034 | | | | | | |
| Count | | | 2 753 | 2 841 | | | | | | |
| *as % of Operating Hours* | | | *67%* | *69%* | | | | | | |
| Minimum | | | 913 | 78 697 | | | | | | |
| Maximum | | | 1 933 | 99 189 | | | | | | |
| Mean | | | 1 457 | 89 755 | | | | | | |
| Standard Deviation | | | 257 | 5 588 | | | | | | |
| **N2O Emissions ( VSG * NCSG * OH)** | **536** | **t N2O** | | | | | | | | |
| **Emission Factor (EF_BL)** | **9.09** | **kgN2O / tHNO3** | | | | | | | | |

# T 5 Project emission factor

| PROJECT EMISSION FACTOR | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *Parameter* | Operating Hours | Nitric Acid Production | N2O Concentration | Gas Volume Flow | Ammonia Flow Rate | Ammonia to Air Ratio | Oxidation Temperature | Oxidation Pressure |
| *Code* | OH | NAP | NCSG | VSG | AFR | AIFR | OT | OP |
| *Unit* | h | t/h | mg N2O/Nm3 | Nm3/h | Nm3/h | % | °C | kPa |
| **Elimination of extreme values** | | | | | | | | |
| Lower limit | | 0 | 0 | 0 | 0 | 0 | - 50 | 0 |
| Upper Limit | | 50.00 | 3 000 | 150 000 | 10 000 | 20.00 | 1 200 | 1 000 |
| **Raw Data Measured Range** | | | | | | | | |
| Count | **4 948** | 7 468 | 4 948 | 4 937 | 9 598 | 7 762 | 9 598 | 9 598 |
| *as % of Dataset* | *52%* | *78%* | *52%* | *51%* | *100%* | *81%* | *100%* | *100%* |
| Minimum | | 0.03 | 227 | 59 270 | 4 | 0 | 14 | 1 |
| Maximum | | 17.70 | 1 138 | 101 494 | 8 000 | 17.14 | 905 | 669 |
| Mean | | 9.60 | 383 | 73 188 | 3 975 | 10.19 | 498 | 464 |
| Standard Deviation | | 6.51 | 103 | 7 323 | 2 655 | 0.64 | 408 | 232 |
| Total | | 71 660 | | | | | | |

| | | |
|---|---|---|
| N2O Emissions ( VSG * NCSG * OH) | 139 | t N2O |
| Emission Factor | 1.94 | kgN2O / tHNO3 |

| **Data within the confidence interval** | NCSG | VSG |
|---|---|---|
| 95% Confidence interval | | |
| Lower bound | 182 | 58 834 |
| Upper bound | 585 | 87 541 |
| Count | 4 688 | 4 441 |
| *as % of Operating Hours* | *95%* | *90%* |
| Minimum | 227 | 58 967 |
| Maximum | 583 | 87 532 |
| Mean | 372 | 70 955 |
| Standard Deviation | 91 | 3 530 |

| | | |
|---|---|---|
| **N2O Emissions ( VSG * NCSG * OH)** | **131** | **t N2O** |
| **Actual Project Emission Factor (EF_PActual)** | **1.82** | **kgN2O / tHNO3** |
| **Abatement Ratio** | **79.9%** | |

| **Moving Average Emission Factor Correction** | | **Actual Factors** | **Moving Average Rule** |
|---|---|---|---|
| | **1** | 2.18 | 2.18 |
| | **2** | 2.93 | 2.93 |
| | **3** | 1.82 | 2.31 |
| | **4** | - | |

| | | |
|---|---|---|
| **Project Emission Factor (EF_P)** | **2.31** | **kgN2O / tHNO3** |
| **Abatement Ratio** | **74.6%** | |

# MONITORING REPORT

**PROJECT:** ACHEMA UKL nitric acid plant $N_2O$ abatement project
**LINE:** Line 8
**MONITORING PERIOD:**
**FROM:** 21/11/2009

**TO:** 25/10/2010

**Prepared by:**

VERTIS

**VERTIS FINANCE**

www.vertisfinance.com

# Table of Contents

# 1. EXECUTIVE SUMMARY

This monitoring report determines baseline emission factor for the Line 8 of ACHEMA UKL nitric acid plant and quantity of emission reduction generated during the third project campaign on Line 8.

The first project campaign on Line 8 started on 17/04/2008. Secondary catalyst was installed on 11/06/2008. Total quantity of emission reductions generated during the third project period from 21/11/2009 through 25/10/2010 on Line 8 is **91 448 ERUs**.

### T 1 Emission reduction calculations

| EMISSION REDUCTION | | | |
|---|---|---|---|
| Baseline Emission Factor | EF_BL | 6.96 | kgN2O/tHNO3 |
| Project Campaign Emission Factor | EF_P | 3.56 | kgN2O/tHNO3 |
| Nitric Acid Produced in the Baseline Campaign | NAP_BL | 63 577 | tHNO3 |
| Nitric Acid Produced in the NCSG Baseline Campaign | NAP_BL_NCSG | 52 603 | tHNO3 |
| Nitric Acid Produced in the Project Campaign | NAP_P | 86 762 | tHNO3 |
| GWP | GWP | 310 | tCO2e/tN2O |
| **Emission Reduction** | **ER** | **91 448** | **tCOe** |
| *ER=(EF_BL-EF_P)*NAP_P*GWP/1000* | | | |
| **Abatement Ratio** | | **70.4%** | |

| EMISSION REDUCTION PER YEAR | | | |
|---|---|---|---|
| Year | 2008 | 2009 | 2010 |
| Date From | | 21 Nov 2009 | 01 Jan 2010 |
| Date To | | 31 Dec 2009 | 25 Oct 2010 |
| Nitric Acid Production | | 10 657 | 76 105 |
| **Emission Reduction** | | **11 233** | **80 215** |
| *ER_YR = ER * NAP_P_YR / NAP_P* | | | |

Baseline emission factor established for the Line 8 during baseline measurement carried from 01/09/2007 through 15/04/2008 is 6.96 $kgN_2O/tHNO_3$.

Project emission factor during the third project campaign after installation of secondary catalysts on Line 8, which started on 21/11/2009 and went through 25/10/2010 with secondary catalyst installed and commissioned on 11/06/2008, is 3.56 $kgN_2O/tHNO_3$.

During the project campaign 86 762 tonnes of nitric acid was produced.

# 2. DESCRIPTION OF THE PROJECT ACTIVITY

Purpose of the Project (the “Project”) is the reduction of nitrous oxide ($N_2O$) emissions from nitric acid production Lines at the UKL-7 nitric acid plant of AB Achema (“Achema” or “the Company”). The Company is situated in Jonava, Lithuania.

Achema has installed and operates secondary $N_2O$ reduction catalysts underneath the primary catalyst precious metal catching and catalytic gauzes package in the ammonium burners of the UKL-7 nitric acid plant.

This monitoring report contains information on Line 8 emission reductions including information on baseline emission factor setting for the Line 8.

The separate treatment of nitric acid lines and overlapping of the monitoring periods are allowed by the clarification issued Joint Implementation Supervisory Committee: “CLARIFICATION REGARDING OVERLAPPING MONITORING PERIODS UNDER THE VERIFICATION PROCEDURE UNDER THE JOINT IMPLEMENTATION SUPERVISORY COMMITTEE”. The Project meets all the requirements set out by the clarification:

1. The Project is composed of clearly identifiable components for which emission reductions or enhancements of removals are calculated independently; and

2. Monitoring is performed independently for each of these components, i.e. the data/parameters monitored for one component are not dependent on/effect data/parameters (to be) monitored for another component; and

3. The monitoring plan ensures that monitoring is performed for all components and that in these cases all the requirements of the JI guidelines and further guidance by the JISC regarding monitoring are met.

# 3. BASELINE SETTING

Baseline emission factor for line 8 has been established on the Line-specific basis. Campaign used for baseline measurements on the line 8 has been carried out from 01/09/2007 through 15/04/2008.

$N_2O$ concentration and gas volume flow are monitored by monitoring system complying with requirements of the European Norm 14181.

Monitoring system provides separate readings for $N_2O$ concentration and gas flow volume for every hour of operation as an average of the measured values for the previous 60 minutes.

Measurement results can be distorted before and after periods of downtime or malfunction of the monitoring system and can lead to mavericks. To eliminate such extremes and to ensure a conservative approach, the following statistical evaluation is applied to the complete data series of $N_2O$ concentration as well as to the data series for gas volume flow. The statistical procedure is applied to data obtained after eliminating data measured for periods where the plant operated outside the permitted ranges:

a) Calculate the sample mean (x)
b) Calculate the sample standard deviation (s)
c) Calculate the 95% confidence interval (equal to 1.96 times the standard deviation)
d) Eliminate all data that lie outside the 95% confidence interval
e) Calculate the new sample mean from the remaining values (volume of stack gas (VSG) and $N_2O$ concentration of stack gas (NCSG))

The average mass of $N_2O$ emissions per hour is estimated as product of the NCSG and VSG. The $N_2O$ emissions per campaign are estimates product of $N_2O$ emission per hour and the total number of complete hours of operation of the campaign using the following equation:

$$BE_{BC} = VSG_{BC} * NCSG_{BC} * 10^{-9} * OH_{BC} \ (tN_2O)$$

The Line specific baseline emissions factor representing the average $N_2O$ emissions per tonne of nitric acid over one full campaign is derived by dividing the total mass of $N_2O$ emissions by the total output of 100% concentrated nitric acid during baseline campaign.

The overall uncertainty of the monitoring system has been determined by the QAL2 report and the measurement error is expressed as a percentage (UNC). The $N_2O$ emission factor per tonne of nitric acid produced in the baseline period (EFBL) has been then be reduced by the percentage error as follows:

$$EF_{BL} = (BE_{BC} / NAP_{BC})\ (1 – UNC/100)\ (tN_2O/tHNO_3)$$

where:

| Variable | Definition |
|---|---|
| $EF_{BL}$ | Baseline $N_2O$ emissions factor ($tN_2O/tHNO_3$) |
| $BE_{BC}$ | Total $N_2O$ emissions during the baseline campaign ($tN_2O$) |
| $NCSG_{BC}$ | Mean concentration of $N_2O$ in the stack gas during the baseline campaign ($mgN_2O/m^3$) |
| $OH_{BC}$ | Operating hours of the baseline campaign (h) |
| $VSG_{BC}$ | Mean gas volume flow rate at the stack in the baseline measurement period ($m^3/h$) |
| $NAP_{BC}$ | Nitric acid production during the baseline campaign ($tHNO_3$) |
| UNC | Overall uncertainty of the monitoring system (%), calculated as the combined uncertainty of the applied monitoring equipment. |

## 3.1 Measurement procedure for $N_2O$ concentration and tail gas volume flow

### 3.1.1 Tail gas $N_2O$ concentration

$N_2O$ concentration is measured by extractive measurement system. Tail gas samples are taken from the Line 8 tail gas duct at sampling point located after expansion turbine and transported by sample Line to the Monitoring room B, where the analyzer is located.

Tail gas samples are filtered and conditioned in the condensation dryer (4°C), so $N_2O$ concentration is measured on a dry basis.

$N_2O$ concentration is measured by concentration infrared absorption principle meters Xentra 4900 using GFX monitoring technology.

Recently there are 8 production lines. $N_2O$ concentration is measured by 3 concentration meters on a switched basis.

$N_2O$ concentration measured data are sent from the analyzer on a 2 sec basis in a form of 4-20mA signal to the datalogger and processed further.

### 3.1.2 Tail gas flow rate, pressure and temperature

Tail gas flow, pressure and temperature is measured by ultrasonic Durag DF-L 200 flowmeters based on ultrasonic pulse fly time across the entire duct cross-section. Tail gas flow, pressure and temperature measured data are sent from the flow meter on a 2 sec basis in a form of 4-20mA signal to the datalogger and processed further.

## 3.2 Permitted range of operating conditions of the nitric acid plant

Under certain circumstances, the operating conditions during the measurement period used to determine baseline $N_2O$ emission factor may be outside the permitted range or limit corresponding to normal operating conditions. $N_2O$ baseline data measured during hours

where the operating conditions were outside the permitted range have been eliminated from the calculation of the baseline emissions factor.

Normal ranges for operating conditions have been determined for the following parameters:

oxidation temperature;
oxidation pressure;
ammonia gas flow rate,
air input flow rate.

The permitted range for these parameters has been established using the plant operation manual, as described in the PDD..

## 3.3 Historic Campaign Length

The average historic campaign length ($CL_{normal}$) defined as the average campaign length for the historic campaigns used to define operating condition (the previous five campaigns), has not been used as a cap on the length of the baseline campaign because of shorter project campaign.

# 4. PROJECT EMISSIONS

During the first project campaign on line 8 the tail gas volume flow in the stack of the nitric acid plant as well as $N_2O$ concentration have been measured on the continuous basis.

### 4.1.1 Estimation of campaign-specific project emissions factor

The monitoring system was installed using the guidance document EN 14181 and provides separate readings for $N_2O$ concentration and gas flow volume for every hour of operation. Same statistical evaluation that was applied to the baseline data series has been applied to the project data series:

a) Calculate the sample mean (x)
b) Calculate the sample standard deviation (s)
c) Calculate the 95% confidence interval (equal to 1.96 times the standard deviation)
d) Eliminate all data that lie outside the 95% confidence interval
e) Calculate the new sample mean from the remaining values

$$PE_n = VSG * NCSG * 10^{-9} * OH \text{ } (tN_2O)$$

where:

| **Variable** | **Definition** |
|---|---|
| VSG | Mean stack gas volume flow rate for the project campaign ($m^3/h$) |
| NCSG | Mean concentration of $N_2O$ in the stack gas for the project campaign ($mgN_2O/m^3$) |
| $PE_n$ | Total $N_2O$ emissions of the $n^{th}$ project campaign ($tN_2O$) |
| OH | Is the number of hours of operation in the specific monitoring period (h) |

### 4.1.2 Derivation of a moving average emission factor

Because the project emission factor measured was lower than the moving average EF of the campaigns on this line so far, we have used the average EF for the calculation of the quantity of emission reductions generated during this campaign.

## 4.2 Minimum project emission factor

The minimum average emission factor established factor will be established after 10th project campaign.

## 4.3 Project Campaign Length

Project campaign production of nitric acid has been below defined nameplate capacity and thus all NAP produced from date of installation of secondary catalysts has been used for calculation of emission reductions.

## 4.4 Leakage

No leakage calculation is required.

## 4.5 Emission reductions

The emission reductions for the project activity during this campaign have been determined by deducting the campaign-specific emission factor from the baseline emission factor and multiplying the result by the production output of 100% concentrated nitric acid over the campaign period and the GWP of $N_2O$:

$$ER = (EFBL – EFP) * NAP *GWPN_2O\ (tCO_2e)$$

Where:

| Variable | Definition |
|---|---|
| ER | Emission reductions of the project for the specific campaign ($tCO_2e$) |
| NAP | Nitric acid production for the project campaign ($tHNO_3$). The maximum value of NAP shall not exceed the design capacity. |
| EFBL | Baseline emissions factor ($tN_2O/tHNO_3$ ) |
| EFP | Emissions factor used to calculate the emissions from this particular campaign (i.e. the higher of $EF_{ma,n}$ and $EF_n$) |

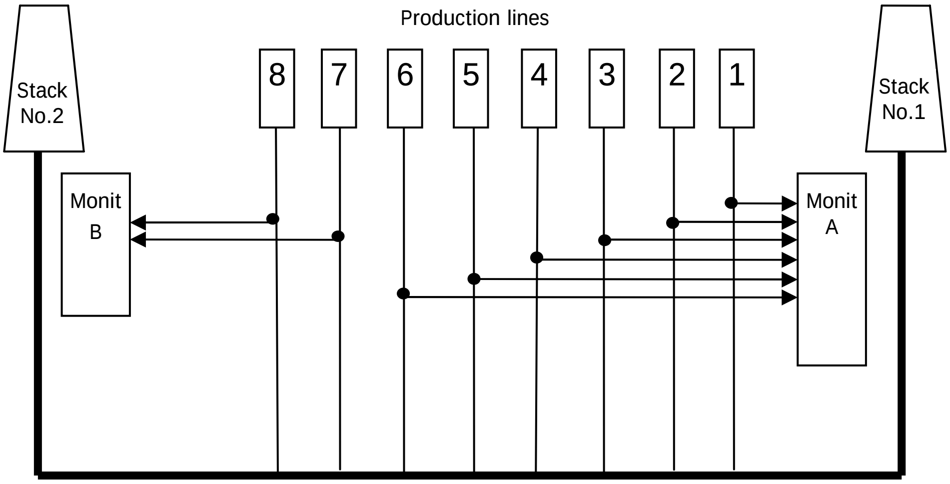
# 5. MONITORING PLAN

## Purpose of the monitoring plan

The purpose of the monitoring plan is to describe the system used to monitor emissions of $N_2O$ from the plant in such a way that is compliant with the prescriptions of the AM0034/Version 02.

## Plant description

The UKL-7 nitric acid plant comprises 8 production Lines numbered from 1 through 8, each with its own burner, absorption column and expansion turbine. Each production Line represents a separate nitric acid production unit independent from each other. The tail gasses from each Line are after expansion turbines led to a common stack bus and vented through two interconnected stacks.



Primary catalyst is changed at different times thus it is necessary to measure the emissions from each Line individually. This means that eight separate sets of monitoring equipment are installed to measure tail gas flow, nitric acid production, nitric acid concentration, and the operating conditions. $N_2O$ concentration in the tail gas is measured by 3 switched concentration meters.

## Monitoring System architecture

Methodology AM0034/Version 02 requires installation of an $N_2O$ monitoring system that includes both a gas volume flow meter to determine the tail gas mass volume flow and an infrared gas analyser to determine the concentration of $N_2O$.

But tail gas $N_2O$ concentration meter and tail gas volume flow meter alone are not sufficient for a JI project purposes. In order of being able to calculate the baseline emission factor expressed as tonnage of $N_2O$ in t $CO_2$e per 1 tonne of $HNO_3$ (100%), it is necessary to include also $HNO_3$ measurement, and in order of being able to document normal operating conditions it is necessary to include also operating conditions measurement.

Because of this we use the term Monitoring System (MS) to describe entire monitoring system directly and indirectly used for the JI purposes, while Automated Measurement System (AMS) covers only $N_2O$ emissions and tail gas mass volume part of the MS.

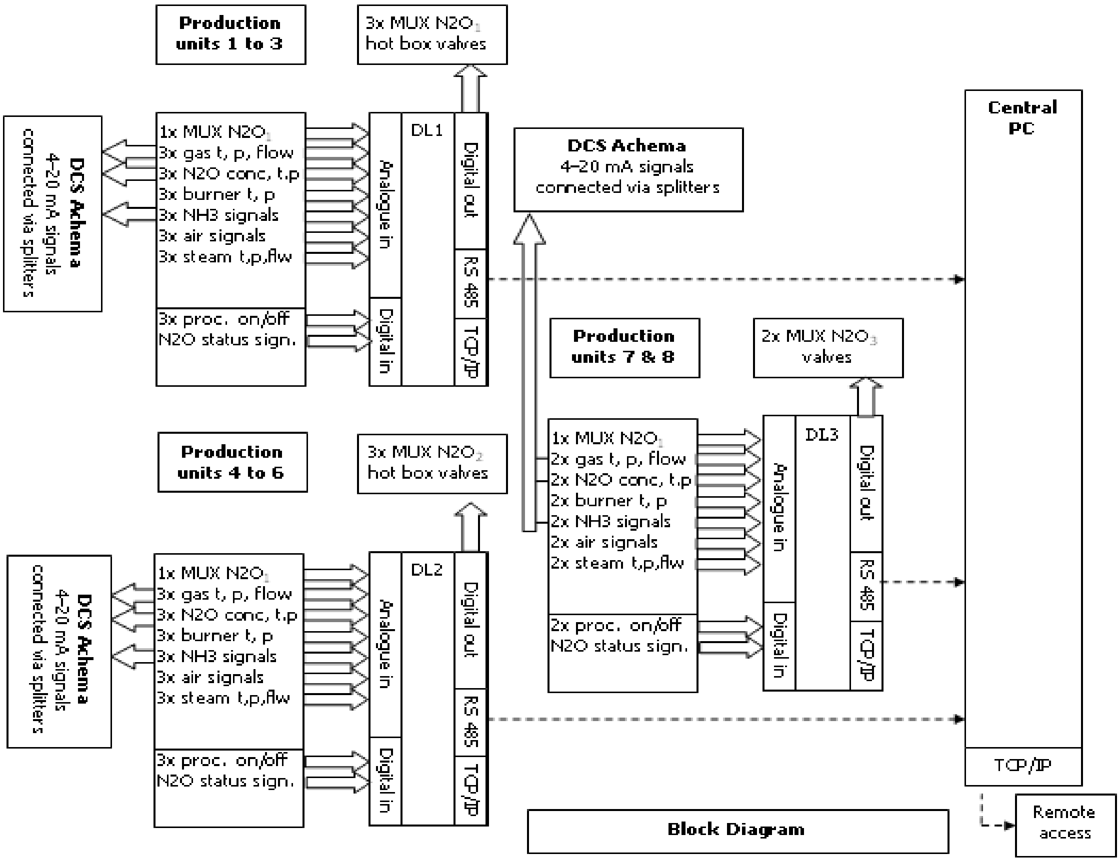
Monitoring System (MS) for purpose of this monitoring plan means:

**monitoring system measuring operational conditions;**
Ammonia volume flow
Ammonia temperature
Ammonia pressure
Primary air volume flow
Primary air temperature
Primary air pressure
Oxidation temperature
Oxidation pressure

**nitric acid 100% concentrate production;**
Nitric acid concentration
Nitric acid flow
Nitric acid temperature

**and newly installed measurement devices for measurement of N2O concentration and tail gas flow, temperature and pressure (AMS)**
$N_2O$ concentration in the stack
Stack volume flow rate
Stack gas temperature
Stack gas pressure

Incorporation of the AMS into the MS by interfacing already existing and newly installed measurement devices is documented by the diagram below.



## $N_2O$ automated measurement system

Main purpose of the $N_2O$ automated measurement system (AMS) is to measure total mass of $N_2O$ emitted during particular campaigns (both baseline and project). In order of calculation of total mass of $N_2O$ emitted during particular campaign it is necessary to measure on an extractive basis the $N_2O$ concentration in a tail gas and on a non-extractive basis tail gas flow, pressure and temperature.

## $N_2O$ concentration

$N_2O$ concentration is measured by extractive measurement system. Tail gas samples are taken from respective tail gas ducts at sampling points located after expansion turbines and transported by heated sample lines to the Monitoring room A located next to the main production hall. This applies to 2 concentration meters measuring lines 1-3 and lines 4-6. lines 7-8 are measured by third concentration meter located at the other side of the production hall (Monitoring room B) physically closer to respective production lines 7 and 8.

Tail gas samples are filtered and conditioned in the condensation dryer (4°C), so $N_2O$ concentration is measured on a dry basis. Correction of dry basis ppmV value to real wet tail

gas conditions based on steam flow injected into the system is part of both - the project emissions calculations and baseline emission factor calculations.

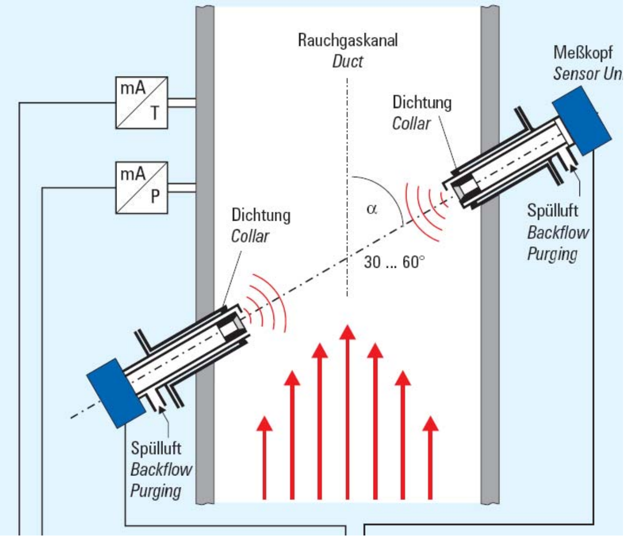
$N_2O$ concentration is measured by concentration infrared absorption principle meters Xentra 4900 using GFX monitoring technology.

Recently there are 8 production Lines. $N_2O$ concentration is measured by 3 concentration meters on a switched basis. Tail gas samples are automatically switched. Under-sampling uncertainty is part of both - the project emissions calculations and baseline emission factor calculations.

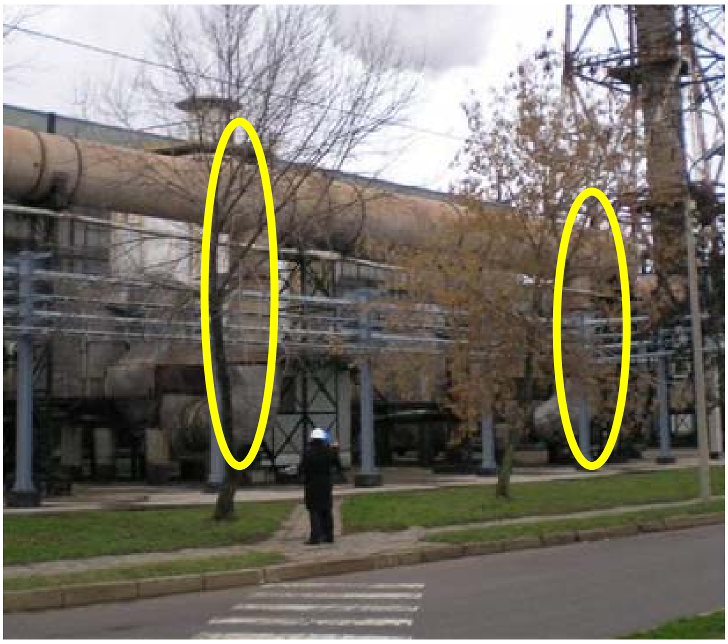
$N_2O$ concentration measured data are sent from the concentration meter on a 2 sec basis in a form of 4-20mA signal to the datalogger and processed further.

**Tail gas flow, pressure and temperature**

Tail gas flow is measured by ultrasonic Durag DF-L 200 flowmeters based on ultrasonic pulse fly time across the entire duct cross-section.



The tail gas ducts do not allow any optimum location to perform the flow monitoring. The only possible location is the quite short vertical tube behind the 90° “knee”.



Since the flow is not really laminar, a classical Pitot tube one point solution wouldn't allow good results. The ultrasonic system is under these conditions superior to differential pressure. Cross duct monitoring is more accurate than a couple of discrete point averaged pressure.

Tail gas flow, pressure and temperature measured data are sent from the flow meter on a 2 sec basis in a form of 4-20mA signal to the datalogger and processed further.

**Tail gas steam injection elimination**

Steam injected into the Achema UKL-7 tail gas for purpose of increasing the turbine output is eliminated from the tail gas mass flow calculation by following formulae:

flow - STVF=L1_Flow_N2O*(273.15/(273.15+L1_Temp))*(L1_Press/101.325)*((100-L1_Humi)/100)

where Humi (water content)=

(L1_Flow_steam*1.2436)/(L1_Flow_N2O*(273.15/(273.15+L1_Temp))*(L1_Press/101.325))*100+0.6

where 1.2436 is the conversion factor from kg/h to Nm3/h and 0.6% is a value of humidity present in a flue gas permanently without steam injection

The Flow_steam parameter necessary for calculation of the water content in the dataloggers is provided in the kg/h unit.

Achema measures steam flow in kg/h using formula Q=C*sqrt(dp) , where C is flow constant which is already integrated using an orifice plate sizing program. The orifice plate calculation for injection steam has been done for temperature 250˚C and pressure 6 bar.

Flow steam in kg/h measured by using the constant steam T and P values is then recalculated to actual steam T and P values valid for relevant hours and as result the STVF value cleaned of the steam injected is used for further emission reductions calculations.

**EN14181 compliance**

As required by the AM0034/Version 02 methodology the $N_2O$ automated measurement system (AMS) complies with requirements of the technical norm EN14181. $N_2O$ AMS consists from the $N_2O$ concentration meter and integrated flowmeter (F, T, P). Both measurement devices are QAL1 certified (concentration meter for the $N_2O$ measurand specifically) and after full commissioning of the monitoring system there was the QAL2 test carried out by an independent laboratory certified according to ISO17025.

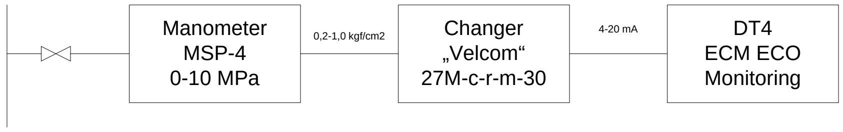
**Operating conditions**

For purpose of the baseline emissions factor setting it is necessary to monitor and report operating conditions in all 8 burners. Namely:

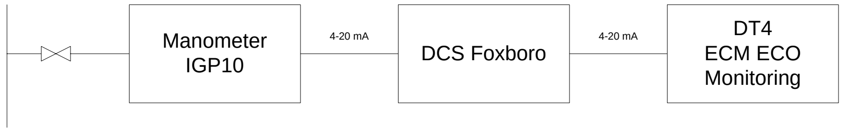
Ammonia flow
Ammonia temperature
Ammonia pressure
Primary air flow
Primary air temperature
Primary air pressure
Oxidation temperature
Oxidation pressure

All these parameters are measured by the plant monitoring system as presented on diagrams below:

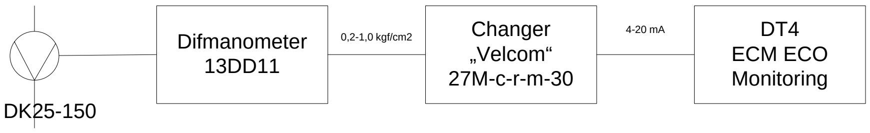
P in mixer 1-6 line



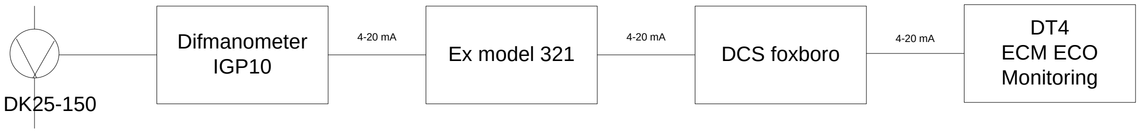
P in mixer 7-8 line



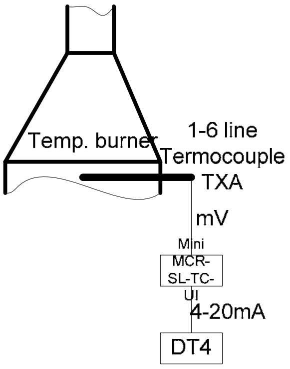
NH3 to mixer 1-6 line

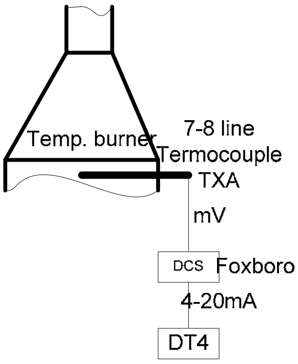


NH3 to mixer 7-8 line



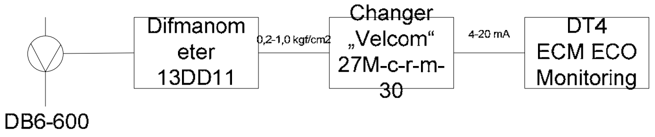
T in burner



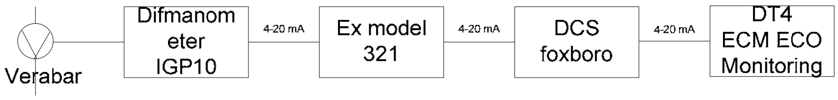


Air to mixer

1-6 line



7-8 line

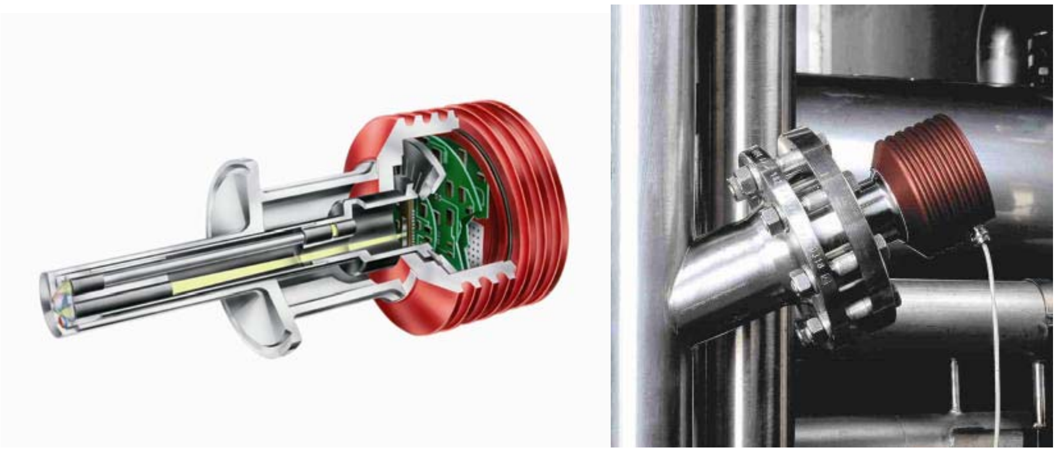


Signals obtained from these measurement devices from production Lines 1-6 are converted from pneumatic to 4-20mA analog signals. Operating conditions measurement devices installed in production Lines 7-8 provide the 4-20mA signals which are digitalized and provided to the monitoring system dataloggers, which process them further. Maintenance procedures for the ammonia oxidation parameters follow the existing procedures for the operation of the nitric acid plant.

## Nitric acid production

Nitric acid concentration is based on two components: nitric acid and water. Standard monitoring method is on-Line refractometry. Measurement of nitric acid (100%) mass volume production per campaign is necessary for calculation of the baseline emissions factor. Nitric acid concentration on all 8 Lines is measured by K-Patents PR-23-GP refractometers.

This analyzer is applying a prism to “return” a generated optical beam back to an LCD detector.



The detector is measuring refraction of monitored liquid based on known refraction of water and nitric acid. The instrument is calibrated for percent concentration of nitric acid. The analyzer is mounted on DIN-flange 2656, PN25 DN80. The optical prism does not require cleaning.

PR-23-GP characteristics:

- Measuring RI is a direct concentration measurement principle. No need to rely or convert magnitudes.
- Digital instrument – no calibration drift
- As it is a robust instrument it is maintenance free
- Dual connectivity if the installation positions allow.
- On-Line data logging, through Ethernet, on whichever web browser.
- No influence by bubbles or particles. It is very common that air enters the process pipeline and still the refractometer measures accurately.

Nitric acid concentration data are in an analog 4-20mA format provided to dataloggers which process these signals further.

In order of being able to calculate total mass volume of nitric acid 100% concentrate produced during the baseline campaign it is necessary to monitor also nitric acid flow and temperature. Measurement of pressure is not necessary for determination of the nitric acid mass volume flow, because nitric acid is in form of liquid and as such it has stabile pressure characteristic.

Signals obtained from the nitric acid flow and temperature measurement devices from production Lines 1-6 are converted from pneumatic to 4-20mA analog signals. Nitric acid flow and temperature measurement devices installed in production Lines 7-8 provide the 4-20mA signals which are digitalized and provided to the monitoring system dataloggers, which process them further.

After installation of refractometers there have been occurrences of their failure and following repair service by the manufacturer. For this period starting from 05/10/2007 and ending on 20/10/2008 project uses $HNO_3$ concentration data provided by the laboratory measurements.

# 6. QAL 2 CALIBRATION ADJUSTMENTS

## 6.1 Applied principle

As required in the applicable norm EN14181: “The relation between the instrument readings of the recording measuring procedure and the quantity of the measuring objects has to be described by using a suitable convention method. The results have to be expressed by a regression analysis.”

As it is described in the Calibration Report issued by Airtec laboratory, the measurement results derived from the analog signals (4 mA to 20 mA) provided the installed instruments have been compared to the comparative measurements.

Linearity check of the instruments characteristics is stated in the QAL2 Calibration Report issued by the laboratory. The valid ranges of Linearity are determined by statistical analysis according to the guideline and the Linearity assumptions are further used in the Calibration Report establishing Linear regression Lines.

The general formula of the regression Line, established in the EN14181 and used in the Calibration Report is:

$$Y= a + bX$$

where:

X is the measured value of the instrument in mA
Y is the value of the parameter being objective of the measurement
a is a constant of the regression Line
b is the slope of the regression Line

After a comparative test the laboratory issued the old and new regression Lines properties, namely “a” and “b” applying for all of the measured parameters that are subject to calibration as stated in the Calibration Report.

The QAL2 corrections are based on the fact that the actual analog current outputs (in mA) of the measurement instruments are relevant for both, the old and new regression Lines:

$$Xo=Xn=X$$

where:

Xn: X new
Yo: Y old

This allows us to derive a calibrating formula that gives us the corrected value of the measured physical parameters. The applied calibrating equation is:

$$Yn=An + (Bn/Bo)*(Yo-Ao)$$

In order to take into account the properties of the AMS and their implication to the QAL 2 implementation in the model, we will further introduce several remarks to the conversion and normalization of the data.

The units returned by the AMS “nm3/h” stand for normalized cubic meters of the gas volume at normal gas conditions (0° C, 1 atm.).

## 6.2 Stack gas volume flow

Based on the real conditions measured and applied by the AMS for normalization (TSG in °C and PSG in hPa), the stack gas volume flow values are converted to real conditions before the regression analysis using the ideal gas law. The actual gas volume flow rates are derived from gas velocity measurements, therefore, before applying the regression analysis the gas speed is calculated from the volume flow and the duct cross-section and is fed into the calibrating equation. The calibrated values derived from the calibrating equation then converted back to normalized units using the calibrated real conditions (calibrated TSG and PSG). The normalized calibrated stack gas flow rates are further fed into the emission calculation model for further processing as set out by the Approved Baseline and Monitoring Methodology AM_0034.

## 6.3 Nitric acid concentration in stack gas

The nitric acid concentration in the raw data set from the AMS is in $mgN_2O/m_3$. The concentration was converted to ppmv to make it compatible with the regression Lines parameters. The nitrous gas concentration values are then calibrated using the provided regression Lines parameters and are input in the model.

## 6.4 Stack gas Temperature

The stack gas temperature was calibrated by the regression conversion formula

## 6.5 Stack gas Pressure

The calibration report provides us with a regression Line for the stack gas pressure. We calibrate the readings of the measurements system using the regression formula and applying the values (in kPa).

# 7. EMISSION REDUCTION CALCULATIONS

Table T 2 illustrates the establishment of historic campaign length based on 5 previous campaigns. Average production in 5 campaigns preceding the baseline campaign was 63 620 $tHNO_3$ and time duration was on average 228 days. Table contains also information on suppliers of primary catalysts for the line 8.

### T 2 Historic campaigns

| **Line** | **ACHEMA UKL-8** | **Production** | **Start** | **End** | **Days** | **Production per day** | **Primary Catalyst** | **Composition** |
|---|---|---|---|---|---|---|---|---|
| **Historic Campaigns** | **1** t HNO3 | - | 00 Jan 1900 | 00 Jan 1900 | - | n/a | 0 | 0 |
| | **2** t HNO3 | 62 575 | 10 Dec 2004 | 17 Aug 2005 | 250 | 250 | Heraeus | 90/5/5 |
| | **3** t HNO3 | 63 418 | 02 Nov 2005 | 14 Jun 2006 | 224 | 283 | Umicore | 95/5 |
| | **4** t HNO3 | 63 138 | 15 Jun 2006 | 01 Feb 2007 | 231 | 273 | Johnson Matthey | n.a. |
| | **5** t HNO3 | 65 347 | 02 Feb 2007 | 28 Aug 2007 | 207 | 316 | Johnson Matthey | n.a. |
| **Average HNO3 production** | t HNO3 | **63 620** | | | **228** | **279** | | |
| **Project Campaigns** | **BL** t HNO3 | 63 577 | 01 Sep 2007 | 15 Apr 2008 | 227 | 280 | Umicore | 95/5 |
| | **PL** t HNO3 | 86 762 | 21 Nov 2009 | 25 Oct 2010 | 338 | 257 | Umicore | 95/5 |

It is business as usual scenario in Achema UKL-7 plant to keep using primary catalysts from several suppliers and with several compositions. Selection of primary catalysts is determined by technical parameters of their use and price levels offered by suppliers in specific time. Primary catalysts used during the baseline campaign, if other than used in previous campaign/s, did not increase emissions of N2O as confirmed by relevant statements provided to the verifier.

T 3 and Chart C 1 define the length of the baseline campaign. Baseline campaign measurements for this project campaign started on 01/09/2007 and continued through 15/04/2008 when the 63 577 $tHNO_3$ nitric acid production was reached. The measurement of baseline Nitrous Acid Concentration (NCSG) was carried out until production reached - $tHNO_3$ .

### T 3 Baseline campaign length

| **ACHEMA UKL-8** | **Historic Campaings End** | **Start of Baseline Measurement** | **End of Baseline Measurement NCSG** | **End of Baseline Measurement** | **End of Baseline Campaign** |
|---|---|---|---|---|---|
| **Dates** | 2007 Aug 28 | 2007 Sep 01 | 2008 Mar 15 | 2008 Apr 15 | 2008 Apr 16 |
| **Baseline Factor kgN2O/tHNO3** | - | - | 6.96 | 6.96 | 6.96 |
| **Production tHNO3** | | - | 52 603 | 63 577 | - |
| **Per Day Production tHNO3** | 279.0 | | | | |
| **Baseline less Historic Production** | **(42.6)** | | | | |
| **Baseline less Historic Days** | **(0.2)** | | | | |
| | | | | | |

## C 1 Baseline campaign length

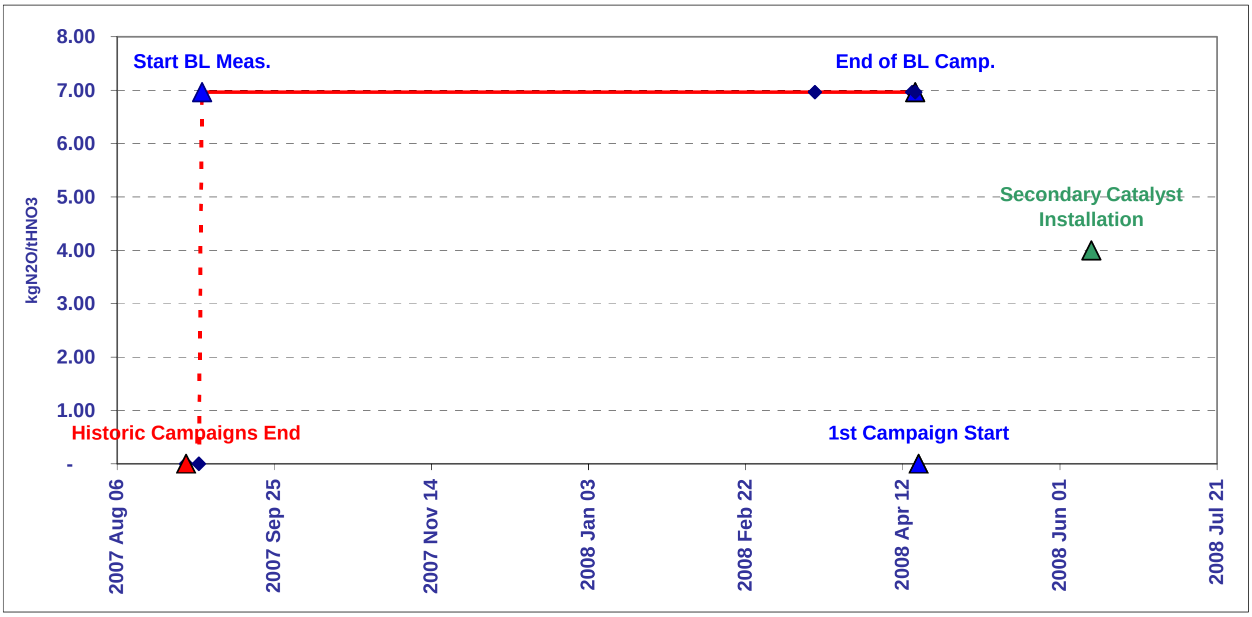


Table T 4 illustrates the calculation of the baseline emission factor on Line 8 using the method as defined in the CDM methodology AM0034 and in the PDD. We have not used overlapping approach allowed by the PDD. Baseline emission factor was determined based on raw data measured from 01/09/2007 through 15/04/2008.

Extreme values and data measured during hours when one or more of operating conditions were outside of the permitted range have been eliminated from the calculations. As a next step we have eliminated data beyond 95% confidence interval and calculated new mean values of $N_2O$ concentration and stack gas volume flow using following method:

a) Calculate the sample mean (x)
b) Calculate the sample standard deviation (s)
c) Calculate the 95% confidence interval (equal to 1.96 times the standard deviation)
d) Eliminate all data that lie outside the 95% confidence interval
e) Calculate the new sample mean from the remaining values (volume of stack gas (VSG) and $N_2O$ concentration of stack gas (NCSG))

Using the means values we have calculated the baseline emissions as set out in the PDD.

$$BE_{BC} = VSG_{BC} * NCSG_{BC} * 10^{-9} * OH_{BC} \ (tN_2O)$$

Operating hours defined as hours, when nitric acid production at least 0.1 tHNO3 and oxidation temperature at least 600˚C occurred. Calculated baseline N2O emissions were 470 $tN_2O$.

$$EF_{BL} = (BE_{BC} / NAP_{BC})\ (1 – UNC/100)\ (tN_2O/tHNO_3)$$

The UNC factor defined by the QAL2 report is 5.890%, which is further modified by an uncertainty of 0.106% due to under-sampling. As a result we have arrived to the baseline emission factor of 6.96 $kgN_2O/tHNO_3$.

Table T 5 shows the calculation of the project emission factor on Line 8 during the project campaign. Project campaign started on 21/11/2009 and went through 25/10/2010.

We have eliminated extreme values and data beyond the 95% confidence interval as prescribed by the PDD.

a) Calculate the sample mean (x)
b) Calculate the sample standard deviation (s)
c) Calculate the 95% confidence interval (equal to 1.96 times the standard deviation)
d) Eliminate all data that lie outside the 95% confidence interval
e) Calculate the new sample mean from the remaining values

Using the mean values we have calculated total mass of $N_2O$ emissions ($PE_n$) as follows:

$$PE_n = VSG * NCSG * 10-9 * OH \ (tN2O)$$

Operating hours (OH) defined as hours, when nitric acid production at least 0.1 tHNO3 and oxidation temperature at least 600˚C occurred.

By dividing total mass of $N_2O$ emissions by the nitric acid production (capped by nameplate capacity 350 tHNO3/day) we have determined the project campaign specific emission factor at value of 3.56 kgN2O/tHNO3.

$$EF_n = PE_n / NAP_n \ (tN_2O/tHNO_3)$$

Because the project emission factor measured was lower than the moving average EF of the campaigns on this line so far, we have used the average EF for the calculation of the quantity of emission reductions generated during this campaign.

# T 4 Baseline emission factor

| BASELINE EMISSION FACTOR | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Parameter* | Operating Hours | Nitric Acid Production | N2O Concentration | Gas Volume Flow | Ammonia Flow Rate | Ammonia to Air Ratio | Oxidation Temperature | Oxidation Pressure | AMS in Operation | Nitric Acid Production NCSG |
| *Code* | OH | NAP | NCSG | VSG | AFR | AIFR | OT | OP | | NAP |
| *Unit* | h | t/h | mg N2O/Nm3 | Nm3/h | Nm3/h | % | °C | kPa | h | t/h |
| **Elimination of extreme values** | | | | | | | | | | |
| Lower limit | | 0 | 0 | 0 | 0 | 0 | - 50 | 0 | | 0 |
| Upper Limit | | 50.00 | 3 000 | 120 000 | 10 000 | 20.00 | 1 200 | 1 000 | | 50 |
| **Raw Data Measured Range** | | | | | | | | | | |
| Count | **4 719** | 4 954 | 4 059 | 4 598 | 4 987 | 4 663 | 5 425 | 5 425 | 4 129 | 4 211 |
| *as % of Dataset* | *87%* | *91%* | *75%* | *84%* | *92%* | *86%* | *100%* | *100%* | *76%* | *77%* |
| Minimum | | 0.00 | 0 | 4 | 0 | 0 | 27 | 5 | | 0 |
| Maximum | | 24.99 | 1 968 | 103 514 | 6 796 | 14.80 | 912 | 654 | | 25 |
| Mean | | 12.83 | 1 067 | 78 981 | 5 591 | 10.07 | 801 | 564 | | 12 |
| Standard Deviation | | 5.07 | 458 | 16 813 | 1 520 | 0.93 | 245 | 116 | | 5 |
| Total | | 63 577 | | | | | | | | 52 603 |
| N2O Emissions ( VSG * NCSG * OH) | 398 | t N2O | | | | | | | | |
| Emission Factor | 5.88 | kgN2O / tHNO3 | | | | | | | | |
| **Permitted Range** | | | | | | | | | | |
| Minimum | | | | | - | 0 | 880 | 550 | | |
| Maximum | | | | | 7 500 | 11.20 | 910 | 800 | | |
| **Data within the permitted range** | | | | | | | | | | |
| Count | **4 453** | | 3 230 | 4 131 | | | | | 4 129 | |
| *as % of Operating Hours* | ***94%*** | | *68%* | *88%* | | | | | *87%* | |
| Minimum | | | 781 | - | | | | | | |
| Maximum | | | 1 732 | 96 663 | | | | | | |
| Mean | | | 1 232 | 77 635 | | | | | | |
| Standard Deviation | | | 206 | 16 881 | | | | | | |
| N2O Emissions ( VSG * NCSG * OH) | 452 | t N2O | | | | | | | | |
| Emission Factor | 6.68 | kgN2O / tHNO3 | | | | | | | | |
| **Data within the confidence interval** | | | | | | | | | | |
| 95% Confidence interval | | | | | | | | | | |
| Lower bound | | | 828 | 44 549 | | | | | | |
| Upper bound | | | 1 637 | 110 722 | | | | | | |
| Count | | | 3 167 | 3 949 | | | | | | |
| *as % of Operating Hours* | | | *67%* | *84%* | | | | | | |
| Minimum | | | 838 | 75 503 | | | | | | |
| Maximum | | | 1 635 | 96 663 | | | | | | |
| Mean | | | 1 227 | 81 213 | | | | | | |
| Standard Deviation | | | 199 | 2 729 | | | | | | |
| **N2O Emissions ( VSG * NCSG * OH)** | **470** | **t N2O** | | | | | | | | |
| **Emission Factor (EF_BL)** | **6.96** | **kgN2O / tHNO3** | | | | | | | | |

# T 5 Project emission factor

| PROJECT EMISSION FACTOR | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *Parameter* | Operating Hours | Nitric Acid Production | N2O Concentration | Gas Volume Flow | Ammonia Flow Rate | Ammonia to Air Ratio | Oxidation Temperature | Oxidation Pressure |
| *Code* | **OH** | **NAP** | **NCSG** | **VSG** | **AFR** | **AIFR** | **OT** | **OP** |
| *Unit* | **h** | **t/h** | **mg N2O/Nm3** | **Nm3/h** | **Nm3/h** | **%** | **°C** | **kPa** |
| **Elimination of extreme values** | | | | | | | | |
| Lower limit | | 0 | 0 | 0 | 0 | 0 | - 50 | 0 |
| Upper Limit | | 50.00 | 3 000 | 120 000 | 10 000 | 20.00 | 1 200 | 1 000 |
| **Raw Data Measured Range** | | | | | | | | |
| Count | **5 907** | 8 108 | 5 914 | 5 893 | 8 110 | 6 460 | 8 110 | 8 110 |
| *as % of Dataset* | *73%* | *100%* | *73%* | *73%* | *100%* | *80%* | *100%* | *100%* |
| Minimum | | 0.02 | 193 | 66 410 | 2 | 0 | 13 | 6 |
| Maximum | | 17.91 | 1 100 | 99 082 | 8 000 | 19.99 | 914 | 709 |
| Mean | | 10.70 | 388 | 78 705 | 4 865 | 9.44 | 672 | 564 |
| Standard Deviation | | 6.41 | 55 | 6 726 | 2 305 | 2.56 | 371 | 149 |
| Total | | 86 762 | | | | | | |
| N2O Emissions ( VSG * NCSG * OH) | 180 | t N2O | | | | | | |
| Emission Factor | 2.08 | kgN2O / tHNO3 | | | | | | |
| **Data within the confidence interval** | | | | | | | | |
| 95% Confidence interval | | | | | | | | |
| Lower bound | | | 281 | 65 521 | | | | |
| Upper bound | | | 495 | 91 889 | | | | |
| Count | | | 5 704 | 5 564 | | | | |
| *as % of Operating Hours* | | | *97%* | *94%* | | | | |
| Minimum | | | 281 | 66 410 | | | | |
| Maximum | | | 495 | 91 886 | | | | |
| Mean | | | 388 | 78 034 | | | | |
| Standard Deviation | | | 48 | 6 189 | | | | |
| **N2O Emissions ( VSG * NCSG * OH)** | **179** | **t N2O** | | | | | | |
| **Actual Project Emission Factor (EF_PActual)** | **2.06** | **kgN2O / tHNO3** | | | | | | |
| **Abatement Ratio** | **70.4%** | | | | | | | |
| **Moving Average Emission Factor Correction** | **Actual Factors** | **Moving Average Rule** | | | | | | |
| **1** | 4.35 | 4.35 | | | | | | |
| **2** | 4.26 | 4.30 | | | | | | |
| **3** | 2.06 | 3.56 | | | | | | |
| **4** | - | | | | | | | |
| **Project Emission Factor (EF_P)** | **3.56** | **kgN2O / tHNO3** | | | | | | |
| **Abatement Ratio** | **48.9%** | | | | | | | |

## Comparison of the baseline emission factors against $N_2O$ mass limit in the IPPC permit

The N2O cap is defined in the IPPC permit on a yearly basis for the whole UKL-7 plant. The emission can be distributed among lines irregularly, as long as the total emission in each year stays under the yearly limit.

The regulatory emission factor EFReg is defined as the emission factor which would result in hitting the emission cap on a plant level.

We apply a method to attribute EFReg values to each campaign in a way that can be considered fair, and demonstrates a balanced scenario. The yearly N2O caps are allocated to campaigns proportionate to the amount of Nitric Acid they produced compared to other lines during the same year. The total cap of a campaign is the sum of such yearly limits. This way the total amount of plant level limit is always allocated. If each and every campaign would operate with those emission levels, the plant would just hit its yearly N2O caps in each year.

In incomplete years, the initial EFReg values will be high for the first campaigns, but will be lowered and balanced out as new campaigns are finished. These values serve informational purposes, and the real IPPC cap is checked on a plant level.

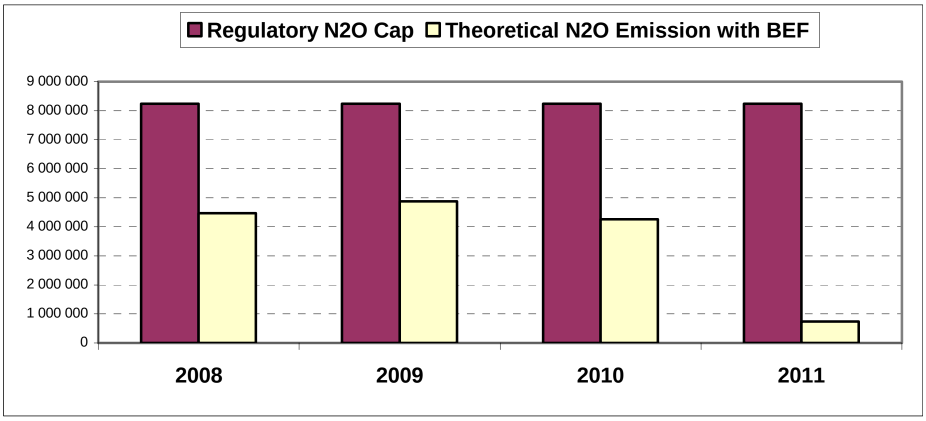
The main indicator of staying under the IPPC limit is the plant level yearly N2O emission calculated with baseline emission factors. Whenever an overflow of N2O emission would occur on plant level in a year, the sum of the product of baseline emission factors and yearly campaign NAP values would immediately indicate this and the projects would not be able to generate more ERU-s in that year.

```
Campaign_N2O_Cap =
      sum( Campaign_NAP[y] / Total_NAP[y] * Plant_N2O_Cap[y]
      for y in [2008,2009,2010,2011] )

Campaign_EFReg = Campaign_N2O_Cap / Campaign_NAP

Plant_N2O_Emission[y] =
      sum( Campaign_BEF[c] * Campaign_NAP[c,y] for c in campaigns )
```

- where Campaign_NAP[y] is the Nitric Acid Produced on a given campaign in year “y”
- Total_NAP is the total production on all lines in that year.
- the campaign EFReg is the campaigns emission cap divided by the campaign’s actual production.
- Plant_N2O_Emission[y] is the theoretical level of N2O emitted in year “y” by using the Baseline Emission Factors of each campaign, and calculating the “sumproduct” of BEF-s and yearly Nitric Acid Production of the lines

| Regulatory values | | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|
| Regulatory N2O Cap | *kgN2O* | 8 494 200 | 9 266 400 | 9 266 400 | 9 266 400 |
| *Excluding Line 9* | *kgN2O* | 8 236 800 | 8 236 800 | 8 236 800 | 8 236 800 |

| Plant emissions under baseline conditions | | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|
| Total Nitric Acid Produced | *tHNO3* | 587 784 | 592 413 | 512 108 | 89 932 |
| Theoretical N2O Emission with BEF | *kgN2O* | 4 472 161 | 4 871 985 | 4 253 083 | 739 232 |
| Weighted average BEF | *kgN2O/tHNO3* | 7.61 | 8.22 | 8.31 | 8.22 |
| Critical BEF to reach cap with actual NAP | *kgN2O/tHNO3* | 14.01 | 13.90 | 16.08 | 91.59 |
| N2O emission overflow | *kgN2O* | **0** | **0** | **0** | **0** |



| Nitric acid produced during project campaigns | | | | | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|
| Line | Campaign | BEF | Start | End | NAP | | | |
| 1 | 0 | 9.63 | 14 Mar 2008 | 21 Oct 2008 | 60 691 | | | |
| 2 | 0 | 7.92 | 09 Nov 2007 | 20 May 2008 | 28 951 | | | |
| 3 | 0 | 4.42 | 01 Feb 2008 | 30 Jun 2008 | 42 999 | | | |
| 4 | 0 | 7.20 | 28 Dec 2007 | 31 Jul 2008 | 57 815 | | | |
| 5 | 0 | 6.61 | 29 Nov 2007 | 17 Jun 2008 | 47 192 | | | |
| 6 | 0 | 10.34 | 11 Jan 2008 | 21 Jul 2008 | 60 850 | | | |
| 7 | 0 | 7.85 | 12 Sep 2007 | 27 Mar 2008 | 26 856 | | | |
| 8 | 0 | 6.61 | 02 Sep 2007 | 15 Apr 2008 | 34 716 | | | |
| 1 | 1 | 9.63 | 04 Nov 2008 | 10 May 2010 | 1 913 | 55 103 | 37 831 | |
| 2 | 1 | 7.92 | 07 Nov 2008 | 16 Jan 2009 | 12 151 | 241 | | |
| 3 | 1 | 4.42 | 04 Jul 2008 | 27 Aug 2008 | 13 520 | | | |
| 4 | 1 | 7.20 | 06 Oct 2008 | 28 Apr 2009 | 11 753 | 27 403 | | |
| 5 | 1 | 6.61 | 02 Jul 2008 | 22 Apr 2009 | 39 871 | 20 358 | | |
| 6 | 1 | 10.34 | 25 Jul 2008 | 21 Apr 2009 | 41 416 | 26 902 | | |
| 7 | 1 | 7.85 | 03 Jul 2008 | 22 Oct 2008 | 31 445 | | | |
| 8 | 1 | 6.61 | 11 Jun 2008 | 26 Nov 2008 | 45 181 | | | |
| 1 | 2 | | | | | | | |
| 2 | 2 | 9.51 | 16 Jan 2009 | 12 Oct 2009 | | 61 628 | | |
| 3 | 2 | 5.45 | 27 Aug 2008 | 16 Jun 2009 | 24 950 | 31 372 | | |
| 4 | 2 | 7.73 | 07 May 2009 | 06 May 2010 | | 42 744 | 22 505 | |
| 5 | 2 | 6.61 | 23 Apr 2009 | 14 Jan 2010 | | 66 630 | 4 642 | |
| 6 | 2 | 10.34 | 27 Apr 2009 | 25 Nov 2009 | | 66 297 | | |
| 7 | 2 | 9.09 | 29 Jan 2009 | 01 Nov 2009 | | 58 897 | | |
| 8 | 2 | 6.96 | 09 Dec 2008 | 20 Nov 2009 | 5 513 | 53 779 | | |
| 1 | 3 | | | | | | | |
| 2 | 3 | 9.51 | 13 Oct 2009 | 21 Oct 2010 | | 17 444 | 68 634 | |
| 3 | 3 | 5.45 | 17 Jun 2009 | 16 Nov 2010 | | 35 016 | 49 304 | |
| 4 | 3 | 7.73 | 03 Aug 2010 | 09 Mar 2011 | | | 38 627 | 20 608 |
| 5 | 3 | 6.61 | 12 Aug 2010 | 17 Mar 2011 | | | 48 928 | 27 358 |
| 6 | 3 | 10.34 | 27 Nov 2009 | 20 Sep 2010 | | 9 863 | 76 524 | |
| 7 | 3 | 9.09 | 03 Nov 2009 | 08 Dec 2010 | | 8 079 | 63 581 | |
| 8 | 3 | 6.96 | 21 Nov 2009 | 25 Oct 2010 | | 10 657 | 76 105 | |
| 1 | 4 | | | | | | | |
| 2 | 4 | 9.51 | 22 Oct 2010 | 12 May 2011 | | | 25 426 | 41 966 |
| 3 | 4 | | | | | | | |
| 4 | 4 | | | | | | | |
| 5 | 4 | | | | | | | |
| 6 | 4 | | | | | | | |
| 7 | 4 | | | | | | | |
| 8 | 4 | | | | | | | |

| NAP Proportionate Regulatory Emission Factor | | | |
|---|---|---|---|
| NAP | N2O Cap | EFReg | N2O with BEF |
| 60 691 | 850 482 | 14.01 | 584 454 |
| 28 951 | 405 704 | 14.01 | 229 295 |
| 42 999 | 602 557 | 14.01 | 190 055 |
| 57 815 | 810 180 | 14.01 | 416 268 |
| 47 192 | 661 323 | 14.01 | 311 942 |
| 60 850 | 852 711 | 14.01 | 629 190 |
| 26 856 | 376 347 | 14.01 | 210 822 |
| 34 716 | 486 487 | 14.01 | 229 473 |
| 94 846 | 1 401 419 | 14.78 | 913 370 |
| 12 392 | 173 627 | 14.01 | 98 145 |
| 13 520 | 189 455 | 14.01 | 59 757 |
| 39 157 | 545 713 | 13.94 | 281 927 |
| 60 229 | 841 780 | 13.98 | 398 114 |
| 68 318 | 954 414 | 13.97 | 706 407 |
| 31 445 | 440 647 | 14.01 | 246 842 |
| 45 181 | 633 132 | 14.01 | 298 644 |
| 0 | | | |
| 61 628 | 856 864 | 13.90 | 586 082 |
| 56 322 | 785 819 | 13.95 | 306 953 |
| 65 249 | 956 279 | 14.66 | 504 375 |
| 71 273 | 1 001 082 | 14.05 | 471 111 |
| 66 297 | 921 776 | 13.90 | 685 507 |
| 58 897 | 818 894 | 13.90 | 535 374 |
| 59 291 | 824 982 | 13.91 | 412 669 |
| 0 | | | |
| 86 079 | 1 346 465 | 15.64 | 818 607 |
| 84 321 | 1 279 879 | 15.18 | 459 548 |
| 59 235 | 2 508 745 | 42.35 | 457 886 |
| 76 285 | 3 292 645 | 43.16 | 504 247 |
| 86 387 | 1 367 957 | 15.84 | 893 243 |
| 71 660 | 1 134 971 | 15.84 | 651 388 |
| 86 762 | 1 372 261 | 15.82 | 603 866 |
| 0 | | | |
| 67 392 | 4 252 605 | 63.10 | 640 901 |
| 0 | | | |
| 0 | | | |
| 0 | | | |
| 0 | | | |
| 0 | | | |
| 0 | | | |

The current verification includes the following line and campaigns pairs: (2,3), (2,4), (3,3), (4,3), (5,3), (7,3) and (8,3). All the EFReg values are green, which indicates that none of the campaigns resulted in excess emission relative to others given their production levels and the plant IPPC limit, and the regulatory emission factor is higher than the baseline emission factor of the campaigns.

The summary table “Plant emission under baseline conditions” contain yearly emission figures, and as all of the “Theoretical N2O Emission with BEF” stay under the yearly caps (made visible by the chart), none of the IPPC limits were ever violated. By taking the currently finished campaigns into account, all the ERU-s can be claimed so far.

# REVISIONS TO THE MONITORING PLAN

**PROJECT:** **ACHEMA UKL nitric acid plant $N_2O$ abatement project**

**Prepared by:**

VERTIS

**VERTIS FINANCE**

As required by PROCEDURES REGARDING CHANGES DURING PROJECT IMPLEMENTATION (Version 01) issued by the Joint Implementation Supervisory Committee we are listing here all changes occurred to the Achema UKL-7 JI project from time when the PDD document including the Monitoring Plan was deemed to be final (November 27, 2009) until December 8, 2010:

**Section D.1. (pages 18-19 and 57-58)**

Updated information on the $N_2O$ concentration measurements done on the switched basis. It does not relate to any change comparing to the Monitoring Plan as determined, it is just insertion of more detailed description.

**Section D.1. (pages 20-21 and 59-60)**

Achema injects steam into tail gas of the UKL-7 plant. This steam is eliminated fro the JI project calculations. Monitoring plan has been updated with detailed description of how this elimination is performed in practice.

**Section D.1. (pages 21-23 and 62-64)**

Achema measures nitric acid production by refractometers and also by laboratory analysis. Insertion into the Monitoring Plan describes in details how these measurements are performed and used.