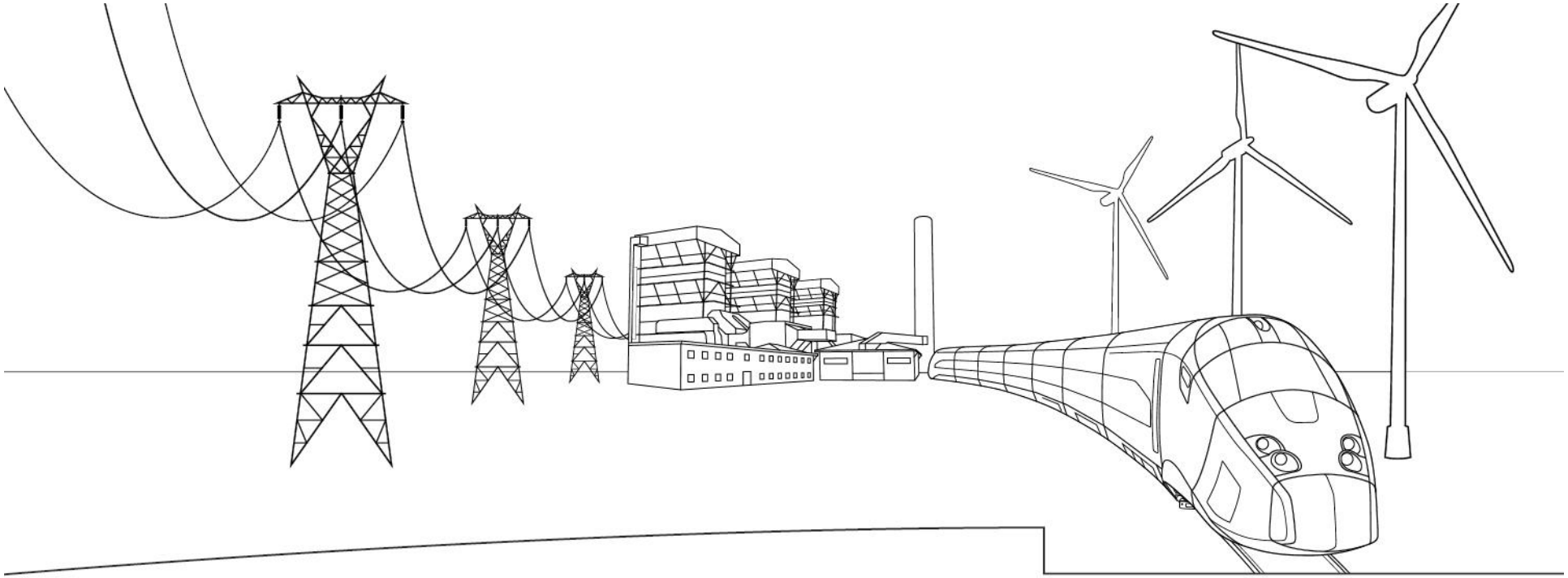


Combining OFA lances with SNCR technology

Dipl.-Ing. Hellmuth Brüggemann

Kraków, Poland

18/05/2015

ALSTOM

Shaping the future

The Seventh International Conference on Clean Coal Technologies

„CCT2015“

17-21 May 2015 in Kraków, Poland

Combining OFA lances with SNCR technology – A promising approach to minimize NO_X emission of lignite-fired power plants

Dr.-Ing. Thomas Hilber, *ALSTOM Boiler Deutschland GmbH, Stuttgart/Germany*
Dipl.-Ing. Klaus Schnieder, *ALSTOM Boiler Deutschland GmbH, Stuttgart/Germany*
Dipl.-Ing. Hellmuth Brüggemann, *ALSTOM Boiler Deutschland GmbH, Stuttgart/Germany*
Dipl.-Ing. Frank Kluger, *ALSTOM Boiler Deutschland GmbH, Stuttgart/Germany*
Dipl.-Ing. Gerald Schmidt, *ALSTOM Boiler Deutschland GmbH, Stuttgart/Germany*

© ALSTOM 2015. All rights reserved. Information contained in this document is indicative only. No representation or warranty is given or should be relied on that it is complete or correct or will apply to any particular project. This will depend on the technical and commercial circumstances. It is provided without liability and is subject to change without notice. Reproduction, use or disclosure to third parties, without express written authority, is strictly prohibited.

ALSTOM

Content

- **Background and motivation**
- **Technical approach**
- **Large-scale tests**
- **Further steps**
- **Summary**

© ALSTOM 2015. All rights reserved. Information contained in this document is indicative only. No representation or warranty is given or should be relied on that it is complete or correct or will apply to any particular project. This will depend on the technical and commercial circumstances. It is provided without liability and is subject to change without notice. Reproduction, use or disclosure to third parties, without express written authority, is strictly prohibited.

ALSTOM

Content

- **Background and motivation**
- Technical approach
- Large-scale tests
- Further steps
- Summary

© ALSTOM 2015. All rights reserved. Information contained in this document is indicative only. No representation or warranty is given or should be relied on that it is complete or correct or will apply to any particular project. This will depend on the technical and commercial circumstances. It is provided without liability and is subject to change without notice. Reproduction, use or disclosure to third parties, without express written authority, is strictly prohibited.

ALSTOM

Combining OFA lances with SNCR technology

Background and motivation

- The reduction of NO_X emissions from existing coal fired power stations acc. to the Industrial Emission Directive (IED) is mandatory from 01.01.2016.
- The relevant emission limit for lignite-fired utilities is an daily average value of 200 mg/Nm³ (dry based) referred to 6 % oxygen.
- Further NO_X emission reduction objectives are currently under discussion at European level (BAT/BREF process).
- Therefore economic NO_X emission reduction solutions for retrofitting existing coal fired power stations are highly requested to fulfil current and (possible) future emission legislation.
- The application of Selective Non-Catalytic Reduction (SNCR) could be such an economic approach to achieve 200 mg/Nm³ or even lower NO_X levels.

© ALSTOM 2015. All rights reserved. Information contained in this document is indicative only. No representation or warranty is given or should be relied on that it is complete or correct or will apply to any particular project. This will depend on the technical and commercial circumstances. It is provided without liability and is subject to change without notice. Reproduction, use or disclosure to third parties, without express written authority, is strictly prohibited.

ALSTOM

Combining OFA lances with SNCR technology

Basic principles of SNCR operation

- The SNCR technology relies on the reductive properties of ammonia based chemicals like urea or ammonia water.
- The SNCR process removes nitrogen oxides (NO_X) by injecting an aqueous solution of urea or ammonia water into the flue gas stream.
- In both cases molecular nitrogen, water vapor, and carbon dioxide are formed.
- Significant NO_X-reductions are obtained in a temperature range of 870 and 1050 °C. However the temperature window may shift depending on the flue gas composition.
- General targets of SNCR application should be
  - High NO_X reduction rate
  - Minimum consumption of reagent
  - Low NH_3 slip

© ALSTOM 2015. All rights reserved. Information contained in this document is indicative only. No representation or warranty is given or should be relied on that it is complete or correct or will apply to any particular project. This will depend on the technical and commercial circumstances. It is provided without liability and is subject to change without notice. Reproduction, use or disclosure to third parties, without express written authority, is strictly prohibited.

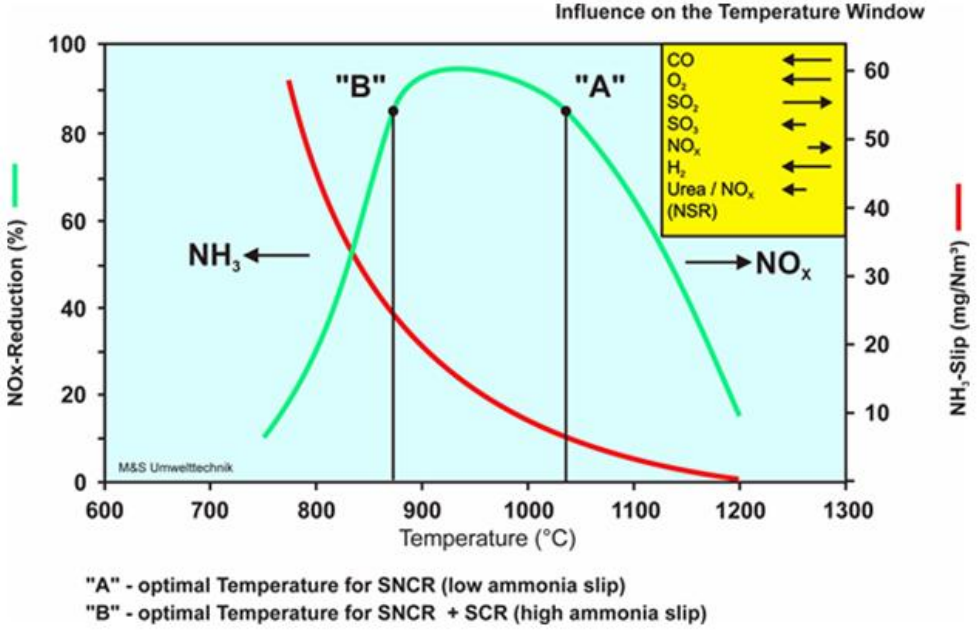
ALSTOM

Combining OFA lances with SNCR technology

Basic principles of SNCR operation

- The temperature window may shift depending on the flue gas composition.
- CO and O_2 shift the temperature window to the left side.
- SO_2 shifts the temperature window to the right side.

The objective of all NO_X control technologies is to reach a high NO_X reduction with a minimum consumption of reagent while the ammonia slip must be kept low at the same time. This only can be achieved with an even distribution of the reagents in the flue gas at the right temperature.



Source: Meldau & Steinfath Umwelttechnik GmbH

© ALSTOM 2015. All rights reserved. Information contained in this document is indicative only. No representation or warranty is given or should be relied on that it is complete or correct or will apply to any particular project. This will depend on the technical and commercial circumstances. It is provided without liability and is subject to change without notice. Reproduction, use or disclosure to third parties, without express written authority, is strictly prohibited.

Combining OFA lances with SNCR technology

Common approach for SNCR application in large utility boilers

The common approach is to inject urea or ammonia solution into the furnace. It shall be understood that the temperature distribution in the furnace is not necessarily suitable for direct injection. Temperatures at the furnace outlet (FOT) are likely in the range of 1100 °C (or even higher). Consequently the reagent should only be injected if the conditions are favorable for the reaction.

The image shows a typical arrangement of furnace injectors. Urea or ammonia solution is atomized with pressurized air to create a substantial momentum thus achieving favorable penetration.

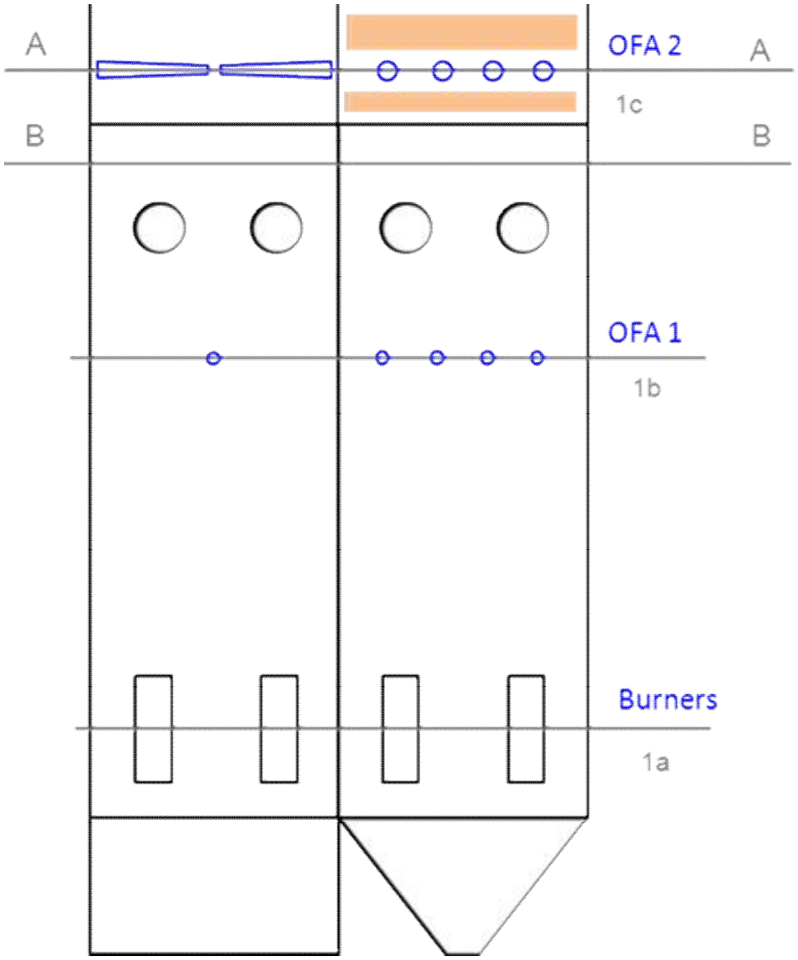
© ALSTOM 2015. All rights reserved. Information contained in this document is indicative only. No representation or warranty is given or should be relied on that it is complete or correct or will apply to any particular project. This will depend on the technical and commercial circumstances. It is provided without liability and is subject to change without notice. Reproduction, use or disclosure to third parties, without express written authority, is strictly prohibited.

ALSTOM

Combining OFA lances with SNCR technology

Alstom LowNO_X firing system for lignite-fired utility boilers

- The basic firing system consists of
  - Alstom jet burners
  - Single OFA 1 level below the flue gas resuction ducts
  - Single OFA 2 level above the flue gas resuction ducts
- OFA levels are usually arranged in the furnace (→ **nozzles**)
- If the available residence time in the furnace is not sufficient the second OFA can be arranged in the final superheater (→ **lances**)



© ALSTOM 2015. All rights reserved. Information contained in this document is indicative only. No representation or warranty is given or should be relied on that it is complete or correct or will apply to any particular project. This will depend on the technical and commercial circumstances. It is provided without liability and is subject to change without notice. Reproduction, use or disclosure to third parties, without express written authority, is strictly prohibited.

ALSTOM

Combining OFA lances with SNCR technology

Utilizing OFA lances for reagent injection

Combination of Alstom's LowNO_X technology for lignite-fired units with SNCR technology. The basic idea is to inject urea into the OFA lances. The urea is fully vaporized before entering the flue gas. The lances ensure a favorable distribution of the reagent in the flue gases at a favorable temperature level.

Fig. 1: Typical OFA 2 lance

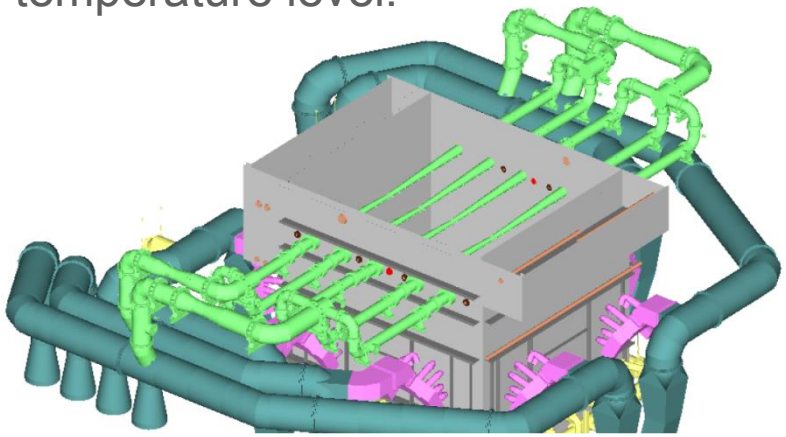


Fig. 2: Typical OFA 2 arrangement

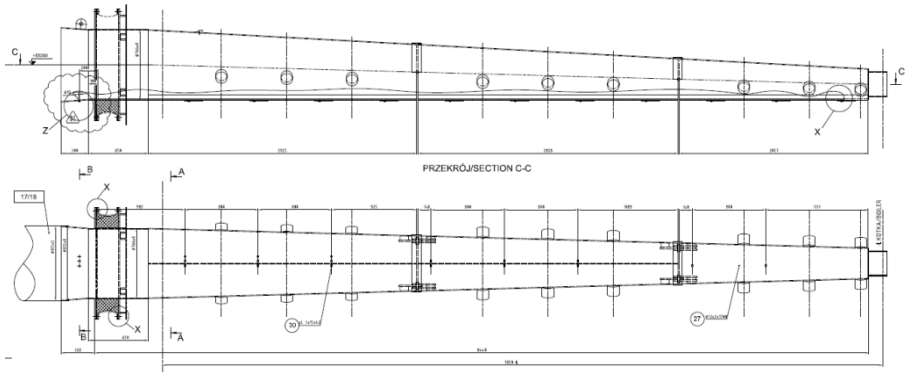


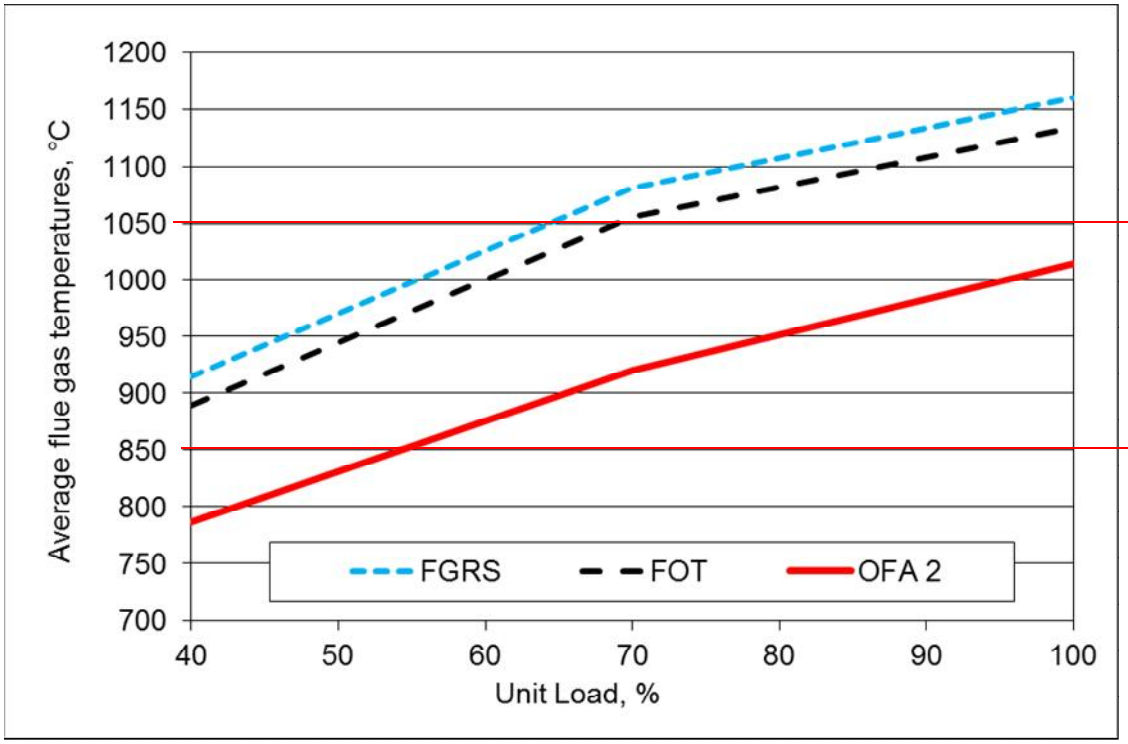
Fig. 3: OFA lance design drawing

© ALSTOM 2015. All rights reserved. Information contained in this document is indicative only. No representation or warranty is given or should be relied on that it is complete or correct or will apply to any particular project. This will depend on the technical and commercial circumstances. It is provided without liability and is subject to change without notice. Reproduction, use or disclosure to third parties, without express written authority, is strictly prohibited.

ALSTOM

Combining OFA lances with SNCR technology

Typical flue gas temperatures in a lignite-fired boiler



Optimal temperature window for SNCR application

- The temperatures are based on thermal balance calculations
- The temperatures in the furnace are likely to be higher than 1050 °C
- The temperatures in the final superheater (location of OFA 2 lances) are in the optimal temperature window for SNCR application

© ALSTOM 2015. All rights reserved. Information contained in this document is indicative only. No representation or warranty is given or should be relied on that it is complete or correct or will apply to any particular project. This will depend on the technical and commercial circumstances. It is provided without liability and is subject to change without notice. Reproduction, use or disclosure to third parties, without express written authority, is strictly prohibited.

ALSTOM

Content

- Background and motivation
- **Technical approach**
- Large-scale tests
- Further steps
- Summary

© ALSTOM 2015. All rights reserved. Information contained in this document is indicative only. No representation or warranty is given or should be relied on that it is complete or correct or will apply to any particular project. This will depend on the technical and commercial circumstances. It is provided without liability and is subject to change without notice. Reproduction, use or disclosure to third parties, without express written authority, is strictly prohibited.

ALSTOM

Combining OFA lances with SNCR technology

Setup for large-scale tests at 1100 t/h lignite-fired boiler

The SNCR system during the test consists of the following components:

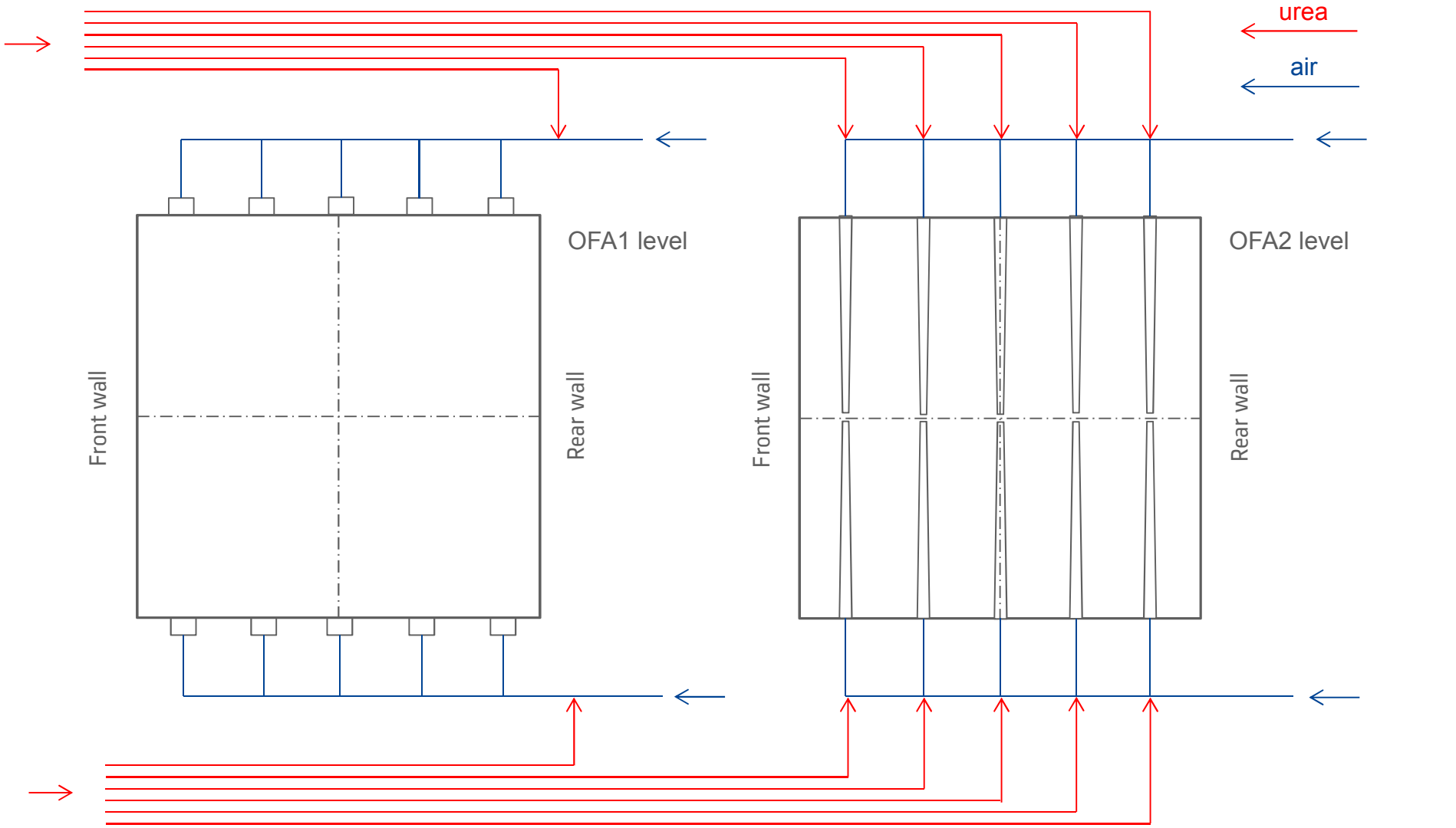
- OFA 2 lances and OFA 1 nozzles
- Urea injectors for OFA 2 (10 x 1) and OFA 1 (left/right boiler side)
  - Each OFA 2 lance equipped with a single injector
  - Air ducts to OFA 1 (left/right) equipped with two injectors
- Urea and air pipes to each injector (flexible tubes)
- Urea control and distribution system
- Manual control of each injector (on/off/flow)
- Pressurized air for atomization
- Central urea storage and main urea pipe to urea distribution system

© ALSTOM 2015. All rights reserved. Information contained in this document is indicative only. No representation or warranty is given or should be relied on that it is complete or correct or will apply to any particular project. This will depend on the technical and commercial circumstances. It is provided without liability and is subject to change without notice. Reproduction, use or disclosure to third parties, without express written authority, is strictly prohibited.

ALSTOM

Combining OFA lances with SNCR technology

Flow diagram OFA system and urea injection system



© ALSTOM 2015. All rights reserved. Information contained in this document is indicative only. No representation or warranty is given or should be relied on that it is complete or correct or will apply to any particular project. This will depend on the technical and commercial circumstances. It is provided without liability and is subject to change without notice. Reproduction, use or disclosure to third parties, without express written authority, is strictly prohibited.

ALSTOM

Combining OFA lances with SNCR technology

Urea distribution and injection

Fig. 1: Air ducts to OFA2 lances (left side)

Fig. 2: Access port air duct to OFA 2

Fig. 4: Urea distribution system at 54m

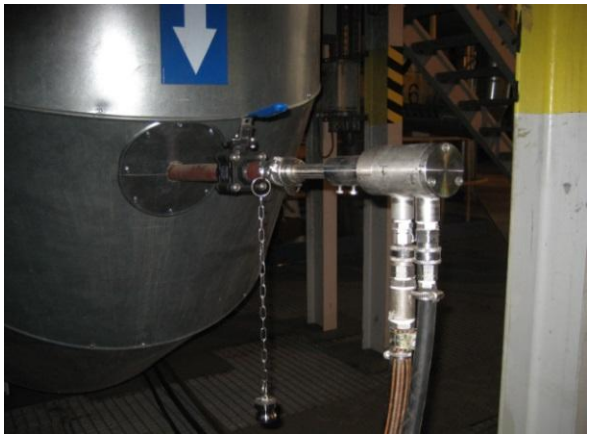


Fig. 3a: Injector (urea / pressurized air)

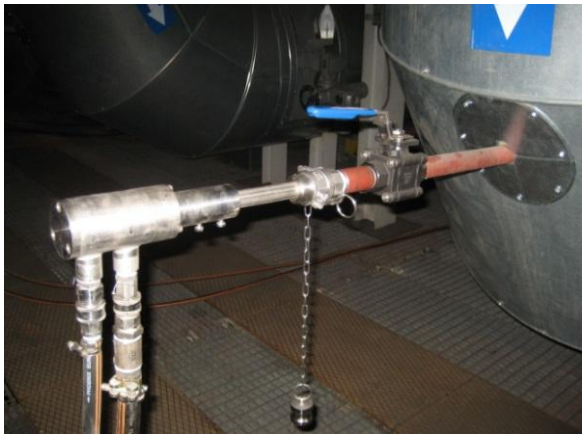


Fig. 3b: Injector (urea / pressurized air)

© ALSTOM 2015. All rights reserved. Information contained in this document is indicative only. No representation or warranty is given or should be relied on that it is complete or correct or will apply to any particular project. This will depend on the technical and commercial circumstances. It is provided without liability and is subject to change without notice. Reproduction, use or disclosure to third parties, without express written authority, is strictly prohibited.

ALSTOM

Combining OFA lances with SNCR technology

Urea delivery and truck unloading station

- Temporary truck unloading station for urea during the long-term tests
  - Stationary tank trailer on 0 m level
  - Pumping station
- Daily delivery of approx. 20,000 l prepared urea (40 %) required significant logistical efforts (on-time)
- For a permanent installation a storage area outside of the boiler house is recommended

© ALSTOM 2015. All rights reserved. Information contained in this document is indicative only. No representation or warranty is given or should be relied on that it is complete or correct or will apply to any particular project. This will depend on the technical and commercial circumstances. It is provided without liability and is subject to change without notice. Reproduction, use or disclosure to third parties, without express written authority, is strictly prohibited.

Content

- Background and motivation
- Technical approach
- **Large-scale tests**
- Further steps
- Summary

© ALSTOM 2015. All rights reserved. Information contained in this document is indicative only. No representation or warranty is given or should be relied on that it is complete or correct or will apply to any particular project. This will depend on the technical and commercial circumstances. It is provided without liability and is subject to change without notice. Reproduction, use or disclosure to third parties, without express written authority, is strictly prohibited.

ALSTOM

Combining OFA lances with SNCR technology

Test campaigns

1st November 2014 (pre-testing)

- General functionality of the technology
- Different short-term scenarios (NO_X / CO) at full boiler load
- Information of urea consumption, NH_3 slippage, NH_3 in ash

2nd April 2015 (long-term performance)

- Focus on long-term operation (1 week setup, 2 week permanent)
- Different loads (100 %, 80 %, 60 %) → Urea consumption
- Injection via OFA 2; option OFA 1 for part-load coverage
- NH_3 slip measurement at the stack
- NH_3 in power plant byproducts (i.e. fly ash, gypsum, FGD waste water)
- Demonstration of reliability of the technology

© ALSTOM 2015. All rights reserved. Information contained in this document is indicative only. No representation or warranty is given or should be relied on that it is complete or correct or will apply to any particular project. This will depend on the technical and commercial circumstances. It is provided without liability and is subject to change without notice. Reproduction, use or disclosure to third parties, without express written authority, is strictly prohibited.

ALSTOM

Combining OFA lances with SNCR technology

Emission performance (pre-tests in Nov 2014)

	NO_X [mg/m³]	NO_X [mg/m³]	CO [mg/m³]	NO_X red	NO_X red
	Baseline	SNCR in operation	Average	Δ, mg/m³	red rate, %
V1	190 - 200	< 200	150 - 160	-	-
V2	190 - 200	155	150 - 160	35 - 45	18 - 22
V3	230 - 240	150	90 - 100	80 - 90	35 - 38
V4	270 - 280	160	40 - 50	110 - 120	40 - 43

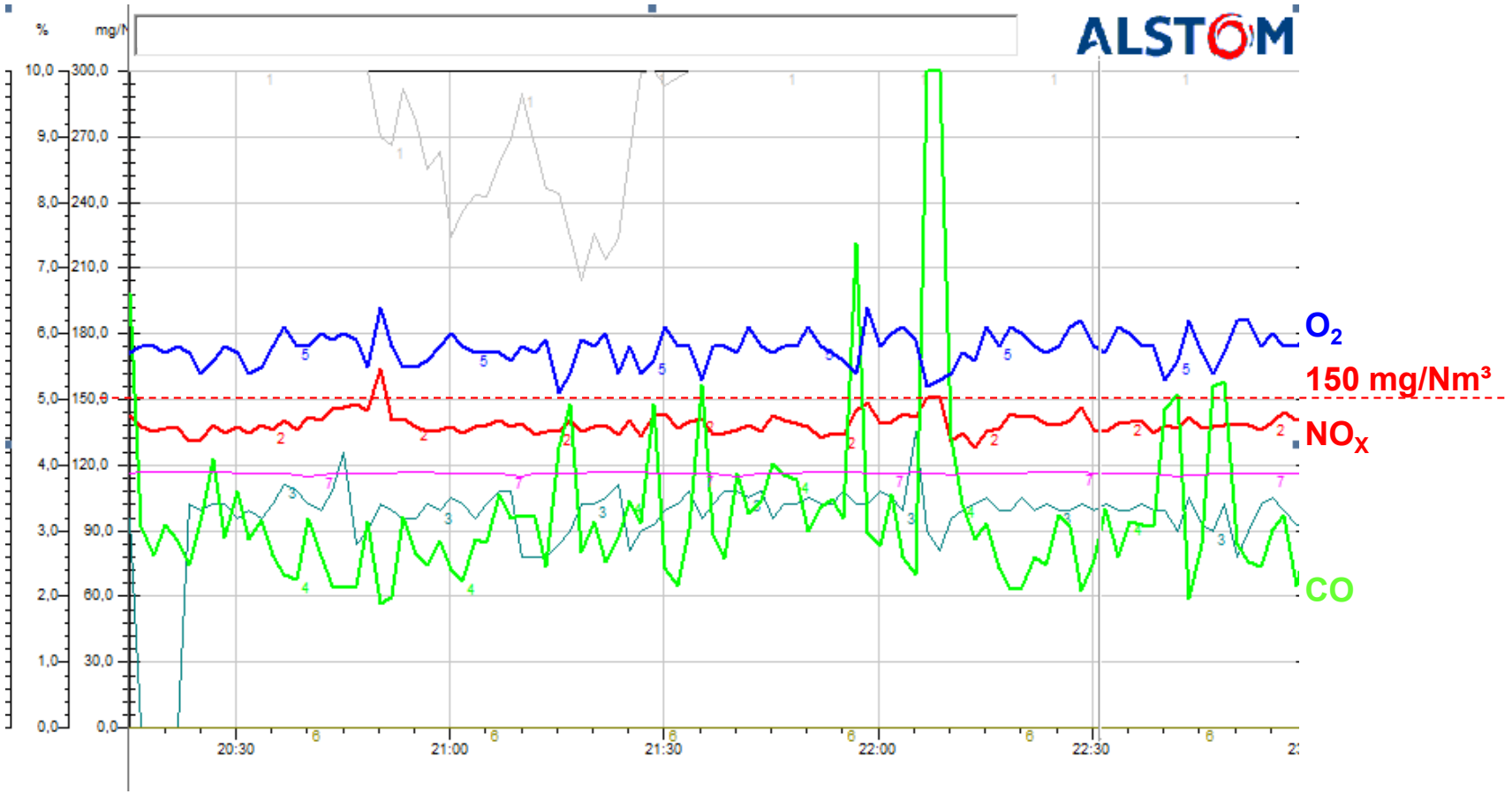
- All tests in Nov 2014 performed under full unit load conditions
- Constant injection of 800 l/h urea (40 % via OFA 2)
- Influence of CO level on SNCR performance investigated

© ALSTOM 2015. All rights reserved. Information contained in this document is indicative only. No representation or warranty is given or should be relied on that it is complete or correct or will apply to any particular project. This will depend on the technical and commercial circumstances. It is provided without liability and is subject to change without notice. Reproduction, use or disclosure to third parties, without express written authority, is strictly prohibited.

ALSTOM

Combining OFA lances with SNCR technology

Continuous operation (April 2015)

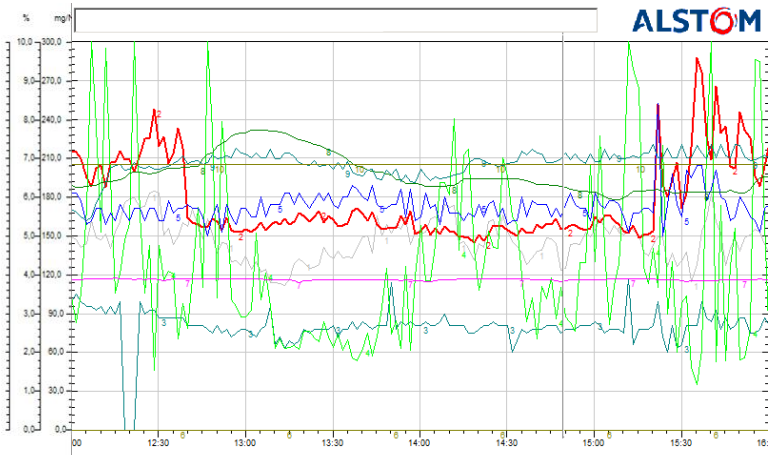


Stable operation NO_X < 150 mg/m³ at 100 % unit load

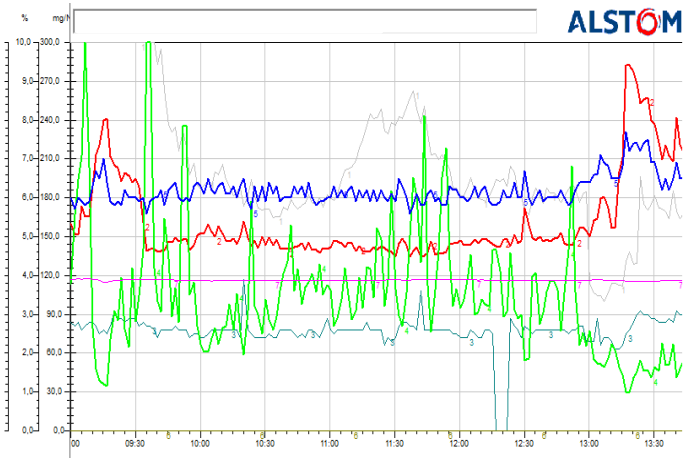
© ALSTOM 2015. All rights reserved. Information contained in this document is indicative only. No representation or warranty is given or should be relied on that it is complete or correct or will apply to any particular project. This will depend on the technical and commercial circumstances. It is provided without liability and is subject to change without notice. Reproduction, use or disclosure to third parties, without express written authority, is strictly prohibited.

Combining OFA lances with SNCR technology

Part-load performance (April 2015)



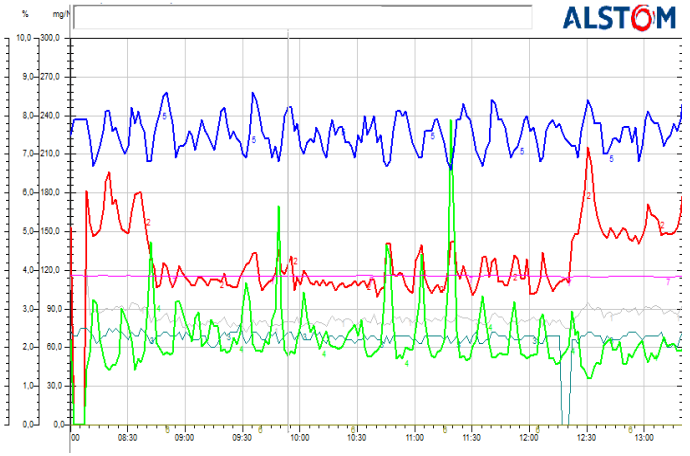
150415_12:50-15:00: **100 % Load** , 800 l/h



150416_09:30-12:00: **85 % Load** , 600 l/h

Load, %	100 (V2)	85 (V4a)	60 (V9)
NO_X, mg/m³ *)	158	142	114
CO, mg/m³ *)	112	113	75
NH_3, mg/m³ *)	2.7	2.6	2.5
Urea, l/h	800	600	400

*) stack emissions measured downstream FGD

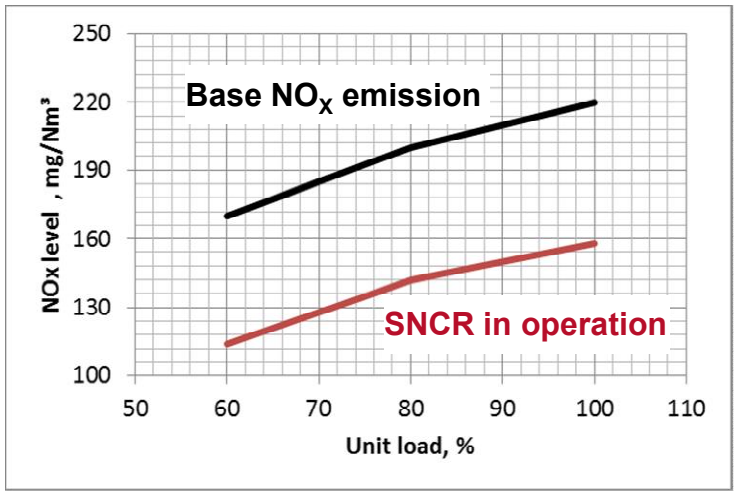


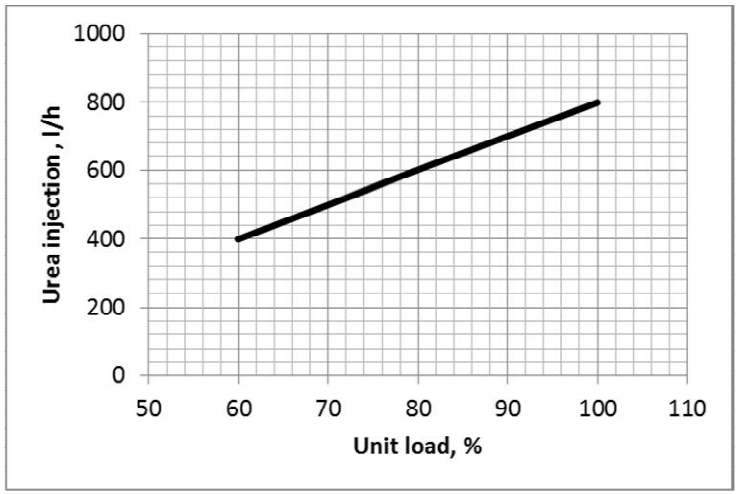
150418_09:00-12:30: **60 % Load** , 400 l/h

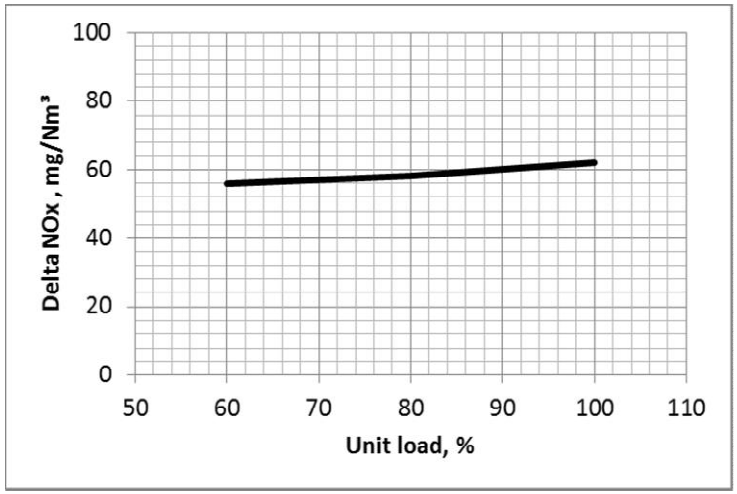
© ALSTOM 2015. All rights reserved. Information contained in this document is indicative only. No representation or warranty is given or should be relied on that it is complete or correct or will apply to any particular project. This will depend on the technical and commercial circumstances. It is provided without liability and is subject to change without notice. Reproduction, use or disclosure to third parties, without express written authority, is strictly prohibited.

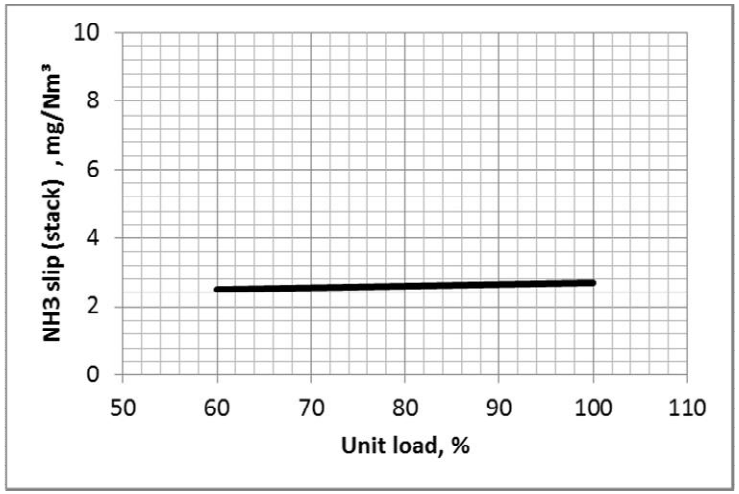
Combining OFA lances with SNCR technology

Evaluation of part-load operation (April 2015)









© ALSTOM 2015. All rights reserved. Information contained in this document is indicative only. No representation or warranty is given or should be relied on that it is complete or correct or will apply to any particular project. This will depend on the technical and commercial circumstances. It is provided without liability and is subject to change without notice. Reproduction, use or disclosure to third parties, without express written authority, is strictly prohibited.

ALSTOM

Combining OFA lances with SNCR technology

Test summary

- 100 % and 80 % load could be covered with OFA 2 injection
- 60 % could be covered with OFA 1 injection (2 x 200 l/h)
- NH_3 slip measured at stack less than 5 mg/Nm³ for all load cases
- NH_3 in gypsum less than 10 mg/kg (all loads)
- NH_3 in fly ash less than 50 mg/kg (all load)*)
- Increased NH_3 concentration in FGD wastewater**)
- Reduction rate of approx. 30 % for all load cases
- Overall stable operation of the system

*) site specific result → depending on ash properties and total ash flow

**) NH_3 is highly water-soluble

© ALSTOM 2015. All rights reserved. Information contained in this document is indicative only. No representation or warranty is given or should be relied on that it is complete or correct or will apply to any particular project. This will depend on the technical and commercial circumstances. It is provided without liability and is subject to change without notice. Reproduction, use or disclosure to third parties, without express written authority, is strictly prohibited.

ALSTOM

Content

- Background and motivation
- Technical approach
- Large-scale tests
- **Further steps**
- Summary

© ALSTOM 2015. All rights reserved. Information contained in this document is indicative only. No representation or warranty is given or should be relied on that it is complete or correct or will apply to any particular project. This will depend on the technical and commercial circumstances. It is provided without liability and is subject to change without notice. Reproduction, use or disclosure to third parties, without express written authority, is strictly prohibited.

ALSTOM

Combining OFA lances with SNCR technology

Further steps

- Combination with temperature measurement system → controlled activation / deactivation of injectors to achieve
  - Higher NO_X reduction rate
  - Lower NH_3 slip
  - Reduced reagent consumption
- Investigate influence of ash properties on NH_3 in ash
- Investigate impact on FGD wastewater
- Elaborate technical concept for permanent installation

© ALSTOM 2015. All rights reserved. Information contained in this document is indicative only. No representation or warranty is given or should be relied on that it is complete or correct or will apply to any particular project. This will depend on the technical and commercial circumstances. It is provided without liability and is subject to change without notice. Reproduction, use or disclosure to third parties, without express written authority, is strictly prohibited.

ALSTOM

Combining OFA lances with SNCR technology

In-situ temperature field measurement (AGAM)

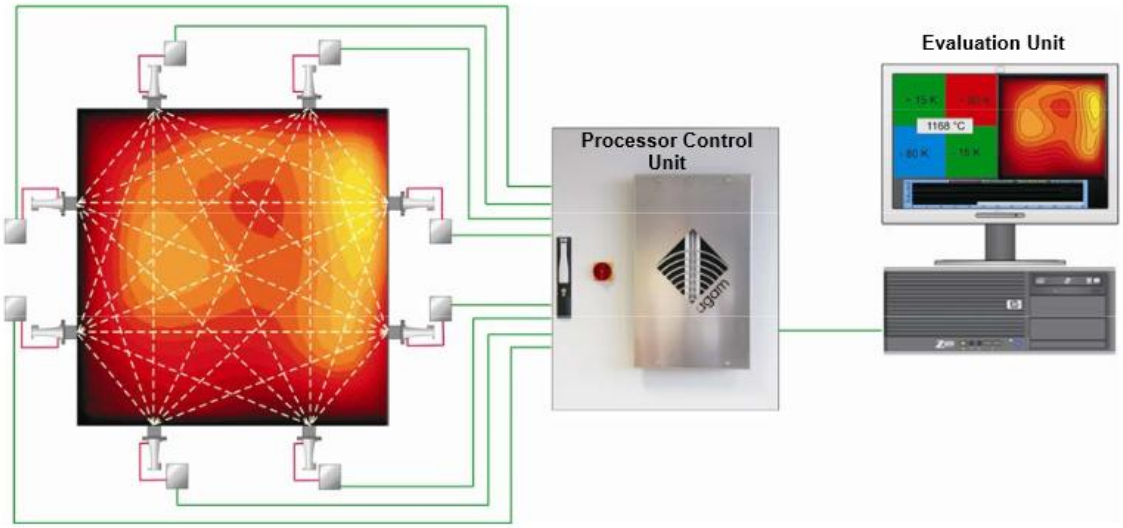


Fig. 1: Typical transmitter/receiver

The acoustic gas temperature measurement technique operates on the principal that the speed of sound in a gas is dependent on its temperature. The acoustic measuring system AGAM measures the transmit time of a sound pulse. Plant air is used to generate the required sound impulse and also serves to keep the opening free of fly ash. The signal is simultaneously recorded at the transmit - and receive sides by piezo microphones. A control unit processes the signals and determines the flight time of the sound pulse. As the distance between the transmitter and receiver is known and fixed, the average temperature of the gas along the acoustic path (path temperature) can be calculated.

A so called multiple path configuration can be obtained by placing several transceivers (can operate as transmitter and receiver) in a plane. By using tomographic algorithms a multiple path measurement system allows the generation of temperature distribution profiles in the plane. The temperature profile is then displayed on the monitor of an evaluation unit either as an isothermal contour plot or as a zone average temperature diagram.

Source: Bonnenberg + Drescher Projektentwicklung GmbH

© ALSTOM 2015. All rights reserved. Information contained in this document is indicative only. No representation or warranty is given or should be relied on that it is complete or correct or will apply to any particular project. This will depend on the technical and commercial circumstances. It is provided without liability and is subject to change without notice. Reproduction, use or disclosure to third parties, without express written authority, is strictly prohibited.

Content

- Background and motivation
- Technical approach
- Large-scale tests
- Further steps
- **Summary**

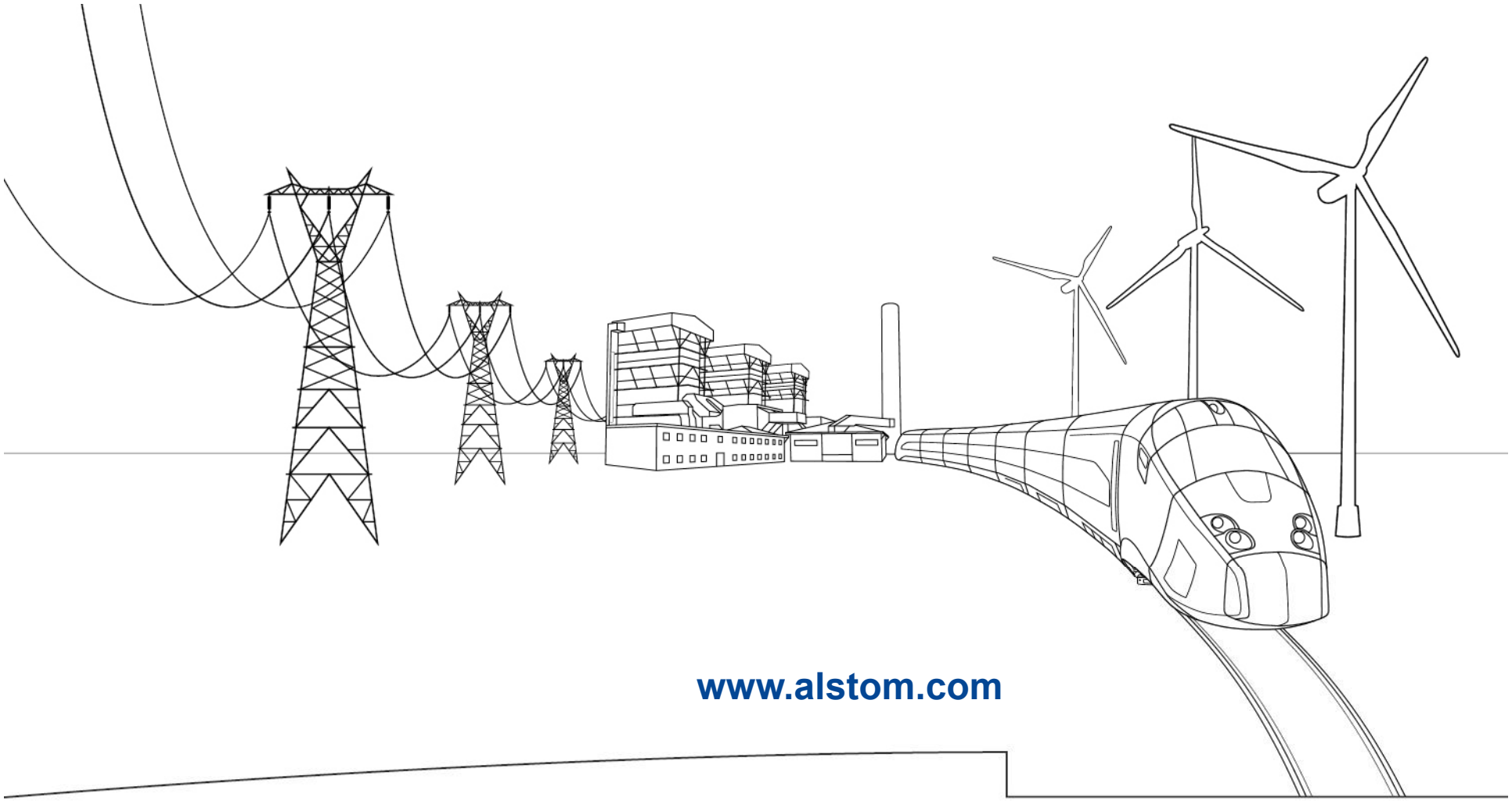
© ALSTOM 2015. All rights reserved. Information contained in this document is indicative only. No representation or warranty is given or should be relied on that it is complete or correct or will apply to any particular project. This will depend on the technical and commercial circumstances. It is provided without liability and is subject to change without notice. Reproduction, use or disclosure to third parties, without express written authority, is strictly prohibited.

ALSTOM

Combining OFA lances with SNCR technology
Summary

- The tests performed show that the SNCR concept is working for large lignite-fired utility boilers. SNCR allows stable LowNOx operation.
- Injection via OFA 2 lance system provides suitable means to achieve reduction rates up to 40 % under operating conditions.
- By means of OFA 1 injection part-load operation could be covered.
- The tests show that an emission level of NO_X < 150 mg/m³ is a reasonable target (NO_X reduction vs. urea consumption).
- It is recommended to combine SNCR technology with a LowNOx firing system to minimize baseline NO_X emissions to reduce reagent consumption.

© ALSTOM 2015. All rights reserved. Information contained in this document is indicative only. No representation or warranty is given or should be relied on that it is complete or correct or will apply to any particular project. This will depend on the technical and commercial circumstances. It is provided without liability and is subject to change without notice. Reproduction, use or disclosure to third parties, without express written authority, is strictly prohibited.



www.alstom.com

ALSTOM

Shaping the future