-Korea Process Simulation Olympiad 2020
Problem Statement

Title: Feasibility study of Hydrogen production plant from coal

1. Background:

Hydrogen was remarked as new clean energy after fossil energy economy by Jeremy Rifkin in 2002. He insisted hydrogen economy would change the system and life of mankind. However, it seemed that it could not overcome the wave of renewal energy and sale gas.

But Hydrogen is emerging as a new clean energy source again. The Korean government is investing in the construction of hydrogen filling stations on the highway and hopes that hydrogen will become a new driving force to create new jobs and benefits.

Traditionally Hydrogen has been produced by gas and oil reforming, water electrolysis and coal gasification. Coal is known to be less environmentally friendly but clean technologies are being developed to overcome it.

2. Problem:

Your company believe that the hydrogen demand will increase in future so wants to know how economically valuable the hydrogen plants are.

Assume that your company executives asked your team to execute the feasibility study of building of a new hydrogen production plant from coal

Your team must perform the following minimum tasks to achieve the goal

- Complete process configuration & material balance of 50,000 Nm3/h H2 production plant by using published papers and process simulation
- Your team don't need to estimate TIC (Total investment cost). But the annual operation cost should be calculated based on simulation result and the reasonable TIC budget has to be proposed considering payout period.
- Production is only Hydrogen. Power generation is ignored.

2.1 Product Capacity & Specifications

Capacity: 50,000 Nm^3/h H_2 production
Product purity: 99.99 mol% H_2
Operating hrs. : 8000 hrs/ yr

2.2 Coal Feed Spec.:

The supplied coal feed spec. is like those;

Proximate analysis	wt%
Moisture	0
Volatile matter	35.7
Fixed carbon	54.3
Ash	10
Total sulfur	0

Ultimate analysis	wt%
Moisture	n/a
Carbon	69.5
Hydrogen	5.3
Oxygen	10.0
Nitrogen	1.3
Sulfur	3.9
Ash	10.0

Gross Heating value (kcal/kg)	4278

2.3 Oxygen supply conditions : 25 C, 12 barg

Note) Oxygen is supplied from a nearby plant.

2.4 CO_2 capture

CO_2 capture solvent : 30wt% MEA solution

Amount of captured CO_2: min. 90 mol% from feed of carbon capture process

Note) CO2 compression and storage facilities don't need to be considered.

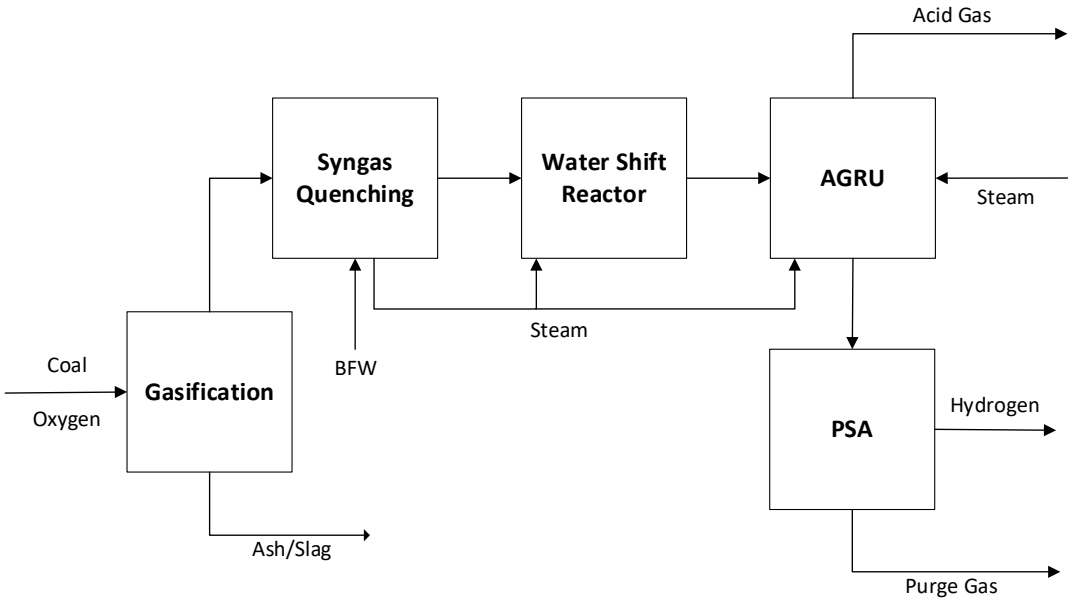
2.5 Utility conditions

CW (supply/ return)	32 C / 42 C
Steam supply	15 barg (saturated)
BFW	80 C/ 1 barg

Note) All of utilities will be supplied from other plant.

2.6 Process configuration:

The below process scheme is only for reference.



2.7 Gasification modeling

The below information is a reference for how to model a gasifier.

<Conversion reactor>
$2H_2 + O_2 \rightarrow 2H_2O$ (H_2 conversion : 100%)

<Gibbs reactor>
$2C + O_2 \rightarrow 2CO$
$2CO + O_2 \rightarrow 2CO_2$
$C + H_2O \rightarrow H_2 + CO$
$H_2 + S \rightarrow H_2S$
$C + CO_2 \rightarrow 2CO$
$CO + H_2O \rightarrow H_2 + CO_2$

Note)
1. Participants should determine O2/Coal ratio to a gasifier based on references
2. Operating pressure of gasifier is assumed to be 10 barg

2.8 Water gas shift reactor

Operating temperature : 200 C
$CO + H_2O \rightarrow H_2 + CO_2$ (CO Conversion : 90%)

2.9 PSA (Pressure Swing Absorber)

Hydrogen absorption efficiency : 98% (mole basis)
Stream calculator can be available for simple PSA simulation in PRO/II

Note) Purge gas will be transferred to nearby power plant.

2.10 Economic conditions:

Coal price : 112 $/ton
Oxygen price: 0.05 $/Nm3
H2 price : 7 $/kg
Steam price : 11$/ton
99.5wt% MEA price : 1.5$/kg
Purge gas price : 0.5$ /kg
Electricity price : 0.08 $/kwh
Circulated cooling water cost : 0.03 $/$m^3$
Annual operating hours: 8000 hrs

3. Report

Applicants need to submit the final report which contains simulation validation report with schematic drawing and material balance and economic analysis.

3.1 Process flow diagram (PFD) with material/energy balances for H2 Plant

Snapshots of flow sheet of major process simulators are acceptable. Temperature, pressure, flow rate and composition of each stream must be indicated on the PFD. Heating or cooling duty of each equipment should be indicated also.

If, the simulator does not produce a flow diagram, applicants can draw it on major drawing software like Microsoft VISIO, Excel or AutoCAD.

Unit of measure should be metric

3.2 Process description

Description of your process should be required.

3.3 Economic analysis

Estimate annual operating cost for the H_2 production plant based on given information and your assumptions. Also, you could estimate minimum required total investment cost to satisfy that payout period is 4 years .