

PRESSURE PULSE TECHNOLOGY FOR BOILER CLEANING

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1. INTRODUCTION

Steam or compressed air continue to be the typical cleaning mediums for long retractable (IK) sootblowers used to clean the convection section of the boiler. Advancements in steam/air nozzle technology have lead to improved cleaning in areas such as the secondary superheater, but due to issues with boiler tube erosion, advanced nozzles have not been routinely used in the convection section. Boiler tube erosion and the resulting forced outages due to tube leaks have consistently been an operational issue for many boilers. Sonic cleaning has offered the hope of cleaning without tube erosion, but cleaning results have been mixed. The energy created by sonic devices is more than an order of magnitude less than a sootblower jet and as a result have not been able to remove many types of deposits.

Controlled detonation combustion technology has recently received attention as an extremely efficient propulsion method for aircraft. By transitioning from typical combustion or slow pulse combustion to detonation the shock waves generated by a combustion event reach supersonic speeds. This detonation or pressure pulse energy also has the ability to be harnessed for use in boiler cleaning. Because it is a pressure wave based like sonic cleaning, boiler tube erosion is virtually eliminated, and because the wave speeds generated are supersonic like a sootblower steam jet it can provide cleaning similar to a traditional sootblower.

Harnessing detonation for boiler cleaning is not a new concept, but has been used in rare instances over the last 20 years. All applications of this technology to date have been with devices mounted to the boiler wall and directing a detonation across the boiler. This approach requires a large amount of energy to provide cleaning which may have a long term impact for parts of the boiler. Diamond Power has recently taken a novel approach to adapting pressure pulse (detonation) technology for use in convection section cleaning of the boiler. By utilizing traditional, retractable sootblowers as the delivery

system, detonation or pressure pulse cleaning can safely provide convection section cleaning while eliminating boiler tube erosion caused by conventional cleaning devices.

2. THEORY

Detonation combustion technology has been utilized in other applications. Detonation combustion differs from more typical combustion (deflagration) in that during a detonation event, a fuel/oxidizer mixture is detonated rather than burned. Detonation combustion leads to a much greater release of energy than deflagration, thereby creating greater pressures, and much greater reaction velocities. For example, while the reaction velocity due to a deflagration process is typically less than 200 meters per second and develops a relatively low pressure, the reaction velocity associated with the detonation combustion typically approaches 2,000 meters per second and offers pressure differentials of approximately 300 pounds per square inch.

Diamond Power's Pressure Pulse sootblower cleaning is based on detonation combustion technology. Unlike a conventional sootblower, this device produces high amplitude supersonic pressure waves which expand in all directions throughout the area to be cleaned. This non-line-of-sight cleaning captures the features of non-directional sonic cleaners but with much greater cleaning energy.

The supersonic pressure waves are generated by simply filling a conventional lance tube with an air-fuel mixture and igniting it, refer to Figures 1 and 2. Pressure pulses from the initial combustion run ahead of the flame and gradually preheat unburned gases inside the lance tube thus increasing the speed of sound. As pressure pulses start traveling at sonic speed, they coalesce and further heat up the unburned gases.

A pocket of unburned gas reaches the auto-ignition temperature and produces a local detonation. Rapidly expanding gases produce a sharp shock wave which exits the lance tube at

supersonic speed. The pressure rises by several factors across the traveling shock wave. As the emanating shock wave impacts the first tube in the line of site, it partially reflects and strikes the next tube. This process continues until the shock wave is totally dissipated.

This unique feature of supersonic shock waves provides deeper penetration into a tube bundle in comparison to conventional subsonic air/steam jets which are greatly impaired by obstructions.

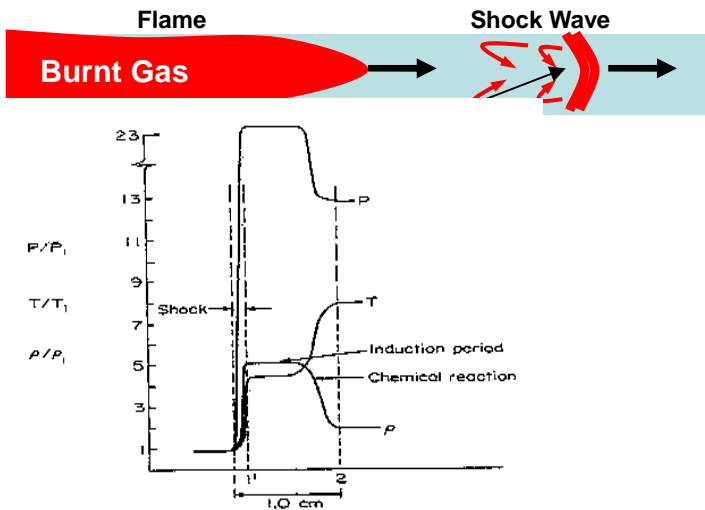


FIGURE 1: PICTORIAL DEPICTS A SHOCK WAVE TRAVELING INSIDE LANCE TUBE, AND SHOWS PRESSURE AND TEMPERATURE RISING ACROSS THE SHOCK WAVE

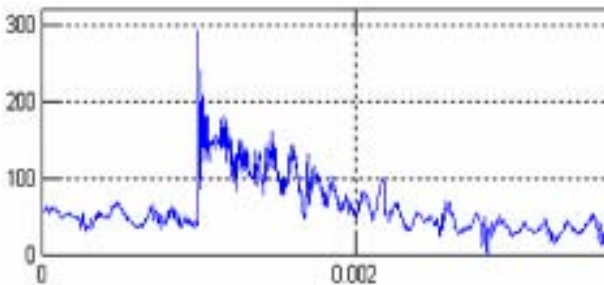


FIGURE 2: PRESSURE PROFILE ACROSS SHOCK WAVE PROFILE

3. OPERATION

A Pressure Pulse cleaning event starts with a request initiated by the sootblower control system. The local controller checks all alarms for the sootblower in question to ensure that all parameters are within the required control band. Once a permissive signal is issued, the propane main isolation valves open and allow the LP hose to pressurize. Next, the carriage starts advancing the lance tube into the boiler. Once the lance tube reaches the designated cleaning area, the injectors and igniters are actuated at a preprogrammed frequency.

For each cycle, the injectors are opened long enough to allow enough propane and air to fill the lance up to the desired length. Then the ignition is triggered at the proper time allowing the combustion process to take place and thereby producing a powerful pressure pulse. Typical firing frequency ranges between 0.5-2 Hertz. The intensity and the frequency of the pressure waves can be varied depending on the tenacity of the deposits.

The magnitude of the pressure pulse delivered by the sootblower is roughly the same as that of a conventional sootblower but the energy is spread out over a wider area instead of being focused on a local spot. In addition, the shock wave energy decays at a slower rate compared to conventional jets, especially as the wave moves away from the discharge point, see Figure 3. This feature allows the pressure pulse to reach deeper into the tube bundle.

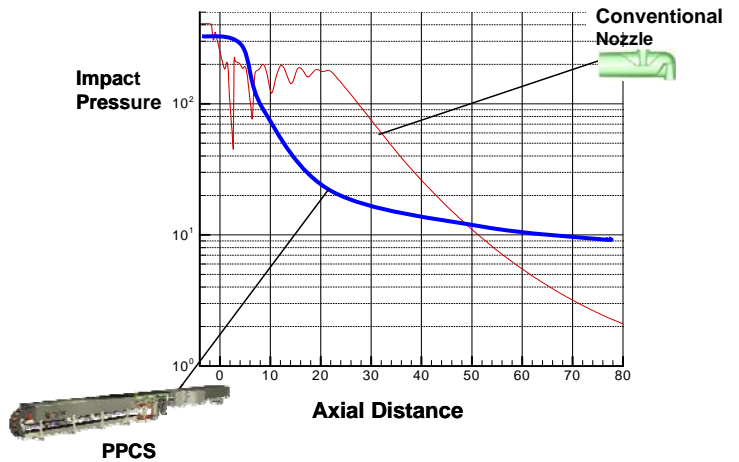


FIGURE 3: PRESSURE PULSE SOOTBLOWER YIELDS IMPACT PRESSURE PROFILE GREATER THAN CONVENTIONAL SOOTBLOWER IN THE FAR FIELD AND LOWER IN THE NEAR FIELD TO PRODUCE NO CLEANING INDUCED TUBE EROSION

4. FIELD PERFORMANCE

The pressure pulse sootblower has been tested over the past three years in the lab and on actual boilers. The lab testing focused on assessing performance determining operating parameters.

The field tests were conducted on several power boilers burning different fuels including lignite and a mixture of coal and bark. The tests focused on assessing the ability of the pulse sootblower in removing deposits. The tests showed that the pulse sootblower was successful in removing non-sintered, porous, and dry deposits typically found in the downpass region of the boiler. Also, the tests showed that the pressure sootblower has two modes of cleaning:

- 1) Direct impact which results in the removal of deposits in line of sight due to wave impingement (see Figures 4 & 5)
- 2) Remote cleaning which results in the removal of clinker and large deposits far from the line of sight due to relatively strong sound waves and tube vibration (see Figures 6 & 7)

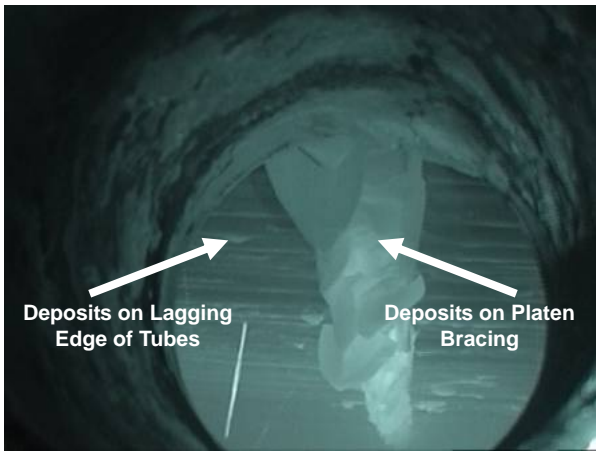


Figure 4: Existing Deposition Prior to Operation of Pressure Pulse™ Cleaning System

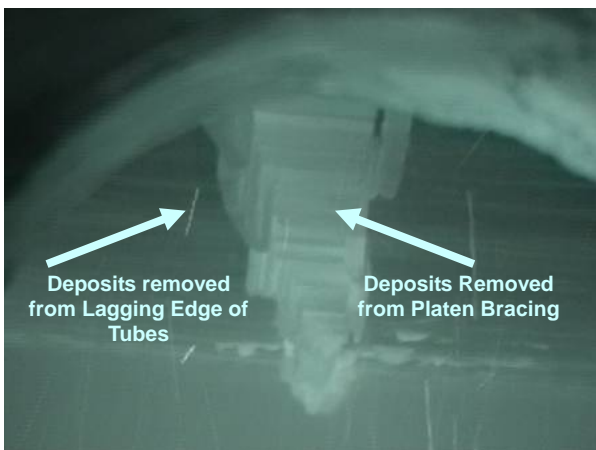


Figure 5: Deposition Following Operation Of Pressure Pulse™ Cleaning System (~40 Runs)



Figure 6: Deposits Removed As Far As 20 Feet From Lance Tube Exit – Non-Line of Site Cleaning



Figure 7: Ash Particles During Pressure Pulse Cleaning – Non-Line of Site Cleaning

5. CONCLUSION

Boiler tube erosion and corrosion continue to be a significant issue in some boiler applications. Conventional sootblowers can be a significant portion of this erosion issue. Pressure pulse technology delivered via a retractable sootblower platform has the potential to maintain boiler cleanliness while significantly reducing erosion.