Development of Oxyfuel Boiler & Update of Callide Oxyfuel Project (COP)

Presentation to:
The 3rd APP OFWG Oxy-fuel Capacity Building Course

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Presentation Outline

• Background
  - Positioning of COP
  - IHI activities
• Callide Oxyfuel Project
• Introduction of IHI new test facility
• Summary
Background – Development schedule (of IHI)-

- R&D under NEDO in the 1990’s
- Collaboration study with Australian from 2004, and project start in 2008


Stage 1: R&D, FS under NEDO project
Joint study with J-POWER

Stage 2: Support research & study under METI
FS of Callide

Stage 3: Demonstration
R&D of new concept oxyfuel boiler
Retrofit work to existing Callide-A
Commissioning

Callide Oxyfuel Project

FS of commercial-scale unit (with A-USC)
Work of commercial plant

Sep., 2011
Background - Oxyfuel CCS Project -

Positioning of COP

2011: Operation start of Callide-A
2015: Operation start of over 200 MWe class oxyfuel power plant
# Background - Commercialization of oxyfuel-

<table>
<thead>
<tr>
<th>Items</th>
<th>Pilot</th>
<th>Demo.</th>
<th>Commercial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant</td>
<td>Test facilities of IHI</td>
<td>Callide-A</td>
<td>???</td>
</tr>
<tr>
<td>Capacity</td>
<td>1MWt</td>
<td>30MWe</td>
<td>200-1000MWe</td>
</tr>
<tr>
<td>Boiler (Furnace)</td>
<td>Refractory wall (φ 1.3m, L:7.5m)</td>
<td>Membrane wall</td>
<td>Membrane wall</td>
</tr>
<tr>
<td>Burner</td>
<td>1 burner</td>
<td>6 burners (Front firing)</td>
<td>Multi burners (Opposed firing)</td>
</tr>
<tr>
<td>Mill</td>
<td>— (Batch type)</td>
<td>3 mills</td>
<td>4 - 6 mills</td>
</tr>
<tr>
<td>ASU</td>
<td>— (From storage tank)</td>
<td>330TPD x 2 units</td>
<td>Multi units (Total: max. 17,000TPD)</td>
</tr>
<tr>
<td>CO2-CPU</td>
<td>— (Batch type)</td>
<td>70 t-CO2/d (Partial capture)</td>
<td>Multi units (Total: max. 19,000 t-CO2/d)</td>
</tr>
</tbody>
</table>

- World largest ASU: 4,000TPD class
IHI activities

Study results

- Combustion test & simulation
- Feasibility study
Combustion test

Test facilities
Capacity: Max. 150kg/h at coal
Furnace: Vertical / Horizontal type
  I.D. 1.3m x L 7.5m
Burner: Swirl stabilized type burner

System configuration
Initial combustion test results

**Flame condition**

- Air (Wind-box O₂: 21%)
- Oxyfuel (Wind-box O₂: 21%)
- Oxyfuel (Wind-box O₂: 30%)

**Flame temperature (by radiation thermometer)**

Difficult of holding the stable flame in case of wind-box O₂ of 21% in oxyfuel

↓

Need to increase the inlet-O₂ in order to keep the stable flame and radiation heat transfer
### Simulation results

<table>
<thead>
<tr>
<th></th>
<th>Air</th>
<th>Oxy 1</th>
<th>Oxy 2</th>
<th>Oxy 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas mass flow</td>
<td>142t/h</td>
<td>117t/h</td>
<td>140t/h</td>
<td>170t/h</td>
</tr>
<tr>
<td>Inlet-O2</td>
<td>21%</td>
<td>30.2%</td>
<td>26.5%</td>
<td>21.7%</td>
</tr>
<tr>
<td>FEGT</td>
<td>Base</td>
<td>Lower</td>
<td>Nearly equal</td>
<td>Higher</td>
</tr>
<tr>
<td>Heat absorption</td>
<td>Base</td>
<td>Higher</td>
<td>Nearly equal</td>
<td>Lower</td>
</tr>
</tbody>
</table>

**Graph:**
- **O2 content of total gas (wetvol%)**
- **Furnace heat absorption (MW)**

**Legend:**
- **Air case**
- **Oxy case**

**Inlet-O2 of 27% in order to be approximately the same furnace heat absorption with air case**
Combustion test results

Flame stability

![Diagram showing flame stability and combustion characteristics]

Combustion characteristics

- NOx, Air mode vs. NOx, Oxy mode
- SO2, Air mode vs. SO2, Oxy mode
- Carbon-in-ash, Air mode vs. Carbon-in-ash, Oxy mode
Callide Oxyfuel Project

Outline
- World first retrofit-case oxyfuel power plant
- Largest capacity of 30MWe
- Total process from CO2 capture with power generation to CO2 storage

Oxyfuel Power Plant & CO2 capture

CO2 transportation & storage

ASU

Air → O2 → Coal → Boiler → Flue gas recirculation → De-dust → Condenser → Stack

N2 → Non-condensable gas → Storage tank

Transportation

CO2 underground storage
Project Structure

**Japanese Government:**
- Funding Support

**JCOAL:**
- CCT/CO2 geological storage experience

**IHI:**
- Oxyfuel pilot plant experience
- Boiler retrofit

**J-POWER:**
- O&M and CCT R&D experience

**Mitsui:**
- Worldwide Project development experience

**CASE Energy:**
- Power plant, O&M experience
- Project Management

**Australian Coal Association:**
- CCT/CCS knowledge

**Schlumberger:**
- CO2 geological storage experience

**Xstrata Coal:**
- CCT/CCS knowledge

**Air Liquide:**
- ASU and CO2 Processing experience

**Australian Government:**
- Funding Support

**Queensland Government:**
- Funding Support

**Global CCS Institute:**
- Funding Support

**Japan**

**Australia**

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**Oxyfuel Joint Venture**

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Project Overview

Callide A Power Station
4 x 30 MWe
Steam 136 t/h at 4.1MPa, 465°C
Commissioned: 1965 – 69
Refurbished 1997/98
Placed in storage in 2002

Scope
• No.4 Boiler refurbishment
• 2 x 330 TPD ASU
• Oxyfuel combustion Retrofit
• 70 TPD liquid CO₂ recovery
• Trucking to CO₂ reservoir
• Injection and monitoring

18 May 2011
Retrofit of Callide-A Power Plant

Main features of Oxyfuel Technology

- High CO₂ concentration in flue gas results in decreasing energy consumption of CO₂ recovery
- Reduced amount of air pollutants, NOx, SOx and particulates
- Multi introduction options, brand new power plant, boiler replacement and retrofit of existing boiler
Evaluation of Heat Absorption on the Furnace Wall

Air-Firing

Oxy-Firing

Furnace

2ry Super Heater (Furnace outlet)

View from the inside of the furnace

View from the inside of the furnace
Optimization of O$_2$ Mixing with Recycled Flue Gas

*O$_2$ conc. & temp. on the duct wall
*O$_2$ distribution at the inlet of burner wind-box (Optimization of O$_2$ nozzle)

<table>
<thead>
<tr>
<th>Operation load</th>
<th>Nozzle type</th>
<th>100%</th>
<th>100%</th>
<th>80%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Type1</td>
<td>(Initial)</td>
<td>Type 2</td>
<td>(Optimum)</td>
</tr>
<tr>
<td>O$_2$ conc. on the duct wall [%] (Max.)</td>
<td>(98%)</td>
<td>(34%)</td>
<td>(34%)</td>
<td></td>
</tr>
<tr>
<td>O$_2$ conc. at the wind-box inlet [%] (Max.-Min.)</td>
<td>(3.3%)</td>
<td>(1.3%)</td>
<td>(0.7%)</td>
<td></td>
</tr>
</tbody>
</table>

* Type of injection nozzle is optimized.
Callide A Unit 4 - Original
Boiler Plant/Equipment Removed Ready for New Equipment
Callide A Unit 4 - After Oxfuel Retrofit

- Oxygen
- Flue Gas Before Air Heaters
- Flue Gas After Air Heaters
- Flue Gas (Clean after FF bags)
- Recycled Gas
- Rich CO2 Flue Gas to CPU
- Secondary Recycled Gas
- Cold Primary Recycled Gas to Mills
- Hot Primary Recycled Gas to Mills

FDF = Forced Draft Fan
IDF = Induced Draft Fan
CPU = CO2 COMPRESSION & PURIFICATION UNIT
ASU = AIR SEPARATION UNIT
Callide A Unit 4 - After Oxfuel Retrofit
ASU & CPU Layout

Air Separation Unit
O₂: 2 x nominal 330 TPD (27.5 tph Total)

CO₂ Purification and Compression Unit
CO₂ Product: 70t/day
Callide A Unit 4 – Update of Retrofit

18 May 2011

30 June 2011
Air-firing test before Retrofit: Mar., 2009

- Plant performance (static & dynamic)
- Air ingress
- Combustion characteristics (NOx/SO2/TE)
- Heat flux, in-furnace temperature
- Cut mode operation of LP heater

Overview of Callide-A

Inside of furnace

Control room

Front wall

Rear wall

Burner throat
Site work: Feb., 2011

Boiler before retrofit

ASU

Site work in the area of ASU and CO2 capture unit

Boiler retrofit work
Commissioning

Commissioning of air-firing after the retrofit have completed and commissioning of ASU have continued.
   23 March, 2011 - First fire on fuel oil (diesel)
   1 April, 2011 - Turbine to 3000rpm
   11 April, 2011 - First coal fire in the furnace
   13 April, 2011 - First synchronization
   17 May, 2011 - Full load (30MWe)
   (Combustion tuning, load swing & MFT testing)
   1 July, 2011 – Commissioning start of ASU

First fire on fuel oil (diesel) on 23 March, 2011
PC flame
Demonstration test

Objectives

◆ Operation of oxyfuel & CO2 capture
◆ Obtain the data and knowhow for the commercialization

● This is the valuable opportunity to obtain the basic data for flame, combustion, heat transfer, ash and trace elements and operation data & knowhow of oxyfuel power plant with CO2 capture, due to the actual power generation plant.
COP key demonstration items – CO$_2$ capture

- Oxyfuel & CO$_2$ capture operation
- Safety
- Operation flexibility
- Durability
- Plant efficiency
- CO$_2$ capture rate & CO$_2$ purity
- Cost data
- Air ingress
- Process control and optimisation
Main evaluation items

Oxyfuel Plant (Integration operation)
Performance: h, CO2 capture rate
Control: Oxyfuel, MFT
Operation: Mode change, load range
Durability and safety

<Oxyfuel process>
- Boiler efficiency
- N & S behavior
- Hg behavior

<CO2 capture process>
- N & S behavior
- Hg behavior

❖ Grindability and dry
❖ Mixing
❖ Flame stability
❖ Radiation heat transfer
❖ Combustion characteristics
❖ Convective heat transfer
❖ Tube corrosion
❖ CO2 conc., etc.
❖ Ash characteristics
❖ Safety
❖ Purity of CO2
❖ Impurities

Purification & compression
Non-condensable gas

Cold Box

CO2 liquefaction

CO2 tank
Callide Oxyfuel Project – Summary

Commissioning of oxyfuel will be started from November 2011 and we will have very valuable opportunity to obtain the data and knowhow towards the commercialization of oxyfuel process during the demonstration operation in Callide-A.

for more information:  www.callideoxyfuel.com
IHI New Test Facility
CCTF (Coal Combustion Test Facility)
Construction work was completed and is now under commissioning. Test operation will be started November 2011.

Introduction of IHI test facilities

D&D Park in AIOI works

1. Large capacity (12MWt) combustion test facilities
2. Basic combustion test facilities
3. Vertical furnace combustion test facilities
4. DeSOx test facilities
5. D&D Park in AIOI works

Japan
Tokyo
Aioi
Introduction of IHI test facilities
- Coal Combustion Test Facility : CCTF -

**Main R&D Items**
- Development of new coal burner
- Combustion of new and multi fuel
- Evaluation of various coal combustion
- CO2 capture technologies
  - Oxyfuel combustion
  - Post-combustion capture

**Facility**
- Capacity: 20MWth
- Furnace: Opposed firing
- Burner: 15 burners
- Mill: IHI VS-16 (Capacity: 5tph)
- Flue gas treatment: DeNOx, DeDust, DeSOx
- CO2 capture process: Oxy-fuel and Post-Combustion (Chemical absorption)
Concluding comments –Technical main issue-

1. Scale-up
2. High efficiency
3. Process optimization
4. Optimum application for the capture-ready plant
Concluding comments

1. Callide Oxyfuel Project
   ● CO2 capture is well advanced in commissioning.
   ● World-first oxyfuel combustion in existing power station is planned in December.
   ● The Project is a major international collaboration between Japan and Australia – at Government level and industry level.

2. Continuous and further development towards the large/commercial-scale demonstration is necessary.