Analysis and Optimization of ASU for Oxyfuel Combustion

Sichuan Air Separation Plant (Group) Co., Ltd.

Jiang Rong
1. Introduction

2. ASU of SASPG for Oxyfuel Combustion

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1 Introduction
CO₂ emissions by fossil fuel combustion has accelerated the global warming.

Oxyfuel combustion is one of the most potential technologies to reduce CO₂ emissions for large scale coal-fired power plant.

- O₂ purity: above 95%
- Analysis optimization
- Reduce Energy consumption
ASU of SASPG for Oxyfuel Combustion
Sichuan Air Separation Plant (Group) Co.Ltd (SASPG) is located in Jianyang City, east to the city of Chengdu, a leading cryogenic plant and equipment manufacturing company.

Since founded in 1966, SASPG has kept on increasing its operation scales. Up to 2015, the annual production capacity reached 50,000 tons, the total asset of SASPG reached 3 billion RMB, and has 2500 Employees.

SASPG consists of 4 branch companies, 17 subsidiaries, 3 research institutes and holds shares of other 7 enterprises.
Introduction of SASPG

Product Profile

- Air Separation Plants
- Natural Gas (Associated Gas) Liquefaction and Separation Plants
- Industry Gases
- Cryogenic Liquid tank and tankers
- Erection Services
- Turbo-expander
- Plate-fin Heat Exchangers
- Vacuum Insulated Piping
- Cryogenic Pumps
- Cryogenic valves
- Medical Machinery, Medical Equipment
Introduction of SASPG

Fabrication Facility

SASPG New Facility in Hangzhou

10m Vacuum Brazing Furnace

Automatic fin cleaning machine
Air separation unit (ASU) and CO₂ compression and purification Unit (CPU) are sponsored by SASPG. (about 15 million yuan)


ASU
✓ Capacity: 600 Nm³/h
✓ Conventional double-column distillation system

CO₂ Compression and Purification Unit
✓ Capacity: 600 Nm³/h

SASPG obtain patents on ASU for oxyfuel combustion and CPU.
35MW\textsubscript{th} Oxyfuel Combustion Industrial Demonstration System (Yingcheng)

- SASPG undertake the subject-----Research and Demonstration of new ASU for Oxyfuel Combustion

- ASU investment partly from project funding and partly sponsored by SASPG (about 13 million yuan)

- ASU parameters:
  - Capacity: 6400Nm\textsuperscript{3}/h
  - GOX Purity: 97.5%
  - GOX Pressure: 50kPa.G
  - New three-column distillation system

- ASU construction completed in June 2015, and started to operation in July 2015
Flowsheet of ASU

Oxygen purity: 97.5%

Radial flow purifier

Booster - high pressure air

High-medium pressure columns

Oxygen self-pressurization process
Normal ASU oxygen purity is 99.6% with conventional double-column distillation system.

New three-column distillation system used for oxygen purity 97.5%, decrease energy consumption by 8%~10% compared with normal ASU.

- High pressure column (4.2 bar G),
- Medium pressure column (2.6 bar G),
- Low pressure column (0.3 bar G),
- Air compressor:
  - 32000 Nm³/h/0.98 bar G,
  - 7000 Nm³/h/2.8 bar G,
  - 25000 Nm³/h/5.5 bar G
LOX self-pressurization process

- LOX pressure is increased through height difference between the main condenser and LOX evaporator, the pressurized LOX is vaporized in LOX evaporator and reheated in main heat exchanger

- Cancel the oxygen compressor, energy saving and more safety
Key3: Vertical radial flow purifier

Vertical radial-flow purifier:

- Lower pressure drop of air and waste nitrogen
- Better air distribution
- Smaller cover area

<table>
<thead>
<tr>
<th></th>
<th>Vertical radial flow purifier</th>
<th>Horizontal purifier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure drop</td>
<td>3~4kpa</td>
<td>7kpa</td>
</tr>
<tr>
<td>Cover area</td>
<td>25%</td>
<td>1</td>
</tr>
<tr>
<td>Energy consumption</td>
<td>-1%</td>
<td>1</td>
</tr>
</tbody>
</table>
The commissioning of ASU started in July 21, 2015

The oxygen product reached design value in July 24, 2015

Oxygen purity, oxygen pressure and energy consumption have reached the design value.
Research of ASU for Oxyfuel Combustion
ASU for 200MWe oxyfuel combustion system

- SASPG signed R&D contact of ASU for 200MWe oxyfuel combustion system with Shenhua Guohua (Beijing) Electric Power Research Institute Co. in June 2014.

- ASU Requirements:
  - ASU Capacity: $2 \times 60000 \text{ Nm}^3/\text{h}$
  - GOX Purity: 95~99.6%
  - GOX Pressure: 50 kPa.G
### Key1: R&D of ASU process

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Two columns process</th>
<th>Three columns process</th>
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<tbody>
<tr>
<td><strong>Type of processes</strong></td>
<td></td>
<td></td>
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<tr>
<td>Equipments</td>
<td></td>
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</tr>
<tr>
<td><strong>Air compressor</strong></td>
<td>Capacity: 290000 Nm³/h Inlet/outlet pressure: 0.095/0.535 MPa(A)</td>
<td>First stage Capacity: 299000 Nm³/h Inlet/outlet pressure: 0.095/0.325 MPa(A)</td>
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<tr>
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<td></td>
<td>Second stage Capacity: 158500 Nm³/h Inlet/outlet pressure: 0.325/0.535 MPa(A)</td>
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<tr>
<td><strong>Cooling system</strong></td>
<td>One air cooling tower and one water cooling tower</td>
<td>two air cooling tower and one water cooling tower</td>
</tr>
<tr>
<td><strong>Purification system</strong></td>
<td>One set of purification system (with two purifiers and one steam heater)</td>
<td>Two sets of purification system (with four purifiers and two steam heaters)</td>
</tr>
</tbody>
</table>
Through the comparison of different processes, using HYSYS software simulation and optimization of different process, we obtained a diagram of ASU energy consumption with different oxygen concentration, as shown below:
Conclusions:

- With the increase of oxygen purity, energy consumption per unit oxygen of two processes increased.

- When oxygen purity between 0.95 to 0.98, the energy consumption per unit oxygen of three-column process is 8%~10% lower than two-column process. So three column process should be used.

- When oxygen purity between 0.98 and 0.99, the energy difference between two processes decrease gradually. So both process can be used users by considering investment cost and energy consumption comprehensively.

- When oxygen purity higher than 0.99, the investment cost and energy consumption of three-column process are higher than two-column process. So two-column process should be used.
According to the characteristics of oxygen used in power plant:

✓ ASU Load change range: 50~105%
✓ Load change rate: no less than 5%/min

Consideration for load change:

✓ Operation cost
✓ Investment cost
✓ Adjust characteristic
Suggestion:

- ASU Load change Range between 75~105%, load change rate no more than 1%/min, automatic load change
- ASU Load change Range between 75~105%, load change rate no less than 5%/min, oxygen-nitrogen exchange and liquid oxygen vaporized
- Load change Range between 50~75%, load change rate no more than 1%/min, automatic load change and oxygen-nitrogen exchange
- Load change Range between 50~75%, load change rate no less than 5%/min, add liquid equipment and liquid oxygen vaporized
Thank you

Quality Promises

We firmly insist on our enterprise spirit—All for Customers, All for Development, we are committed to providing our customers with reliable, safe, advanced and state-of-art products.

With the pragmatic attitude and honest work, we manufacture the best products, provide excellent services and would like to join hands with our venerable “Lord” (Customers) to create a bright future.

Sichuan Air Separation Plant (Group) Co., Ltd
Mr. Shan Jinming, Chairman of Board of Directors, General Manager

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