Improving Flexibility of IGCC for Harmonizing with Renewable Energy

- Osaki CoolGen’s Efforts -

September 11th, 2018
Osaki CoolGen Corporation
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2. Progress of Osaki CoolGen Project
   (1) Outline of Osaki CoolGen Project
   (2) Progress of the Step 1
       - Demonstration of Oxygen-blown IGCC -
   (3) Progress of the Step 2
       - Demonstration of IGCC with CO$_2$ capture -

3. Challenges for Improving Flexibility

4. Goal of Osaki CoolGen Project
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4. Goal of Osaki CoolGen Project
Development Roadmap of HELE Coal Power Generation Technology in Japan

Fuel Cell (FC) (MCFC) (SOFC)

Integrated coal Gasification Fuel Cell combined cycle (IGFC)

Integrated coal Gasification Combined Cycle (IGCC)

Pulverized Coal Fired (PCF)

HRSG

Gasifier Gas turbine Steam turbine

1300°C IGCC 1500°C IGCC 1700°C IGCC

46 ~ 48% CO₂ reduction about ▲30%

Efficiency :Net / Higher heating value

Fuel cell Gas turbine Steam turbine

55%~ CO₂ reduction about ▲30%

38%

38 ~ 41%

base

Super Critical (SC)

Ultra SC (USC)

Advanced USC (A-USC)

46 ~ 48%
Significance of Osaki CoolGen Project

Global Sustainable Development
- Efficiently use low cost coal for increased Power Demand
- Drastically reduce CO₂ emissions against Global Warming

In Resources Importing Countries (as Japan)
- Coal is indispensable to achieve sustainable power supply

Development of High Efficient Clean Coal Technology

Osaki Coolgen Demonstration Project

(Step-1) Oxygen-blown IGCC
(Step-2) IGCC + CO₂ Capture
(Step-3) IGFC + CO₂ Capture
Significance of Developing Oxygen-blown Type “EAGLE” Gasifier

- High efficiency and low carbonization of coal-fired power generation and effective utilization of coal and its byproduct
  - Drastically to improve power generation efficiency and significantly to reduce carbon dioxide emission.
  - Efficiently to capture CO$_2$ by pre-combustion method.
  - To use low-grade coal (sub-bituminous coal and brown coal) and high-grade coal (bituminous coal) for gasification.
  - To re-use coal ash and reduce in volume as slug of glass type

- Multi-purpose uses of coal gasification gas
  - For the gasification gas to be widely used as synthetic fuels and chemical raw materials.
Feature of EAGLE Gasifier
Oxygen-blown, Two-stage, Spiral-flow Gasifier

Upper stage: Lean oxygen
Coal → Char
Char + CO₂ + H₂O → CO + H₂

Lower stage: Lean oxygen
Coal + O₂ → CO₂ + H₂

High-efficiency gasification
Stable slag discharge
Applicable Coal Types for “EAGLE” Gasifier

- EAGLE Gasifier
- PCF Power Plant
- Previous Gasifier

Sub bituminous Coal area
Bituminous Coal area

Fixed carbon/Volatile matter [-]
Ash Melting temperature [℃]

Source: JPOWER EAGLE brochure
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4. Goal of Osaki CoolGen Project
Outline of Osaki CoolGen Project

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<td>Step1 Oxygen-blown IGCC</td>
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<td>Step2 IGCC with CO$_2$ capture unit</td>
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<td>Step3 IGFC with CO$_2$ capture unit</td>
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</table>

**Step-1**
- Gasifier
- Gas Clean-up
- CO, H$_2$
- Coal
- N$_2$
- O$_2$
- ASU

**Step-2**
- CO$_2$
- H$_2$-rich gas

**Step-3**
- Fuel Cell
- Generator

*The project does not include CO$_2$ transportation and storage.*
Project Scheme

METI (FY2012~2015) : Ministry of Economy, Trade and Industry
NEDO(FY2016~) : New Energy and Industrial Technology Development Organization

The Chugoku Electric Power Co., Inc. (Energia)
Electric Power Development Co., Ltd. (J-POWER)

Subsidy
Joint Investment

Osaki CoolGen Corporation
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3. Challenges for Improving Flexibility

4. Goal of Osaki CoolGen Project
Oxygen-blown IGCC Process Flow (Step-1)

**Coal pretreatment; pulverized coal blowing unit**
- Coal
- Mill
- Hopper

**Coal gasification unit**
- Gasifier
- Syngas cooler
- Cyclone filter
- Slag
- Char recycle

**Gas clean-up unit**
- First water scrubber
- COS converter
- Second water scrubber
- H₂S absorber
- H₂S regenerator

**Gas clean-up unit** (continued)
- Acid gas furnace
- Sulfur recovery unit
- Gypsum

**Combined cycle unit**
- HRSG
- Steam turbine
- Condenser
- Cooling water
- DeNOx

**Air separation unit**
- O₂
- N₂

**Water treatment unit**
- Water treatment unit
- Treated water
- Sludge
- Waste water

**Mitsubishi Hitachi Power Systems, LTD**
**JGC Corporation**
**Diamond Engineering Co. Ltd.**
### Demonstration Targets and Results (Step1)

<table>
<thead>
<tr>
<th>Item</th>
<th>Targets</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Plant efficiency</strong></td>
<td>➢ Net efficiency 40.5% (HHV)</td>
<td>➢ Net efficiency 40.8% (HHV)</td>
</tr>
<tr>
<td><strong>Environmental performance</strong></td>
<td>➢ SOx : 8ppm</td>
<td>➢ SOx : &lt;8ppm</td>
</tr>
<tr>
<td></td>
<td>➢ NOx : 5ppm</td>
<td>➢ NOx : &lt;5ppm</td>
</tr>
<tr>
<td></td>
<td>➢ Particulate : 3mg/m³N (O₂ equivalent 16 %)</td>
<td>➢ Particulate : &lt;3mg/m³N (O₂ equivalent 16 %)</td>
</tr>
<tr>
<td><strong>Coal types compatibility</strong></td>
<td>➢ Applicable to variety coal</td>
<td>➢ Verified with a design coal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Planning more kinds of coal</td>
</tr>
<tr>
<td><strong>Reliability</strong></td>
<td>➢ Commercial-level annual plant availability of 70% or higher</td>
<td>➢ Endurance test 5,119h(accumulated)</td>
</tr>
<tr>
<td></td>
<td>(5,000 hours endurance test)</td>
<td>➢ Continuous operation 2,168h</td>
</tr>
<tr>
<td><strong>Plant controllability &amp; operability</strong></td>
<td>➢ Commercial-level (load change rate of 1-3%/min)</td>
<td>➢ Load change rate ～10 %/min</td>
</tr>
<tr>
<td><strong>Economy</strong></td>
<td>➢ To obtain a prospect of the equivalent or less generating cost with commercial PCF plant</td>
<td>➢ Under analyzing the demonstration data</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Continue to analyze</td>
</tr>
</tbody>
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**CO₂ Capture Test**

**Feed Gas**
17% slipstream syngas equivalent to 15% of total CO₂ volume

**CO₂ Capture method**
Physical solvent (Selexol Max™)

**CO₂ Capture Test**

**Feed Gas**
17% slipstream syngas equivalent to 15% of total CO₂ volume

**CO shift section**
Sweet Shift (Downstream of AGR)

**CO₂ Capture method**
Physical solvent (Selexol Max™)

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**Major Specifications (Step2)**

### Sour Shift Catalyst Pilot Test

**Feed Gas**
Sour Shift (Upstream of AGR)

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**Diagram**
- **CO₂ Capture unit**
  - Sweet Shift Reactors: CO + H₂O → CO₂ + H₂
  - CO₂ Absorber
  - CO₂ Flash Drums
- **IGCC**
  - Gasifier
  - Water Scruber
  - H₂S absorber
- **ASU**
  - Coal
  - N₂
  - O₂
  - Low Temperature Sour Shift Reactor
  - Gas clean up unit
- **Sour Shift Catalyst pilot test**
  - Steam
  - Low Temperature Sour Shift Reactor
## Demonstration Test Targets (Step2)

<table>
<thead>
<tr>
<th>Item</th>
<th>Targets</th>
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</thead>
<tbody>
<tr>
<td>CO₂ capture performance</td>
<td>CO₂ Capture rate*¹: 90% or more</td>
</tr>
<tr>
<td></td>
<td>CO₂ Purity: 99% or more</td>
</tr>
<tr>
<td>Plant Efficiency</td>
<td>To obtain a prospect of 40%(HHV) net efficiency while capturing 90% of CO₂ volume in newly-installed commercial-scale IGCC with 1,500°C class gas turbine</td>
</tr>
<tr>
<td>Operability</td>
<td>To establish load-following operation procedures of CO₂ capture plant in IGCC system</td>
</tr>
<tr>
<td>Economy</td>
<td>To evaluate cost per amount of recovered CO₂ in the commercial-scale IGCC using cost target data shown in the “Development Roadmap of CO₂ Capture Technology” as a benchmark</td>
</tr>
</tbody>
</table>

*¹ CO₂ Capture rate: (Amount of C in the captured CO₂ gas / Amount of C in the gas introduced in the CO₂ capture unit) × 100
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Background of Challenges for Improving Flexibility

- Changes in social environment
  - Thermal power plants are required output adjustability under the expansion of renewable energy

- The potential of oxygen-blown IGCC
  - We have realized the further potential of operability in the oxygen-blown IGCC through the demonstration test

Challenges for improving flexibility in oxygen-blown IGCC
Operational Flexibility to be Required for Thermal Power Plant

Changes in social environment (1)

- **Essential flexibility of thermal power plant for power grids stability**
  - **Normal Operation**
    - Improvement of load change rate: Rapidly adjust to electric power demand with fluctuation of renewable energy
    - Reduction of minimum load: Flexible respond to decreasing demand for thermal power generation
  - **Emergency Operation**
    - Rapidly start & stop: Respond to sudden change of demand and supply due to power grids accident

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**Demand & supply balance in Kyushu area (April 30th 2017)**

- PV output 5,650MW (over half of the total demand)
- Thermal etc.
- Nuclear, Hydro, Geothermal

---

**Source:** Agency for Natural Resources and Energy HP

[Graph showing demand curve and operational flexibility requirements]
# Feature of Power sources

## Changes in social environment (2)

<table>
<thead>
<tr>
<th>Feature</th>
<th>Coal / PCF</th>
<th>LNG / GTCC</th>
<th>Oil</th>
<th>Renewable Energy</th>
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</thead>
<tbody>
<tr>
<td>Securement of fuel</td>
<td>☀ Middle-East dependence 0%</td>
<td>△ Middle-East dependence 23%</td>
<td>× Middle-East dependence 86%</td>
<td>△ Depend on weather condition</td>
</tr>
<tr>
<td>Stocks of fuel</td>
<td>○ 28 days</td>
<td>× 9 days</td>
<td>○ 78 days</td>
<td>× Need a battery</td>
</tr>
<tr>
<td>Electricity cost (Fuel cost) [JPY/kWh]</td>
<td>☀ 12.2 JPY (5.5)</td>
<td>○ 13.7 JPY (10.8)</td>
<td>△ 30.6 JPY (21.7)</td>
<td>Solar PV: 21 JPY Wind: 15.6 JPY (0)</td>
</tr>
<tr>
<td>CO2 emissions [g-CO2/kWh]</td>
<td>× 860</td>
<td>○ 380</td>
<td>△ 700</td>
<td>○ 0</td>
</tr>
<tr>
<td>Ramp rate [%/min]</td>
<td>○ 3%</td>
<td>○ 7~10%</td>
<td>○ 5%</td>
<td>×</td>
</tr>
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</table>

- **Source:** Trade statistics, Ministry of Economy, Trade and Industry (METI)’s cost working report in 2015, Agency for Natural Resources and Energy’s report and Central Research Institute of Electric Power’s report.
Characteristics of Oxygen-blown IGCC Having high Load Change Rate

The Potential of Oxygen-blown IGCC (1)

- Rapid gasification reaction by nearly pure oxygen supply
- Lock hopper system and differential pressure carrier system have high load followability
- Few operational constraints and high followability because of the small heat capacity
- Large gas volume enough to compensate pressure fluctuation
- Utilizing high capability of GT load change rate (GT load change rate: approx. 20%/min)

**Reasons of high load change rate**
- GT leads the generation load
- Oxygen-blown gasifier rapidly follows the GT load change
Characteristics of Oxygen-blown IGCC
Having high Load Change Rate

Load change rate: 10%/min

- Generation output [MW]
- Gasifier load
- Gasifier pressure

- Gasifier load follows the generation output within 5 minutes
- Gasifier pressure is controlled by the fuel (gasifier load)
- ΔP ± 1%

Achievement of high load change rate → 10%/min

- GT leads the generation load
- Oxygen-blown gasifier rapidly follows the GT load change
### Results of the Flexibility Improvement tests and Further Challenges

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<thead>
<tr>
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<th>Results</th>
<th>Further Challenges</th>
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</thead>
<tbody>
<tr>
<td>Load change rate</td>
<td>➢ 10%/min</td>
<td>➢ Further improvement of load change rate</td>
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<td>➢ AFC and GF operation (continuous load adjustment)</td>
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<td>➢ Hot start-up mode test</td>
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<td>Prospect : within an hour</td>
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<tr>
<td>Minimum load</td>
<td>➢ 0MW (net) (equivalent to isolated operation)</td>
<td>➢ Very hot start-up mode test</td>
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<td>Prospect : within an hour</td>
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<tr>
<td>Start-up time</td>
<td>➢ within 8 hours (cold start-up mode) (prospect)</td>
<td>➢ Continue to challenge for making the best of the potential of oxygen-blown IGCC</td>
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</tbody>
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- Continue to challenge for making the best of the potential of oxygen-blown IGCC
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4. Goal of Osaki CoolGen Project
Goal of Osaki CoolGen Project

Energy Mix Policy

- **Energy Security**
  - Wide range of coal varieties (from low grade to high grade coal)
  - Drastic reduction of CO2 emissions by high efficiency IGCC/IGFC with CCUS

- **Economy**
  - High efficiency
  - Using low grade coal

- **Environmental conservation**

- **Flexibility**
  - Contribution to stable power grids

Challenge for sustainable energy system development
We would like to express our gratitude to the Ministry of Economy, Trade and Industry (METI), and the New Energy and Industrial Technology Development Organization (NEDO) for continuous support to the Osaki CoolGen Project. We will carry on design, construction and demonstration steadily and safely, and make our best effort to achieve successful completion of the Osaki CoolGen Project.