Continuous Boiler Cleaning with Explosion Generators – the Alternative to Soot Blowers, Shower Cleaning and Water Canons

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Summary

The Explosion Generator was recently developed by Explosion Power GmbH.
With Explosion Generators, the boiler is cleaned by pressure waves, which are created by controlled gas explosions of natural gas and oxygen. The Explosion Generator is mounted at the outside of the boiler and keeps the heat transfer surfaces clean during continuous operation of the boiler, by periodic explosions, e.g. every hour.

The Explosion Generator consists of an explosion resistant case, which is closed by a valve. At the ignition of the explosion, the valve opens rapidly and the created explosion pressure wave is directed into the boiler via the discharge tube. Within the boiler, the walls and bundles are put into a short oscillation, so that deposits fall off.

The long-term experience of operation in the WtE plant in Lucerne shows, that the cleaning efficiency of the Explosion Generators is much higher than that of sootblowers. The 8 Explosion Generators in operation at 3 boilers in the WtE plant in Lucerne have carried out more than 180’000 explosions.

Explosion Generators are installed world wide in more than 25 different plants. Explosion Generators are capable to keep all types of boilers clean, independent of fuel type and boiler size.
The main advantages compared with other boiler cleaning equipment are:

- Improved cleaning efficiency
- Larger impact distance, also through tube bundles
- No tube leakages due to steam erosion

- Lower operating cost
- Lower investment cost for new plants

Introduction

The Explosion Generator EG10 was recently developed by Explosion Power GmbH.
As with the manual Bang&Clean cleaning technology of Kesselreinigung Rüegg GmbH (Bürgin et al, 2005) the boiler is cleaned by controlled gas explosions of a combustible gas and oxygen. Bang &Clean is usually used for de-blocking strongly fouled boilers. Explosion Generators keep heat exchanger areas of boilers clean by automated periodical explosions. Contrary to the Bang&Clean technology, where the explosion is created within the boiler by bags filled with the explosive gas mixture, the Explosion Generator creates the explosion outside of the boiler, in an explosion resistant device. The pressure wave is then introduced into the boiler by means of a valve and the discharge tube and sets walls and bundles into motion so that fouling is removed.

The experience of continuous operation of 2 Explosion Generators at the boiler No 2 in the WtE plant in Lucerne since February 2009 shows that the cleaning efficiency of the Explosion Generators is much higher than those of the previously installed six soot blowers. By now, 8 Explosion Generators are in operation at 3 boilers in the WtE plant in Lucerne, by which over 180’000 explosions so far have taken place. The WtE plant in Lucerne has dismantled all soot blowers and is cleaning their boilers solely with Explosion Generators.
Based on these good experiences and the positive results of the “Bang & Clean” technology in many hundreds of WtE plants, we are convinced that the fouling can be significantly reduced and critical areas can be kept in a reasonably clean condition during long operating periods.

Currently 80 Explosion Generators in more than 25 plants show that fouling of boilers in WtE and biomass power stations can be significantly and permanently reduced and time between stops can be prolonged.
Compared to soot blowers, where the effect is limited to the area directly hit by the air or steam, the effect of the pressure wave covers a wider area of the boiler around the Explosion Generator.
Contrary to the appliance of soot blowers, the boiler tubes are not damaged by the shock wave of the Explosion-Generator.

The Explosion Generators create one to maximum four explosions per hour and device, so that the ash transportation equipment is able to remove the boiler ash without any problem.

Explosion Generators are suited for retrofit of existing plants as well as for new installations where the small installation volume brings large savings in steelworks and civil works.
It is planned in the medium-term to introduce Explosion Generators also into coal-fired power stations in order to increase efficiency, to reduce CO_2 emissions and to prolong the time between two stops for boiler cleaning.

1 Function

Filling of Dosing Tank

After release by the programmable logic control the solenoid valves of the gas supply and the dosing tanks are opened, and the dosing tanks are filled with Oxygen and Natural Gas (Fig. 1) until the setting pressure is reached. Afterwards, the solenoid valves are closed again. The two gases are completely separated from each other and therefore not explosive.

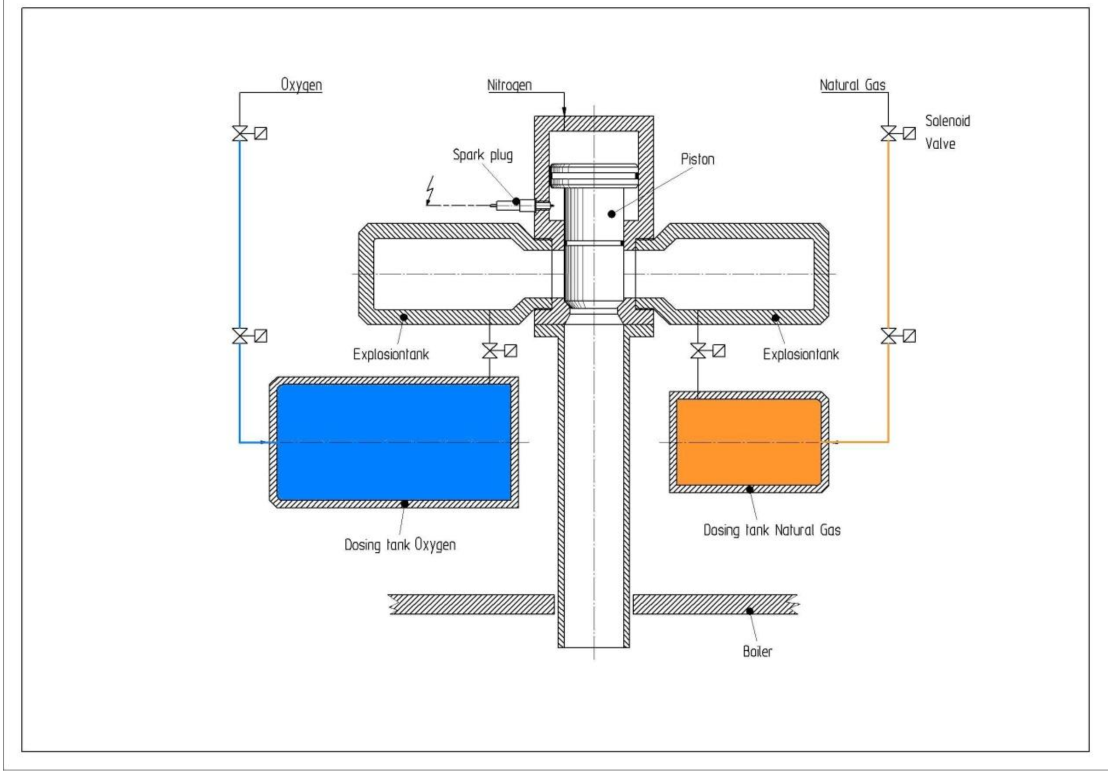

Fig. 1: Filling of Dosing Tank

Transfer and Mixing

The transfer solenoid valves for Oxygen and Natural Gas are opened. The two gases flow into the explosion tanks and are mixed. Afterwards, the solenoid valves are closed again. The piston is pressed against the discharge opening by the Nitrogen pressure and closes it gastight (Fig. 2).

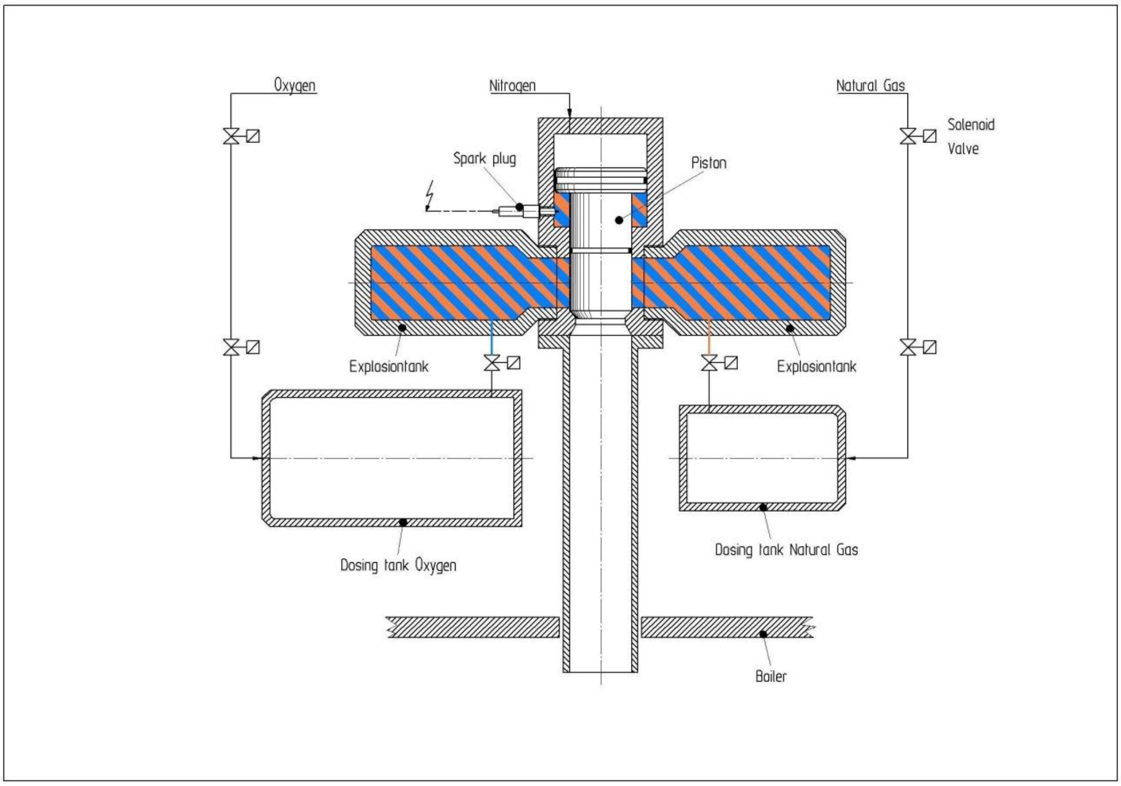

Fig. 2 Transfer and Mixing

Explosion and Injection of Pressure Wave into the Plant

The spark plug is activated and ignites the explosive mixture of gas (Fig. 3). The pressure rise in the explosion chamber of 350 bar makes the piston move backward, whereby the discharge opening is unblocked. The pressure wave is transmitted into the plant through the connection pipe. The pressure wave makes slag and ash deposits break off and put walls and bundles into short vibrations, which further enhances the cleaning efficiency. After the pressure wave is ejected, the piston is pressed again to the discharge opening by the Nitrogen and completely closes the discharge opening. The Explosion Generator is ready for the next explosion.

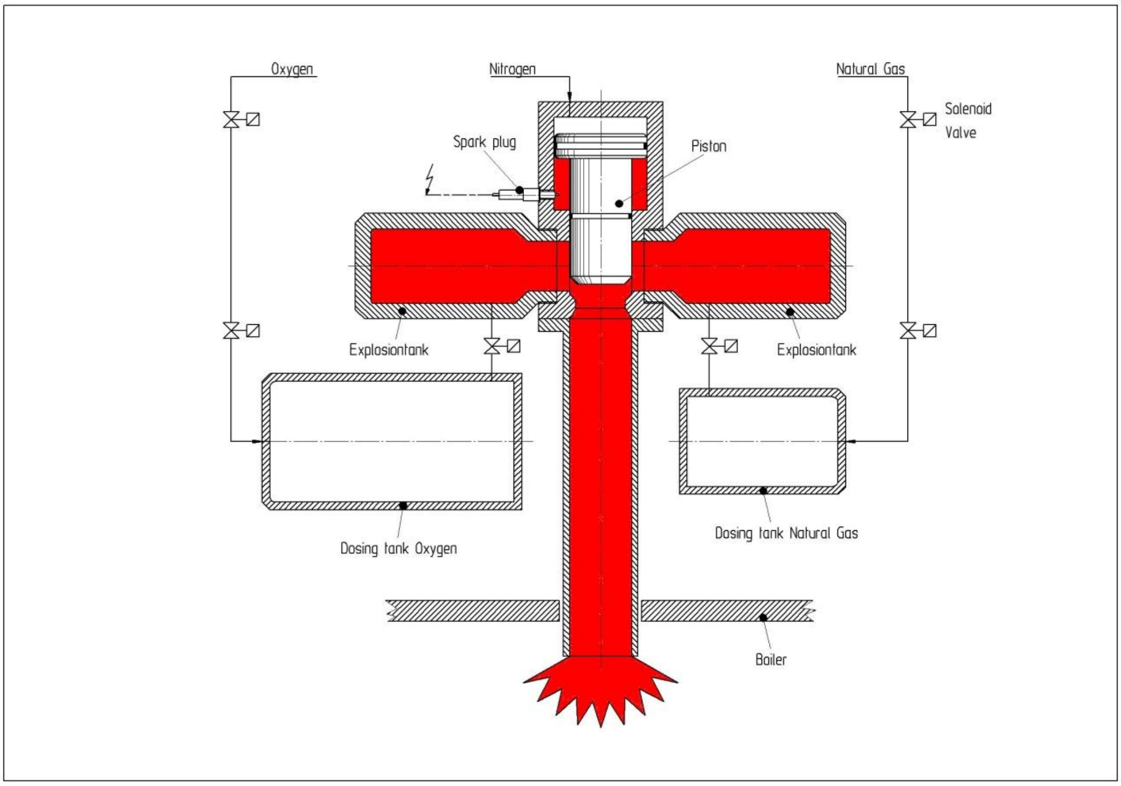

Fig. 3 Explosion and Injection of Pressure Wave

2 Installation of Explosion Generator

Installation of the Explosion Generator can be done by firm mounting with a flange or elastic mounting outside of the boiler wall (Fig. 4). At the operating position, the connection pipe intrudes the boiler wall by approx. 50 mm. The springs avoid that the impulse of the Explosion Generator is directly transferred to the boiler wall. In case of firm mounting the impulse can work as an additional rapping of the boiler wall.

The Explosion Generator is supported by means of an overhead track and trolley.

The space requirement of the whole installation is approx. 1 m3.

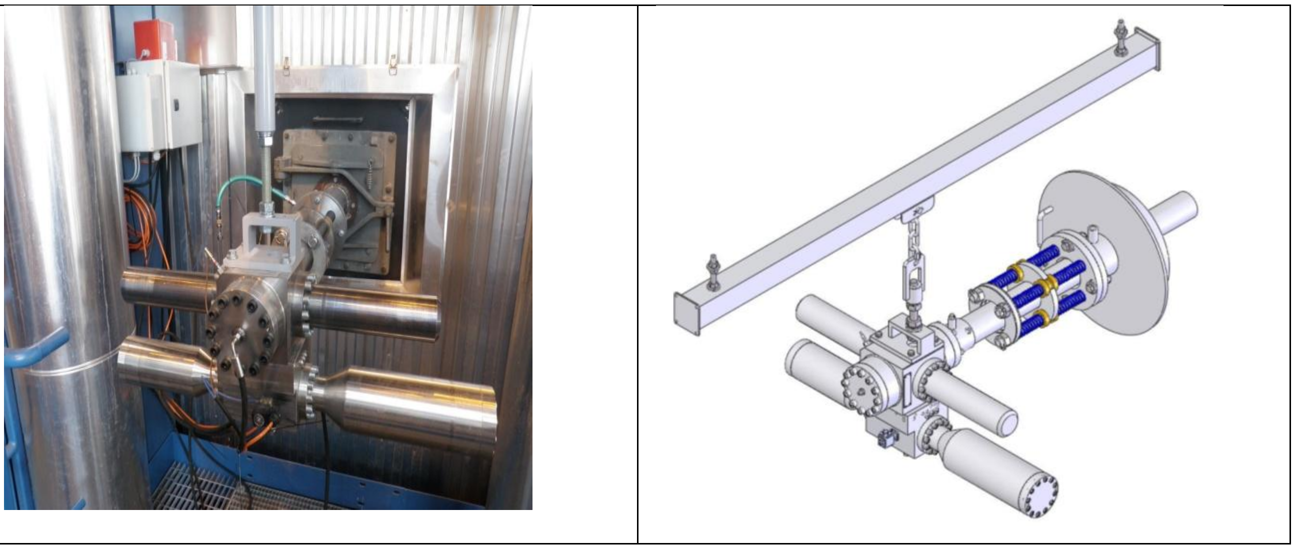

Fig. 4: Installation with springs at a maintenance door

3 Gas supply

Explosion Generators are operated with natural gas or methane and oxygen. Both gases are usually stored in single gas cylinders or cylinder bundles with 200 bar. They are fed to the generators via stainless steel pipes DN10 (Fig.5) Pressure in the pipes is 40 bar. Hence pipe work is much simpler than steam piping for soot blowers. For natural gas, a small compressor (as for filling stations of gas-driven vehicles) can be used if natural gas is available from a network.

One single gas cylinder of nitrogen is needed for the gas spring of the piston.

Fig. 5: Components of gas supply: gas cylinder bundles; pressure reduction station; ball valves at each generator

Operating costs of an Explosion Generator are strongly dependent on the form of gas supply (Tab. 6) but are much lower than those for soot blowers.

			Natural gas	Oxygen
Gas consumption per explosion	kg		0.011	0.044
Gas prices (assumption)	€/kg		1 - 7	1.95
Gas cost per explosion	€	0.10 - 0.16	0.01 - 0.08	0.09
Number of explosions per day		24		
Gas cost for 8000 hours	**€/a**	**800 - 1302**		
Compared with				
Steam sootblower	travel way 10 m			
Steam price (assumption)	€/t	10		
Number of cleaning runs per day		3		
Steam cost for 8000 hours	**€/a**	**3514**		

Tab. 6: Yearly gas cost of one Explosion Generator compared with a soot blower

4 Safety

The Explosion Generator is CE-certified and has got a conformity declaration according to the European Pressure Equipment Directive PED (Category II).

For certification Dekra Exam GmbH, Fachstelle für Explosionsschutz – Bergbau- Versuchsstrecke, Bochum, has given an assessment report on the safe operation of the Explosion Generator. The conditions given in this report have to be met for installation and operation. The Explosion Generators are not equipment subject to Directive 94/9/EC (equipment in Potentially Explosive Atmospheres (ATEX)). The area around an Explosion Generator and the gas inlet piping do not become potentially explosive atmosphere. Only the Natural gas cylinders or gas bundles are potentially explosive atmosphere.

5 Reference plant WtE Lucerne

The waste-to-energy plant “Kehrichtverwertungsanlage (KVA) Lucerne” has the most extended experience in operating Explosion Generators. There are 8 Explosion Generators EG10 installed in 3 boiler streams. From February 2009 until today over 180’000 explosions have been carried out. Besides the Explosion Generators there are no other boiler cleaning devices in operation. 20 soot blowers and one shot ball cleaning system have been removed.

Detailed Information on Boiler 1 and 2 (Thermal Load 10 MW each):

First tests with Explosion Generators took place from summer 2008. In February 2009, 6 pressurized air soot blowers of the vertical 3rd pass of boiler 2 were replaced by 2 Explosion Generators (Fig. 7). In July 2009 the same replacement was made in boiler 1. The frequency of explosions is set by the operator according to their needs in a range of one explosion per unit and 30 to 120 minutes.

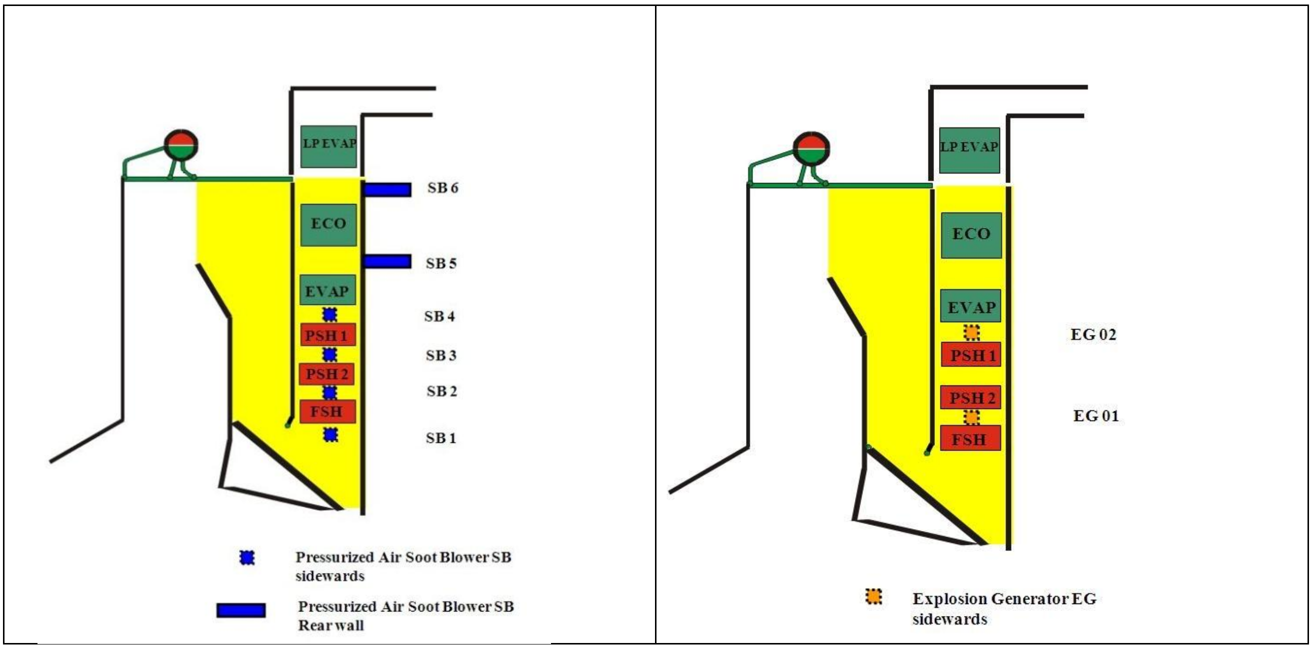

Figure 7: Mounting position of soot blowers (until 02/2009) and of Explosion Generators (from 02/2009) in boiler 2 of KVA Lucerne

The trend curve (Figure 8) shows the last years of operation of the second boiler since October 2007. One can see that until February 2009 when operating with 6 soot blowers, the flue gas tem-

perature at the entrance to the 3rd pass increased strongly because of periodic fouling of the second pass as there were no facilities in place for cleaning, and the soot blower from the 3rd pass had no influence on this area.
The increase in inlet temperature to the 3rd pass has always been connected with an increase of the boiler outlet temperature and of the frequency of the ID fan since the deposits in the bundle areas resulted in severe reduction of the free cross-section.
To achieve 8500 hours travel time despite these problems and to reduce corrosion of the super heater, the operator worked with 3-4 intermediate Bang & Clean Online cleanings per year, each of which led to significant temperature drops at the inlet and outlet of the 3rd pass.

Since 11/02/2009 the boiler cleaning is done with 2 Explosion Generators EG10 only. It is evident that in particular the flue gas temperature at the entrance to the 3rd pass, due to reduced fouling of the 2nd pass can be kept at a much lower range. This means that the pressure wave of the generators installed in the 3rd pass of the boiler, also flows back into the second pass against the flue gas stream, where it removes deposits. Because only small deposits occur in the bundles, the cross-section remains open and no increased frequency of the ID fan can be found any more. The flue gas temperature at the boiler exit can be maintained throughout the year in the desired range. The boiler can therefore run 12 months in continuous operation until the next annual maintenance shutdown takes place.

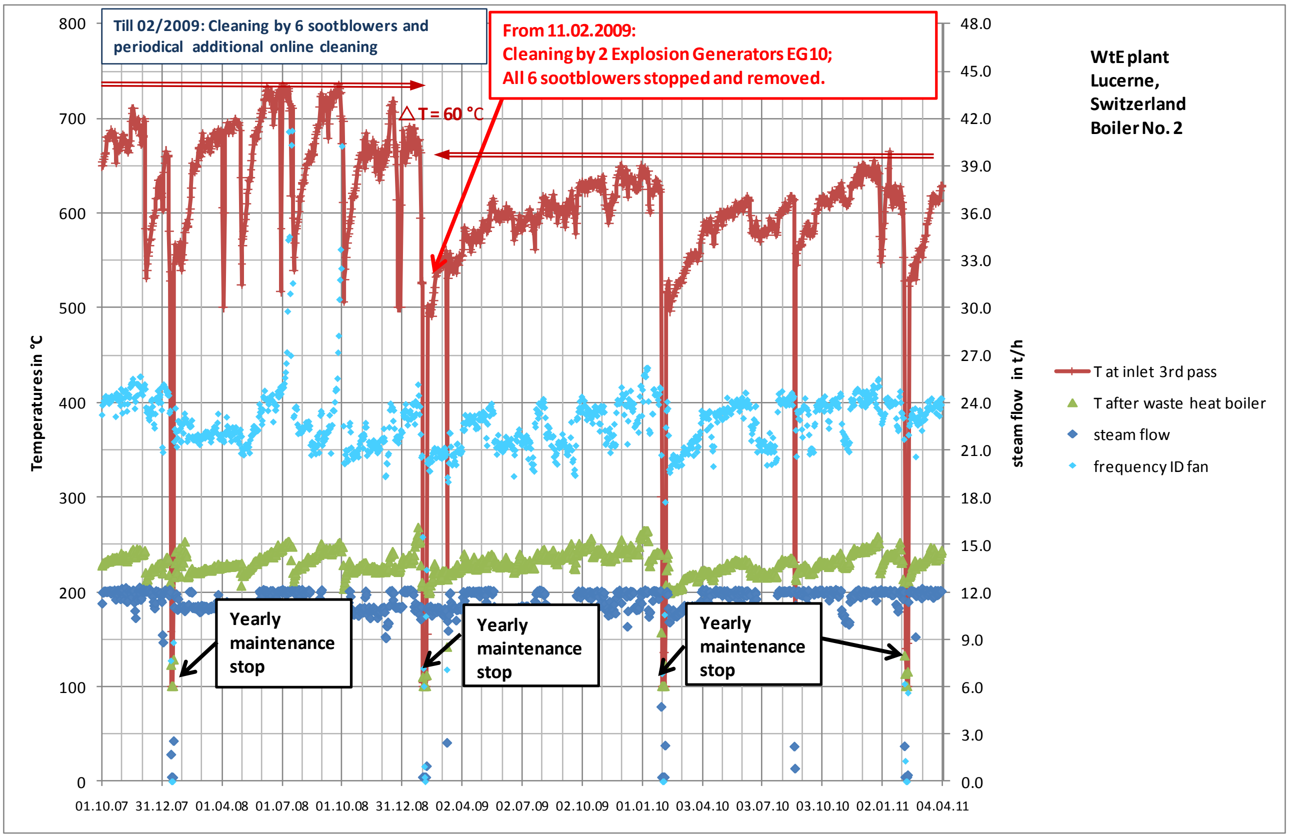

Figure 8: Trend curve WtE Lucerne boiler 2

Detailed Information on Boiler 3 (Thermal Load 16 MW):

In June 2009, the 8 air soot blowers of the third vertical pass were replaced by 2 Explosion Generators (Figure 9). In November 2009 and February 2010 2 additional Explosion Generators were installed, to further increase the cleaning efficiency. The shot ball cleaning in the external economizer could be shut off. The explosion frequency in each case has been set according to the current need in the range of 30-240 minutes.

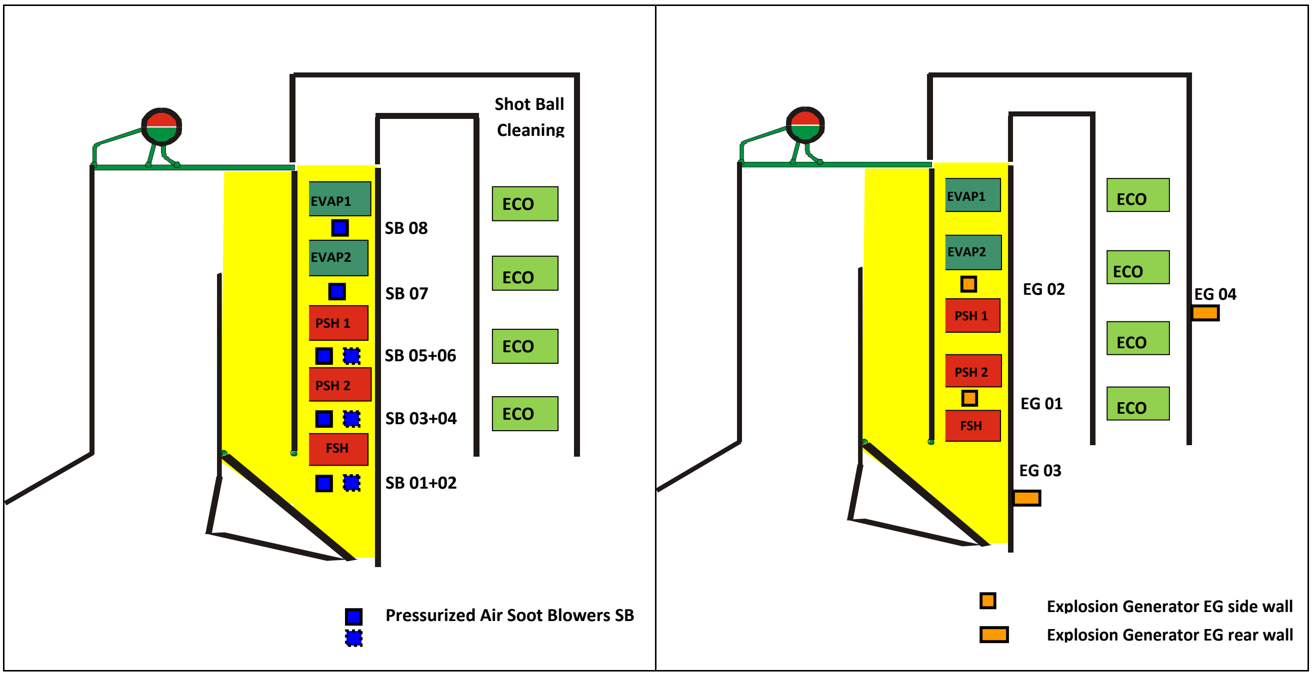

Figure 9: Mounting position of soot blowers (until 06/2009) and of Explosion Generators (from 06/2009) in boiler 3 of KVA Lucerne

The trend curve (Figure 10) shows the last 3 years of operation of boiler 3. Until June 2009 8 soot blowers were installed for boiler cleaning in the 3rd pass followed by shot ball cleaning in the economizer. As described above for boiler 2, regular sharp increases in inlet temperatures to the 3rd pass and from time to time high frequency of the ID fan could be observed. With additional Bang & Clean Online cleanings every 2-4 months the plant could still operate without stop during one year.

The 2 Explosion Generators EG10 installed in June 2009 were able to reduce the increase of the flue gas temperature at the inlet of the 3rd pass, but were not able to hold it below 650 ° C. The reason for this is a larger boiler capacity compared to boilers 1 and 2, and different type of evapo-rator in the 2nd pass. By installing a 3rd Explosion Generator in November 2009 at the back wall of the 3rd pass, the temperature could be reduced in a step-change by more than 100 ° C and can now be permanently kept below 650 ° C. This means that the pressure wave of this generator goes against the flow direction into the second pass and contributes there effectively to prevention of fouling. In February 2010 the shot ball cleaning in the external economizer was replaced by a 4th Explosion Generator and keeps the flue gas temperature at the boiler exit lower over the year than previously. Thus, this boiler can be kept for 12 months in continuous operation with nearly clean boiler conditions.

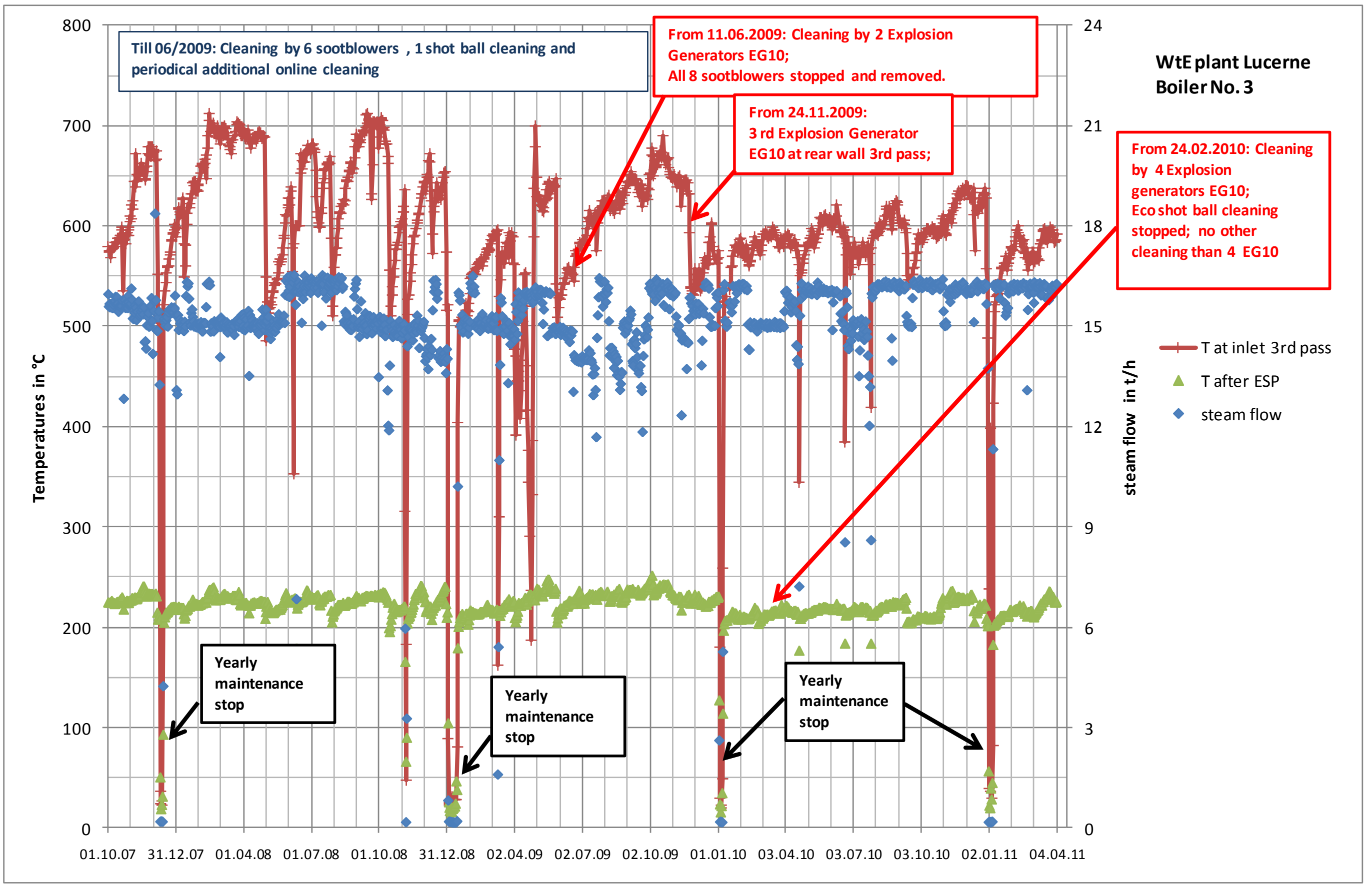

Figure 10: Trend curve WtE Lucerne boiler 3

The operator of the KVA Lucerne launched further actions due to these positive results which will further reduce the maintenance costs in the future. Thus, the protective shells were removed from the heat exchanger bundles, since such protection of the pipes is no longer necessary for explosion cleaning. Furthermore, much less work is required at the beginning of the planned annual maintenance shutdown for the additional cleaning of the boiler, thus saving work, and the duration of the maintenance downtime can be shortened.

6 Other References and Mounting Positions

Good results were also found in larger waste- and biomass-fired boilers (cf. reference list) and at other mounting positions, e.g. in the empty pass and in horizontal passes (Figure 11).

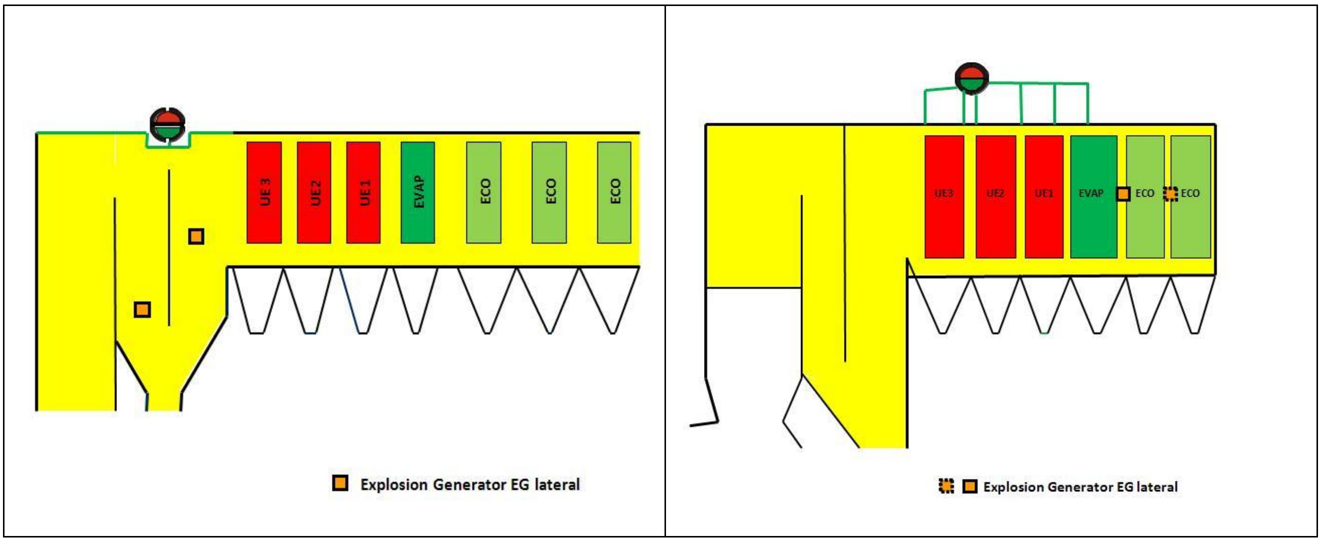

Figure 11: Mounting position in empty pass or horizontal pass

When installed into the empty pass Explosion Generators can replace membrane wall cleaning systems such as water cannons or shower cleaning. Usually, the membrane walls have certain flexibility within the buckstays. Therefore, when the pressure wave hits the walls and sets them into short oscillations, the fouling deposits drop off from all areas of the empty pass. Accordingly, each Explosion Generator can reach a large boiler volume. As a result, the fouling level of the empty pass can be kept permanently low, and an almost constant inlet temperature in the downstream heating surfaces can be achieved. This prevents fly ash in these downstream areas from getting stickier due to higher temperatures with increasing travel time. Compared to cleaning systems working with water, an additional advantage can be gained because the ash in the economizers remains dusty and does not produce hardening fouling. The economizer surfaces can be cleaned more easily under such conditions.

Installed in a horizontal pass the Explosion Generators replace rappers. In one of the reference plants, the rapping of the bundles equipped with Explosion Generators was stopped during more than 6 months. The outlet temperature from the horizontal pass could be kept lower than before installation of the Explosion Generators. The pressure wave of the Explosion Generator hits the entire tube bundle, whereas the impulse of the rapper can only be introduced to the rapped collector.

7 Benefits for Power Plant Operation

There are significant advantages for power plant operation:

- Improved cleaning effects compared to conventional technologies due to explosion pressure of 350 bar
- Higher boiler efficiency due to reduced fouling and lower flue gas temperatures
- Less planned and unplanned shutdowns of boiler
- Increased plant availability by reducing downtime because of reduced cleaning efforts needed during shutdowns
- Lower operating costs and no steam consumption
- Lower maintenance costs
- Better CO2 system balance (reduced CO2 emission)
- no boiler tube erosion by steam, thus fewer tube failures
- no damage to the Explosion Generator possible by flue gas temperature and by flue gas corrosion

In addition, for new plants the following additional benefits will apply:

- Reduction of heating surfaces for same thermal load, thereby reducing boiler size
- Reduced need of space on the side of the boiler, especially for multi-stream plants (saving of enclosed space), easier piping
- Lower investment costs
- Reduced number of devices because of long-range effect

8 Summary

The Explosion Generators installed so far show very good results with respect to an improvement of the boiler cleaning facilities while at the same time reducing boiler damages. These findings will lead to a modified boiler design in the future for new plants. Detailed analysis of the results of additional reference plants and growing experience with installed Explosion Generators will contribute significantly to further development. Explosion Power GmbH is currently developing a more powerful type of Explosion Generator to achieve sufficient cleaning effect even in heat exchanger areas of very large boilers in coal-fired power plants.

9 Literature

M. Bürgin, H. Rüegg, „Increased Plant Safety and Plant Availability by Cleaning with Dosed Gas Explosions"; VGB Power Tech 12/2005, p. 82-85.