

# Infrasound Solution for Fouled SCR and the Economizer in World's Largest Waste-to-Energy Boiler

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Infracone, with headquarters in Stockholm, Sweden, is using infrasound as a soot cleaning method and has plenty of experiences from various fuels and applications. The technical development has resulted in a product with much higher acoustic power than any other similar products on the market and acoustic modelling software that is unique. Infrasound cleaning increases the efficiency, the availability and the lifetime of industrial and marine boilers. In this text we start by describing the properties of infrasound and the product, while finishing by looking deeper into a couple of recent results obtained on waste to energy boilers.

## 1. Cleaning applications

In power plants and heating plants the infrasound technology is used for a cost-efficient cleaning method mainly for economizers, air preheaters, catalysts and ducts. Deposits on heat exchanging surfaces have very different characteristics for different fuels and in different parts of a boiler though. At high flue gas temperature, melted components such as alkali chlorides, lead chlorides and zinc chlorides result in sticky ash, reaching the heat exchanging surfaces and other surfaces. At flue gas temperature typical of economizers, air preheaters and catalysts, the stickiness of the ash is low, resulting in efficient cleaning using infrasound. For fuels with relatively dry deposits such as coal or e.g. a mixture of wood chips and peat the infrasound can be efficient enough to be the

only cleaning method required even for superheaters and temperatures up to approximately 800 °C. For waste and for biomass fuels such as wood chips, demolition wood, bark, tops and branches, the infrasound is successful in cleaning up to approximately 500 °C. Some customers have however reported a reduction of the rate of particle deposition on heat exchanger surfaces also at about 650 °C flue gas temperature. In smoke tube boilers infrasound cleaning is successful up to approximately 800 °C for biomass fuels. The reason for this is infrasound intensity being very high in such boilers due to the small cross-section of the flue gas pass through such boilers.

## 2. Infrasound

The infrasound generator is typically installed at the top of an economizer. One infrasound generator, or two generators for very large applications such as coal fired boilers, is enough for covering a large cleaning area, such as a whole economizer or even economizer plus air preheater if located in the same back pass. The long cleaning range comes from the long wavelength of infrasound. The frequency of sound is related to the wavelength  $\lambda$  according to the expression  $\lambda = c/f$ , where  $c$  is the speed of sound. Hence high frequencies of sound have short wavelengths and low frequencies of sound have long wavelengths. Infrasound cleaning uses typically around 20 Hz, which has a wavelength of around 20 m.

From a cleaning point of view low frequency sound has several advantages. One is that infrasound is omnidirectional, which means it spreads in all directions. Furthermore, sound absorption in tube bundles is very low at these frequencies. Infrasound can reach all parts of a tube bundles in e.g. an economizer, which in many cases means a lower and more stable differential pressure compared to e.g. steam soot blowing.

A third property of infrasound that is advantageous from a soot cleaning point of view is the high degree of turbulence that infrasound creates in the flue gas stream. The typical flue gas velocities at heat exchangers in power plants are low and the flue gas flow has a low degree of turbulence. This results in areas with a very low flue gas velocity near the surface of e.g. tube bundles. Ash particles accumulate in these low velocity area and grow to large deposits with time. For efficient removal of the ash particles, the particle displacement of the flue gas due to the sound has to be maximised. The particle displacement is the magnitude that is related to the distance of the movement of the particles when excited by a sound wave. The particle displacement of sinusoidal oscillations, such as sound, is inversely proportional to the frequency, thus low sound frequency results in large particle displacement. The oscillation with large particle displacement creates a high degree of turbulence in the flue gas and this high degree of turbulence around the tubes of a heat exchanger helps to keep the tube surface clean.

The infrasound is generated for 1 to 2 seconds every 4 to 5 minutes. The system is a continuous and dry on-line cleaning method. The infrasound cannot clean surfaces where ash has already build up thick and hard layers so the system should be taken into operation starting with cleaned surfaces.

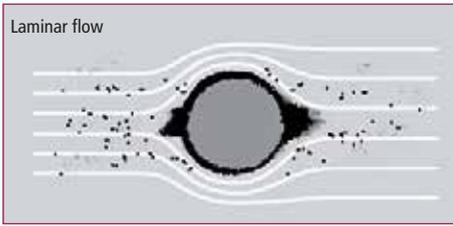


Figure 1: Laminar flow

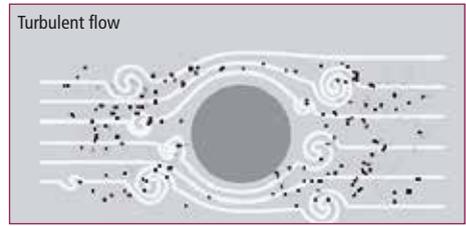


Figure 2: Turbulent flow

In summary, the main advantages of using infrasound for cleaning are:

- low absorption of sound energy,
- omni-directionality, can be installed both upstream and downstream the cleaning area, and reaches all parts of tube bundles,
- large particle displacement, high degree of turbulence,
- dry cleaning method,
- non-abrasive,
- continuous cleaning method.

### 3. Acoustic modelling

A crucial part of success using infrasound cleaning is knowledge of acoustic modelling that is used for simulating the sound propagation in great detail. An acoustic model is designed for each boiler where an infrasound generator is to be installed. Inner dimensions of the flue gas ducts and the dimensions of the heat exchangers are first introduced in this model. Flue gas temperature distribution and flue gas velocity are also entered since these are related to wavelength of the sound and attenuation of sound energy in the tube bundles. By using the acoustic model it is possible to choose the optimal installation position, the optimal generator design and the frequency of sound in order to obtain the required acoustic power in the desired cleaning area. The acoustic model

is always confirmed by carrying out sound pressure level measurements inside the boiler.

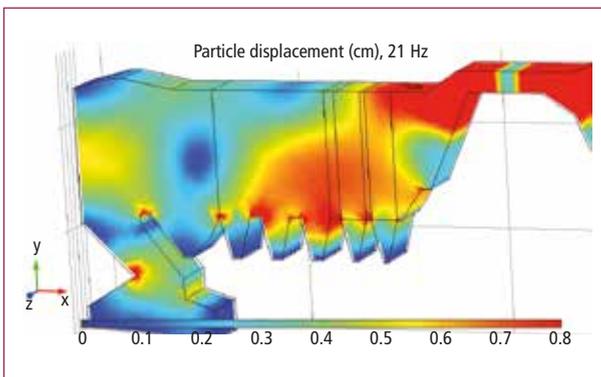


Figure 3:

Acoustic modelling graph

## 4. Infrasound cleaner technology

The infrasound cleaner consists of an attachment socket, a diffuser, a resonance tube, a resonance chamber and a pulsator. The attachment socket is welded directly to the flue gas duct. The resonance tube can be designed in different shapes in order to fit in the installation position and surroundings.

The frequency of the infrasound can be fine-tuned by a moveable plate inside the resonance chamber. The total length of the infrasound cleaner is related to the frequency generated, as for a musical instrument.

The pulsator is placed on the top of the resonance plate and is connected to a compressed air source. The compressed air should have a pressure of 6 to 8 bar(g). The pulsator is the component, which produces the air pulses that are reinforced in the resonance tube and generates the infrasound. The pulsator consists of a cylinder, a piston and a titanium spring. The axially moving system is simple with few moving parts that are easily accessible for overhaul or replacement.

A unique feature of the infrasound generator allows the pulsator to auto-regulate itself by the positive feedback produced by the reflected acoustic waves in the resonance tube. In this way the maximum acoustic power is always generated independently of load changes and changes in flue gas temperature in the boiler system. Without positive feedback a change of some degrees in temperature inside the boiler means a decrease in acoustic power emitted by the infrasound generator.

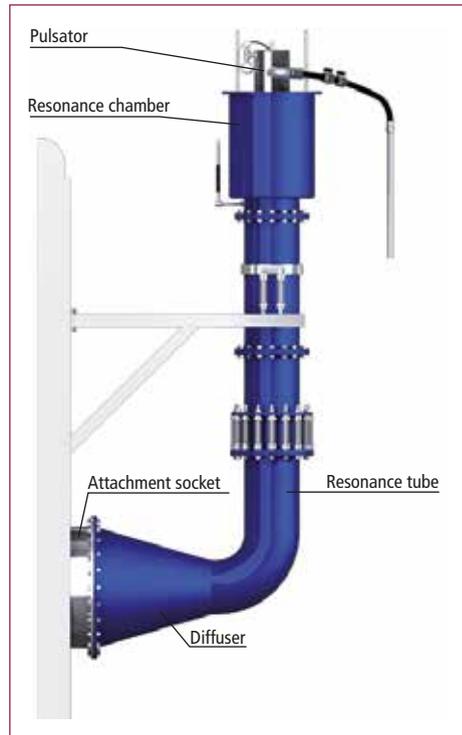


Figure 4: Infrasound generator

The acoustic power delivered is proportional to the square of the cross section area of the open end of an infrasound generator. The attachment socket's diameter of the biggest and most powerful unit is 1,500 mm.

The infrasound generator is very powerful, so to prevent any movement of the infrasound generator, reinforcement beams around the attachment socket are welded to the boiler wall and a vibration damper that is tuned to the sound frequency is absorbing vibration energy, resulting in low level of vibration transmitted to the boiler. An automatic control system that sets operating time short is also crucial for obtaining high cleaning effect and low vibration level. This solution allows for operating time as low as 0.6 seconds.

## 5. Comparison with sonic horns

Audible frequencies are used in so called horns. The sonic horns typically use sound frequencies from 75 Hz up to a few hundred Hz. This results in short cleaning range due to the short acoustic wavelengths.

Furthermore, the sound used by the sonic horns is not omnidirectional and the sound absorption is higher for these sound frequencies compared to infrasound. For this reason the sonic horns are producing only a local cleaning effect close to the installation position. Due to the limited cleaning range several sonic horns must be installed, as seen in Figure 5.

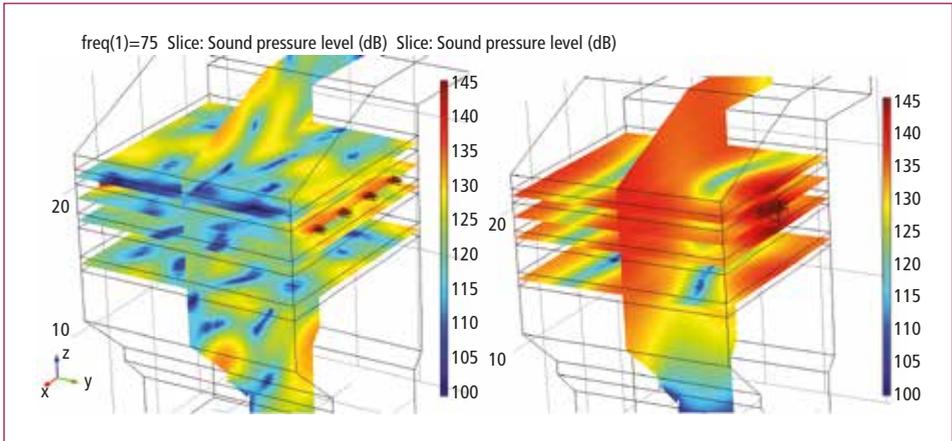


Figure 5: Calculated sound pressure by 4+4 pcs 75 Hz horns on two sides of a large SCR (left) and the sound pressure created by a single infrasound unit on the right wall (right)

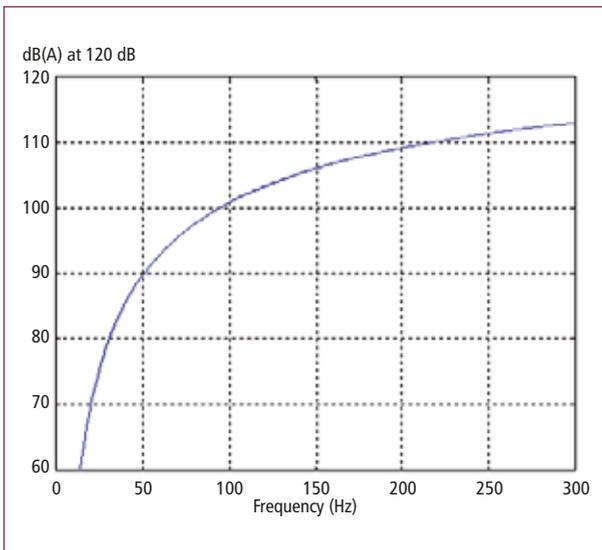


Figure 6:

The difference between unweighted dB and dB(A), illustrating the reason why lower frequency of sound is less disturbing for a certain sound pressure level. In this figure the dB(A) corresponding to an unweighted sound pressure level of 120 dB is shown. At 25 Hz we obtain 75 dB(A). At 200 to 300 Hz around 110 dB(A) is obtained for the same sound pressure in dB

With infrasound cleaning the sound frequency is very low, typically 15 to 30 Hz. When using so low frequency the level of noise generated is significantly lower than for higher frequencies. The reason for higher frequencies being more disturbing is that the human ear is more sensitive to higher frequencies. This is also the reason for using the dB(A) scale when quantifying noise. The dB(A) scale is the sound pressure level measured in dB and weighted according to the sensitivity of the human ear. The difference between unweighted dB and dB(A) is shown in Figure 6.

## 6. Potential savings from using infrasound cleaning

Cleaner heat exchangers, catalysts and ducts

- fewer outages for manual cleaning, increased availability,
- increased efficiency of SCR's.

Reduced operational and maintenance costs

- saved steam can be used for increased production of electricity,
- reduced wear on tubes and SCR elements by replacing steam soot blowing or shot cleaning,
- saved de-ionized water when replacing steam soot blowing.

Stable and low  $\Delta p$ :

- stable boiler operation,
- reduced fan power consumption.

Lower risk for high flue gas velocity in local areas

- less erosion of tubes and SCR elements.

Steam soot blowing and shot cleaning can cause expensive damages on the tubes of e.g. an economizer due to the local impact pressure. The water added to the flue gas through steam soot blowers makes the situation even worse due to increased corrosion and fouling due to ash being hygroscopic. For areas with flue gas temperature typical for e.g. economizers, where the deposits are dry, the infrasound technology is advantageous to steam soot blowing since the infrasound does not cause any damages to the tubes. This is due to the fact that it is a completely dry cleaning method and that no vibrating force on the tubes is created. Thanks to the very long wavelength of infrasound the sound pressure is the same on the windward and the leeward side of a tube so no net resulting force is created.

Erosion damages can appear on the tubes of e.g. an economizer if the steam soot blowing is incapable of reaching the whole tube bundles. Consequently the flue gas velocity increases where the tube bundle is not blocked by deposits and the wear on the tubes increases in these areas.

Where the steam hits a tube the surface is often cleaned to bare metal, which increases the corrosion of the material in those areas. When it comes to cleaning of catalyst elements the wear caused by steam soot blowing is often a big problem. The infrasound technology is highly suitable for this application due to the non-existent wear, the global cleaning effect and the low noise level.



Figure 7: Water tubes with damages caused by steam soot blowing

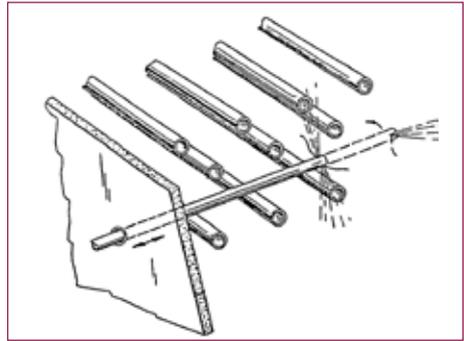


Figure 8: The steam is blocked partly by the tubes which reduces the cleaning effect deeper into the tube bundle

## 7. Case study, Mälarenergi Västerås, 167 MW<sub>th</sub> WtE boiler

Block 6 in Västerås is today the world's largest waste to energy boiler. It is a Valmet CFB commissioned 2014 and the fuel consists of sorted waste (RDF) imported from Great Britain. Content of glass and aluminum is relatively high. The boiler is used as base load on the plant and cheapest production line so priority is high. The boiler design is shown in Figure 9.

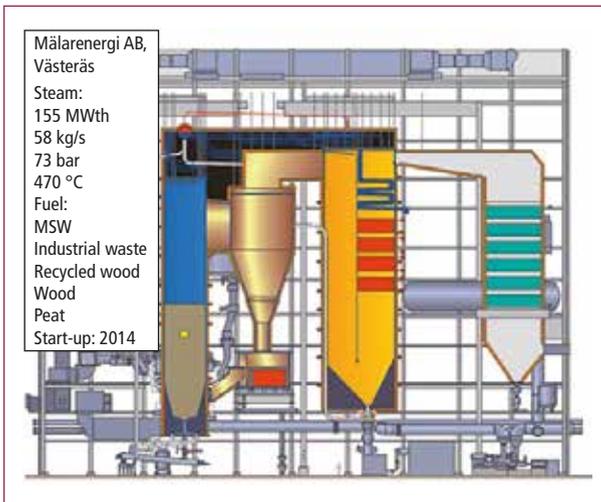


Figure 9:

Boiler design, the infrasound generator is installed on the ECO inlet hood, cleaning the six tube bundles in the ECO

The Economizer (ECO) turned out to be blocked by deposits despite steam soot blowing every 12 hours so a solution to this problem had to be found. The ECO needed sand blasting and sanitization at large costs already after 3 to 6 months of operation. At this point the two lowest ECO tube bundles were clogged 80 to 90 percent. Higher up in the ECO the tube bundles were clogged 5 to 40 percent.

To increase availability of the boiler an infrasound generator was installed and operation started in October 2015.



Figure 10:

Infrasound generator, available for service from the ECO roof



Figure 11: Before installing infrasound cleaning: severe fouling in the lower part of the ECO after 5 months

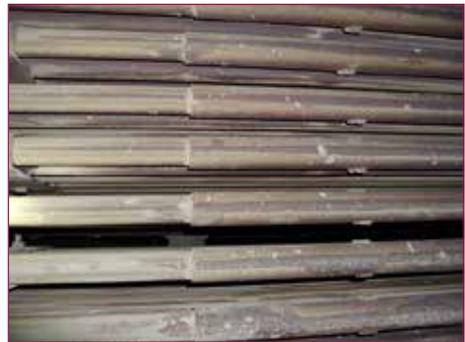


Figure 12: After 7 months of operation with infrasound cleaning and steam soot blowing reduced 50 %; all six tube bundles are this clean

Summary of results obtained at Mälarenergi:

- Elimination of the blocking problem in the ECO, which results in substantial savings. Earlier the ECO had to be sand blasted every 3 to 6 months. All 6 tube bundles are kept clean, demonstrating the long cleaning range of the single infrasound generator installed on the ECO inlet.
- The transportation of ash from the ECO ash hoppers is operating smoother since ash is collected more evenly with the infrasound generator.

- Steam soot blowing has been reduced by 50 percent since installing the infrasound generator. The possibility of reducing steam soot blowing in the ECO even further will be investigated later on.

## 8. Case study, EEW Delfzijl, SCR on WtE boilers

The waste to energy plant in Delfzijl in the Netherlands has two identical lines combusting RDF, approximately 60/40 domestic/industrial waste. A third identical line will be built soon. Honeycomb layer SCRs are used and there are two element layers in each SCR. The element pitch is 4.6 mm and the cross section of the SCRs is 20 m<sup>2</sup>.

It is a low dust application with the SCRs located downstream a bag filter, however the SCRs suffered from clogging of the first layer, requiring explosion cleaning being performed every 2 to 3 weeks. Differential pressure was rising rapidly over the top layer. The frequent use of explosion cleaning resulted in high costs and also caused damages to the elements, so an alternative cleaning method was sought.

An infrasound generator was installed and commissioned in November 2015 to improve cleaning efficiency and reduce costs. Figure 13 shows the infrasound generator installed at the inlet expansion of the SCR, slightly above the first layer of the SCR.



Figure 13:

Infrasound generator installed at the inlet of the SCR

After 2 months of operation with the first infrasound generator it was obvious that the cleaning effect was very good. The differential pressure over the SCR elements had been stable the whole time so the decision was taken to order an infrasound generator for the other SCR as well. This second unit (Line 1) was commissioned in April 2016. To this date (June 2016) the differential pressure over both SCRs are stable and explosion cleaning has not been required. Figure 14 shows the differential pressure trends for Line 1 before/after installing the infrasound generator. For Line 2, the first installation, the differential pressure has been stable since starting the infrasound generator in November 2015.

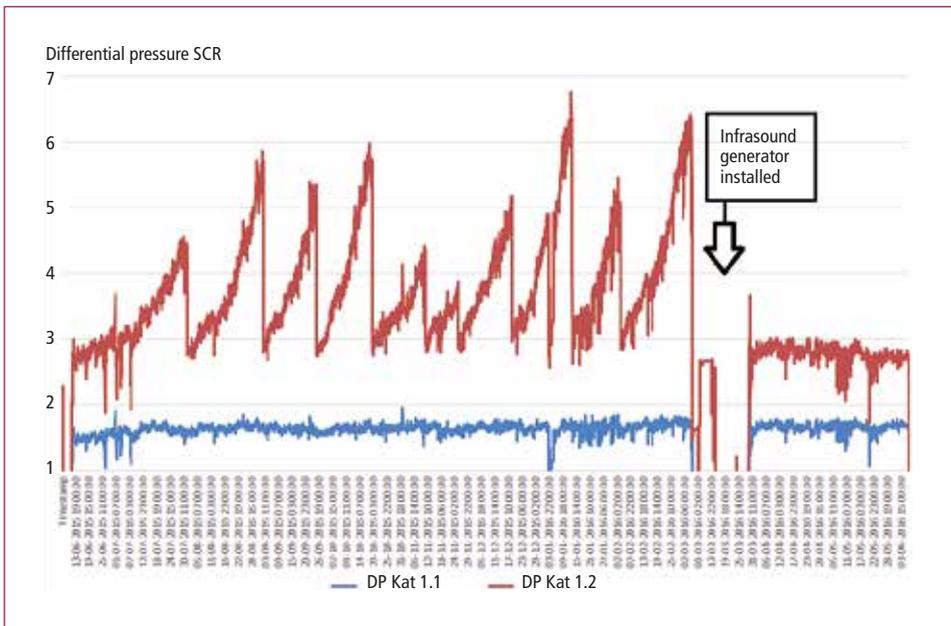


Figure 14: Differential pressure over the two layers in Line 1 after installing infrasound cleaning. red is the top layer

## 9. Summary

Infrasound cleaning is a cost-efficient way of keeping clean low temperature areas, such as economizers, air preheaters, catalysts etc. The technique eliminates or reduces drastically the need for other cleaning methods such as steam soot blowing, shot cleaning, air soot blowing, explosion cleaning and manual cleaning in those areas of a boiler.

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