No single technology is the best choice for handling fire side fouling of heat transfer surfaces, catalyst surfaces etc. Cleaning technologies available on the market include steam soot-blowing, shot cleaning, explosion cleaning, water cannons, sonic cleaning, air pulse cleaning, rapping etc.

After merging two Swedish companies with complementary technologies Wave Impact Heat Management, with headquarters in Stockholm, has gathered a unique set of tools for increasing the efficiency and availability of boilers. The tools consist partly of ash removal technologies and partly of computer software for analysis and modelling.

The technologies for ash removal/fouling prevention are:

- **HISS** – A method of upgrading retractable steam soot-blowers for reduced steam consumption and more frequent cleaning,
- infrasound (low frequency) acoustic cleaning.

And the technologies for analysis are:

- big data analysis of plant operation,
- CFD, computational fluid dynamics, for flow simulation.

This text summarizes HISS, Infrasound cleaning and big data operation analysis. We start by looking at the technologies for removing or preventing ash fouling.

Figure 1 shows the typical application areas for both cleaning methods in a boiler. Infrasound cleaning is used at lower flue gas temperatures such as economizers, air preheaters and SCR (catalysts). HISS is used primarily at high flue gas temperature such as superheaters.
1. HISS – an optimizing upgrade of sootblowers

This patented method of upgrading a steam soot-blower can be used on all brands of retractable soot-blowers. The upgrade consists of equipping the soot-blower poppet valve with an actuator for local control of the steam flow. Such a pneumatically controlled actuator is shown in Figure 2.
At a chosen time, typically when starting to reverse a soot-blower, the steam flow is switched off or set at a small cooling flow. Observations of soot-blower cleaning performance shows that around 90% of the cleaning effect of a steam soot-blower is obtained with a single stroke. This means up to 50% of the steam is wasted when blowing steam both on forward and reverse stroke.

Consequently, using this system will result in up to 50% steam savings. The system also reduces wear since less high-pressure steam is blown onto the heating surfaces. A cooling flow of steam may be required if flue gas temperature is high in the area. Cooling flow is set by measuring the temperature of the lances when exiting the boiler.

The system controls the steam flow locally at each soot-blower. Other systems for one-way soot-blowing controls the main steam header valve. The system gives greater flexibility of soot-blower operation. Controlling the steam pressure on the steam header valve can result in pressure hammers and issues with condensate in the steam header, which can increase wear on heat transfer surfaces. It can also wear out the steam header valve fast.

The system gives the ability to operate the soot-blowers twice as often, with the same amount of steam and making the time for a soot-blowing cycle half as long by operating the soot-blowers overlapping, starting the 2nd soot-blower when the 1st soot-blower is starting to retract. This is especially relevant in recovery boilers on pulp mills, where soot-blowers are operated 100% of the time and cannot be operated more often with any other technology. This will give the possibility of soot-blowing 100% more often, preventing blockages and increasing the production. Operating more frequent or with half the time for a soot-blowing cycle is however relevant for other boilers, such as WtE boilers, as well. To be able to handle the increased flue gas volume when blowing steam into the flue gas, the boiler is typically operated on reduced load during soot-blowing, so minimizing the time for a soot-blowing cycle increases the average power produced by a boiler. Some boilers, typically smaller boilers, can also be quite sensitive at soot-blower operation, with boiler tripping as an outcome.

Relatively often there is also a significant reduction of outlet steam temperature of superheaters between soot-blowing of these heat transfer surfaces. Soot-blowing these surfaces twice as often, without increasing wear or steam consumption, can lead to significant increase of average steam temperature and total boiler efficiency.

The local control of the soot-blower can be coupled with a user interface that diagnoses each soot-blower, giving real time status of each soot-blower and helps maintenance stay one step ahead in their soot-blower management program. This makes sure soot-blowers are operating as intended and prevents break down of equipment.

Equipping the poppet valves with the actuator can be done during operation of the boiler so there will be no disturbance of boiler operation. Taking the system into operation can be postponed to a suitable occasion. When the time is right a locking bolt is released in the linkage between the actuator and the steam poppet valve.
Typical results of using this system:

- reducing steam consumption of retractable soot-blowers by up to 50%. Resulting in less wear and higher efficiency of the boiler,

- keeping heat exchangers in difficult areas cleaner. Solving clogging issues or resulting in higher efficiency of the boiler,

- a combination of above.

All areas of boilers equipped with retractable soot-blowers can benefit from this optimization, but the technology is mainly used in high temperature areas such as superheaters. The reason for this is Infrasound cleaning being even more efficient in cleaning low temperature areas such as economizers, air preheaters and SCRs. The technology of Infrasound cleaning and the possible benefits are explained further in the following section.

2. Infrasound cleaning

In power plants and heating plants the infrasound technology is used as a preventive and 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
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as wood chips and demolition wood the infrasound is successful in cleaning up to approximately 500 °C. Some clients 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.

The infrasound generator is typically installed at the inlet of an economizer or SCR. Figure 4 shows an example of the largest size of infrasound cleaner, installed on the economizer inlet hood of a large CFB boiler. One infrasound generator, or two generators for very large applications, 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 wavelength of sound is inversely proportional the frequency, hence high frequencies of sound have short wavelengths and low frequencies of sound have long wavelengths. Infrasound cleaning typically uses 20-28 Hz, which has a very long wavelength, around 20 m. The frequencies used are of much lower frequency than the frequency of products widely called sonic horn. Those horns use audible frequencies, typically from 60 Hz up to a few hundred Hz.

From a cleaning point of view low frequency sound has several advantages. One is that very low sound absorption in tube bundles these frequencies, so the infrasound reaches all parts of all tube bundles in e.g. an economizer, which typically means a lower and more stable differential pressure compared to using e.g. steam soot blowing only.

Another property of infrasound that is advantageous from a soot cleaning point of view is the high degree of turbulence created by the infrasound 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. This is visualized in Figure 5. Ash particles accumulates in the low velocity area and grow to large deposits with time. For efficient removal of the ash particles, the displacement of the flue gas due to the sound needs to be maximised. The displacement is the magnitude of the flue gas oscillation when excited by a sound wave. The displacement of sinusoidal oscillations, such as sound, is inversely proportional to the frequency, thus low sound frequency results in large displacement. The oscillation with large displacement creates a high degree of turbulence in the flue gas, which helps to keep the tube surface clean.

The infrasound is typically generated for 2 seconds every 4 minutes, a short enough interval to prevent build-up of layers of deposits. It is a dry and preventive cleaning method, which is advantageous since ash fuses from moisture. An important aspect is that the infrasound cannot clean surfaces where ash has already build up thick and hard layers of ash deposits so the system should always be taken into operation starting with clean surfaces.

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 optimal frequency
of sound in order to obtain the required acoustic power in the desired cleaning area.
If not using optimal frequency and installation location the sound levels reached in
the cleaning area will be significantly lower. The acoustic model is always confirmed
by carrying out sound pressure level measurements inside the boiler.

The frequency of the infrasound can be fine-tuned by a moveable plate inside the re-
sonance 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 6-8 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 and patented feature of the infrasound generator allows the piston movement
in 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.

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. Many installed large infrasound cleaners
have a rectangular shape of the attachment socket, with cross section corresponding
to cross-section of a circular attachment.

Typical results obtained using infrasound cleaning in waste incineration:
- reduced use of steam soot blowers in economizers by 70 to 100 %. Resulting is
  reduced wear or increased boiler efficiency,
- preventing clogging of economizers and catalysts. Increasing boiler availability,
- only method needed for keeping SCRs clean the whole operational season. Increas-
  ing boiler availability, reducing wear of catalyst elements and improving catalyst
  performance.

3. Big data operation analysis

Operation analysis can be used for locating where to use a certain cleaning method
and to quantify the return of investment of a new cleaning system. By studying the
operational parameters both on a long time scale, typically a whole season, as well on a
short time scale, typically seconds, for identifying the impact of e.g steam soot-blowing
a certain tube bundle. Figure 6 shows an example of a study performed using the big
data tool, focusing on steam temperature after the various superheater stages and the flue gas temperature and the impact of soot-blowing on the power delivered by the economizer and the various stages of the superheater.

Figure 6: Operation analysis

The investigation was used for identifying where the soot-blowing was most needed, with the objective of not wasting steam in regions having less impact on the total performance and efficiency of the boiler.

Another important feature of the software is the possibility to investigate the correlation between operational parameters. This is investigated through linear regression analysis. The regression shows the covariation, i.e. to which degree a parameter follows other parameters. A screenshot of such a regression analysis is shown in Figure 7. In the example of this Figure the steam temperature in the dome is studied. Parameters close to 100 % means these parameter follows the steam temperature almost linearly. 100 % means perfectly linear relationship. Parameters with lower percentages are not as directly related to the studied parameter and very low percentages are not at all related.

Performing such a regression analysis gives deeper understanding of which parameters are most strongly related. For some cases it has also unveiled parameter relationships that was not expected, revealing something malfunctioning or not performing optimally.
The best choice of technology for solving a fouling related problem or improving the efficiency of a boiler depends on the details of the specific case.

For some boilers there is a specific problem to solve, i.e. a clogged economizer or SCR. In other cases, a more efficient or less wearing cleaning solution is sought, e.g. by reducing the consumption of steam for soot-blowing.

If there is a clogged economizer or SCR the choice of cleaning method would be Infrasound cleaning. The efficiency of the technology has been verified on numerous installations on a wide range of fuels, such as waste, biofuel and coal.

If the objective is to reduce steam consumption or wear from soot-blowing, the case must always be studied in some details for quantifying the possible savings and return of investment from optimizing the soot-blowers and/or installing Infrasound cleaning. The consumption of steam and its value is quantified and used as basis for decision making in the purchase process.
For some cases there is a need to dig deeper into the operational data of a boiler, to be able to find out in which parts there is a potential for improvements. In such cases there is a great advantage to have a tool for analysis that is able to easily overlook all operational parameters both on a short and long time scale. This can add further detail to the return of investment calculation.

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