Korea Process Simulation Olympiad 2021
Problem Statement

Title: Feasibility study of Hydrogen liquefaction

1. Background:

Many processes are known to produce hydrogen such as reforming, electrolysis, gasification, etc. and most of them have already been technically proven.

But hydrogen storage and transportation technologies still have a lot of room for development to popularize the use of hydrogen. Hydrogen in refineries and petrochemical complexes is transported through pipes, but this method is difficult to supply long-distance or isolated areas, and it is also hard to transport gas phase hydrogen on a large scale. Therefore, as a part of building hydrogen economy infrastructure, research on hydrogen storage and transportation is being actively conducted, and interest in hydrogen liquefaction technology can be seen as a part of it.

2. Problem:

Your company consider constructing a commercial hydrogen liquefaction plant at Daesan area and has a plan to complete the liquid hydrogen supply chain in Korea.

As part of that plan, your company has signed two memorandums of understanding with a waste plastic gasification company and a refinery/petrochemical company, respectively. Thus 50 tons/day of syngas and 5 tons/day of blue hydrogen will be supplied to your future plant which generates hydrogen from syngas and liquefies that hydrogen and imported blue hydrogen.

Your team is assigned to the project to build a commercial liquefaction plant during the feasibility study stage. The project manager asked your team to study preliminary process configuration and estimate operating costs of the plant. Your team also provide an appropriate liquid hydrogen sale price based on the study result

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

- Complete process configuration & material balance having capacity of 50 tons per day of syngas and 5 tons per day of blue hydrogen to product 99.99 mol% liquid hydrogen.
- The plant will have the facilities to produce hydrogen from syngas and a cryogenic process to liquefy produced hydrogen and imported hydrogen.
- As hydrogen gas cools and liquefies, the ratio of its ortho to para spin isomers decreases. And the heat of conversion from ortho-hydrogen to para-hydrogen is generated. But don’t consider it to simplify the simulation model.

- If you need liquid nitrogen as refrigerant, it can be supplied through the pipeline by paying a fee.
- Your team don't need to estimate TIC (Total investment cost). Focus on only operating cost and decide what the price of liquid hydrogen products will be to make profit based on the study.

2.1 Product Capacity & Specifications

Capacity: 50 tons/day of syngas , 5 tons /day of 99.99 vol% blue hydrogen
Product purity: 99.99 mol% H_2
Operating hrs. : 8000 hrs/ yr
Liquid H_2 OSBL condition : -244 deg C / 8bar (a)

2.2 Feed Spec.:

The syngas specifications are like those;

Components	vol%
Nitrogen	55
Hydrogen	28
Carbon monoxide	2
Carbon dioxide	15
Flow rate	50 ton/day
Pressure	3 bar(a)
Temperature	600 deg C

The below is the specification of imported hydrogen

Components	vol%
Hydrogen	99.99
Nitrogen	0.01
Flow rate	5 ton/day
Pressure	10 bar(a)
Temperature	25 deg C

2.3 CO_2 capture

CO_2 capture solvent : 30wt% MEA solution
Amount of captured CO_2: min. 92 mol% from feed of carbon capture process

Note) CO_2 compression and storage facilities don't need to be considered.

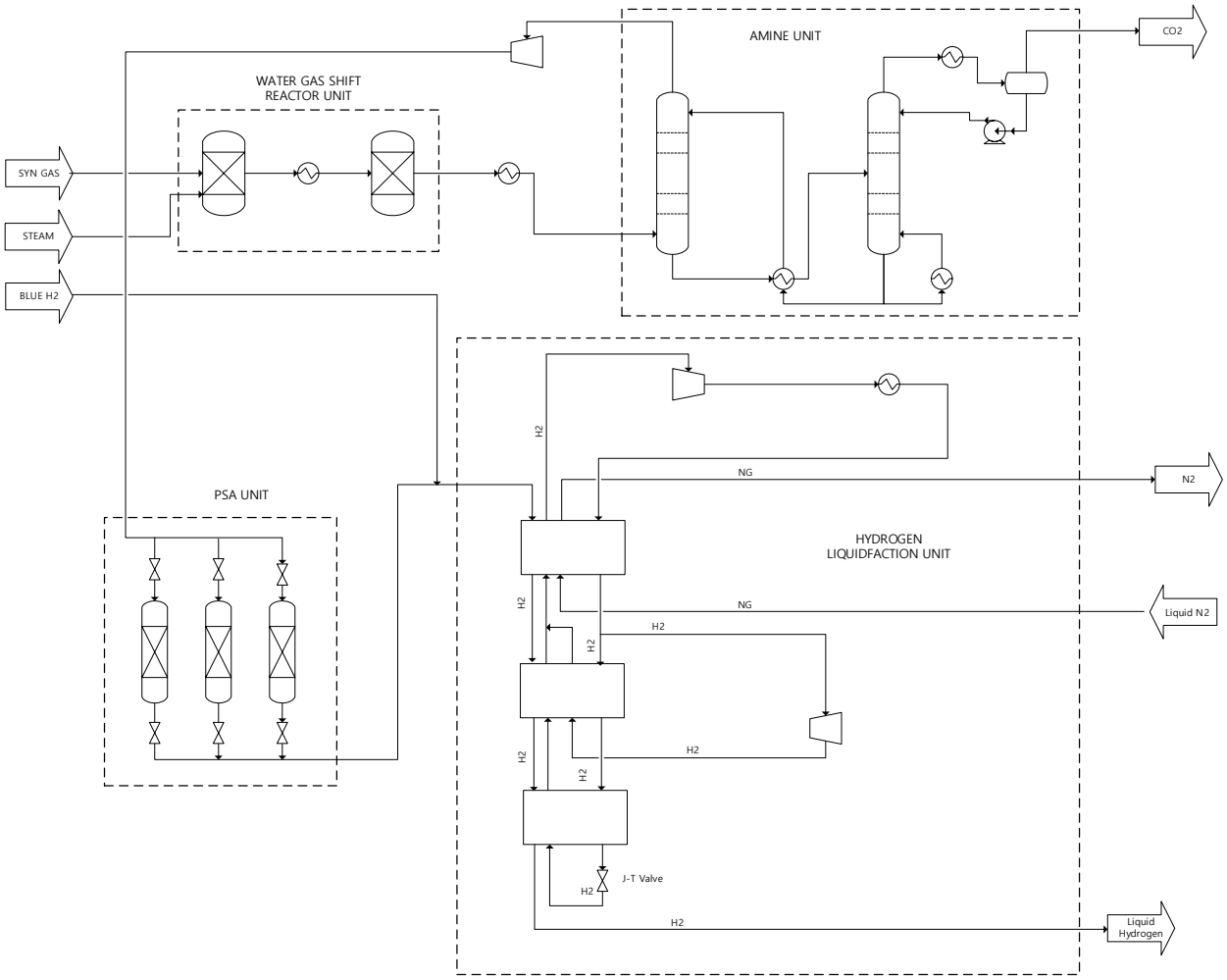
2.4 Available utilities

CW (supply/ return)	32 deg C / max. 42 deg C
Steam supply	15 bar(g) (saturated), 4 bar(g) (saturated)
BFW	80 deg C/ 1 bar(g)
Liquid N2 (supply/return)	-195 deg C @ 1.5bar(g) / above 10 deg C from dew point @ 1bar(g)

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

2.5 Process configuration:

The below process scheme is only for reference.



2.6 Water gas shift reactor

$CO + H_2O \leftrightarrow H_2 + CO_2$

1st reactor : Operating temperature : 400 deg C (Equilibrium Reaction)
2nd reactor : Operating temperature : 200 deg C (Equilibrium Reaction

Total conversion of CO is min. 98 mol% in 1st and 2nd reactor.

2.7 PSA (Pressure Swing Adsorption)

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.

2.8 Economic conditions:

Syngas price : 0.1 $/kg
Blue H2 price : 2 $/kg
Steam price : 9$/ton
99.5wt% MEA price : 1.5$/kg
Purge gas price : 0.1$/kg
Electricity price : 0.05 $/kwh
Circulated cooling water cost : 0.03 $/$m^3$
Liquid Nitrogen usage price : 0.05 $/ m^3
Annual operating hours: 8000 hrs

Note :

1) If the data you need is not in the information provided, make appropriate assumptions and use them.
2) Initial filling in closed loop system don't need to be considered for operating cost estimation.

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 liquefaction 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.

Applicants can draw it on major drawing software like Microsoft VISIO, Excel or AutoCAD. And simulation drawing also can be used for PFD.

Unit of measure should be metric

3.2 Process analysis

Description and analysis of your process should be required.

3.3 Economic analysis

Estimate annual operating cost for the H_2 liquefaction plant based on given information and your assumptions. Make sure that total investment cost is not required.
The final objective is to estimate the selling price of liquid hydrogen.