Development progress of energy-saving CO₂ capture technology utilizing solid sorbent

Takeshi Okumura
Kawasaki Heavy Industries, Ltd.
TOPICS

- About Our Company
- The KCC (Kawasaki CO₂ Capture) System
- KCC Bench-scale Test
- Future Development
# History of Kawasaki

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1878</td>
<td>Shozo Kawasaki, the founder opens Kawasaki Tsukiji Shipyard (Tokyo).</td>
</tr>
<tr>
<td>1902</td>
<td>Finishes construction on Dry Dock at Kobe Shipyard.</td>
</tr>
<tr>
<td>1926</td>
<td>Constructs Eitaibashi Bridge, Tokyo.</td>
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<tr>
<td>1941</td>
<td>Starts production of Hien fighter.</td>
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<tr>
<td>1975</td>
<td>Begins production of motorcycles in the U.S.</td>
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<tr>
<td>1976</td>
<td>develops GPS200 gas turbine generator.</td>
</tr>
<tr>
<td>1981</td>
<td>Delivers the first LNG carrier built in Japan.</td>
</tr>
<tr>
<td>1996</td>
<td>Excavation on the Tokyo Bay Aqua-line is completed by the world's largest shield machines</td>
</tr>
<tr>
<td>2001</td>
<td>Opens state-of-the-art, fully integrated rolling stock factory unique in the U.S.</td>
</tr>
<tr>
<td>2004</td>
<td>Ships first 700T train to Taiwan High Speed Rail</td>
</tr>
</tbody>
</table>
Overview

- **Net Sales**: ¥1,518 billion
- **Employee**: 35,127 people (As of March 31, 2017)
- **Global Network**: 93 Subsidiaries

(As of March 31, 2017)
Expansion into the world; “Global Kawasaki”

- Australia (4 sites)
- Brazil (4 sites)
- Canada (2 sites)
- China (21 sites)
- Germany (2 sites)
- Netherlands (2 sites)
- UK (3 sites)
- India (3 sites)
- Indonesia (2 sites)
- Korea (2 sites)
- Malaysia
- Philippines (2 sites)
- Singapore
- Thailand (2 sites)
- Taiwan
- UAE (3 sites)
- Japan (44 sites)
- USA (6 sites)

Offices / Subsidiaries
Net Sales Business Segment
(Year ended March 31, 2017)

- Motorcycle & Engine 20.6%
- Precision Machinery 10.2%
- Plant & Infrastructure Engineering 10.5%
- Gas Turbines & Machinery 15.9%
- Aerospace 21.7%
- Rolling Stock 9.0%
- Ship & Offshore Structure 6.7%
- Other 5.0%

¥ 1,518 billion
Technical Background of CO₂ Capture

Kawasaki has developed the solid sorbent technology for more than 30 years

Closed/Semi-closed space
- Aircraft cabin
- Office air-conditioning
- Submarine life support, etc.

CO₂ Concentration: 1000-5000 ppm

Original solid sorbent: Amine-impregnated porous material

KCC (Kawasaki CO₂ Capture)

Application to a high concentration CO₂ gas (e.g., 13%)
Features of KCC

CO₂ desorption at low temperature (e.g., 60 °C)

Utilization of low-temperature waste heat
Background of KCC Moving-bed System

CO₂ capture unit for air conditioner:
Fixed-bed system

Dioxine adsorber for waste disposal center:
Moving-bed system

KCC moving-bed system
Advantages of moving-bed system:
- Compact equipment (smaller than fixed-bed system)
- Easy filling up / exchange of sorbent during operation
- Follow-up capability to CO$_2$ load variation
KCC Bench-scale Test Facilities

Located at Akashi works, KHI
Constructed adjacent to powdered coal firing facility

Coal firing facility

KCC bench-scale test facilities
- Fixed bed
- Moving bed
Fixed-bed Bench Test Plant

The fixed-bed system has been examined since 2010

Fixed bed
Bench-scale test plant
(10 ton-CO$_2$/d scale)

Breakthrough curves

2nd Post Combustion Capture Conference
September 17th-20th, 2013, Norway
Moving-bed Bench Test Plant

The moving-bed system has been examined since 2012

<The bench-scale test plant>

Adsorption Reactor

Desorption Reactor

sorbent Dryer

(20 m height)
Improvement of Moving-bed System

- Development of high-strength sorbent
- Improvement the equipment not to crush sorbents

<Part of the equipment>

- Pulverization is effectively restrained

<table>
<thead>
<tr>
<th>Phase</th>
<th>Amount of pulverization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase1</td>
<td>100</td>
</tr>
<tr>
<td>Phase2</td>
<td>11</td>
</tr>
<tr>
<td>Phase3</td>
<td>3</td>
</tr>
</tbody>
</table>

Pulverized sorbent remained

After improvement

Decrease pulverization from 100% to 3%
Test Condition

System Chart of the Test Plant

Exhaust gas flow rate: 820 Nm³/h
CO₂ concentration of adsorption gas: 13 %
Exhaust gas temperature: 35 °C
Steam temperature: 60 °C
Typical Results (Adsorption)

- CO$_2$ was adsorbed from coal-combustion exhaust gas
- The amount of adsorbed CO$_2$ was about 3 t/day
Typical Results (Desorption)

- The amount of captured \( \text{CO}_2 \) was about 3 t/day
- The concentration of the captured \( \text{CO}_2 \) was >95%
Future Development

Research (Lab → Bench)

Bench-scale Test

Laboratory Test

2014

Practical realization (Practical test → On the market)

Practical test

40 ton/day

2015

Improvement:
Efficiency
Economic Performance

Demonstration, Commercialization of large scale

500 ton/day
Large-scale CCS

2019

2020-

Thermal power plant, Cement plant, etc.
RITE’s Solid Sorbent

High performance amine was developed by RITE

1.47 GJ/t-CO₂ with 93% recovery + 98% purity is achieved.
Practical Demonstration Site

Bird's eye view of the practical test plant

Practical demonstration will be conducted at Maizuru Power Station of The Kansai Electric Power Co., Inc. (KEPCO)

Maizuru Power Station (coal-fired plant)

Maizuru City

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Conclusions

- Kawasaki has developed the solid sorbent CO$_2$ capture technology for large-scale plant.

- Our bench plant demonstrated that CO$_2$ was successfully captured from the coal-combustion exhaust gas using low-temperature steam.

- Practical demonstration project is ongoing with RITE and KEPCO supported by METI, and the practical demonstration will be conducted at Maizuru Power Station.
Kawasaki, working as one for the good of the planet

“Global Kawasaki”