Ammonia Slip and Measurement in Power Plants with SCR and Oxidation Catalyst

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Release History

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1 IED / BAT Conclusion

The legal basis for the emission limits and the associated monitoring methods of power plants in Europe is shown by the **Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control).** Even though there is no Emission Limit Value (ELV) for ammonia (NH_3) emissions of large combustion power plants (> 50 MW), the BAT conclusions must be taken into account.

The **Commission Implementing Decision (EU) 2021/2326 of 30 November 2021 establishing best available techniques (BAT) conclusions, under Directive 2010/75/EU of the European Parliament and of the Council, for large combustion plants (notified under document C (2021) 8580)** states, that NH_3 emissions have to be continuously monitored when SCR and / or SNCR is used, but leaves it open to reduce the frequency of the measurement to at least once a year, if the emission levels are proven to be sufficiently stable. Since there are components such as formaldehyde and methane, which are already measured once a year, the measurement of NH_3 can simply be added to the schedule.

BAT 4. BAT is to monitor emissions to air with at least the frequency given below and in accordance with EN standards. If EN standards are not available, BAT is to use ISO, national or other international standards that ensure the provision of data of an equivalent scientific quality.

Substance/Parameter	Fuel/Process/Type of combustion plant	Combustion plant total rated thermal input	Standard(s) (4)	Minimum monitoring frequency (5)	Monitoring associated with
NH_3	—When SCR and/or SNCR is used	All sizes	Generic EN standards	Continuous (6) (7)	BAT 7

(7) In the case of use of SCR, the minimum monitoring frequency may be at least once every year, if the emission levels are proven to be sufficiently stable.

Additionally the BAT conclusions define the range of BAT-associated emission levels for NH_3, which range from < 3 to 10 mg/Nm³.

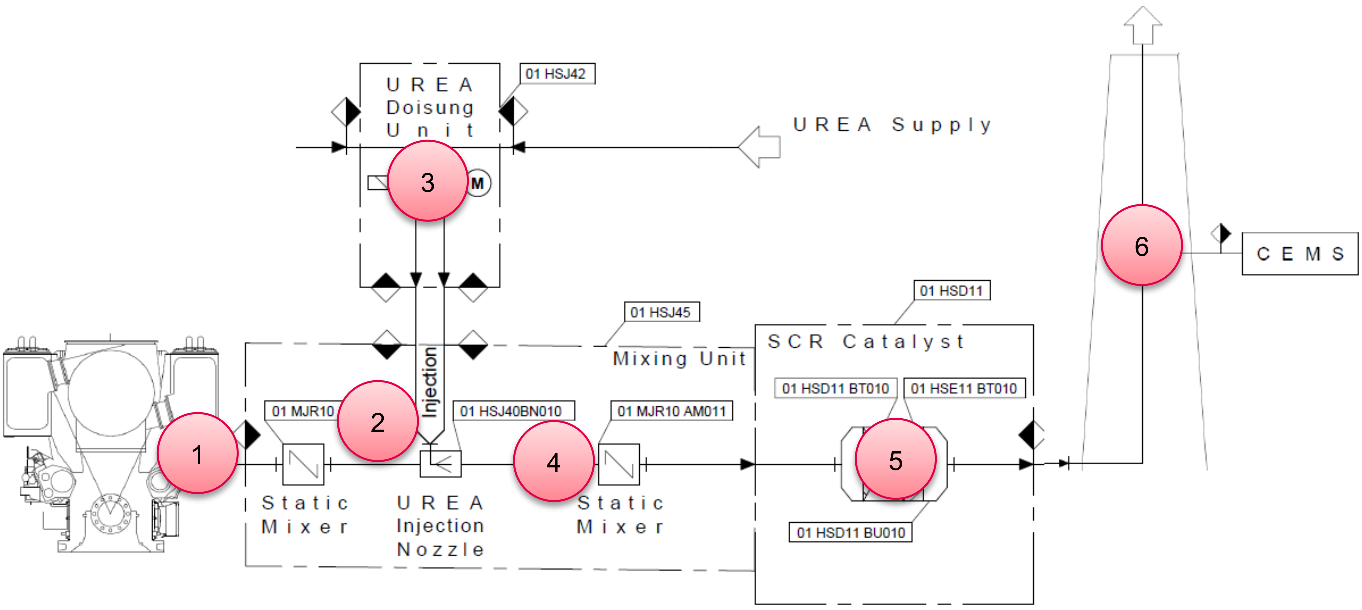
BAT 7. In order to reduce emissions of ammonia to air from the use of selective catalytic reduction (SCR) and/or selective non-catalytic reduction (SNCR) for the abatement of NO_X emissions, BAT is to optimise the design and/or operation of SCR and/or SNCR (e.g. optimised reagent to NO_X ratio, homogeneous reagent distribution and optimum size of the reagent drops).

BAT-associated emission levels

The BAT-associated emission level (BAT-AEL) for emissions of NH_3 to air from the use of SCR and/or SNCR is < 3–10 mg/Nm³ as a yearly average or average over the sampling period. The lower end of the range can be achieved when using SCR and the upper end of the range can be achieved when using SNCR without wet abatement techniques. In the case of plants combusting biomass and operating at variable loads as well as in the case of engines combusting HFO and/or gas oil, the higher end of the BAT-AEL range is 15 mg/Nm³.

2 Exhaust Aftertreatment System

2.1 Functional Description



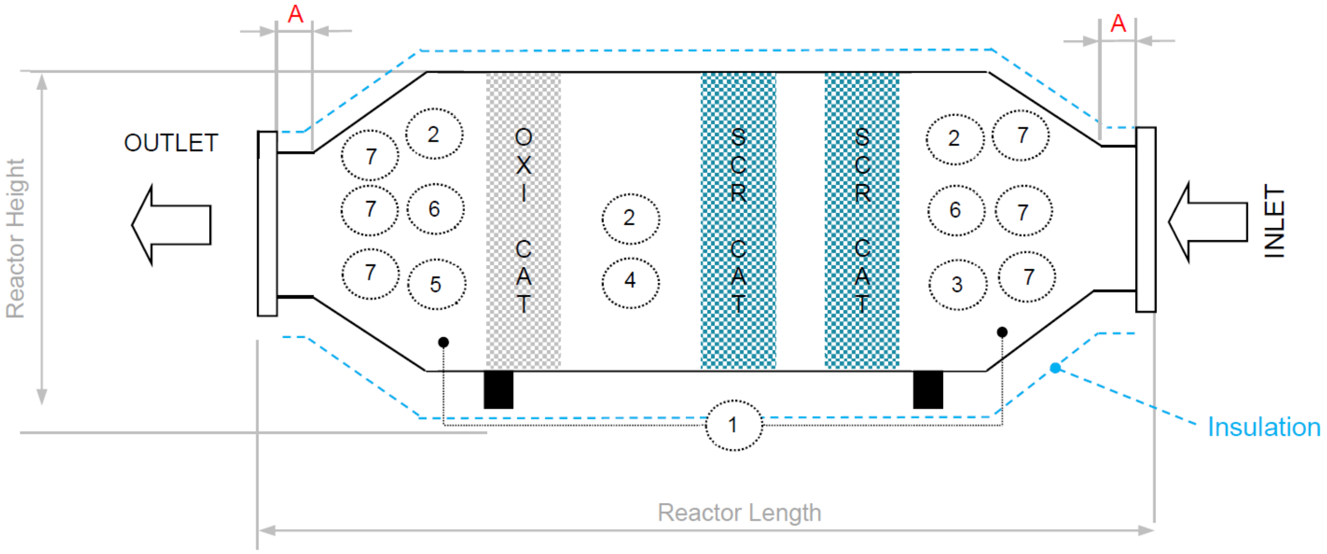
A SCR system is installed to reduce the nitrogen oxides (NO_x) emissions of the exhaust gas. It consists of the controlled injection (2) of the reduction agent (urea) as small droplets through the injection nozzle into the exhaust gas (1).
The amount of urea is controlled in the dosing unit (3) over the load of the engine and also adjusted by in-situ NOx measurement.

In the mixing unit (4), the urea is evaporating and reacting to ammonia. With static mixers, a homogeneous mixture of exhaust gas and ammonia is accomplished.

This mixture flows into the reactor (5) which contains the catalysts for the emission reduction and also sensors like temperature, pressure and in-situ NOx for process monitoring.
In the reactor the NOx is reduced with the NH_3 to N2 and H2O over the SCR catalyst layers. Downstream additional emissions, such as carbon monoxide (CO) and formaldehyde (HCHO), are reduced by the oxidation catalyst layer.

With the certified Continuous Emission Monitoring System (CEMS) (6), the concentration of the exhaust gas (CO, NOx and O_2) are measured.

2.2 Ammonia Slip



On one hand, NH_3 slip after the SCR catalyst is possible. The amount of NH_3 in the exhaust gas is only depending on the amount of injected urea in the mixing unit as there is no ammonia in the fuel of the engine. In case of too much injected urea, the ratio of NOx to NH_3 is out of balance and results in a NH_3 slip after the SCR catalyst layers.
But on the other hand, due to the oxidation catalyst the NH_3 slip nearly completely reacts to NOx, N2 and H2O. The reason for this is the highly reactive surface of the oxidation catalyst, which consists of platinum and/or palladium for the reduction of CO and HCHO.

To detect possible ammonia slip without direct measurement, there are different systems in place.

All faults of the SCR system which are affecting the operation of the SCR and therefore the reduction of NOx will be sent to and logged by the CEMS / Emission PC.
A failure of the dosing unit or the SCR system, resulting in large amounts of NH_3 or NOx, would not be left unnoticed, since this results in rising NOx emissions to the environment, which will be detected by the CEMS.
Furthermore, the SCR control system is monitoring the urea flow. In case of too high or too low values, the system will direct an error signal to the plant control system.

If the oxidation catalyst is faulty or the activity is decreasing, it’s possible that not the entirety of NH_3 is converted. In this case also a rise of the continuously measured CO value will occur. Since the oxidation catalyst is a passive part, it is important to follow the maintenance instructions, which include replacing the catalyst after a given amount of time or operating hours.

3 Previous Data

To verify the stable and low emissions of the combination of SCR with downstream oxidation catalyst regarding NH_3 emissions, the emission monitoring data of various power plants constructed by MAN with similar exhaust gas treatment systems have been collected. The following gas engine power plants measured the ammonia emissions of each engine separately.

The reason for the continuous NH_3 measurement in German power plants is the 2021 released 13. BImSchV, which is the national equivalent to the IED. The definition implies a continuous measurement of NH_3. Other European plants (and German ones built before 2021) only measure NH_3 discontinuously.

The German law requires to reference the emission value at 5 % oxygen. For a value comparable to the BAT AEL **(< 3 to 10 mg/Nm³)**, the concentration was additionally calculated at 15% oxygen and marked **bold** in the tables.

$$E_B = \frac{21 - O_{2,B}}{21 - O_{2,M}} \cdot E_M$$

E_B
= emissions, based on the reference oxygen content
E_M
= measured emissions
$O_{2,B}$
= Reference oxygen content in percent by volume
$O_{2,M}$
= measured oxygen content in percent by volume.

3.1 Continuous NH_3 Measurements of 2023

The source of the data is the report of the Continuous Emission Monitoring System (CEMS) for the year 2023.

Plant 1 is a power plant with five natural gas engines in eastern Germany. The plant is equipped with a FTIR (ABB ACF 5000) CEMS. According to the QAL1 certificate, the total expanded uncertainty of the ACF5000 regarding NH_3 is **0,35 mg/m³** (see appendix).

Plant 1	Operation time subject to monitoring [h]	Annual average [mg/Nm³] @5% O2	**Annual average [mg/Nm³] @15% O2**	Mass Flow [kg/a]
Engine 1	904,5	0	**0**	5,37
Engine 2	667,0	0	**0**	2,52
Engine 3	787,0	0	**0**	2,80
Engine 4	554,5	0	**0**	1,78
Engine 5	803,0	0	**0**	3,58

Plant 2 is a power plant with seven natural gas engines in eastern Germany. The plant is equipped with a FTIR (ABB ACF5000) CEMS as well.

Plant 2	Operation time subject to monitoring [h]	Annual average [mg/Nm³] @5% O2	**Annual average [mg/Nm³] @15% O2**	Mass Flow [kg/a]
Engine 1	939,0	0	**0**	0,17
Engine 2	670,5	0	**0**	0,24
Engine 3	817,5	0	**0**	0,28

Engine 4	887,0	0	**0**	2,29
Engine 5	993,5	0	**0**	0,24
Engine 6	775,5	0	**0**	0,84
Engine 7	1059,5	0	**0**	0,10

Plant 3 is a power plant with three natural gas engines in south Germany. The plant is equipped with a FTIR (ABB ACF5000) CEMS as well.

Plant 3	Operation time subject to monitoring [h]	Annual average [mg/Nm³] @5% O2	**Annual average [mg/Nm³] @15% O2**	Mass Flow [kg/a]
Engine 1	2495,5	0,14	**0,05**	14,05
Engine 2	2304,5	0,00	**0,00**	3,57
Engine 3	3183,0	0,13	**0,05**	21,51

3.2 Average NH_3 Values 2019-2023

In case of plant 3, also the previous annual averages of the CEMS (FTIR ABB ACF5000) for the last five years are available.

Plant 3 - Engine 1 Year	Valid Daily Averages [d]	Annual Average [mg/Nm³] @5% O2	**Annual Average [mg/Nm³] @15% O2**
2023	136	0,14	**0,05**
2022	101	0,11	**0,04**
2021	203	0,07	**0,03**
2020	265	0,07	**0,03**
2019	225	0,09	**0,03**

Plant 3 - Engine 2 Year	Valid Daily Averages [d]	Annual Average [mg/Nm³] @5% O2	**Annual Average [mg/Nm³] @15% O2**
2023	129	0,00	**0,00**
2022	110	0,01	**0,00**
2021	225	0,00	**0,00**
2020	250	0,00	**0,00**
2019	215	0,06	**0,02**

Plant 3 - Engine 3 Year	Valid Daily Averages [d]	Annual Average [mg/Nm³] @5% O2	**Annual Average [mg/Nm³] @15% O2**
2023	176	0,13	**0,05**
2022	99	0,02	**0,01**
2021	219	0,04	**0,02**
2020	262	0,04	**0,02**
2019	223	0,04	**0,02**

3.3 Yearly Measurement 2022

Plant 4 is a power plant with five natural gas engines in north eastern Germany which was built before 2021. The Plant is equipped with a NDIR CEMS. Due to the cold / dry measurement of the NDIR CEMS and the steady NH_3 emissions, the emissions are measured during the yearly measurement. Below the NH_3 emissions of 2022 at 100% engine load are shown.

Plant 4 2022 At 100% load	Maximum measured value minus expanded measurement uncertainty [mg/Nm³] @ 5%O2	**Maximum measured value minus expanded measurement uncertainty [mg/Nm³] @ 15%O2**	Maximum measured value plus expanded measurement uncertainty [mg/Nm³] @ 5%O2	**Maximum measured value plus expanded measurement uncertainty [mg/Nm³] @ 15%O2**
Engine 1	0,30	**0,11**	0,50	**0,19**
Engine 2	0,30	**0,11**	0,50	**0,19**
Engine 3	1,00	**0,38**	1,00	**0,38**
Engine 4	1,00	**0,38**	1,00	**0,38**
Engine 5	0,40	**0,15**	1,00	**0,38**

4 Conclusion

The IED does not demand NH_3 measurement and the BAT conclusions allow a reduction of the measurement frequency from continuously to yearly if certain factors are fulfilled.

A low and stable NH_3 value is achieved by the design of the system, in which a potential NH_3 slip is reduced by the oxidation catalyst. Deviation from the normal aftertreatment operation which could result in higher NH_3 emissions will either result in higher values of CO or NOx or will generate an error signal which are logged by the CEMS and require action by, or at least will notify, the operator anyhow.

Previous data, either continuously or yearly measured, shows that the average values of NH_3 fall far below the BAT AEL of < 3 to 10 mg/Nm³ and most of the time are within the extended uncertainty of the used analyzer. Continuous measurement is only realized in German power plants due to even stricter NH_3 demands than the BAT.

In conclusion, a yearly NH_3 measurement is complete sufficient for the used exhaust aftertreatment system.

5 Appendix

5.1 QAL1 Certificate ACF5000

(https://www.qal1.de/content-media-files/qal1/abb/0000053802_02_abb_acf5000_en.pdf)

Umwelt Bundesamt

Certificate:
0000053802_02 / 02 March 2022

TÜVRheinland®
Precisely Right.

Calculation of overall uncertainty according to EN 14181 and EN 15267-3

Measuring system					
Manufacturer	ABB Automation GmbH				
AMS designation	ACF5000				
Serial number of units under test	3.351922.3 / Beta2 / 3.351923.3 / Beta3				
Measuring principle	FTIR				
Test report	936/21219814/E				
Test laboratory	TÜV Rheinland				
Date of report	2017-03-10				
Measured component	NH_3				
Certification range	0 - 5 mg/m³				
Evaluation of the cross-sensitivity (CS)					
(system with largest CS)					
Sum of positive CS at zero point		0.00	mg/m³		
Sum of negative CS at zero point		-0.09	mg/m³		
Sum of postive CS at span point		0.00	mg/m³		
Sum of negative CS at span point		-0.19	mg/m³		
Maximum sum of cross-sensitivities		-0.19	mg/m³		
Uncertainty of cross-sensitivity	u_i	-0.110	mg/m³		
Calculation of the combined standard uncertainty					
Tested parameter				u²	
Repeatability standard deviation at set point *	u_r	0.042	mg/m³	0.002	(mg/m³)²
Lack of fit	u_{lof}	-0.029	mg/m³	0.001	(mg/m³)²
Zero drift from field test	$u_{d,z}$	-0.066	mg/m³	0.004	(mg/m³)²
Span drift from field test	$u_{d,s}$	-0.069	mg/m³	0.005	(mg/m³)²
Influence of ambient temperature at span	u_t	0.062	mg/m³	0.004	(mg/m³)²
Influence of supply voltage	u_v	0.040	mg/m³	0.002	(mg/m³)²
Cross-sensitivity (interference)	u_i	-0.110	mg/m³	0.012	(mg/m³)²
Influence of sample gas flow	u_p	-0.019	mg/m³	0.000	(mg/m³)²
Uncertainty of reference material at 70% of certification range	u_{rm}	0.040	mg/m³	0.002	(mg/m³)²

* The larger value is used :
"Repeatability standard deviation at set point" or
"Standard deviation from paired measurements under field conditions"

Combined standard uncertainty (u_C)	$u_c = \sqrt{\sum (u_{max,j})^2}$	0.18	mg/m³
Total expanded uncertainty	$U = u_c * k = u_c * 1.96$	0.35	mg/m³

Relative total expanded uncertainty	**U in % of the ELV 2 mg/m³**	**17.3**
Requirement of 2010/75/EU	**U in % of the ELV 2 mg/m³**	**40.0** **
Requirement of EN 15267-3	U in % of the ELV 2 mg/m³	30.0

** The EU-directive 2010/75/EU on industrial emissions provides no requirements for this component.
A value of 40.0 % was used for this.