OPERATING EXPERIENCE AND CURRENT STATUS OF PUERTOLLANO IGCC POWER PLANT

ELCOGAS S.A

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Introduction:

IGCC technology. General description
INTRODUCTION: IGCC TECHNOLOGY. GENERAL DESCRIPTION

IGCC Technology. Advantages (1)

✓ High efficiency. Higher than others technologies of power generation from coal, and great potential to increase: net 42% → 50%

✓ Feedstock flexibility →
  • Coal (diversity of qualities)
  • Alternative fuels (pet-coke, municipal wastes, biomass, etc.)
  • Availability of secondary fuel to the combined cycle

Reliability on energy supply

✓ Product flexibility → Electricity, H₂, CO₂, methanol, NH₃, gasolines, etc

Minor risk: Production according to markets

✓ Sustainability:
  • Coal stocks for more than 200 years and better distribution
  • Almost any fuel with enough carbon content is admitted
IGCC Technology. Advantages (2)

**Environment:**
- Lower CO\textsubscript{2} emissions than other coal based plants. Best possibilities for zero emissions
- Low emissions of acid gases (SO\textsubscript{2}, NO\textsubscript{x}) and particles. Similar or better than NGCC
- Less wastes. Slag, ash, sulphur and salts are sub-products
- Less water consumption than other coal based plant. Similar to NGCC
- No dioxins/furans are produced when organic fuels are used
- Best method to eliminate Hg emissions

**Economics:**
- Low cost fuel. Very competitive with natural gas. Fuels cost of KWh produced with coal is currently one third of produced with natural gas
- Lowest cost of CO\textsubscript{2} capture (pre-combustion)
- Wastes are commercial products. No cost disposal
IGCC Technology. Disadvantages

- **Technology is in demonstration level**
  - Four existing large coal based plants (USA & EU) report current IGCC availability between 60 and 75% (> 90 % considering secondary fuel)
  - Main unavailability causes have been related to lack of maturity:
    - Design of auxiliary systems: Solids handling, down time corrosion, candle filters, proper materials and procedures
    - Performance of gas turbine high class with synthetic gas and other
    - Excessive integration between units, high dependence and delays start up
    - Processes are more complex than other coal based power plants. Learning is required. Existing IGCCs operated by petrochemical companies with refinery residues report IGCC availability over 92 % (Complexity of process similar to chemical industry, several trains in parallel, solids handling easier)

- **High investment cost**
  - Existing plants cost have been between 1,500 and 2,000 €/KW
IGCC technology in Spain.

ELCOGAS experience.
Spanish company shared by European companies, which was established in April 1992 to undertake the planning, construction, exploitation and commercialization of a 335 MW ISO IGCC plant located in Puertollano (Spain)
ELCOGAS operating data

**Fuel composition**
Mixture of low quality coal (high ash content) and petcoke (high sulphur content)

<table>
<thead>
<tr>
<th></th>
<th>RAW GAS</th>
<th>CLEAN GAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO (%)</td>
<td>59,26</td>
<td>59,30</td>
</tr>
<tr>
<td>H₂ (%)</td>
<td>21,44</td>
<td>21,95</td>
</tr>
<tr>
<td>CO₂ (%)</td>
<td>2,84</td>
<td>2,41</td>
</tr>
<tr>
<td>N₂ (%)</td>
<td>14,32</td>
<td>14,76</td>
</tr>
<tr>
<td>Ar (%)</td>
<td>0,90</td>
<td>1,18</td>
</tr>
<tr>
<td>SH₂</td>
<td>0,83 %</td>
<td>3 ppmv</td>
</tr>
<tr>
<td>COS</td>
<td>0,31 %</td>
<td>9 ppmv</td>
</tr>
<tr>
<td>HCN (ppmv)</td>
<td>23</td>
<td>--</td>
</tr>
<tr>
<td>LHV (MJ/Kg)</td>
<td>10,36</td>
<td>9,76</td>
</tr>
<tr>
<td>HHV (MJ/Kg)</td>
<td>10,83</td>
<td>10,19</td>
</tr>
<tr>
<td>Kg/s</td>
<td>56,26</td>
<td>52,37</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>COAL</th>
<th>PETCOKE</th>
<th>MIXTURE (50:50w)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture (%)</td>
<td>11,80</td>
<td>7,00</td>
<td>9,40</td>
</tr>
<tr>
<td>Ash (%)</td>
<td>41,10</td>
<td>0,26</td>
<td>20,68</td>
</tr>
<tr>
<td>Carbon (%)</td>
<td>36,27</td>
<td>82,21</td>
<td>59,21</td>
</tr>
<tr>
<td>Hydrogen (%)</td>
<td>2,48</td>
<td>3,11</td>
<td>2,80</td>
</tr>
<tr>
<td>Nitrogen (%)</td>
<td>0,81</td>
<td>1,90</td>
<td>1,36</td>
</tr>
<tr>
<td>Oxygen (%)</td>
<td>6,62</td>
<td>0,02</td>
<td>3,32</td>
</tr>
<tr>
<td>Sulphur (%)</td>
<td>0,93</td>
<td>5,50</td>
<td>3,21</td>
</tr>
<tr>
<td>LHV (MJ/kg)</td>
<td>13,10</td>
<td>31,99</td>
<td>22,55</td>
</tr>
<tr>
<td>HHV (MJ/kg)</td>
<td>13,58</td>
<td>32,65</td>
<td>23,12</td>
</tr>
<tr>
<td>Kg/s</td>
<td></td>
<td></td>
<td>29,68</td>
</tr>
</tbody>
</table>

**Syngas composition**
Operational experience

Environmental results (2004)

The environmental emissions of $SO_2$, $NO_x$ and particulated material are much lower than the maximum allowed by the ELCOGAS Permission.
Operational experience

Commercial viability results: Production costs (2004)

<table>
<thead>
<tr>
<th>Operating mode</th>
<th>Fuel</th>
<th>Heat rate (kJ&lt;sub&gt;HHV&lt;/sub&gt;/kWh)</th>
<th>Fuel price (€/GJ&lt;sub&gt;HHV&lt;/sub&gt;)</th>
<th>Fuel partial cost (€/MWh)</th>
<th>Production cost (€/MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GNCC</td>
<td>Natural gas</td>
<td>7.649</td>
<td>3.84</td>
<td>29.37</td>
<td>29.37</td>
</tr>
<tr>
<td>IGCC</td>
<td>Coal</td>
<td>2.934</td>
<td>2.06</td>
<td>6.04</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Petcoke</td>
<td>5.994</td>
<td>1.18</td>
<td>7.07</td>
<td>14.55</td>
</tr>
<tr>
<td></td>
<td>Additional NG</td>
<td>376</td>
<td>3.84</td>
<td>1.44</td>
<td></td>
</tr>
<tr>
<td></td>
<td>consumption</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The resulting production cost demonstrates IGCC competitiveness in the Spanish liberalized electricity market.
Operational experience

Commercial viability results: Learning curve

IGCC, NGCC and Total Yearly Production

YEAR

IGCC
NGCC

GWh

1998 1999 2000 2001 2002 2003 2004

9 743 836 622 321 343 301 451

1595 1371 1293
Main unavailability causes (1)

1. **Gas Turbine**
   - Optimization of syngas burners to prevent overheating / humming and to accomplish more stability and remaining life of the hot components.
   - Up to last design of syngas burner was installed in 2003 preventive inspections of hot gas path every 500 - 1000 syngas operating hours. High rate of ceramic tiles change.

2. **Gasifier**
   - Water leakage of membrane tubes due to flow blockages or local erosion. Design of distributors. Chemical control. Particle filtration. Loose parts.
   - Gas leakage due to piping corrosion. Proper selection of materials. To avoid “cold ends” and down time corrosion.
   - Fouling of Waste Heat boilers:
     - Sticky fly ash (reduced by decreasing gas inlet temperature to cooling surfaces. More quench flow)
     - Fluffy fly ash (reduced by increasing the velocity of the gas)
3. **Grinding and mixing systems**  
Clogging in mills feeding and mixing conveyors. Two trains of 60%. Lack of robustness of equipment.

4. **Solids handling (slag and fly ash)**  
Erosion of components by local high velocities. Substitution of parts for abrasion resistant materials. Revision of design and operating procedures.

5. **Ceramic filters**  
Life time of filtrating elements is half of expected (4000 h). Very expensive cost. To improve by changing supporting design of elements.

6. **Fuel dust conveying and feeding systems**  
Pressure control and fluidization stability. Design of fluidization systems and preventive maintenance of components.

7. **COS catalyst**  
2 - 3 changes by year of alumina based catalyst. Water carryover. Change to Titanium oxide catalyst (3 - 4 years) and preheater installation.
### Lessons learned: Summary of improvements (1)

<table>
<thead>
<tr>
<th>System / equipment</th>
<th>Potential improvements</th>
<th>Cost reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal preparation</td>
<td>Natural Gas consumption 3 grinding trains for availability</td>
<td>Elimination of mixing equipment. Elimination of steam preheaters</td>
</tr>
<tr>
<td>Coal dust conveying, sluicing and feeding</td>
<td>N₂ saving Resizing of vessels and nozzles</td>
<td>Elimination of concrete building, coal storage and lock hopper system simplification by pneumatic pumps</td>
</tr>
<tr>
<td>Gasifier</td>
<td>Recycling of fine slag Membranes flow distribution Quench gas ratio</td>
<td>Removing auxiliary burners. Reduction of surfaces by increasing velocity</td>
</tr>
<tr>
<td>Slag handling</td>
<td>Replacement of filtering system by settling system.</td>
<td>Simplification of slag water circuit. Elimination of one slag lock hopper and extractor.</td>
</tr>
</tbody>
</table>
### Lessons learned: Summary of improvements (2)

<table>
<thead>
<tr>
<th>System / equipment</th>
<th>Potential improvements</th>
<th>Cost reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry dedusting filter</td>
<td>Improvement of candle filter cleaning system. Improvement of candle filter material and design.</td>
<td>Fly ash recycle removal, reduction of vessels Elimination of fly ash wet discharge system</td>
</tr>
<tr>
<td>Gas scrubbing and stripping</td>
<td>Reduction of water carryover from scrubber (Start up)</td>
<td>Controlling filter removing/Scrubber resizing</td>
</tr>
<tr>
<td>Sulphur removal</td>
<td>COS catalyst</td>
<td>Equipment dimension decrease using enriched air</td>
</tr>
<tr>
<td>Air Separation Unit</td>
<td>Increase of liquid N\textsubscript{2} storage capacity Start up compressor</td>
<td>Oxygen storage removing</td>
</tr>
<tr>
<td>Gas turbine</td>
<td>New higher efficiency gas turbine Syngas preparation</td>
<td>Scale benefits Simplification of control &amp; control components</td>
</tr>
</tbody>
</table>
Future R&D overview
Future of IGCC technology

**IGCC TECHNOLOGY. FUTURE OVERVIEW**

**GASIFICATION**
- RAW GAS
- WATER STEAM
- COAL WASTES BIOMASS

**GAS CLEANING**
- WATER STEAM
- CO + H₂O ⇌ CO₂ + H₂

**PREPARATION**
- CO₂ SEPARATION
- H₂ PURIFICATION

**COMBINED CYCLE**
- FUEL CELL
- CHEMICALS

**AIR SEPARATION UNIT**
- N₂
- O₂

**START UP**
- COMPRESSOR

**BFW**
- STEAM

**H₂**
### Future of IGCC technology

**IEA estimation $H_2$ production cost year 2020 (€/GJ)**

<table>
<thead>
<tr>
<th>Source of Hydrogen</th>
<th>Range (€/GJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$H_2$ from natural gas with $CO_2$ capture</td>
<td>5.6 – 8.9</td>
</tr>
<tr>
<td>$H_2$ from coal – IGCC, with $CO_2$ capture</td>
<td>6.5 – 8.9</td>
</tr>
<tr>
<td>$H_2$ from biomass (gasification)</td>
<td>8.1 – 14.5</td>
</tr>
<tr>
<td>$H_2$ from nuclear energy</td>
<td>12.1 – 16.2</td>
</tr>
<tr>
<td>$H_2$ from wind energy</td>
<td>13.7 – 18.6</td>
</tr>
<tr>
<td>$H_2$ from solar thermic</td>
<td>21.8 – 28.3</td>
</tr>
<tr>
<td>$H_2$ from solar photovoltaic</td>
<td>38.0 – 60.6</td>
</tr>
</tbody>
</table>
IGCC technology: Main challenges

1. **To improve reliability.** It has to be achieved by introducing in next generation of plants the lessons learned, giving continuity to the technology.

2. **To decrease investment costs.** Main points are: scale economy (larger plants), better efficiency with last generation of gas turbines and combined cycles, design optimization according to lessons learned.

3. **To introduce CO₂ capture concept.** IGCC technology is the best option for zero emission plants based on fossil fuels.

4. **To introduce the technology in the H₂ economy.** Diversification of products will improve economic scenarios.

5. **To improve environmental performance even more.** By considering the use of wastes and biomass in co-gasification with coal.
Project aims: CO₂ capture and hydrogen production from a 2% of the syngas produced at the plant:

- **H₂ production:** 2,500 Nm³/h, to direct sold or to applications (fuel for engines, gas turbines or fuel cells, chemical synthesis)

- **CO₂ captured:** 25,000 t/year (capture efficiency > 85%) to direct use or to geological sequestration tests

✓ **Total investment:** 15 million €

✓ **Project has been presented to the spanish R&D National Programme (2005)**
**IGCC TECHNOLOGY. FUTURE OVERVIEW**

**ELCOGAS pilot plant process**

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- **GASIFICATION**
  - COAL / PETCOKE
  - RAW GAS

- **Cleaning & Desulfuration**
  - CLEAN GAS
    - 19.4 bar
    - 302 °C
    - 60.5 % CO
    - 22.1 % H₂

- **Saturator**
  - SATURATOR
  - 183,000 Nm³/h
  - CLEAN GAS

- **Shift Reactor**
  - H₂ - RICH GAS
    - 39.0 % CO₂
    - 50.5 % H₂
    - 1.9 % CO

- **CO₂ Separation**
  - (ABSORPTION)
  - CO₂

- **H₂ Purification**
  - (PSA)
  - RAW H₂
    - 6.5 % CO₂
    - 77.4 % H₂
    - 2.9 % CO
  - 99.99 %
  - FUEL GAS (1.3 bar)

- **Air Separation**
  - N₂
  - O₂

- **Compressed Air**
  - WASTE N₂