Automated Radiation Pass Cleaning in Waste-to-Energy Plants – Experience from 70+ Shock Pulse Generator Installations

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The Shock Pulse Generator (SPG) automatically creates powerful shock waves by pressurized gas combustion [1]. SPGs have been shown to decrease boiler downtime for preventive maintenance and cleaning as compared to other automated radiation pass cleaning technologies like shower cleaning, water cannons and wall blowers. While there are 70+ SPG installations, this article presents case studies from six installations of SPGs in radiation passes of Waste-to-Energy plants worldwide. These installations are found worldwide, and represent plants retrofitted with SPGs as well as newly-designed plants. Typical information about operating expenditures are then put into relation to customer benefits.

1. Automatic Removal of Slag and Deposits

A Waste-to-Energy boiler consists of different sections. In the schematic drawing in Figure 1, green boxes show economizer bundles (i.e. feed water is heated close to saturation temperature). Blue boxes or sections show evaporator bundles or panels (not boiler walls), and red boxes show superheater bundles. The colour profile, shifting from dark red (grate/furnace on the left) to yellow (at the boiler outlet to the right), shows the flue gases being cooled down from about 1200°C to 150-200°C.

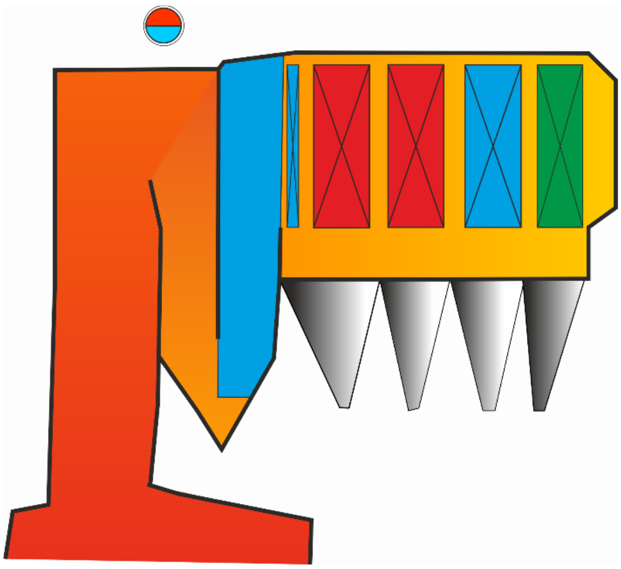

Figure 1: Schematic boiler drawing

Because waste is a resource used to produce electricity and heat, Waste-to-Energy Plants are designed to use this resource efficiently. In order to maximize thermal efficiency, steam should be superheated to the highest possible temperatures. Superheater bundles or panels should be placed as closely to the furnace as possible. On the other hand, there is the risk of superheater corrosion [2]. If the tube material becomes too hot, the superheater tubes are damaged quickly due to chlorine attack of the metal matrix. Therefore, Waste-to-Energy boilers are normally designed for final superheater bundles to exchange heat with flue gas temperatures of less than 700°C, and with superheated steam temperatures in the range of 380-

430°C. Hence, the flue gases have to be cooled down before the heat can be exchanged with the superheater bundles. Cooling is achieved through evaporator membrane walls and protective evaporators. These walls are usually operated in natural convection and contain a mixture of saturated water and steam. The water / steam mixture rises by free convection to the steam drum placed above. These boiler sections are called radiation passes since heat is mainly exchanged by radiation and not by convection like downstream of the boiler.

The surface areas of these radiation passes are defined in the design phase. If during boiler operation the heat exchanged in these radiation passes is higher than the design value (i.e. flue gas temperatures at the exit of the radiation section are lower than designed), the boiler can have problems reaching the required live steam temperature. If the exchanged heat is smaller than the design value (i.e. flue gas temperatures at the exit of the radiation section are higher than designed), this leads to increased corrosion and has a negative impact on fouling in the convective section. Hence, there is a need to control the exchanged heat in the radiation passes, and this can only be done by actively controlling the slagging / fouling at the walls of radiation passes.

2. History of Radiation Pass Cleaning in Waste-to-Energy Plants

A survey in 2010/2011 [2] of 70 Waste Incineration and 30 Refuse Derived Fuel Plants in Germany (a total of 121 incineration lines) showed that only 20% had a system to automatically remove slag/deposits in the radiation passes during boiler operation. Water was the dominating cleaning medium.

The reason why many older plants do not have any radiation pass cleaning system is that during the design and construction of these plants, there was no effective technology on the market. Hence, the surfaces of radiation passes were designed large, because they were supposed to slag / build up deposits during operation. At the time, rapping or vibrating systems were the only means of automatic radiation pass cleaning.

At the beginning of the 21st century, radiation pass cleaning technologies like shower cleaning, water cannons and wall blowers entered the market [4]. In 2009, the first Shock Pulse Generators (SPGs) were installed in Waste-to-Energy Plants. Since then, more than 500 SPGs have been delivered worldwide. Today, more than 70 units are installed in order to clean radiation passes (see Figure 2). Basically, all new Waste-to-Energy plants in Europe use a system to automatically remove slag/deposits in radiation passes during boiler operation.

Figure 2: Installed TwinL Shock Pulse Generator in Waste to Energy Plant Zurich Josefstrasse

3. SPG Radiation Pass Cleaning – Case Studies

In Figure 3, six European Waste-to-Energy plants are shown where SPGs are permanently installed to clean the radiation passes. The mounting positions are marked by a blue rectangle. All installation positions are situated either on the side or on the rear of the boiler walls. The plants are ranked from A to F according to their steam load. Plant A generates 17 tons/hr (t/h), plant F generates 100 t/h (see Table 1). Plant E is newly-built, the other plants have been retrofitted. Plants A to E clean the radiation passes solely by means of SPGs. Plant F uses SPGs and Shower Cleaning in parallel. The SPGs were installed between 2009 and 2015. Plant A was shut down in 2015, and replaced by plant E. The six installations are discussed below.

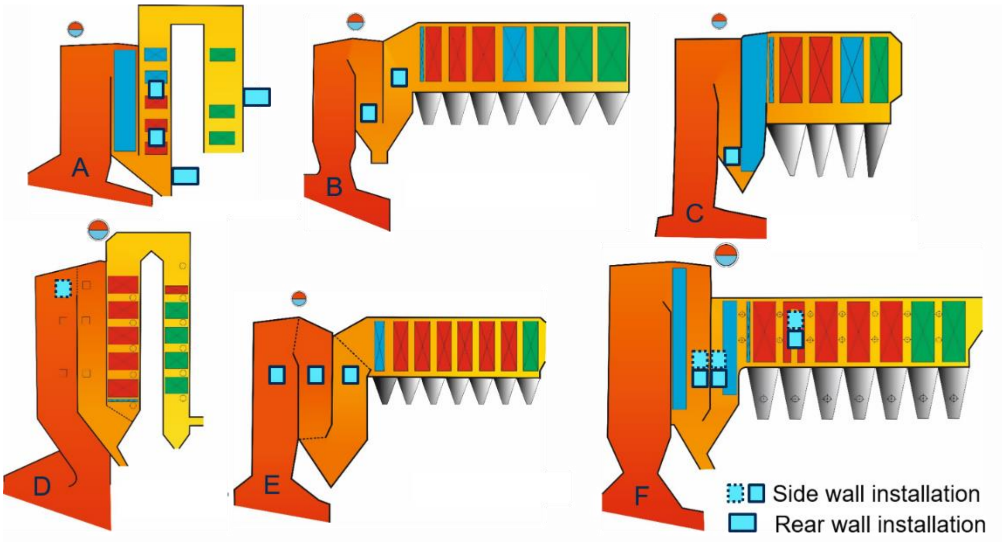

Figure 3: Chosen case studies of radiation pass cleaning from 17 t/h (A) to 100 (F) t/h steam load.

Table 1: Information on case study plants (see also Figure 3)

Plant	Country	Steam load [t/h]	Rad. pass width [mm]	New / Retrofit	Total # SPGs inst.	Year of SPG install.	# of rad. passes	Evap. panels rad. pass
A	CH	17	3100	Retrofit	4	2009	2	2nd pass
B	FI	39	4900	Retrofit	2	2010	3	no
C	CH	52	7200	Retrofit	1	2015	3	3rd pass
D	DE	55	4800	Retrofit	2	2012	2	no
E	CH	58	5500	New	6	2015	3	no
F	DE	100	9000	Retrofit	6	2011	3	2nd and 3rd pass

3.1. Plant A – Cleaning a Radiation Pass Upstream of the SPG

In Plant A, one SPG is installed at the rear wall of the third convective pass to clean the radiation pass 2 located upstream of the SPG. The temperature profile in Figure 3 shows stable inlet temperatures at the third pass since the SPG was installed in 2009. Previously, values of more than 700°C occurred, which led to a high corrosion rate in the final superheater. Plant A was shut down at the start of 2015, as it was replaced by a new waste-fired cogeneration plant (Plant E, see Section 3.5).

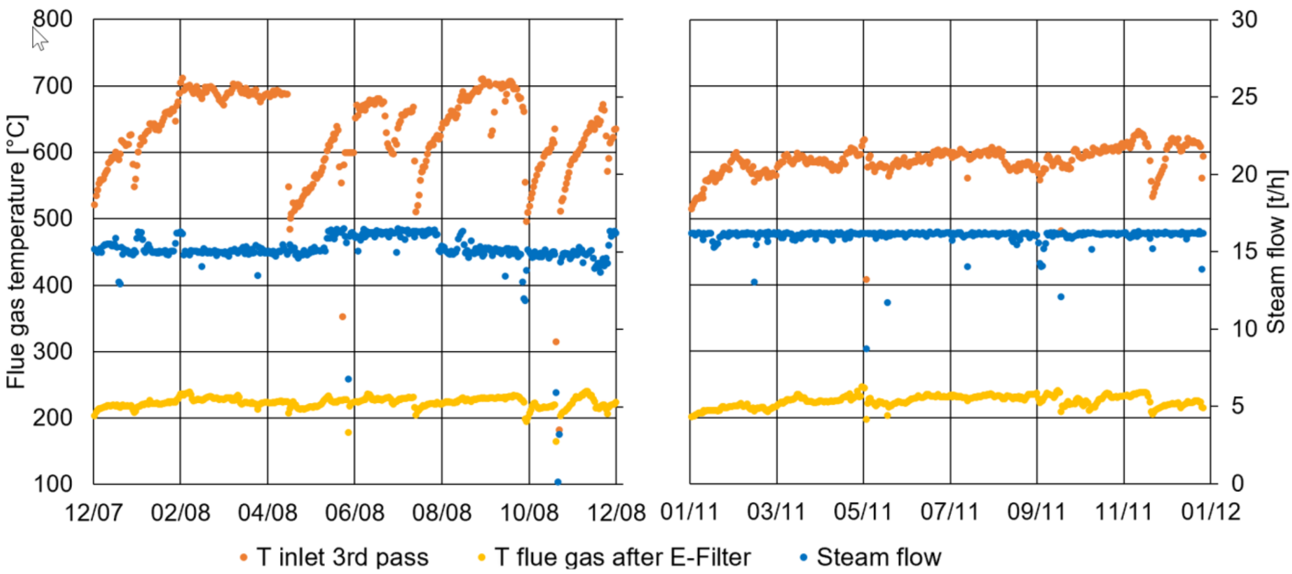

Figure 3: Flue gas temperatures at outlet of radiation passes, after E-Filter and steam flow. On the left: year 2008 (without SPGs), on the right: year 2011 (with SPGs).

3.2. Plant B – Replacing Water Cannons

SPGs in Plant B replaced existing water cannons in the radiation passes 2 and 3. Since the installation of the SPGs, the flue gas temperature at the entrance to the 4th pass remains below 640°C, and SH3 does not clog anymore. The plant can achieve the desired continuous operating period even without any additional manual boiler cleaning interventions which were required semi-annually before the installation of SPGs.

3.3. Plant C – Replacing Shower Cleaning System

In this plant, the third radiation pass contains a membrane evaporation wall, subdividing the pass into a left and a right half. In order to prevent an excessive corrosion rate of superheater tubes, a maximum flue gas temperature of 700°C should not be exceeded at the inlet of the horizontal pass.

In 2016, one SPG was installed at the lower part of the 2nd radiation pass in order to improve the cleaning process of the radiation passes.

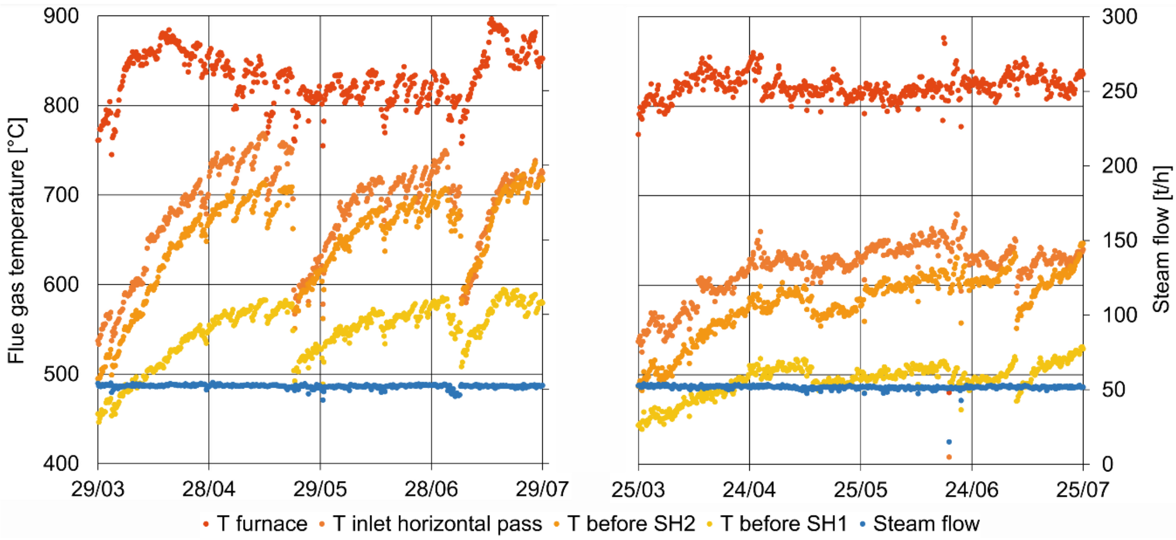

Figure 4: Temperature plots before and after installation of SPG

In 2015 (see left half of Figure 4), the flue gas temperature at the inlet of the horizontal pass increased almost linearly by 7°C per day and reached the critical value of 700°C less than one month after boiler start up. By using a shower cleaning system, the temperature could be kept around 700°C for 2-3 weeks. In order to avoid a further increase of the temperature, a manual online boiler cleaning was required which reduced the temperature to a value similar to the one after the maintenance stop. Thereafter, the periods until shower cleaning and manual boiler cleaning were necessary again and became shorter and shorter.

After the installation of the SPG (see right half of Figure 4), the flue gas temperature at the inlet of the horizontal pass increased to 600°C in the first month but could then be kept within 600 and 650 °C for the rest of the four months operating period. The SPG was commissioned one week after boiler start up. During week two and three, the interval between shock pulses amounted 4 hours, during week four to five two hours and from week six onward, it was 1 hour.

The reduced flue gas temperature lowered corrosion rate at the superheater bundles. Also, the operator noticed positive effects on the additional manual online cleaning at the horizontal pass, which could be reduced from 3 to 1 intervention per 6 months of operation. Additionally, the sand blasting during the maintenance stop could be carried out faster because less material had to be removed. Finally, the reduction of the flue gas temperature will allow overload operation of the boiler during periods with peak demand of the district heating. A recent test proved to run a complete year without any boiler stop, hence eliminating a previously planned shutdown after six months.

3.4. Plant D – Furnace Pass and Screen Grid Cleaning

In Plant D, a good cleaning effect at the grid tubes between the 1st and the 2nd pass was reached due to the SPG installation. The cleaning effect is also clearly visible at the walls of the 1st pass by reduced outlet temperatures at the 1st pass. The boiler load was increased by 15% in 2008, therefore the plant operator encountered increased flue gas temperature, velocity and boiler fouling. After the SPG installation, the number of manual online cleanings within one traveling period was reduced to approximately one third.

3.5. Plant E – Newly-Built Plant with Radiation Pass Inconel Cladding

In Plant E, SPGs for the three radiation passes were planned from the design. The boiler was commissioned in 2015. It is a newly-built boiler with Inconel cladding in the furnace pass. Table 2 shows that the mean temperature after 8000 h was within tolerances. The three SPGs installed per boiler create a shock pulse every 4.5 h, on average. This improvement leads to low operating cost.

Table 2: Flue gas temperatures after 8000 h of operation

Measurement position	Mean Temperature After 8000 h [°C]
Flue gas temperature at inlet 2nd pass	<800
Flue gas temperature at inlet of horizontal pass	<600

3.6. Plant F – 100t/h Boiler with Clean Radiation Passes

Plant F has a 9m wide boiler. Its radiation passes 2 and 3 are designed with evaporator panels, covering some parts of the boiler passes. The cleaning effect of the unit is superior, the travelling period of the boiler was increased by 100% after the installation. Before the retrofit, intermediate manual boiler cleanings were required on a weekly basis. These SPGs are operated together with a shower cleaning system.

4. Different Types of SPG

Nowadays, four different SPG types are available (see Figure 5). The units differ by the amount of gas needed per one shock pulse. The following rules are based on the experience from radiation pass installations worldwide. They can be taken as a rule of thumb for a first design proposal. For detailed planning, please confirm with the supplier or one of its partner companies.

Radiation passes without evaporator or superheater panels (i.e. only front wall, 2x side wall and rear wall as well as membrane walls) should be equipped as follows:

- pass width <= 6 m: 1 EG10L/pass
- pass width 6 to 8m: 1 EG10XL/pass from one wall (side or front wall)
- pass width 8 to 12m: 2 EG10XL/pass, from both sides, or 1 TwinL/pass from one side
- pass width 12 to 16m: 2 TwinL/pass, from both side walls

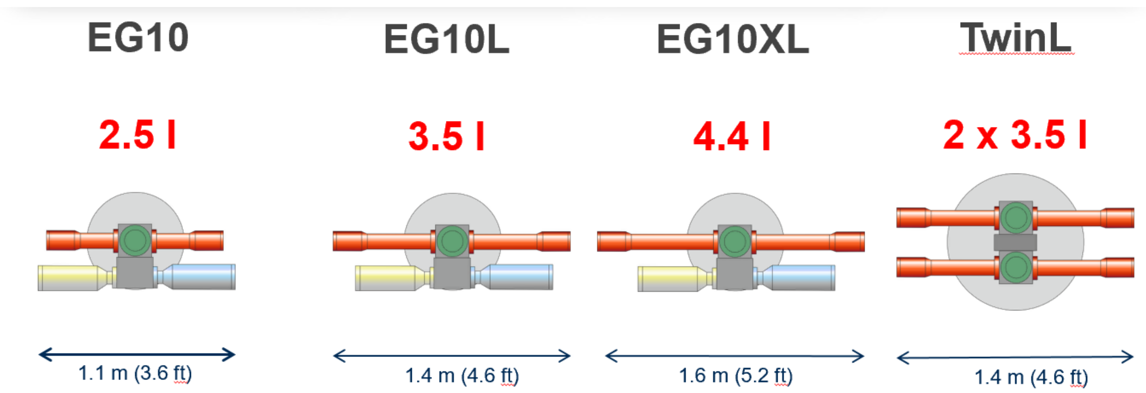

Figure 5: Four different SPG types are available today

If any evaporator or superheater panels are installed in the radiation pass (i.e. in addition to one front wall, two side walls and one rear wall) it is more difficult to deliver rules of thumb. A safe way would be to provide some boiler drawings to the supplier or its partner companies for a detailed analysis. However, if the panels do not extend over the full length from the front to the rear wall, the following design guidelines can be used for preliminary planning:

- pass width < 3 m and pitch of panels > 500mm: 1 EG10L/pass
- pass width 3 to 6m and pitch of panels > 500mm: 1 EG10XL/pass
- pass width 6 to 10m and pitch of panels > 500mm: 2 EG10XL/pass, from both sides, or from rear wall, or 1 TwinL/pass from one wall
- pass width 10 to 14m and pitch of panels > 500mm: 2 TwinL/pass, from both sidewalls

For a pass height of more than 15 m or if the evaporator and superheater panels are extending from the front to the rear wall, a detailed analysis must be performed. Also if refractory or tiles are installed in the corresponding radiation pass, some information about type, area and condition of the refractory is necessary.

<Here we could also provide a diagram that demonstrates each of these dimensions>

5. Operating Expenditures and Customer Benefits

The operation cost expenditures of the automated radiation pass cleaning system is mainly a function of the Shock Pulse Interval (SPI), i.e. how often the units are creating shock pulses. The shock waves are created by means of combustion of methane or natural gas and oxygen, and thus consume fuel with each shock pulse. SPGs in radiation passes are operated on average with an SPI of 2 hours. Maintenance cost, as well as gas consumption, are related to these values. The units require a planned maintenance every 3000 cycles. The discharge nozzle is protected by permanent purge air (6 bar) and cooling air (e.g. 20mbar).

In Table 2, operating costs for two different references are shown. Hence, the customer in Plant C has yearly operation cost for the radiation pass cleaning of 15,000 CHF for one boiler. The customer in Plant E cleans the radiation passes of two boilers with yearly operation cost of 15,500 CHF per line (i.e. total 31,000 CHF).

Table 3: Operating cost summary for a retrofit or newly-built Waste-To-Energy plant

	Cost of operating media (methane or natural gas, oxygen and nitrogen –)	Maintenance cost (by maintenance contract; customer can also order maintenance training and perform maintenance on his own)
	[kCHF/year and boiler line]	[kCHF/year and boiler line]
Retrofit (Plant C)	3	12
Newly-built (Plant E)	1.5	14

The benefits of an effective radiation pass cleaning are significant:

- In many cases, payback times of few years have been reported.
- No additional water or steam is added to the flue gases, which might increase convective pass fouling.
- Small installation volume of about 1 m^3 (also manhole installation possible).
- No klinker (risk to fall down) development in the radiation passes
- Shorter downtime due to cleaning and less material to be dumped during boiler shutdown for cleaning.
- Customers prolonged the traveling period by up to 100%, with less intermediate manual cleaning.

- Generally lower and more stable flue gas temperatures at the outlet of the radiation passes were reached, contributing to overall smooth boiler operation and reduced corrosion rates.

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