Experiences with On-Line Explosive De-Slagging at Covanta WTE Facilities

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An on-line cleaning technique perfected in Europe, which places low-yield explosive charges in close proximity to tube lane pluggage, and uses pre- and post-cleaning video camera surveillance to document results, has been tested at three WTE facilities in the western U.S. operated by Covanta. Testing indicates several tangible benefits relative to the more traditional off-line blasting, water washing (on-line and off-line), and stick blasting (on-line), including:

- substantial elimination of cleaning related downtime between maintenance outages;
- longer run times with less overall fouling and pluggage related ailments;
- reduced off-line cleaning time at the beginning of major outages to the benefit of the outage schedule;
- exemplary safety of the on-line cleaning process;
- less wear and tear on pressure parts and boiler casings; and,
- almost no fugitive dust problems in the boiler house that may occur with off-line blasting.

The process starts with an initial video survey of fouling conditions. A water-cooled camera with purge air and temperature monitoring is inserted into the flue gas to record the fouling condition of the boiler. Following the survey, a cleaning plan is developed. Shots consist of low-yield detonating cord encased in thin gage aluminum alloy tubing. The charges are positioned in the gas lanes between tubes while being cooled with a water-air mixture, and detonated. Following the cleaning effort, a final camera survey is done to verify the cleaning effectiveness, and to follow up with touch-up cleaning if necessary.

While a considerable effort may be necessary to provide adequate access and to determine the optimal interval between cleanings, significant improvements in cleaning effectiveness and availability have been seen at some facilities.

Introduction & Background

U.S. municipal waste-to-energy (WTE) facilities operate using a number of different economic models, with the majority incorporating built-in incentives to maximize waste processing capacity. Facility operators seek to maximize throughput rates to their practical limits, reducing both scheduled and unscheduled downtime so that more hours per contract period can be spent at those throughput rates, to capitalize on these incentives.

Combustion of municipal solid waste generates significant fouling of boiler convection surfaces over time, which if left to build up can result in a number of detrimental consequences including reduced processing capacity. Cleaning methods currently employed in the U.S. inevitably require downtime to deal with the fouling and its consequences.

The most prevalent cleaning methods used today include off-line explosive cleaning (dynamite and detonation cord, or “det-cord”) and medium and high pressure water washing. Covanta’s WTE facilities use both of these approaches, with explosive cleaning the most common.

Explosive cleaning uses shock waves to remove slag buildup from tube banks, while water washing relies on high velocity jets to scour the slag off the tubes. Some on-line explosive cleaning has also been tried at a few Covanta facilities. This typically involves detonating a water-cooled “stick charge” of dynamite along the front or rear face of a tube bank. The size of the charge is necessarily large in order for the concussive force of the blast to penetrate beyond the face of the tube bank and clean an area covering multiple lanes. Tube shield and support bracket damage is common when this is done.
The experiences at Covanta Energy’s West Region facilities are typical of many in the WTE industry. As little as two to three months into an operating campaign, significant fouling can accumulate, even with regular cleaning by soot blowing or mechanical rapping. This can require several days of downtime to clear, depending on boiler size and design. Covanta has been using off-line explosive cleaning as its standard for about the last 10 years. Even when combined with scheduled maintenance outages, the cleaning activity usually prevents other work from taking place simultaneously in the boiler or connected equipment, thereby extending total outage time by 2 to 3 days per outage.

The Case for a New Way of On-line Explosive Cleaning

Off-line explosive cleaning uses high energy explosive charges in order to accomplish cleaning in a reasonable amount of time and minimize downtime impact. Repeated exposure to such concussive forces risks damage to pressure parts, tube shields and tube supports, and boiler casing structure. Off-line explosive cleaning done while the boiler is still hot can also expose plant personnel to the hazards of hot ash if they have to enter the boiler to shovel, air-lance, or otherwise convey loosened material to a collection/removal point. Covanta routinely seeks to identify possible exposure to workplace hazards, hence minimizing the manual handling of hot ash is a high priority.

Covanta’s West Region has experimented with on-line explosive cleaning in the past by “stick” blasting using dynamite charges. Several problems were encountered, including:

- limited ability to clean a bank beyond its face
- high likelihood of tube or shield damage
- creation of large, fragmented pieces of slag which actually increased overall pluggage in the generating tube bank, forcing a boiler shut down and off-line cleaning.

Off-line water washing generates cleanup issues and can contribute to accelerated corrosion of just about all fireside surfaces, due to the extremely low pH and corrosive species found in MWC boiler ash. Some Covanta facilities use on-line water washing, but it is considered to be of limited effectiveness, and is used primarily as a method to prolong runtime between off-line cleanings. Where on-line water washing is used, it must be done frequently to maintain operation, and accelerated corrosion is still a concern.

In September 2005, Covanta’s West Region became aware of a new method of on-line explosive cleaning which was developed in Europe by On-Line Services B.V. of the Netherlands (Helmkamp 40, 7091 HR Dinxperlo, Netherlands).

This method represents an advancement over current state-of-the-art on-line explosive cleaning practiced in the U.S. in that it places low energy explosive charges directly into individual lanes of a tube bank to target the pluggage. The method appealed to us for the following reasons:

- Minimizes damage to tubes, shields and support brackets, while maintaining boiler operation.
- Uses video surveillance to document initial fouling and final cleaning results.
- Cleans convection banks thoroughly so that operations can continue to the end of the run without excessive pressure drop or the need to reduce load.
- Clears bridged-over tube lanes; and.
- Reduces worker exposure to safety hazards.

The goal of the on-line explosive cleaning testing described in this paper was to reduce unscheduled outages by reducing boiler fouling during a 6-month operating campaign.

Description of the On-Line Explosive Cleaning Method

Pre-cleaning Activity

The first time a boiler is cleaned using the on-line approach, the process starts with a complete camera survey of the convection bank to identify any fouling deposits which may exist.

Next, a work plan to clean the convection zone tube banks is developed. Considerations include:

- Effect of the order of tube bank cleaning on important operating parameters, such as steam temperature.
- Whether two boilers in close proximity can be cleaned more efficiently if cleaning alternates between the two boilers instead of progressing through each sequentially along the convection zone.
- Strategies to ensure that ash falling from the convection banks will continuously flow out of the boiler.
Cleaning Activity

The heart of the cleaning process is the actual explosive cleaning. Each explosive assembly consists of a length of det-cord inserted into a matching length of aluminum tubing. Figure 1 shows the preparation of some of these charges in advance of a cleaning.

The tubing is a thin-walled, low strength aluminum alloy and the tubing disintegrates in the process of penetrating the boiler and detonating the charge. Tubing length is varied to fit the particular tube bank depth. The purpose of the tubing is to maintain a rigid linear shape of the charge while it is being placed within a lane of a tube bank, and to deliver cooling to the charge to prevent pre-ignition.

The equipment used to position the explosive charge inside the boiler includes a hollow lance whose length is selected for the width of the boiler to be cleaned and an articulating “knuckle” joint fastened to the end of the lance to which the explosive assembly is connected.

A valve manifold is used to mix water from a high pressure booster pump and air. This mixture flows down the hollow lance and out past the explosive charge. The flow is turned on just before the explosive assembly is maneuvered through the access port into the boiler. Detonating wire from the remote control station is passed through a sealed fitting on the manifold and out to the det-cord. Figures 2 and 3 show the articulating knuckle and valve manifold.

Additional equipment is used with the explosive assemblies, including a mobile local operator station at the boiler, a fixed remote control station, and communications equipment (See Figures 4 and 5.)

A local technician handles the explosives at the boiler, while another operator views the technician’s activities remotely through the console monitor, and communicates by 2-way phone (See Figures 6 and 7). Hardwired interlocks between the local interface and remote control station prevent any voltage being made available to the detonator circuit until the explosives technician provides an electronic permissive to the remote operator.

Covanta U.S. Experience

Three of Covanta Energy’s West Region WTE facilities decided that the potential benefits justified a trial period with this alternative cleaning method, and evaluated on-line cleaning in 2006. Those facilities are:

- Covanta Marion, Inc (Marion), located in Brooks, OR
- Covanta Honolulu Resource Recovery Venture (HPower), located in Honolulu, HI
- Covanta Hennepin Energy Resource Company (Hennepin), located in Minneapolis, MN

Initially, the vendor stressed the axiom, “If we can get to it, we can clean it.” While this appears to be true, the cost to achieve the necessary access to the convection zone tube banks can be significant.

Subsequently another valuable axiom became apparent – “Cleaning is much easier and less costly if done at the right time in the cleaning cycle”. Fouling of the tube banks reaches a “point of no return”, when it becomes harder and closes off lanes between tubes. Prior to this point, on-line cleaning is very effective, but afterwards the process is very time-consuming and much less effective. Determining the optimal cleaning cycle has been the greatest challenge in optimizing the process for Covanta.

Each facility had slightly different goals, experiences, and levels of success during the evaluation of this cleaning method. A medium sized mass-burn WTE boiler (~400 Tons Per Day) can require 200 “shots” to cover all lanes of all tube banks that require cleaning – about a 2 day process; while a large refuse derived fuel (RDF) unit (1000 TPD MSW equivalent) can require 400-500 shots.

Marion County

Marion is a mass-burn facility that performs thorough explosive deslagging during each semi-annual scheduled maintenance outage. Following the semi-annual outages, the units operated very well for the first 3 months, but typically struggled with pluggage and high back-end temperatures during the last 3 months. Facility management had previously experimented with on-line stick blasting at two locations: the superheater inlet and top of the generating bank, where pluggage tended to accumulate first. This kept the units operating without shutting down, but substantial pluggage remained in the gen bank and re-accumulated in the superheater.

On-line cleaning trials began in April 2006, with the goal of more effectively cleaning the units between maintenance outages to reduce plugging in the last half of the 6 month run. Also, the tests were intended to shorten the off-line cleaning time during scheduled

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maintenance outages by doing on-line cleaning prior to the outage.

Initial results of the on-line explosive cleaning indicated partial success. In order to improve the process, plant personnel provided frequent oversight throughout the cleaning process, including routine inspections to verify that the visible lanes were being cleared. The plant also performed a camera survey during mid-run cleanings to verify sufficient cleaning within the tube bundles. With this increased inspection and oversight, the most recent cleaning was very successful.

On-line cleaning ahead of the 2006 spring and fall maintenance outages saved an average of 18 hours of up-front outage time over the previous outage timelines for each boiler, although some manual cleaning around the mud drum was usually still necessary while off line.

HPower

HPower is an RDF facility that has typically had 4 outages per year involving off-line cleaning, including the 2 annual maintenance outages.

On-line cleaning trials began in Spring of 2006, with the goals of eliminating the off-line mid-run cleaning outages, and reducing off-line cleaning time at the start of each maintenance outage by 30 hours.

As the trials began, it quickly became apparent that cleaning would be difficult because of the limited number and size of boiler access ports. Figure 8 depicts the access ports at the start of cleaning. The narrow ports, which were previously added for water washing trials, were too narrow to allow penetration of the explosives assembly or the camera. HPower's VU-40 boilers were simply not designed with much forethought to on-line fouling mitigation. It was obvious that if HPower was to reap the benefits of on-line cleaning, additional access would have to be installed.

During the period between mid March and mid July 2006, the boilers were cleaned five times (three on-line and two off-line) to enable the boilers to run until the scheduled outage. These difficulties constitute the learning curve both for the contractor on the specifics of cleaning the HPower boilers, and for Covanta to develop the methods required to make this process successful.

During the Summer 2006 outage, HPower made a sizeable investment to enlarge and install additional cleaning ports to access all sections of the generating bank and superheaters. HPower asked the vendor to commit to keeping the boilers on-line between August 2006 and February 2007. The cleaning schedule runs on a 60 day cycle and typically takes 30 – 40 hours per boiler.

In addition to access, HPower found that another factor critical to success was timing of the cleaning within the fouling cycle. Figure 9 is a graph of convection section pressure drop over time, which illustrates the transition from off-line to on-cleaning. The boilers tend to experience a slow rate of increase in pressure drop over the course of 60 to 70 days after an off-line cleaning, followed by a marked acceleration in the rate of increase in pressure drop.

By the time this point is reached, the majority of the generating bank gas lanes, the main contributor to pressure drop, are already partially choked off; the gas lanes are beginning to bridge over and block the gas flow. As more gas lanes close it becomes increasingly difficult for the on-line system of cleaning to work properly. The ash in the generating bank seems to get harder once the lanes become substantially plugged. With the lanes 100% blocked it is necessary to "chip away" at the ash with the explosives. This uses significantly more explosives and takes much longer than if the lanes were partially open to place the charges correctly, and the low yield of these charges does not always do the job, even with additional time.

Therefore, the goal is to schedule the cleanings while the majority of the gas lanes are still open. HPower has determined through historical trending that the optimum schedule for cleaning is every 60 days. This means that cleaning is performed before the pressure drop begins to significantly increase. The small pressure drop change makes it essential that the camera be used to verify the cleaning.

After overcoming accessibility issues by installing additional ports, the facility has been successful in meeting its goal of operating for 6 month runs without a shutdown for off-line cleaning. The impact on annual availability is more than 0.5% each time a mid-run cleaning is accomplished on line. The second goal of reducing cleaning time at the start of each maintenance outage will be evaluated during the next maintenance outage in Spring 2007.

Hennepin

Hennepin is a mass burn facility that normally budgets four quarterly off-line cleanings in a calendar year; two at the start of semi-annual maintenance outages, and two at the mid-run points. These cleanings can take up to 48 hours each and can adversely affect the timeline of the maintenance outages.
On-line cleaning trials began in July 2006, and were tried again in October, November, and December. Trials were suspended at the end of December 2006.

The primary goal of the trials was to see if this technique could improve availability and capacity. The major challenge to cleaning the convection sections on-line is the configuration of the tube bundles. As can be seen in Figure 10, the bundles utilize a header-return design, and the tight header spacing creates a series of slag traps which proved difficult to clean during the trials.

A second challenge is access to the convection banks that foul the most. The availability of only one access door level on each side of the convection section hindered access to the top of the tube bundles and to the bottom where the headers were trapping dislodged slag. Additional ports were installed to handle the latter on one of the units, and this did help with clearing slag from the bottom of the tube bundles.

A third challenge is the current condition of some of the tube banks. The secondary superheater tube banks in both boilers are nearing their end of life, and are scheduled for replacement in the next two years. This led to tube leaks and forced shutdowns on two occasions during the trials.

After several trials it became clear that the on-line cleaning had been initiated well beyond the optimum point in the fouling cycle, thus the cleaning was not able to "get ahead of the curve."

For these reasons, the facility elected to suspend further trials of the on-line cleaning method. Nevertheless, unit 1 did stay on line for 4-1/2 months, which was the longest run without an off-line cleaning in over 4 years.

Cost-Benefit

Over the past 12 months, the annual costs of on-line cleaning at Marion and HPower were about 5% higher than the costs of the previous off-line cleaning approach. Marion has seen approximately 0.5% improvement in availability, and other benefits including a sizeable reduction in superheater shield and support bracket repairs, and savings on downtime and overtime at the tail end of the outages. The improvement in availability at HPower, approximately 1.5% per year, has paid for the cost premium many times over.

Conclusions

The trials and experiences at Covanta’s Western Region facilities over the past year indicate that on-line boiler cleaning has real potential to be successful under a variety of facility circumstances. However, as judged by the experience so far at Hennepin, success is by no means a guarantee. The effectiveness is facility-specific, and an evaluation should include:

- What is the real economic value of:
  - A marginal (say, ~1%) improvement in annual availability?
  - Reduced damage to pressure parts, shields, casings, and other non-pressure part items?
  - Minimizing fugitive dust in the boiler house from explosive cleaning?

- Are the existing access doors and ports adequate to reach all tube banks that need to be cleaned, or will more be required, and at what cost?

- Are there any unique challenges to successful on-line cleaning of the tube banks, such as:
  - Has tube condition deteriorated to the point of risking leaks?
  - Do tube configurations make it difficult for material to flow through?

- Are present methods of measuring and predicting fouling sophisticated enough to pinpoint when cleaning is optimized, or do they need to be improved?

There is a significant effort and cost required to make this process work. The unique circumstances of each facility must be considered in evaluating whether on-line cleaning can produce meaningful dividends. In the final analysis, the value of downtime will determine whether the process makes economic sense. Finally, as with any new approach to an old problem, a key ingredient of success is a long term vision that the change is worth it, backed up by never-ending, dogged, sheer perseverance!
Figure 1. Det-cord charges in their aluminum tubes with couplers attached.

Figure 2. Articulating "knuckle" at the tip of the lance, before attaching explosive charge.
Figure 3. Valve Manifold strapped to handrail. High pressure water line is on the bottom while air line is on the top.

Figure 4. Local interface station with 2-way phone, communication cable, detonator interlock switch, and camera (between phone and cable jack).
Figure 5. Remote control station with TV monitor, detonator, phone, and interlocks.

Figure 6. Inserting the water-cooled air-purged camera housing into an economizer bundle.
Figure 7. Monitor video showing economizer tubes. Some fouling can be seen on monitor screen as lighter shaded areas on and between tubes.

Figure 8. HPOWER access port arrangement. Large squares are access doors. Thinnest ones are water wash ports – too small for camera or articulating “knuckle”. Middle sized ports are “Dutch Oven” doors.
Figure 9. HPOWER trending of furnace convection DP as primary indicator of fouling cycle. Cleanest condition appears at 0.4” H2O. Note after 8/1/06 with additional access the reduction in severe fouling cycle peaks.
Figure 10. CHERC Secondary Superheater bundle. Bottom headers created slag traps and greatly hindered on-line removal by the time on-line cleaning was attempted.