IMPULSE™ Cleaner Overview
Value Proposition of the IMPULSE™ Cleaning System

The IMPULSE Cleaning System can improve heat transfer efficiency, reduce operational and maintenance costs, and minimize or eliminate costly unplanned outages.

It does this by:

• Creating intense shockwaves that are utilized to proactively dislodge fly ash without damage to equipment
• Replacing, augmenting, or significantly reducing soot blowing
• Demonstrating the ability over the last 10 years to lower exit gas temperatures by as much as 15 to 30 degrees. (Many installations have less than an 18 month payback!)
Additional Advantages of the IMPULSE Cleaner

• Elimination of opacity spikes due to more regular, more efficient cleaning

• No costly repair, maintenance or operational costs

• Does not scavenge steam/Reduces steam use (cost of steam)

• Minimal intrusion into and out of boiler, has minimal installation footprint and minimal installation costs.
Soot blowers are not able to clean the shaded areas behind the first rows of tubes. The accumulations in these blinded areas and are difficult to clean once they have had an opportunity to form a structure.

Soot blower erosion is often the main contributing factor for loss of boiler availability.
Benefits of the IMPULSE Cleaning System

**Tube Erosion**

*Tube Leak Outage*
Cost of 2 day outage

<table>
<thead>
<tr>
<th>Revenue Lost</th>
<th>$ 751,680</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repair Cost</td>
<td>$ 80,000</td>
</tr>
<tr>
<td>Total Annual Cost</td>
<td>$ 831,680</td>
</tr>
</tbody>
</table>

Note: Revenue based on 600 Mwatt* 0.87% *24hr* 2days*30$/MWh

**Platenization or Pluggage**

Improve economizer efficiency by effectively removing platenization

Example: 15° delta change across economizer can save over $500K in fuel cost per year
## Benefits of the IMPULSE Cleaning System

### Comparisons of Typical Fuel Operating Cost per System

<table>
<thead>
<tr>
<th>Operating Cost per Cleaning System</th>
<th>Air Sootblower</th>
<th>Steam Sootblower</th>
<th>IMPULSE™ Cleaning System (Operated with the most proactive cycle)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Rate</td>
<td>5,100 scfm</td>
<td>12,000 lb/hr</td>
<td>40 SCF air** / 300 SCFH gas</td>
</tr>
<tr>
<td>Cycles per Day</td>
<td>6</td>
<td>6</td>
<td>48 (960 “impulses”)</td>
</tr>
<tr>
<td>Cycle Time</td>
<td>6 minutes</td>
<td>6 minutes</td>
<td>30 Seconds</td>
</tr>
<tr>
<td>Operating Days per Year</td>
<td>310</td>
<td>310</td>
<td>310</td>
</tr>
<tr>
<td>Usage Cost</td>
<td>$0.0005/scf</td>
<td>$5/ton</td>
<td>$0.01 of air/impulse  $0.0125 of gas/impulse</td>
</tr>
<tr>
<td>Make-up Water Costs</td>
<td>NA</td>
<td>$2 / 1,000 gallons</td>
<td>NA</td>
</tr>
<tr>
<td>Cost per Cycle</td>
<td>$15.30</td>
<td>$3.30</td>
<td>1.08</td>
</tr>
<tr>
<td>Cost per Day</td>
<td>$137.70</td>
<td>$29.70</td>
<td>$21.60</td>
</tr>
<tr>
<td>Annual Operating Cost</td>
<td>$42,687</td>
<td>$9,207</td>
<td>$6,696</td>
</tr>
<tr>
<td>NA= not applicable</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note:** Air consumption based on typical reduced air pressure of 30 psi to each IMPULSE cleaner = 20 SCF consumed per 30 second cycle

Ethylene gas costs based on average price of $180 per 300 series gas cylinder
Impulse Cleaning Action

- Intense cleaning waves approach tube surfaces, encompass tube surfaces, transition around to back side, reconnect, and continue travelling.
- Non-Line-Of-Sight Cleaning
- Deep Penetration throughout tube bundle
- Non Erosive
How It Works

Cleaning with Sound

Acoustic cleaners utilize sound waves to create particle displacement in order to resonate and dislodge particulate deposits.

VS

Pulse Detonation

A shock wave is characterized by a sharp increase in pressure and temperature across a boundary.

They are orders of magnitude more intense than sound waves.

The resulting shockwaves provide a large amount of cleaning energy.

The instantaneous rise in pressure excites the deposits.

A typical cleaning cycle would consist of 2 detonations per second, for 10 seconds (20 detonations).

Shockwaves create an extremely rapid rise in pressure and density. They can produce localized pressures above 14 PSI.
How It Works

An Impulse cleaning wave is made up of compressed parts and loose parts.

A compression is the area of the wave that is pushed together - this is the wave's crest (or peak). A rarefaction is the area of a wave that is spread out - this is the wave's trough.

You can also think of a rarefaction in terms of density: The rarefaction is the part of the wave that has the lowest density.
How It Works

Impulse Cleaning Action

- Supersonic shock waves penetrate the deposited material and reflects from tube walls and interior surfaces
- Reflected waves propagate through the deposited material on the tube surface and reflect from this surface as rarefaction waves
- Rarefaction waves propagate back toward the tube surface
- The sequence of reflection waves and their subsequent attenuation lead to loosening and removal of deposit
IMPULSE Cleaning System Specifications
System Specifications

Combustion Assembly
Control System
Fuel Manifold

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical</td>
<td>110/220 VAC</td>
</tr>
<tr>
<td>Fuel</td>
<td>Ethylene gas (C2H4)</td>
</tr>
<tr>
<td>Fuel consumption</td>
<td>Based on operation</td>
</tr>
<tr>
<td>Impulse/cycle</td>
<td>20 bursts (typical)</td>
</tr>
<tr>
<td>Cycle frequency</td>
<td>Every 15 min. to 1 hour</td>
</tr>
<tr>
<td>Oxidizer</td>
<td>Air</td>
</tr>
<tr>
<td>Air Consumption</td>
<td>100-120 SCFM @ 70-90 PSI</td>
</tr>
<tr>
<td>Output power</td>
<td>Up to 180 dB (internal)</td>
</tr>
<tr>
<td>Material</td>
<td>Stainless steel</td>
</tr>
<tr>
<td>Weight</td>
<td>205 lbs. (93 kg)</td>
</tr>
</tbody>
</table>
System Specifications

The IMPULSE Cleaner is constructed from 3 separate pieces that are bolted together in the field.

The “A”-section, also referred to as the combustion chamber, is fabricated from stainless steel and is about 48” long and two-inches in diameter.

The “B”-section is a casting that diverges from two-inches out to approximately 6 inches in diameter over an axial length of 30 inches. There are 2 options: a straight or curved version. The curved section has a 90-degree bend in it, which allows for a slim mounting profile.

The “C”-section diverges from 6 inches out to 16 inches over an axial length of 30 inches and is typically located inside the boiler, or it can be recessed so it is mounted flush with the inside wall of the boiler.
Compressed Air Specifications

The PowerPlus IMPULSE Cleaner can operate using existing plant air systems that meet ISO 8573.1 Class 5 (dirt), 4 (water), 5 (oil). The instantaneous air consumption for each IMPULSE cleaner is a maximum of 120 SCFM @ 90 PSI.

If the cleaners are operated at the recommended, periodic sequencing, each cleaner will consume 80 SCF per operation. Actual air usage will depend on the operating sequence that is being used and the actual line supply pressure. Typically each cleaning system will be operated every 30 to 180 minutes.
System Specifications

Fuel Specifications

The fuel used by the IMPULSE Cleaner is Ethylene gas (C₂H₄). This is a non-liquefied compressed gas. It is characterized as a light hydrocarbon fuel stored at high pressures that reliably and effectively combusts in the compact design of the PowerPlus.

Any grade of ethylene is acceptable for operation of the IMPULSE Cleaner from industrial grade up to chemically pure. Fuel is delivered to the IMPULSE Cleaner via (2) fast acting solenoid valves that are actuated by the IMPULSE Cleaner Control System.

There is a check valve (1 psi cracking rated to 600 psi) and a filter (60 um mesh) located on each IMPULSE cleaner, upstream of the two fuel solenoid valves.

Fuel is supplied to each IMPULSE Cleaner via piping and regulated down to the operating pressure of *approximately 225 psi. (*Typical ranges are between 180 to 240 psi).

Each impulse uses approximately 0.003 pounds of ethylene fuel. A standard type K cylinder of fuel will generate approximately 10,000 impulses. Gas flow rate would be approx. 300 SCFH based on the typically recommended cycle and fill rate. Each IMPULSE cleaner would typically consume approximately one standard K cylinder every 15 days.

Fuel can be stored in a multitude of containers (typically at grade level for safety and easy access) and plumbed to a common manifold to supply multiple cleaning systems.
IMPULSE Cleaning System Applications
IMPULSE Cleaner on Boilers

Areas of the boiler conducive to cleaning by PowerPlus IMPULSE cleaner

- **Molten deposits** - Not receptive to cleaning by IMPULSE cleaner*
  
*NOTE: Unless deposits are chemically altered to enhance removal

- Elevated temps, possible “plastic” ash - Use caution

- Temps lower than 1,500°F – Very receptive to impulse cleaning
Air Heaters

IMPULSE Cleaner
Spray Dyers, SDA’s and EGC’s

Spray Dryer

Spray Dryer Absorber

Evaporative Gas Conditioning
HRSG
PowerPlus IMPULSE Cleaning System

Summary

- Intense shockwaves are utilized to proactively dislodge fly ash without damage to equipment

- Can replace, augment, or significantly reduce back pass soot blowing

- Much lower operational and maintenance costs

- Can dramatically increase heat transfer efficiency and minimize unplanned outages

- Minimal installation footprint