Innovative Ship and Offshore Plant Design

Part II. Offshore Plant Design

Ch. 1 Introduction to Offshore Plant Design

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Myung-Il Roh

Department of Naval Architecture and Ocean Engineering
Seoul National University

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Ch. 1 Introduction to Offshore Plant Design

Natural Gas (NG)

☑ **Natural Gas**

- **Hydrocarbon gas mixture consisting primarily of**
  for preventing environmental pollution ➡ Used for all fields of home, commerce, transportation, industry, etc.
- **Providing about ¼ of energy consumption of the world ➡ It will be continuously increased.**

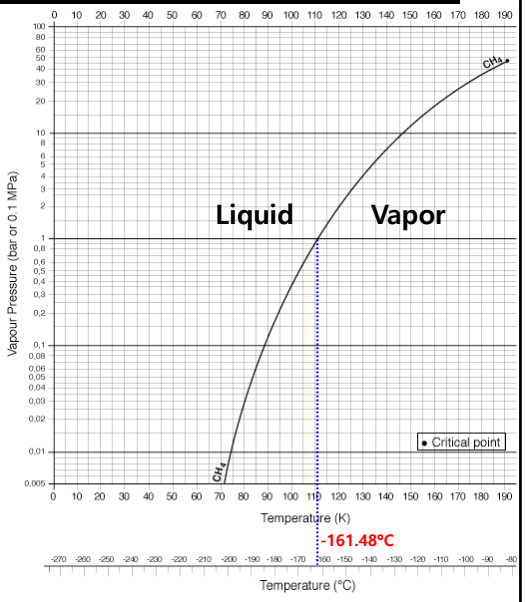
☑ **Special Features**

- **Liquefied at under atmospheric pressure ➡**
- **When liquefied, the volume becomes . ➡**

[Reference] Material Property of Natural Gas

Gas Properties

Molecular Weight	Molecular weight : 16.043 g/mol
Solid phase	Melting point : -182.46 °C Latent heat of fusion (1.013 bar, at melting point) : 58.682 kJ/kg
Liquid phase	Liquid density (1.013 bar at boiling point) : 422.36 kg/m^3 Liquid/gas equivalent (1.013 bar and 15 °C (59 °F)) : 621.4 vol/vol Boiling point (1.013 bar) : -161.48 °C Latent heat of vaporization (1.013 bar at boiling point) : 510.83 kJ/kg
Critical point	Critical temperature : -82.59 °C Critical pressure : 45.99 bar Critical density : 162.7 kg/m^3
Triple point	Triple point temperature : -182.46 °C Triple point pressure : 0.117 bar
Gaseous phase	Gas density (1.013 bar at boiling point) : 1.816 kg/m^3 Gas density (1.013 bar and 15 °C (59 °F)) : 0.6797 kg/m^3 Compressibility Factor (Z) (1.013 bar and 15 °C (59 °F)) : 0.99802 Specific gravity : 0.555 Specific volume (1.013 bar and 25 °C (77 °F)) : 1.5227 m^3/kg Heat capacity at constant pressure (Cp) (1.013 bar and 25 °C (77 °F)) : 0.0358 kJ/(mol.K) Heat capacity at constant volume (Cv) (1.013 bar and 25 °C (77 °F)) : 0.0274 kJ/(mol.K) Ratio of specific heats (Gamma:Cp/Cv) (1.013 bar and 25 °C (77 °F)) : 1.3062 Viscosity (1.013 bar and 0 °C (32 °F)) : 1.0245E-04 Poise Thermal conductivity (1.013 bar and 0 °C (32 °F)) : 30.57 mW/(m.K)
Miscellaneous	Solubility in water (1.013 bar and 2 °C (35.6 °F)) : 0.054 vol/vol Autoignition temperature : 595 °C

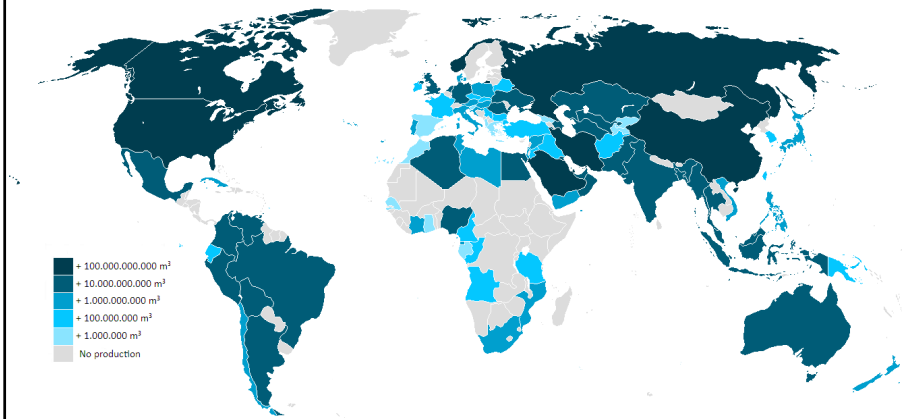


* Reference: http://encyclopedia.airliquide.com

Worldwide Reserves of Natural Gas (2014)

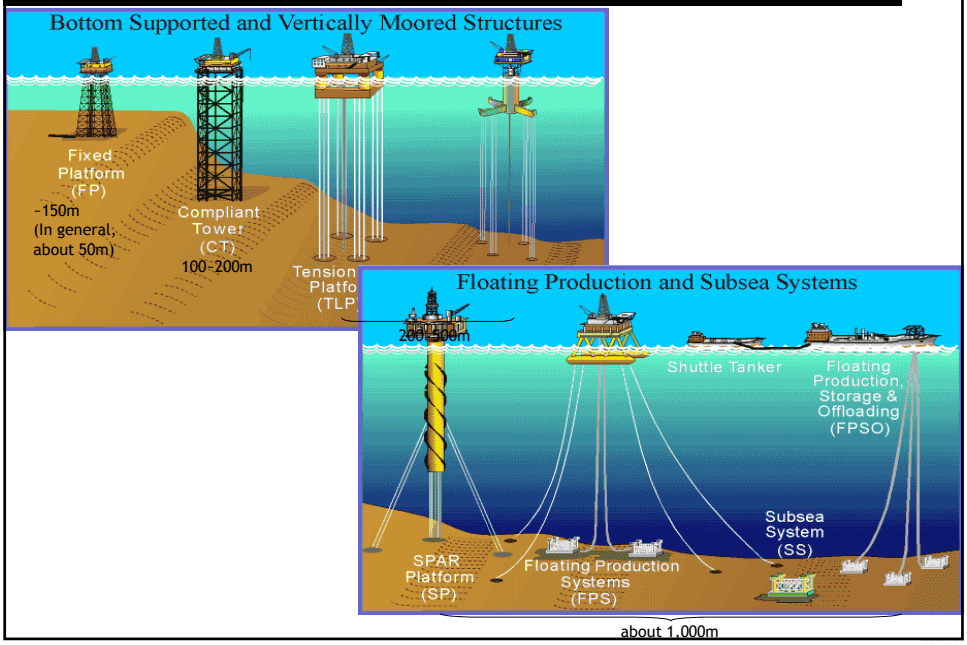
☑ The reserves are not biased to the Middle East and are

☑ The development field



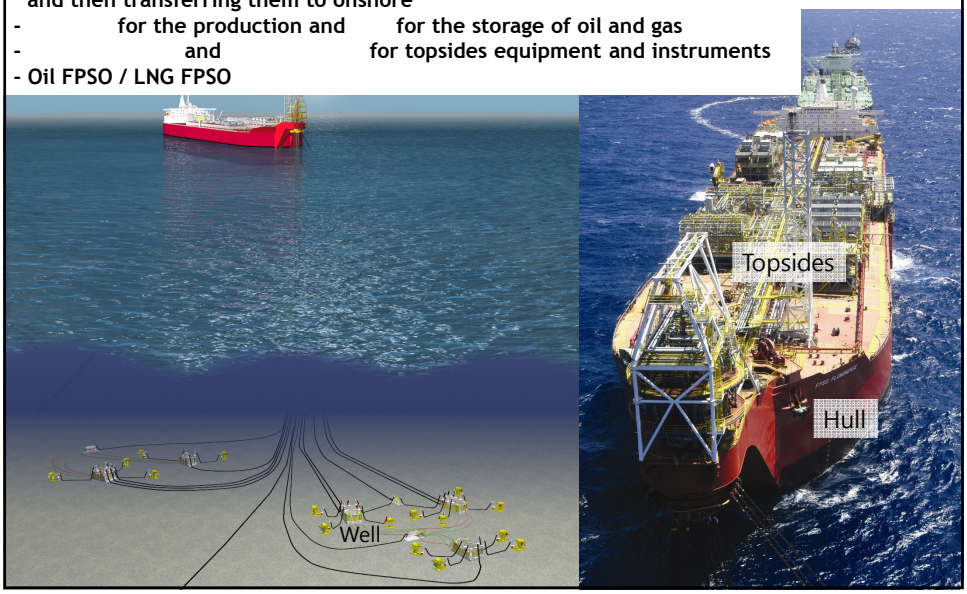
* Reference: http://en.wikipedia.org

Offshore Plants for Oil and Gas Development



Offshore Plant for the Development of Deep Sea

- Production plant for separating the well stream into oil, gas, and water and then transferring them to onshore
- for the production and for the storage of oil and gas
- and for topsides equipment and instruments
- Oil FPSO / LNG FPSO



Well Components

LNG	C1:CH_4	Condensate	C5:$CH_3(CH_2)_3CH_3$
	C2:CH_3CH_3		C6:$CH_3(CH_2)_4CH_3$
LPG	C3:$CH_3CH_2CH_3$	Oil	C7-
	C4:$CH_3(CH_2)_2CH_3$		

Well

Refining

Distillation & Fractionation

Gasoline C5~C10

Kerosene C10~C16

Light Oil C16~C20

Heavy Oil C20~C25

Asphalt

C25~C30

Pitch

Heavy Components

Refining

Refrigeration

LNG C1(CH_4)

NGL C2

LPG C3, C4

Condensate C5, C6

Light Components

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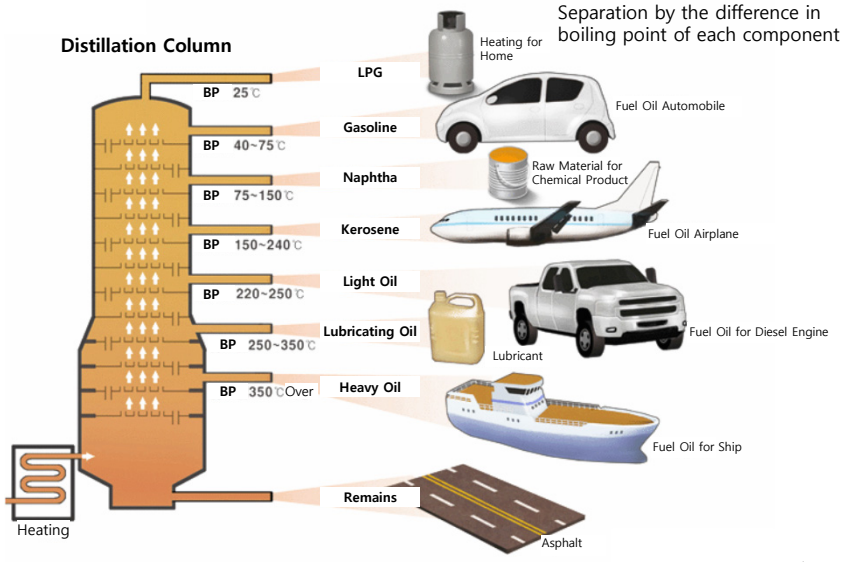
[Reference] Distillation and Fractionation of Oil

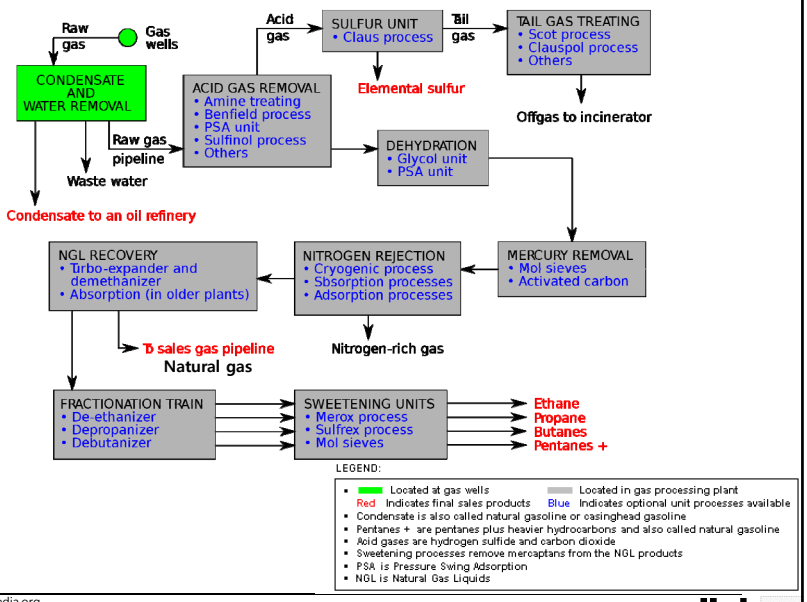
Separation by the difference in boiling point of each component



* BP: Boiling Point

* Reference: http://doopedia.co.kr

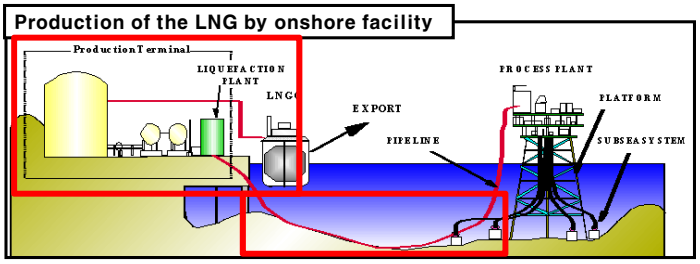
[Reference] Processing of Raw Natural Gas



* Reference: http://en.wikipedia.org

Concept of LNG FPSO( )

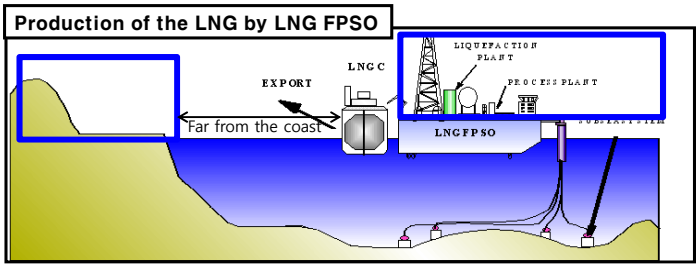
Production of the LNG by onshore facility



Natural gas from the offshore production site is transported by the pipe line to the onshore LNG plant where the NG is liquefied to the LNG.

The LNG FPSO is a having the , and turret system.

Production of the LNG by LNG FPSO



The natural gas is liquefied direct in the LNG FPSO.
➡ Onshore LNG plant and transport pipeline are not needed.

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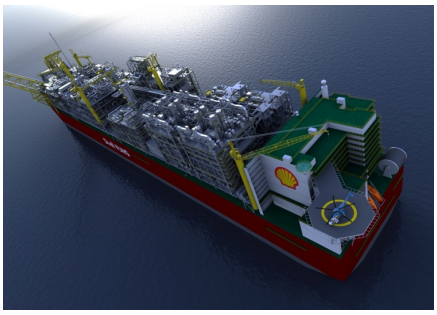
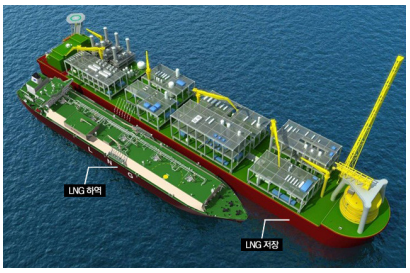
[Article] Shell decides to move forward with groundbreaking LNG FPSO.

The World's First LNG FPSO

Shell, the world's largest oil company, is now ready to start construction of what will be the world's first LNG FPSO, in a ship yard, Samsung heavy industry, in South Korea.



LNG FPSO cools down the temperature of the natural gas (NG) from 27°C to -162°C to shrink in volume by 600 times.



The for LNG is most important system of the LNG FPSO.

* MTPA: Million Ton Per Annual

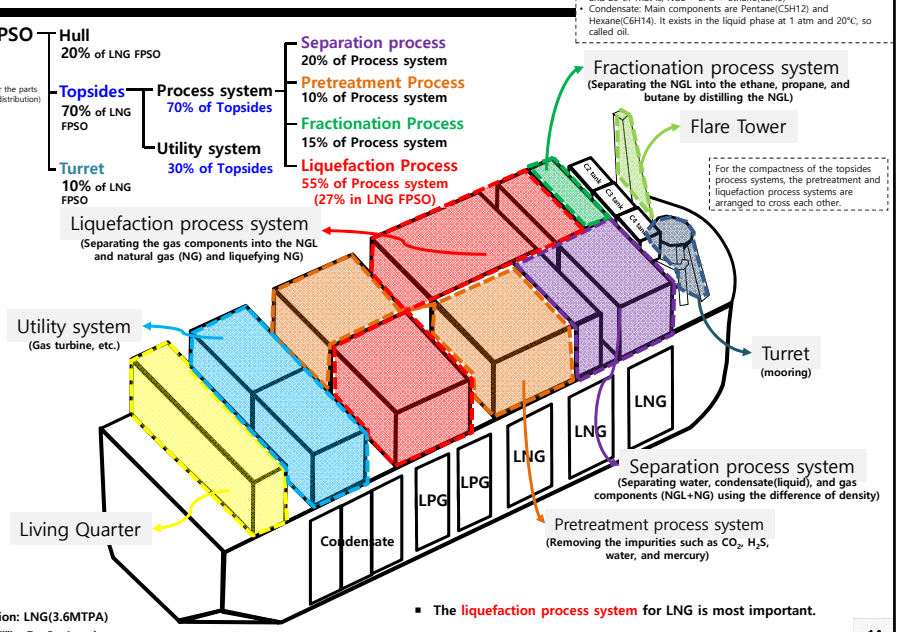
* Reference: [Article] Yonhapnews, Shell decides to move forward with groundbreaking floating LNG, 2011.5.20

Configuration of LNG FPSO

- NG(Natural Gas): Main component is methane(CH4).
- **LPG(Liquefied Petroleum Gas):** Main components are propane(C3H8) and butane(C4H10).
- NGL(Natural Gas Liquids): Main components are ethane(C2H6), propane(C3H8) and butane(C4H10). It exists in the gas phase at 1 atm and 20°C. That is, NGL = LPG + ethane(C2H6)
- Condensate: Main components are Pentane(C5H12) and Hexane(C6H14). It exists in the liquid phase at 1 atm and 20°C, so called oil.

LNG FPSO
- **Hull** 20% of LNG FPSO
- **Topsides** 70% of LNG FPSO
  - Process system 70% of Topsides
    - Separation process 20% of Process system
    - Pretreatment Process 10% of Process system
    - Fractionation Process 15% of Process system
    - Liquefaction Process 55% of Process system (27% in LNG FPSO)
  - Utility system 30% of Topsides
- **Turret** 10% of LNG FPSO

(Numbers under the parts mean the cost distribution)



- **Production: LNG(3.6MTPA)**
  - *** MTPA: Million Ton Per Annual**
- The liquefaction process system for LNG is most important.

Reference] [Article] Yonhapnews, Shell decides to move forward with groundbreaking floating LNG, 2011.5.20

Topsides Process System of LNG FPSO (1/3)

- NG(Natural Gas): Main component is methane(CH4).
- **LPG(Liquefied Petroleum Gas):** Main components are propane(C3H8) and butane(C4H10).
- NGL(Natural Gas Liquids): Main components are ethane(C2H6), propane(C3H8) and butane(C4H10). It exists in the gas phase at 1 atm and 20°C. That is, NGL = LPG + ethane(C2H6)
- Condensate: Main components are Pentane(C5H12) and Hexane(C6H14). It exists in the liquid phase at 1 atm and 20°C, so called oil.

: Condensate + NGL+ NG
: Condensate (C5~C6)
: NGL + NG

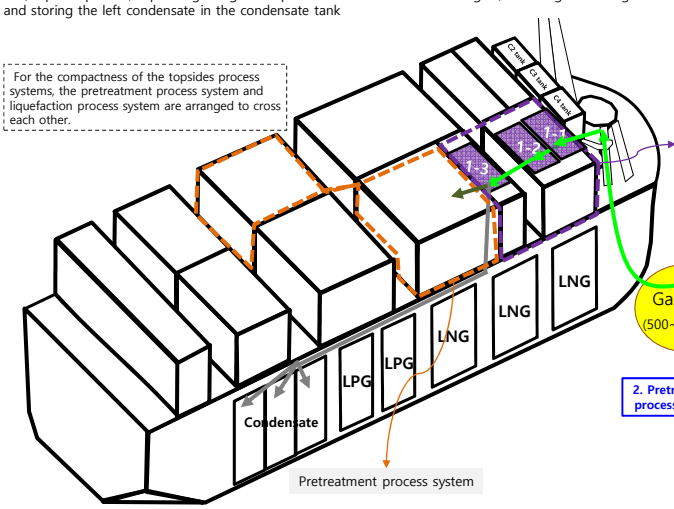
1. Separation process system

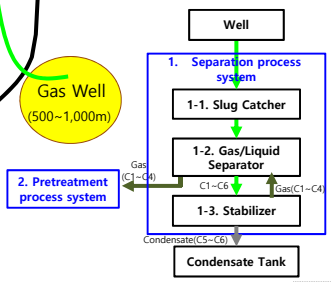
1-1. Slug Catcher: Stabilizing slug flow from gas well

1-2. Gas/Liquid Separator: Separating water, condensate (liquid), and gas components (NGL+NG) using the difference of density

1-3. Stabilizer: Since a part of gas components is not separated from the condensate completely in the Gas/Liquid separator, separating the gas components from the condensate again, returning it to the gas flow and storing the left condensate in the condensate tank

For the compactness of the topsides process systems, the pretreatment process system and liquefaction process system are arranged to cross each other.





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Topsides Process System of LNG FPSO (2/3)

- NG(Natural Gas): Main component is methane(CH4).
- **LPG(Liquefied Petroleum Gas):** Main components are propane(C3H8) and butane(C4H10).
- NGL(Natural Gas Liquids): Main components are ethane(C2H6), propane(C3H8) and butane(C4H10). It exists in the gas phase at 1 atm and 20°C. That is, NGL = LPG + ethane(C2H6)
- Condensate: Main components are Pentane(C5H12) and Hexane(C6H14). It exists in the liquid phase at 1 atm and 20°C, so called oil.

: Condensate + NGL+ NG
: Condensate (C5~C6)
: NGL + NG
: CO_2

2. Pretreatment process system

2-1. Acid Gas Removal System: Removing the acid gases (H_2S, CO_2) which are corrosive to materials and toxic to human being

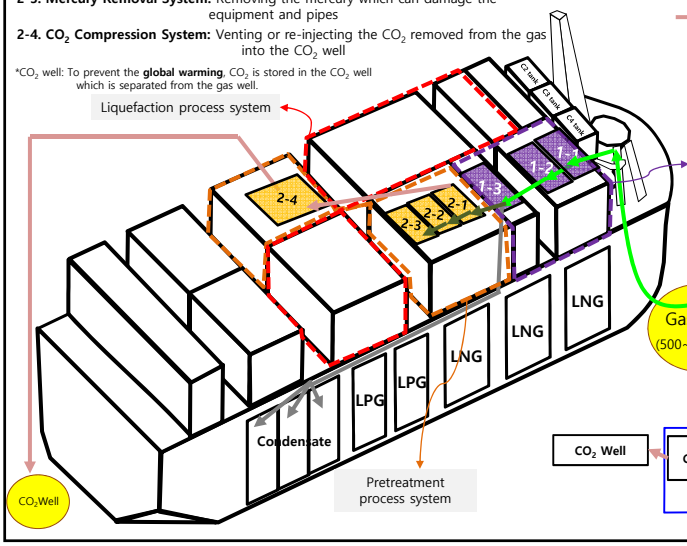
2-2. Dehydrate System: Removing the water which can forms the ice

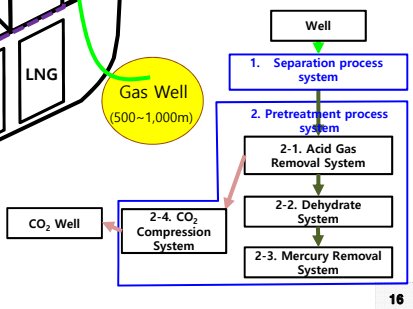
2-3. Mercury Removal System: Removing the mercury which can damage the equipment and pipes

2-4. CO_2 Compression System: Venting or re-injecting the CO_2 removed from the gas into the CO_2 well

*CO_2 well: To prevent the **global warming**, CO_2 is stored in the CO_2 well which is separated from the gas well.

Liquefaction process system





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Topsides Process System of LNG FPSO (3/3)

- NG(Natural Gas): Main component is methane(CH4).
- **LPG(Liquefied Petroleum Gas):** Main components are propane(C3H8) and butane(C4H10).
- NGL(Natural Gas Liquids): Main components are ethane(C2H6), propane(C3H8) and butane(C4H10). It exists in the gas phase at 1 atm and 20°C. That is, NGL = LPG + ethane(C2H6)
- Condensate: Main components are Pentane(C5H12) and Hexane(C6H14). It exists in the liquid phase at 1 atm and 20°C, so called oil.

3. Fractionation process system

3.1 Ethane Distillation System: Separating NGL into the ethane and LPG and using it as the refrigerant in the liquefaction system. Some of LPG is stored in the LPG tank and the rest goes to Propane Distillation system

3.2 Propane Distillation System: Separating LPG into the propane (C3) and butane (C4) by distilling them which are used as the refrigerant in the liquefaction system

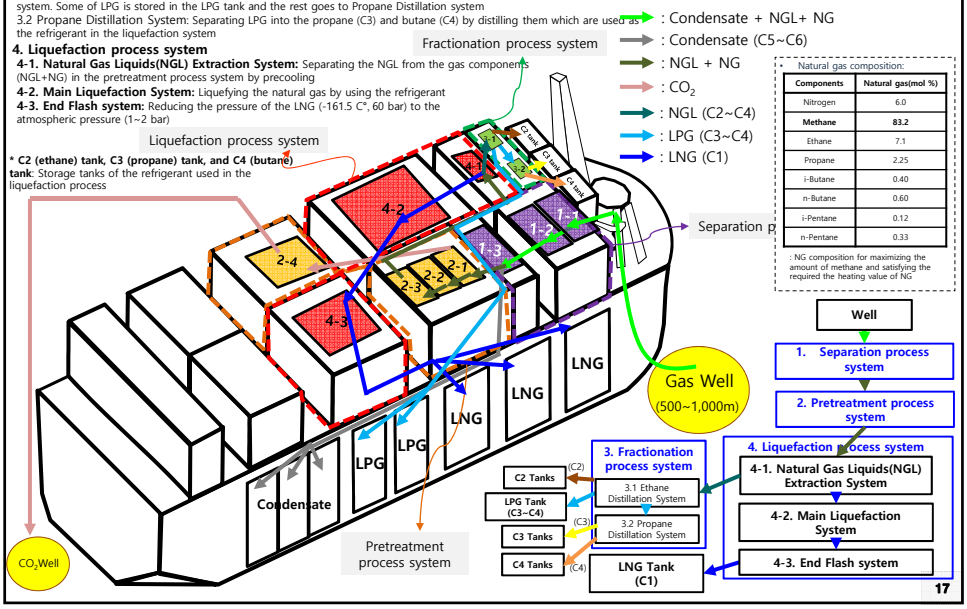
4. Liquefaction process system

4-1. Natural Gas Liquids(NGL) Extraction System: Separating the NGL from the gas components (NGL+NG) in the pretreatment process system by precooling

4-2. Main Liquefaction System: Liquefying the natural gas by using the refrigerant

4-3. End Flash system: Reducing the pressure of the LNG (-161.5 C°, 60 bar) to the atmospheric pressure (1~2 bar)

* **C2 (ethane) tank, C3 (propane) tank, and C4 (butane) tank**: Storage tanks of the refrigerant used in the liquefaction process



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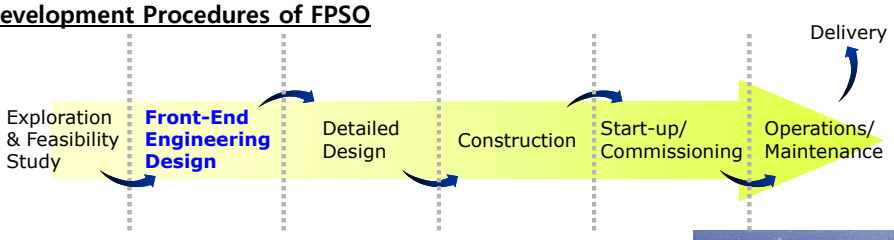
Development Procedures of FPSO and Importance of FEED

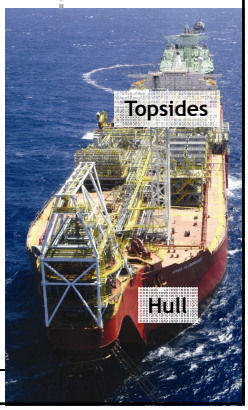
Development Procedures of FPSO



☑ **Topsides FEED(Initial or Basic Design):** by determining specifications of all systems according to owner's requirements

☑ **Our shipyards only take charge of after detailed design or production.**

☑ **In the case of topsides FEED, they are dependent on foreign design companies with about 10~20M$ per offshore plant.**



Procedures of Topsides Process FEED of Offshore Plant