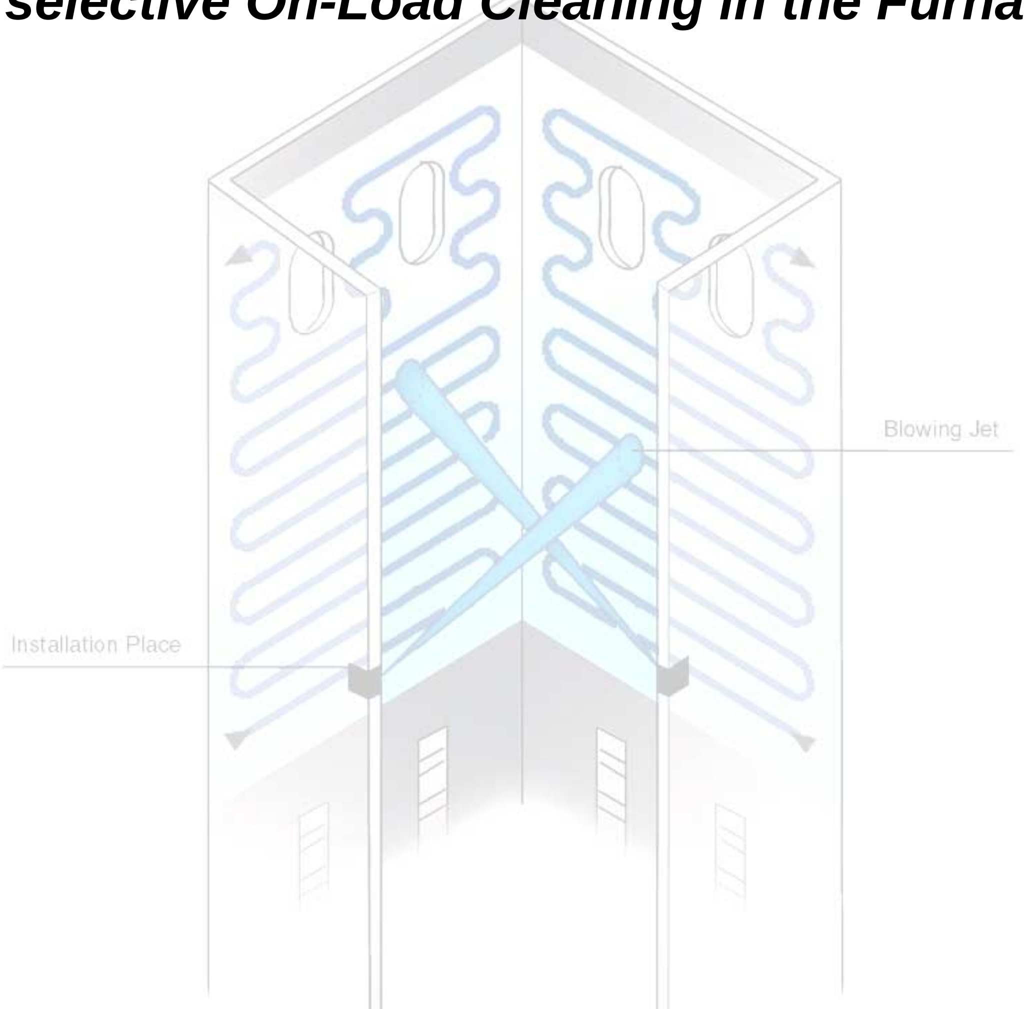
Significant Increase of Boiler Performance gained by using advanced and intelligent Solutions for selective On-Load Cleaning in the Furnace



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1. INTRODUCTION

1.1 Broad fuel range for plants fired with bituminous coal

The liberalisation of the energy markets - also in Germany, especially since 1998 - led to a reduction of the electricity prices. But this also involves intensified pressure for the power plant owners to save production costs. Since the fuel price constitutes a considerable portion of the production costs, especially bituminous coals of international origin are fired, whenever possible, but these coals show varying fuel characteristics.

This varying fuel characteristic is mostly combined with a lower ranked coal lead to a changed fouling behaviour in the combustion chamber and to heavy slagging at the burner openings.

As a result of this slagging, operational safety and availability is affected and flame control is changed. Intensified non-homogeneous fouling of the evaporator walls leads to a reduction of the heat absorption in the radiant section and thus to an increase of the furnace exit gas temperature. At least these factors also have economic consequences.

The resulting effects on the steam generator will be described in detail with the following chapters.

Figure 1: Coal Burner with Slagging

1.2 Major fuel switch for lignite-fired steam generators

For the lignite-based utility power plants in the German Rhenish region a serious fuel switch took place in recent years. Opening of the new Hambach open-cast mine, which in the years to come will supply a considerable portion of the lignite for the installed power plant capacity of overall some 10,000 MW in the Rhenish lignite region, entails a decisive change of the fuel properties [1]. The lignite from the Hambach open-cast mine is particularly characterised by a high calorific value and high iron and sodium contents – also see Table 1.

In that respect it should be taken into account that many of the steam generators (150, 300 and 600 MW) went into service already between 1955 and 1976 and originally were designed for a different - less critical - fuel qualities. The transition to coal supply from the Hambach open-cast mine with the described new fuel quality mainly entails the following effects:

The higher calorific value leads to higher combustion temperatures and, as a result, to an increased furnace exit gas temperature. The increased iron and alkaline content combined with silicon lead to a reduction of the ash fusion temperature.

These two processes, especially in combination, caused considerable and heavy slagging of the evaporator walls and molten deposits in the first superheater banks of the convection part. This development could be countered only partially by the adjustment of the coal feeding strategy so that intensive formation of deposits still was observed in the radiant as well as the convection heating surfaces.

Data for Rough Coal from Open Mine Hambach Average Coal Quality						
Calorific Value [kJ/kg]	Ash [%]	Iron [ppm]	Sodium [ppm]	Potassium [ppm]	Calcium [ppm]	Sulphur [ppm]
9700	3,0 to 3,5	2700	700	150	5500	0,26

Table 1: Coal Analyses

1.3 Importance of furnace exit gas temperature

As described above, the change of the fuel quality results in a considerable increase of furnace exit gas temperature (FEGT) for the coal-fired steam generators. The significance of this important process characteristic lies in particular in the effects on the fouling behaviour for the convective heat exchanger.

The rising furnace temperatures makes it necessary that the heat transfer to the radiant heat exchanger surfaces will be increased disproportionately with T^4. Additionally in the area of the first convection heating surface (superheater) combustion is not yet fully completed, the temperature level increases above the ash fusion point and, as a result, partly molten tenacious slagging is produced which cannot be removed.

Heat absorption in the convection part is intensified, however, without completely balancing the heat rate losses of the fouled combustion chamber. This leads to an increased boiler outlet gas temperature.

These two factors directly cause a loss of efficiency of the steam generator.

The above-mentioned points show quite clearly, that effective high performance and on-demand cleaning of the furnace is a driving factor for save and efficient operation of a steam generator.

2. OPTIMISED FURNACE CLEANING AT THE 600 MWe UNIT "G" OF RWE RHEINBRAUN POWER STATION NIEDERAUSSEM

Below the optimised and demand-controlled system for furnace cleaning will be described in detail for the lignite-fired steam generator Unit G at the RWE Rheinbraun Niederaußem Power Plant. This steam generator is a tower type boiler with a capacity of 1,868 t/h and was taken into service in 1974. The evaporator has been constructed as a membrane wall with a square cross section of 20 x 20 meters.

In the course of the years several modifications were done at this steam generator in order to optimise combustion and to reduce emissions. One of these modifications was in 1998 the installation of 14 Clyde Bergemann Water Cannons (WLBs). They were installed to replace the existing 72 wall deslaggers. The new Cannons are arranged with 12 WLBs installed at 3 levels, each with 4 WLBs, and 2 extra WLBs in the lower section, for cleaning the hopper area, acc. to Figure 3

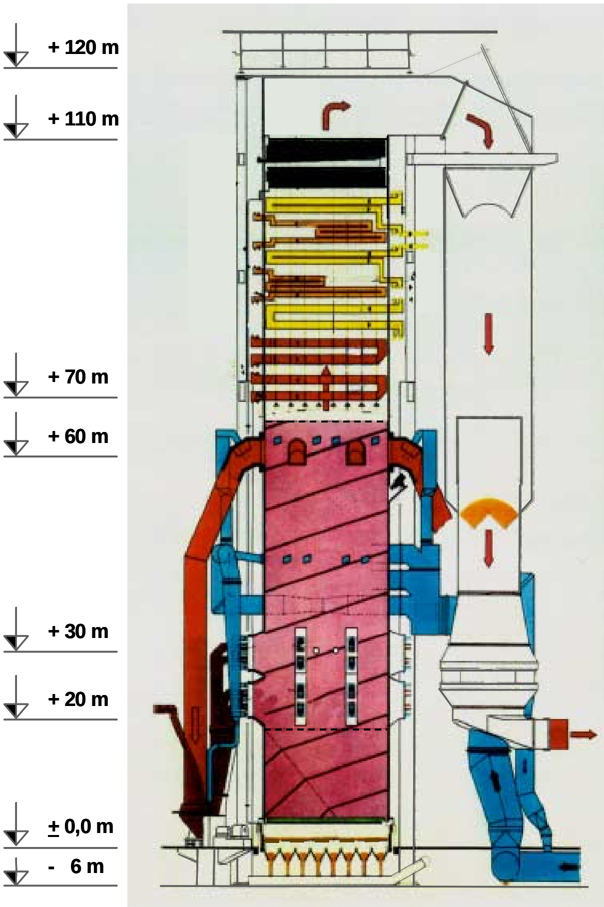

Figure 2: Steam Generator RWE Rheinbraun Power Station Niederaußem Unit G

2.1 Clyde Bergemann Water Cannon Technology

The Water Cannon Technology is particularly characterised by the fact that a concentrated water jet impinges across the furnace onto the opposite wall heating surface and there forms a meander belt-shaped cleaning pattern which is individually adjustable but pre-programmed with a basic set up according to the individual cleaning purpose.

The cleaning mechanism basically differs from that of sootblowers, which work with steam as cleaning medium. In case of the Water Cannons the high performance nozzle send a droplet range of water, which penetrates the pores of the deposits. Sudden evaporation takes place and, as a result the volume expand abruptly. This effect leads to the "explosion" of the deposits from the heating surface.

The success of cleaning depends on the optimum penetration of the deposits. This is primarily influenced by parameters such as

- Jet progression speed on the opposite wall
- Impinging water quantity
- Impact angle of the water jet on the opposite wall
- Characteristic of fouling (porous or slagged deposits)

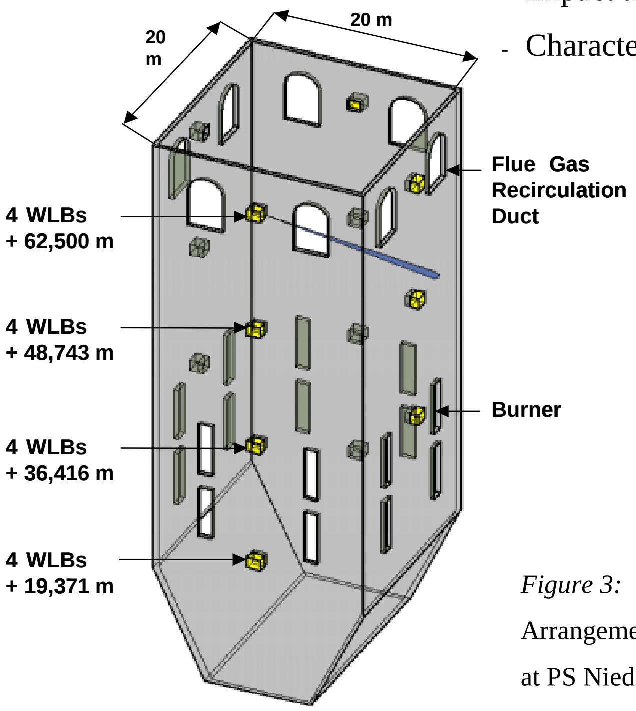

Figure 3:
Arrangement of Water Cannons
at PS Niederaußem Unit G

The PLC Control System fully automatically controls the Water Cannons. There are several safety features embedded to secure the optimum operation mode. The specially developed high performance nozzle system cares for intensive concentration of the water jet so that also distances of up to 35 meters are covered in furnaces, which are run at full load.

The initial first installation of Water Cannons was done at RWE Rheinbraun Power Plant Weisweiler in 1992 [2], [3].
To date more than 1,080 Water Cannons are successfully in cleaning operations at steam generators worldwide, which are fired with the most various fuels, such as for example:

- lignite
- bituminous coal
- Powder River Basin Coal
- Oremulsion
- White liquor

Furthermore, Water Cannons have been used already since 1998 for cleaning radiant heating surfaces in refuse incineration plants and biomass boilers.

In 2001 Clyde Bergemann introduced the 2nd generation of Water Cannons (WLB-CB 100), which offers additional benefits like a 15% more compact design, extremely maintenance friendly concept and a considerable increase in the precision of control.

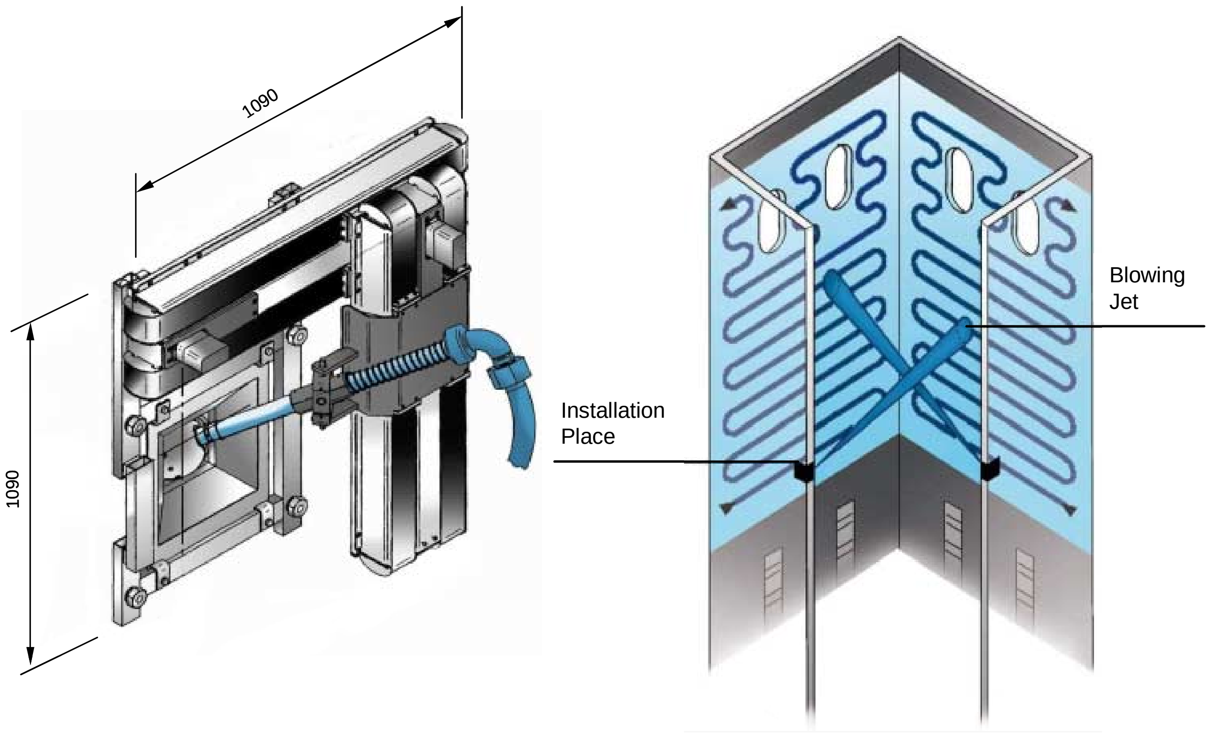

Figure 3: SMART CANNON™ WLB-CB 100 and Cleaning Principle

The installation experience from more than 12 years of operation shows that the risk of thermal impact and the related reduction of service life are excluded for the wall tubes of the steam generator if the cleaning parameters are correctly adjusted. This is also proved by the extensive measurements and calculations conducted by independent experts and research institutes in Germany, Australia and the USA.

When compared with the conventional wall deslaggers the application of the Water Cannon Technology provides important advantages for the power plant operators such as:

- Reduction of operating costs because water is used as cleaning medium instead of superheated steam
- Reduction of maintenance costs since one Water Cannon (WLB) replaces up to 15 conventional wall deslaggers
- Increase of heat absorption in the evaporator and significant reduction of the furnace exit gas temperature because the effectiveness of the heat exchanger is maintained almost completely with the Water Cannon Technology.

During cleaning with conventional wall deslaggers, which produce circular cleaning areas, uncleaned areas are left between the various cleaning circles. This results in up to 35 % of uncleaned wall heating surface, which participates in the heat exchange only with greatly reduced effectiveness.

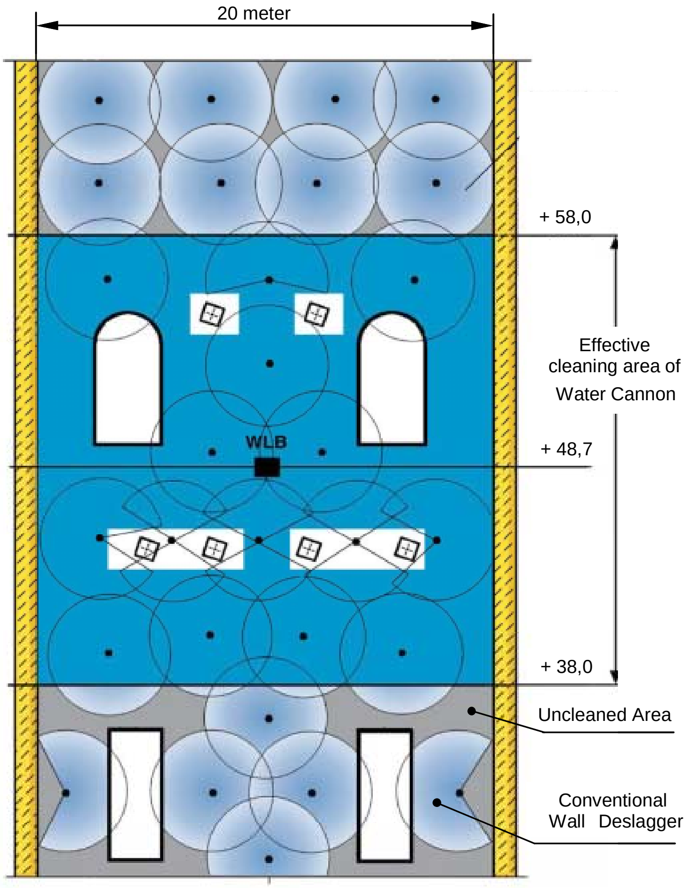

Figure 5:
Comparison of Cleaning Areas Conventional Wall Deslaggers vs. Water Cannons