Product Overview
Orbital ATK is developing a new method for CO₂ capture, known as the Inertial CO₂ Extraction System (ICES), that utilizes a unique aero-thermodynamic separation device derived from aerospace applications. Flue gas from coal burning power plants is directed to a converging-diverging nozzle and expanded to supersonic velocities. This inertial process converts pressure and temperature into kinetic energy. The rapid temperature and pressure decrease de-sublimates the CO₂ which is then collected as dry ice. The CO₂ can subsequently be allowed to vaporize to pipeline pressures for transport and storage.

Application
ICES is designed to meet future emission standards for Pulverized Coal (PC) power plants.

Patent and Development Data
- Patent pending (US 20130228076 A1) – September 2013
- Phase I development – 2010 to 2013
- Phase II development – 2013 to 2016

Product Features and Benefits
- Captures CO₂ with a lower cost of electricity penalty
- No chemicals, additives or other consumable media
- No refrigeration expense
- Inexpensive construction; no moving parts
- Significantly smaller footprint and complexity than other CO₂ capture technologies
- Readily scalable

Facts at a Glance

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Inertial CO₂ Extraction System (ICES)

Representation of carbon dioxide freezing and subsequent removal from the flue gas stream of a pulverized coal power plant.

Specifications

Technical Data

| Construction | Concrete and steel |
| Footprint | 125’ (w) x 96’ (d) x 45’ (h) |
| based on 550 MW ICES array |
| Pipeline pressure | > 2000 psia |
| ICES units | Equivalent to 250-500KW slip stream (in test) |

Orbital ATK Capabilities

Orbital ATK’s aerothermal laboratory is a world class facility that features extensive test cell and wind tunnel infrastructure to address technology development for high speed propulsion, combustion systems and related technologies.

For over 60 years Orbital ATK researchers have delivered many innovative solutions for the aerospace and energy sectors including:

- Hypersonic propulsion
- High pressure combustion heaters
- Fuel reformation
- Hydrogen generation and storage
- Clean coal technologies
- Enhanced oil recovery

Key Metrics Comparison and Performance Data

<table>
<thead>
<tr>
<th>Metric</th>
<th>550MW Pulverized Coal Fired Power Plant</th>
<th>Amine-based CO₂ extraction system</th>
<th>ICES</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂ capture</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Net plant efficiency (HHV basis)</td>
<td>39.3%</td>
<td>28.4%</td>
<td>34.5%</td>
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<tr>
<td>COE % increase</td>
<td>0%</td>
<td>77%</td>
<td>35-42%*</td>
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<tr>
<td>Parasitic Load</td>
<td>5.5%</td>
<td>20.5%</td>
<td>7.3%</td>
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<tr>
<td>Cost per ton of CO₂ avoided</td>
<td>N/A</td>
<td>US $90.7</td>
<td>US $48.4</td>
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</tbody>
</table>

*Cost of Electricity % increase range is dependent on capital expenditure estimate assumptions. Refinement is ongoing.

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