Lecture Note of Design Theory of Ships and Offshore Structures

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Ch. 1 Introduction to Design of Ships and Offshore Structures

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Contents

Ch. 1 Introduction to Design of Ships and Offshore Structures
Ch. 2 Design Equations
Ch. 3 Design Model
Ch. 4 Deadweight Carrier and Volume Carrier
Ch. 5 Freeboard Calculation
Ch. 6 Resistance Prediction
Ch. 7 Propeller Design and Main Engine Selection
Ch. 8 Hull Form Design
Ch. 9 General Arrangement Design
Ch. 10 Structural Design
Ch. 11 Outfitting Design

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Ch. 1 Introduction to Design of Ship and Offshore Structure

1. Basic Functions of a Ship
2. Main Terminology
3. Comparisons of a Ship with Other Structures
4. Construction Procedure of a Ship

3. 선박과 다른 구조물의 비교

4. 선박의 건조 절차

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Ship Design

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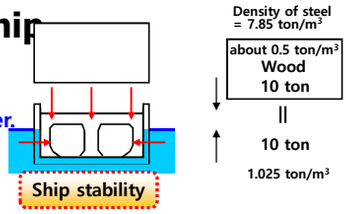
1. Basic Functions of a Ship

1. 선박의 기본 기능

Basic Requirements of a Ship



(1) The ship should float and be stable in seawater.

➡ **Weight of the ship is equal to the buoyancy* in static equilibrium.**

Ship stability

(2) The ship should transport cargoes.

Ship compartment design

➡ **The inner space should be large enough to store the cargoes.**

선박 내부 공간은 화물을 저장할 수 있을 만큼 충분히 커야 한다.

(3) The ship should move fast to the destination and be possible to control itself.

Hull form design, Ship hydrodynamics, Propeller design, Ship maneuverability and control

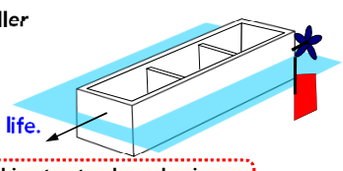
(3) 선박은 목적지까지 빠르게 이동해야 한다 그리고 스스로 제어할 수 있어야 한다.

➡ **Shape: It should be made to maintain resistance (e.g., streamlined shape).**

형상: 저항을 줄이도록 설계되어야 한다(예: 유선형).

➡ **Propulsion equipment: Diesel engine, Helical propeller**

➡ **Steering equipment: Steering gear, Rudder**



(4) The ship should be strong enough throughout her life.

➡ **It is made of a welded structure of steel plates (about 10-30 mm thickness) and stiffeners.**

Ship structural mechanics, Structural design & analysis

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* Archimedes' Principle: The buoyancy of the floating body is equal to the weight of the fluid that is displaced by the ship.

6

물에 떠 있음(부양성)

Basic Functions of a Ship

▪ Floating in the water (부양성)

물 위에 떠 있기(부양성)

- **Static equilibrium**

정적 평형

▪ Containing like a strong bowl (적재성)

강한 그릇처럼 담기(적재성)

- **Welded structure of plates (thickness of about 20-30 mm), stiffeners, and brackets**

두께 약 20~30 mm인 판재, 보강재 및 브래킷의 용접 구조

- **A VLCC has a lightweight of about 45,000 tons and can carry crude oil of about 300,000 tons.**

VLCC의 경하중량은 약 45,000톤이며, 약 300,000톤의 원유를 운송할 수 있다.

▪ Going fast on the water (이동성)

물 위를 빠르게 이동하기(이동성)

- **Hull form: Streamlined shape having small resistance**

선형: 저항이 작은 유선형 형상

- **Propulsion: Diesel engine, Helical propeller**

추진: 디젤 엔진, 나선형 프로펠러

- **The speed of a ship is represented in knots. 1 knot is a speed that can go 1 nautical mile (1,852 m) in 1 hour.**

선박의 속도는 노트로 표시한다. 1노트는 1시간에 1해리(1,852 m)를 이동할 수 있는 속도이다.

- **A ship has less motion for the comfort and safe of passengers and cargo.**

승객과 화물의 편안함과 안전을 위해 선박은 운동이 적다.

- **Maneuvering equipment: Rudder**

조종 장치: 방향타

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7

How Does a Ship Float? (1/3)

▪ The force that enables a ship to float ➡ "Buoyant Force"

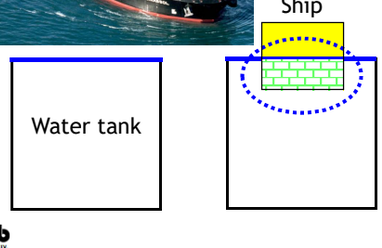
선박을 뜨게 하는 힘 "부력"

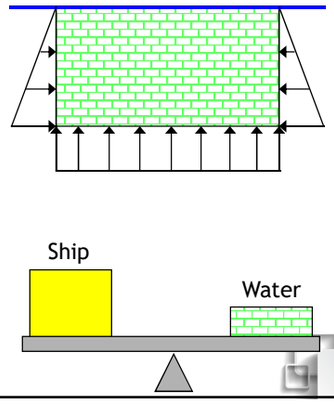
- **It is directed upward.**

이 힘은 위쪽으로 작용한다.

- **It has a magnitude equal to the weight of the fluid that is displaced by the ship.**

그 크기는 선박이 밀어낸 유체의 중량과 같다.





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How Does a Ship Float? (2/3)

- **Archimedes' Principle**

아르키메데스의 원리

- **The magnitude of the buoyant force acting on a floating body in the fluid is equal to the weight of the fluid that is displaced by the floating body.**

유체 속 부유체에 작용하는 부력의 크기는 부유체가 밀어낸 유체의 중량과 같다.

- **The direction of the buoyant force is opposite to the gravitational force.**

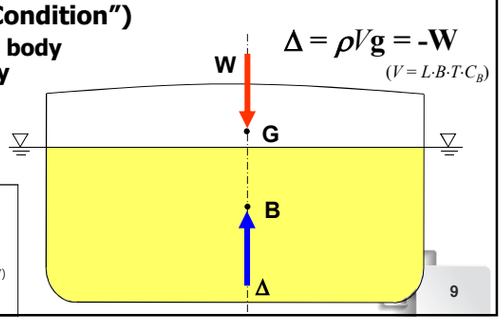
부력의 방향은 중력과 반대이다.

Buoyant force of a floating body
= the weight of the fluid which is displaced by the floating body ("Displacement")
➡ Archimedes' Principle

- **Equilibrium State ("Floating Condition")**
  - **Buoyant force of the floating body = Weight of the floating body**

$$\Delta = \rho V \mathbf{g} = \mathbf{-W} \qquad (V = L \cdot B \cdot T \cdot C_B)$$

∴ Displacement = Weight



G: Center of gravity
B: Center of buoyancy
W: Weight, **Δ**: Displacement
ρ: Density of fluid
g: Gravitational acceleration
V: Submerged volume (Displacement volume, ∇)
L: Length, B: Breadth, T: Draft
C_B: Block coefficient

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평형 상태("부유 조건") 부유체의 부력 = Vg = -W = 부유체의 중량 W (V = L B T CB) 배수량 = 중량

How Does a Ship Float? (3/3)

- **Displacement (Δ) = Buoyant Force = Weight (W)**

배수량 ( ) = 부력 = 중량 (W)

$$\Delta \cdot (g) = L \cdot B \cdot T \cdot C_B \cdot \rho \cdot (g)$$
$$= W \cdot (g) = (LWT + DWT) \cdot (g)$$

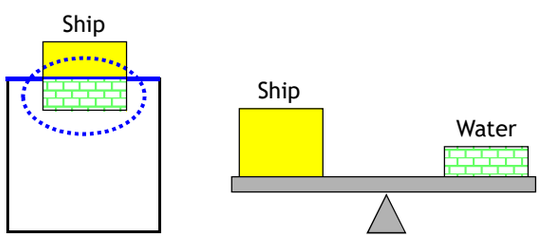
T: Draft
C_B: Block coefficient
ρ: Density of seawater
g: Gravitational acceleration
LWT: Lightweight
DWT: Deadweight

T: 흘수 CB: 방형계수 : 해수의 밀도

g: 중력가속도 LWT: 경하중량 DWT: 재화중량

- **Weight = Ship weight (Lightweight) + Cargo weight (Deadweight)**

중량 = 선박 중량(경하중량) + 화물 중량(재화중량)



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10

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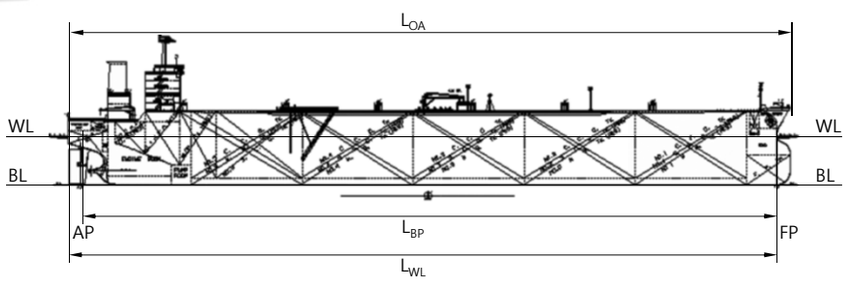
2. Main Terminology

2. 주요 용어

Principal Dimensions (1/2)



- **L_{OA} (Length Over All) [m]: Maximum length of the ship**

LOA (Length Over All) [m]: 선박의 최대 길이

- **L_{BP} (Length Between Perpendiculars (AP and FP)) [m]: Length between AP and FP**

LBP (Length Between Perpendiculars (AP and FP)) [m]: AP와 FP 사이의 길이

  - **AP: After perpendicular (normally, the center line of the rudder stock)**
  - **FP: Intersection line between the designed draft and the fore side of the stem, which is perpendicular to the baseline**

AP: 후부 수선(일반적으로 방향타 축의 중심선) FP: 기준선에 수직인, 설계 흘수선과 선수재 전면의 교선

- **L_{WL} (Length of WaterLine) [m]: The length of a ship at the level where it sits in the water. Basis of resistance calculation**

LWL (Length of WaterLine) [m]: 선박이 물에 잠겨 있는 수면 높이에서의 길이. 저항 계산의 기준이 된다

- **L_f (Freeboard Length) [m]: Basis of freeboard assignment, damage stability calculation**

Lf (Freeboard Length) [m]: 건현 지정 및 손상 복원성 계산의 기준이 된다

  - **96% of L_{WL} at 0.85D or L_{BP} at 0.85D, whichever is greater**

0.85D에서의 LWL의 96% 또는 0.85D에서의 LBP 중 더 큰 값

- **L_s or Rule Length (Scantling Length) [m]: Basis of structural design and equipment selection**
  - **Intermediate one among 0.96 L_{WL} at T_s, 0.97 L_{WL} at T_s, or L_{BP} at T_s**

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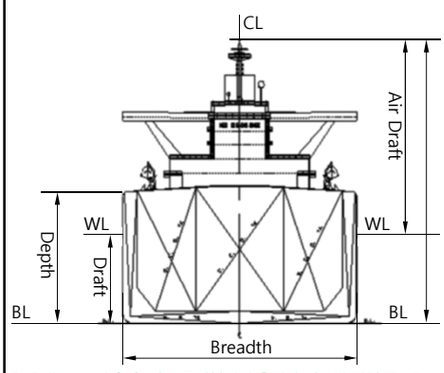
Ls 또는 규정 길이(치수 산정 길이) [m]: 구조 설계 및 장비 선정의 기준이 된다 0.96 LWL(Ts), 0.97 LWL(Ts), LBP(Ts) 중 중간값

Principal Dimensions (2/2)



- **B (Breadth) [m]: Maximum breadth of the ship, measured amidships**
  - **B_{molded}: excluding shell plate thickness**
  - **$B_{extreme}$: including shell plate thickness**
- **D (Depth) [m]: Distance from the baseline to the deck side line**
  - **D_{molded}: excluding keel plate thickness**
  - **$D_{extreme}$: including keel plate thickness**
- **T_d (Designed Draft) [m]: Main operating draft**
  - **In general, the basis of the ship's deadweight and speed/power performance**
- **T_s (Scantling Draft) [m]: Basis of structural design**

CL B (Breadth) [m]: 선박 중앙부에서 측정한 선박의 최대 폭 - Bmolded: 외판 두께 제외□- Bextreme: 외판 두께 포함 D (Depth) [m]: 기준선에서 갑판 측선까지의 거리 - Dmolded: 용골판 두께 제외□- Dextreme: 용골판 두께 포함 WL WL Td (Designed Draft) [m]: 주요 운항 흘수□- 일반적으로 선박의 재화중량 및 속도·출력 성능의 기준이 된다 BL BL Ts (Scantling Draft) [m]: 구조 설계의 기준 설계

- **Air Draft [m]: Distance (height above waterline only or including operating draft) restricted by the port facilities, navigating route, etc.**

공기 흘수 [m]: 항만 시설, 항로 등에 의해 제한되는 거리(수선 위 높이만 고려하거나 운항 흘수를 포함함)

- **Air draft from baseline to the top of the mast**
- **Air draft from waterline to the top of the mast**
- **Air draft from waterline to the top of the hatch cover**

- 기준선에서 마스트 상단까지의 공기 흘수□- 수선에서 마스트 상단까지의 공기 흘수□- 수선에서 해치 커버 상단까지의 공기 흘수

- **…**

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13

…

What is a "Hull form"?

- **Hull form**

선형

- **Outer shape of the hull that is streamlined in order to satisfy the requirements of a ship owner, such as deadweight, ship speed, and so on**

재화중량, 선속 등 선주의 요구 사항을 충족하도록 유선형으로 만든 선체의 외형

- **Like the skin of a human**

사람의 피부와 같다

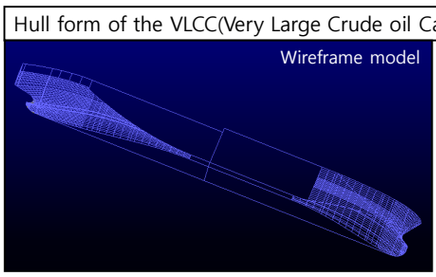
- **Hull form design**

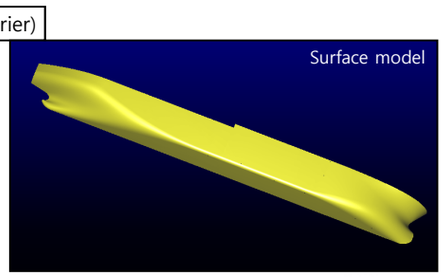
선형을 설계하는 설계 작업

- **Design task that designs the hull form**

선형 설계 작업

Hull form of the VLCC(Very Large Crude oil Carrier)





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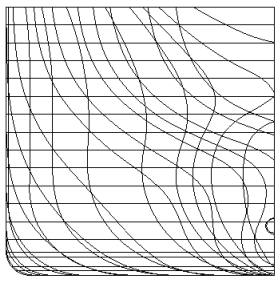
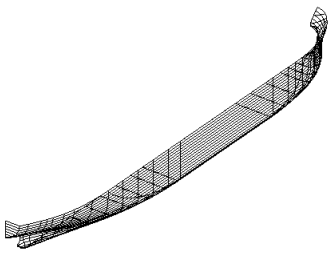
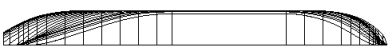
14

Lines of a 320K VLCC

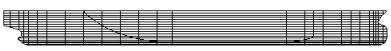




Body Plan



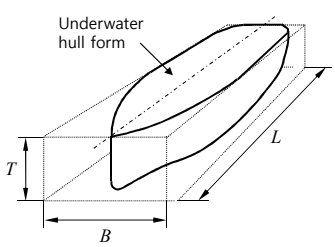
Water Plan



Sheer Plan

15

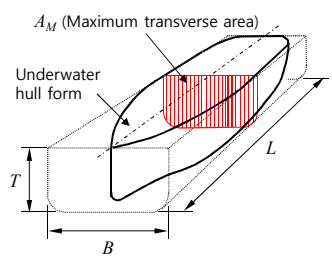
Hull Form Coefficients (1/2)



- C_B (Block Coefficient)
  - = Displacement Volume/(L x B x T)
  - = Displacement/(L x B x T x Density)

  where, density of seawater = 1.025 [ton/m^3]

수중 CB (방형계수) = 배수량 체적/(L x B x T) = 배수량/(L x B x T x 밀도) 여기서, 해수의 밀도 = 1.025 [ton/m3]



- C_M (Midship Section Coefficient)
  - = A_M/(B x T)
- C_P (Prismatic Coefficient)
  - = Displacement Volume/(A_M x L)
  - = Displacement/(A_M x L x Density)

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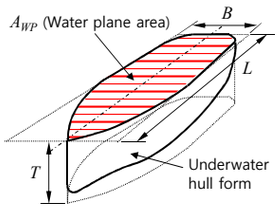
16

Hull Form Coefficients (2/2)



- C_{WP} (Water Plane Area Coefficient)
  = A_{WP}/(L x B)

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What is a "Compartment"?

- **Compartment**

구획

- **Space to load cargoes in the ship**

선박에서 화물을 적재하는 공간

- **It is divided by a bulkhead, which is the diaphragm or peritoneum of a human.**

이는 인간의 횡격막 또는 복막에 해당하는 격벽으로 나뉜다.

- **Compartment design (General arrangement design)**

구획 설계(일반 배치 설계)

- **Compartment modeling + Ship calculation**

구획 모델링 + 선박 계산

- **Compartment modeling**

구획 모델링

- **Design a task that divides the interior parts of a hull form into a number of compartments**

선형 내부를 여러 구획으로 나누는 설계 작업

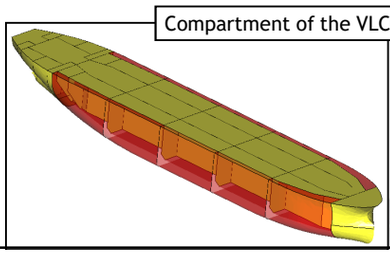
- **Ship calculation (Naval architecture calculation)**

선박 계산(선박공학 계산)

- **Design task that evaluates whether the ship satisfies the required cargo capacity by a ship owner and, at the same time, the international regulations related to stability, such as MARPOL and SOLAS, or not**

선주가 요구한 화물 적재 능력을 선박이 충족하는지 평가하는 동시에, MARPOL 및 SOLAS와 같은 복원성 관련 국제 규정을 충족하는지를 평가하는 설계 작업

Compartment of the VLCC



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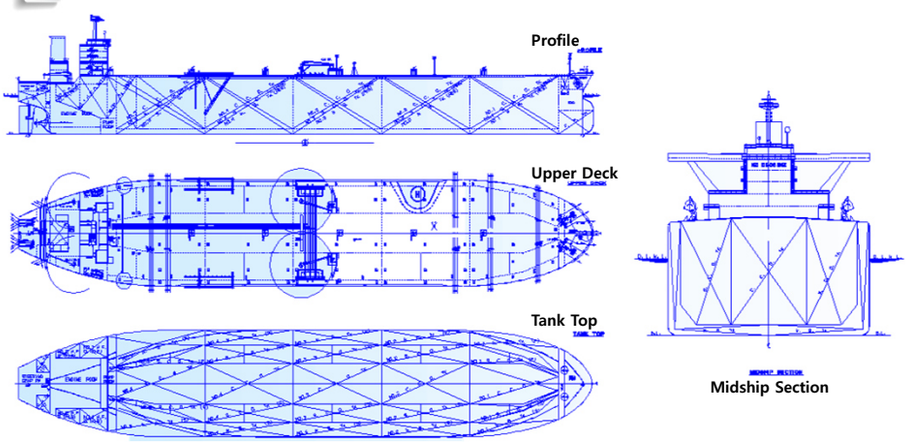
G/A of a 320K VLCC



Principal Dimensions	
LOA	332.0 m
LBP	320.0 m
B	60.0 m
D	30.5 m
Td/Ts	21.0/22.5 m
Deadweight at Ts	320,000 tons
Service speed at Td at NCR with 15% sea margin	16.0 knots

Capacities	
Cargo tank	357,000 m^3
Water ballast	101,500 m^3

Main Engine SULZER 7RTA84T-D	
MCR	39,060 PS x 76.0 rpm
NCR	35,150 PS x 73.4 rpm
No. of cargo segregation	Three (3)
Cruising range	26,500 NM

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19

LOA 332.0 m 화물 탱크 357,000 m3 LBP 320.0 m 물 밸러스트 101,500 m3 B 60.0 m D 30.5 m 주기관 SULZER 7RTA84T-D Td/Ts 21.0/22.5 m MCR 39,060 PS × 76.0 rpm Ts에서의 재화중량 320,000톤 NCR 35,150 PS × 73.4 rpm Td에서의 서비스 속도 16.0노트 수. 화물 분리 수 3개 (3) NCR에서 해상 여유 15% 조건의 항속 거리 26,500 NM

What is a "Hull Structure"?

- **Hull structure**

선체 구조

  - **Frame of a ship comprising a number of hull structural parts such as plates, stiffeners, brackets, and so on**

판, 보강재, 브래킷 등 여러 선체 구조 부재로 구성된 선박의 골격

  - **Like a skeleton of a human**

인간의 골격과 같다

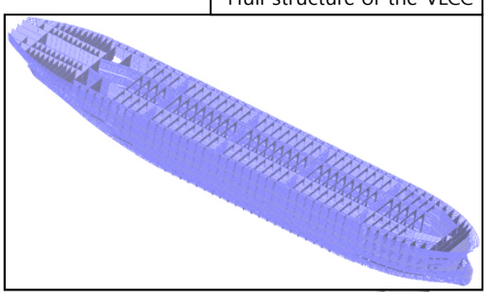
- **Hull structural design**

선체 구조 부재의 크기, 재료 등을 결정하는 구조 설계 업무

  - **Design task that determines the specifications of the hull structural parts, such as the size, material, and so on**

320K VLCC의 구조 도면

Hull structure of the VLCC



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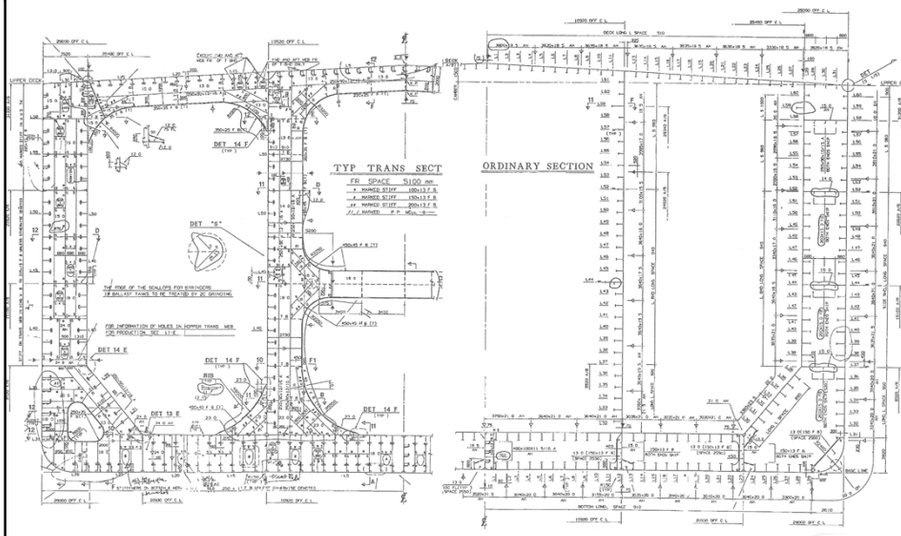
20

Structural Drawing of a 320K VLCC

320K VLCC의 구조도



Web Frame Drawing

Midship Section (Ordinary Frame Section) Drawing

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21

What is a "Outfitting"?

- **Outfitting**

의장

- **All equipment and instruments required for showing all functions of the ship**

선박의 모든 기능을 구현하는 데 필요한 모든 장비와 계기

  - **Hull outfitting: Propeller, rudder, anchor/mooring equipment, etc.**

선체 의장: 프로펠러, 방향타, 앵커/계류 장비 등

  - **Machinery outfitting: Equipment, pipes, ducts, etc. in the engine room**

기관 의장: 기관실의 장비, 배관, 덕트 등

  - **Accommodation outfitting: Deck house (accommodation), voyage equipment, etc.**

거주구 의장: 데크하우스(거주구), 항해 장비 등

  - **Electric outfitting: Power, lighting, cables, and so on**

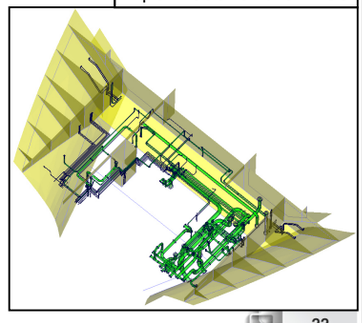
전기 의장: 전원, 조명, 케이블 등

- **Like internal organs or blood vessels of a human**

인체의 내부 장기나 혈관과 같다

- **Outfitting design**
  - **Design task that determines the types, numbers, and specifications of outfitting**

Pipe model of the VLCC



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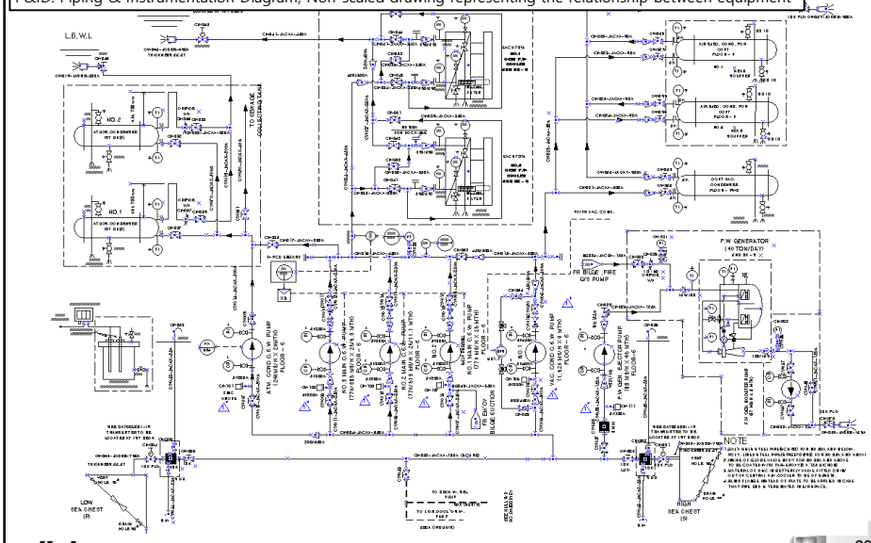
22

의장 설계 의장의 종류, VLCC의 배관 모델 수 및 사양을 결정하는 설계 작업

P&ID of a 320K VLCC

P&ID: Piping & Instrumentation Diagram, Non-scaled drawing representing the relationship between equipment



Criteria for the Size of a Ship

▪ Displacement

배수량

- **Weight of water displaced by the ship's submerged part**

선박의 잠긴 부분이 배제한 물의 중량

- **Equal to the total weight of the ship**
- **Used when representing the size of naval ships**

선박 전체 중량과 같다 * F.O.: 연료유 군함의 크기를 나타낼 때 사용한다 * D.O.: 경유

* L.O.: 윤활유 * F.W.: 담수

* F.O.: Fuel Oil
* D.O.: Diesel Oil
* L.O.: Lubricating Oil

* F.W.: Fresh Water

▪ Deadweight

재화중량

- **Total weight of cargo. Actually, Cargo payload + Consumables (F.O., D.O., L.O., F.W., etc.) + DWT Constant**

화물의 총중량이다. 실제로는 화물 적재량 + 소모품(F.O., D.O., L.O., F.W. 등) + DWT 상수로 구성된다

- **Used when representing the size of commercial ships (tanker, bulk carrier, ore carrier, etc.)**

상선(탱커, 벌크선, 광석 운반선 등)의 크기를 나타낼 때 사용한다

▪ Tonnage

톤수

- **Total volume of the ship**

선박의 총용적

- **Basis for statistics, tax, etc.**

통계, 세금 등의 기준

- **Used when representing the size of passenger ships**

여객선의 크기를 나타낼 때 사용한다

Tonnage

- **Tonnage: normally, 100 ft^3 (= 2.83 m^3) = 1 ton**

톤수: 일반적으로 100 ft3 (= 2.83 m3) = 1톤

- **Basis of various fees and taxes**

각종 수수료와 세금의 산정 기준

- **GT (Gross Tonnage): Total sum of the volumes of every enclosed space**

GT (총톤수): 모든 폐쇄된 공간의 용적 총합

- **NT (Net Tonnage): Total sum of the volumes of every cargo space**

NT (순톤수): 모든 화물 공간의 용적 총합

  - **GT and NT should be calculated in accordance with "IMO 1969 Tonnage Measurement Regulation."**

GT와 NT는 "IMO 1969 Tonnage Measurement Regulation"에 따라 계산해야 한다.

- **CGT (Compensated Gross Tonnage)**

CGT (보정 총톤수)

- **The Panama and Suez Canals have their own tonnage regulations.**

Panama 운하와 Suez 운하는 자체적인 톤수 규정을 적용한다.

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25

[Reference] Old Conversion Factor between GT and CGT

船種 \ 船型(DWT)	100–4,000	4,000–10,000	10,000–30,000		30,000–50,000	50,000–80,000	80,000–160,000	160,000–250,000	250,000 이상	비 고
Crude oil carrier	1.70	1.15	0.75		0.60	0.50	0.40	0.30	0.25	Single hull tanker
	1.85	1.30	0.85		0.70	0.55	0.45	0.35	0.30	Double hull tanker
Product carriers & Chemical carriers	2.30	1.60	1.05		0.80	0.60	0.55			Black product carrier White product carrier
Bulk C+arriers	1.60	1.10	0.70		0.60	0.50	0.40	0.30		Chip carrier, Lumber Carrier, Car/bulk, Bulk/container, Open bulk
Combined carriers	1.60	1.10	0.90		0.75	0.60	0.50	0.40		Ore/bulk/oil
General Cargo Ships	1.85	1.35	1.00		0.75	0.60	0.50	0.40		Semi–container, Multi–purpose cargo
Reefers	2.05	1.50	1.25							
Full container ships	1.85	1.20	10,000–20,000	20,000–30,000	0.75	0.65				
			0.90	0.80						
Ro–Ro vessels	1.50	1.05	0.80	0.70	0.65					
Car carriers	1.10	0.75	0.65	0.55	0.45					Ro–Ro/Container
L.P.G. carriers	2.05	1.60	1.15	0.90	0.80	0.70				
L.N.G. carriers	2.05	1.60	1.25	1.15	1.00	0.75				

船種 \ 船型(GT)	100–1,000	1,000–3,000	3,000–10,000	10,000–20,000	20,000–40,000	40,000–60,000	60,000 이 상	비 고
Ferries	3.00	2.25	1.65	1.15	0.90			
Passenger ships	6.00	4.00	3.00	2.00	1.60	1.40	1.25	
Fishing vessels	4.00	3.00	2.00					Fishing vessel & Fish factory ship
Other non–cargo vessels	5.00	3.20	2.00	1.50				Tug & Supply vessel, Dredger, Ice breaker, Cable layer, Research ship, etc

註 : 100GT 이상 선박

26

[Reference] New Conversion Factor between GT and CGT

[참고] GT와 CGT 간 새로운 환산 계수

- **The previous method was based on CGT coefficients, depending on the type and deadweight of ships.**

기존 방법은 선박의 종류와 재화중량에 따라 달라지는 CGT 계수에 기반하였다.

- **The new method is based on a formula.**

새로운 방법은 공식에 기반한다.

- **Instead of deadweight as a base for the choice of the coefficients,**

계수 선택의 기준으로 재화중량을 사용하는 대신,

the method is based on gross tonnage.

$$CGT = A \cdot GT^{B}$$

where,
GT: Declared gross tonnage of the ship
A: Factor representing the influence of ship type
B: Factor representing the influence of ship size

Ship Type	A	B
Oil Tanker (double hull)	48	0.57
Chemical Tankers	84	0.55
Bulk Carriers	29	0.61
Combined Carriers	33	0.62
General Cargo	27	0.64
Reefers	27	0.68
Full Container	19	0.68
RO-RO Ships	32	0.63
Car Carriers	15	0.70
LPG Carriers	62	0.57
LNG Carriers	32	0.68
Ferries	20	0.71
Passenger Ships	49	0.67
Fishing Ships	24	0.71
NCCV	46	0.62

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27

Weight and COG (Center Of Gravity)

중량 및 COG(무게중심)

- **Displacement [ton]**

배수량 [ton]

- **Weight of water displaced by the ship's submerged part**

선박의 잠긴 부분이 밀어낸 물의 중량

- **Deadweight (DWT) [ton]: Cargo payload + Consumables (F.O., D.O., L.O., F.W., etc.) + DWT Constant = Displacement - Lightweight**

재화중량 (DWT) [ton]: 화물 적재량 + 소모품(F.O., D.O., L.O., F.W. 등) + DWT 상수 = 배수량 - 경하중량

- **Cargo Payload [ton]: Weight of loaded cargo at the loaded draft**

화물 적재량 [ton]: 만재 흘수에서 적재된 화물의 중량

- **DWT Constant [ton]: Operational liquid in the machinery and pipes, provisions for crew, etc.**

DWT 상수 [ton]: 기관 및 배관 내 작동 유체, 승무원용 식량 등의 중량

- **Lightweight (LWT) [ton]: Total of hull steel weight and weight of equipment on board**

경하중량 (LWT) [ton]: 선체 강재 중량과 탑재 장비 중량의 합계

- **LCB: Longitudinal Center of Buoyancy**

LCB: 종방향 부심

- **LCG: Longitudinal Center of Gravity**

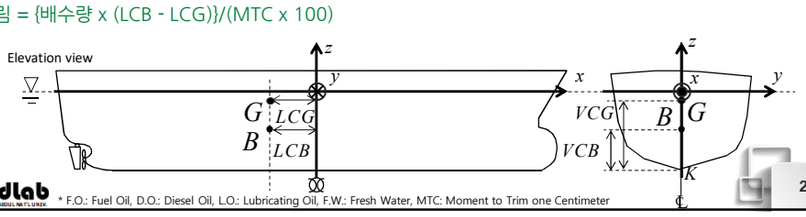
LCG: 종방향 무게중심

- **Trim: difference between draft at AP and FP**

트림: AP와 FP에서의 흘수 차이

- **Trim = {Displacement x (LCB - LCG)}/(MTC x 100)**

트림 = {배수량 x (LCB - LCG)}/(MTC x 100)



sydlab SEOUL NAT'L UNIV. * F.O.: Fuel Oil, D.O.: Diesel Oil, L.O.: Lubricating Oil, F.W.: Fresh Water, MTC: Moment to Trim one Centimeter

28

Speed and Power (1/2)

- **NMCR (Nominal Maximum Continuous Rating) [PS x rpm]**

NMCR (공칭 최대 연속 정격) [PS x rpm]

- **MCR (Maximum Continuous Rating) or DMCR (Derated MCR) [PS x rpm]**

MCR (최대 연속 정격) 또는 DMCR (감소된 MCR) [PS x rpm]

- **NCR (Normal Continuous Rating) [PS x rpm]**

NCR (정상 연속 정격) [PS x rpm]

- **BHP (Brake Horse Power) [PS x rpm]: Required power without sea margin at the service speed**

BHP (제동 마력) [PS x rpm]: 서비스 속도에서 해상 여유를 고려하지 않은 필요 출력

- **Sea Margin [%]: Power reserve for the influence of waves and wind, including the effects of fouling and corrosion.**

해상 여유 [%]: 부착물과 부식의 영향을 포함하여 파랑과 바람의 영향에 대비한 출력 여유

- **Service Speed [knot]: Speed at NCR power with the specific sea margin (e.g., 15%). One of shipowner's requirements**

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29

서비스 속도 [knot]: 특정 해상 여유(예: 15%)를 적용한 NCR 출력에서의 속도. 선주의 요구 사항 중 하나이다

Speed and Power (2/2)

- **DHP (Delivered Horse Power)**

DHP (전달 마력)

- **Power actually delivered to the propeller with some power loss in the stern tube bearing and in any shaft tunnel bearings between the stern tube and the site of the torsion-meter**

선미에서 일부 출력 손실이 발생한 후 프로펠러에 실제로 전달되는 출력

선미관 베어링과 선미관 및 비틀림 진동계 설치 위치 사이의 모든 축 터널 베어링

- **EHP (Effective Horse Power)**

EHP (유효 마력)

- **Required power to maintain the intended speed of the ship**

선박의 의도된 속도를 유지하는 데 필요한 출력

- **η_D (propulsive coefficient) = EHP/DHP**

D (추진계수) = EHP/DHP

- **RPM margin**

RPM 여유

- **To provide a sufficient torque reserve whenever full power must be attained under unfavorable weather conditions**

전출력을 발휘해야 할 때 충분한 토크 여유를 확보하기 위한 것 불리한 기상 조건에서

- **To compensate for the expected future drop in revolutions for constant-power operation**

정출력 운항 시 예상되는 향후 회전수 감소를 보상하기 위한 것

LT (롱톤, 영국식) = 1.016 [ton], ST (숏톤, 미국식) = 0.907 [ton], MT (미터톤, 표준) = 1.0 [ton]

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30

Unit (1/2)

- **LT (Long Ton, British) = 1.016 [ton], ST (Short Ton, American) = 0.907 [ton], MT (Metric Ton, Standard) = 1.0 [ton]**

LT (영국식 롱톤) = 1.016 [ton], ST (미국식 쇼트톤) = 0.907 [ton], MT (표준 미터톤) = 1.0 [ton]이다

- **Density ➡ [ton/m^3 or Mg/m^3]**

밀도 [ton/m3 또는 Mg/m3]

  - **e.g., density of seawater = 1.025 [ton/m^3], density of fresh water = 1.0 [ton/m^3], density of steel = 7.85 [ton/m^3]**

예: 해수의 밀도 = 1.025 [ton/m3], 담수의 밀도 = 1.0 [ton/m3], 강철의 밀도 = 7.85 [ton/m3]

- **1 [knot] = 1 [NM/hr] = 1.852 [km/hr] = 0.5144 [m/sec]**

속도 환산은 다음과 같다: 1 [knot] = 1 [NM/hr] = 1.852 [km/hr] = 0.5144 [m/sec]이다

- **1 [PS] = 75 [kgf·m/s] = 75×10^{-3} [Mg]·9.81 [m/s^2]·[m/s] = 0.73575 [kW] (Pferdestarke, German translation of horsepower)**

= 0.73575 [kW] (Pferdestarke, 마력의 독일어 번역)

  - **NMCR of the main engine (B&W6S60MC): 12,240 [kW] = 16,680 [PS]**

주기관(B&W6S60MC)의 NMCR: 12,240 [kW] = 16,680 [PS]

- **1 [BHP] = 76 [kgf·m/s] = 76×10^{-3} [Mg]·9.81 [m/s^2]·[m/s] = 0.74556 [KW] (British horsepower)**

마력 환산은 다음과 같다: 1 [BHP] = 76 [kgf m/s] = 76 10-3 [Mg] 9.81 [m/s2] [m/s]이다

= 0.74556 [KW] (영국 마력)

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31

Unit (2/2)

- **SG (Specific Gravity) ➡ No dimension**

SG (비중) 무차원

  - **SG of material = density of material/density of water**

물질의 SG = 물질의 밀도/물의 밀도

  - **e.g., SG of seawater = 1.025, SG of fresh water = 1.0, SG of steel = 7.8**

예: 해수의 SG = 1.025, 담수의 SG = 1.0, 강철의 SG = 7.8

- **SF (Stowage Factor) ➡ [ft^3/LT]**

SF (적재계수) [ft3/LT]

  - **e.g., SF = 15 [ft^3/LT] ➡ SG = 2.4 [ton/m^3]**

- **API (American Petroleum Institute) gravity or API degree = (141.5/SG) - 131.5**

API (American Petroleum Institute) 비중 또는 API 도 = (141.5/SG) - 131.5

  - **measure of how heavy or light a petroleum liquid is compared to water**

석유 액체가 물에 비해 얼마나 무겁거나 가벼운지를 나타내는 척도

  - **e.g., API 40 ➡ SG = 0.8251**

- **1 [barrel] = 0.159 [m^3]**
  - **e.g., 1 [mil. barrels] = 159,000 [m^3]**

예: 1 [mil. barrels] = 159,000 [m3]

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32

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3. Comparisons of a Ship with Other Structures

3. 선박과 다른 구조물의 비교

Features of a Ship

- **Comparison with Other Structures (Building, Automobile, Airplane)**

다른 구조물과의 비교(건축물, 자동차, 항공기)

- **Objective: moving vs. living**

목적: 이동 vs. 거주

- **Moving or fixed: moving vs. fixed**

이동 또는 고정: 이동 vs. 고정

- **External force acting on the structure: forces induced by winds, waves, currents, etc. vs. wind force, frictional force, etc.**

구조물에 작용하는 외력: 바람, 파도, 해류 등에 의해 유발되는 힘 vs. 풍력, 마찰력 등

- **Design concept: individual design vs. one design**

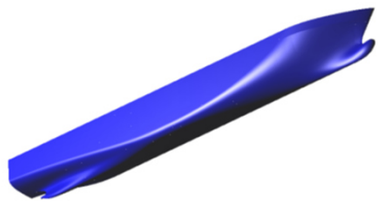
설계 개념: 개별 설계 vs. 단일 설계

- **Production method: order (customized) production vs. mass production**

생산 방식: 주문형(맞춤형) 생산 vs. 대량 생산

Hull Form Design vs. Car Exterior Design

선형 설계와 자동차 외관 설계의 비교



Hull form design

- A hull form is related to **the resistance and propulsion performance** of a ship.
- Order production: new design for each order
- Large structure of about 100-400 m in length
- **Performance, such as speed and deadweight, is most important**.

선형 설계 선형은 선박의 저항 및 추진 성능과 관련된다. 주문 생산: 주문마다 새로운 설계 길이가 약 100~400 m인 대형 구조물 속도와 재화중량 등의 성능이 가장 중요하다.

Car exterior design

- An exterior is related to the air resistance and aesthetic **design** of a car.
- Mass production: one-time design for each model
- Small structure of about 3-5 m in length
- **The performance and aesthetic design are simultaneously important**.

자동차 외관 설계 외관은 자동차의 공기 저항 및 미적 설계와 관련된다. 대량 생산: 모델별 1회 설계 길이가 약 3~5 m인 소형 구조물 성능과 미적 설계가 동시에 중요하다.

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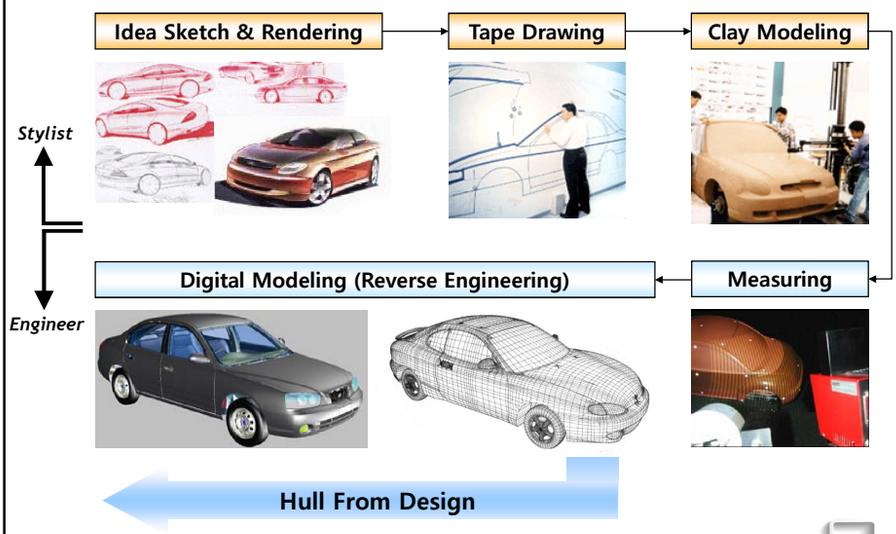
35

Procedure of Car Exterior Design

자동차 외관 설계 절차



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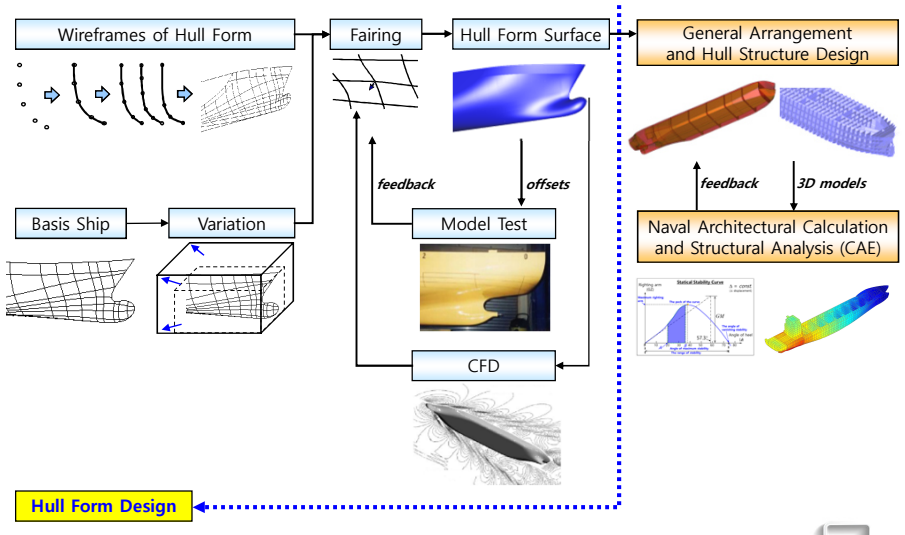
36

Procedure of Hull Form Design



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37

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4. Construction Procedure of a Ship

4. 선박 건조 절차

Construction Procedures of a Ship (Overview)

선박 건조 절차(개요)

5 key events of construction procedures

* Deadweight 300,000 ton VLCC, L: 320.0 m, B: 58.0 m, D: 31.2 m,
3 soccer fields can be located on the deck.
* 63 building in Seoul, 249.0 m from the ground

Contract → Steel Cutting (S/C) → Keel Laying (K/L) → Launching (L/C) → Delivery (D/L)

Contract Basic design Detailed design S/C Production design K/L L/C D/L

-6 -4 -2 0 +3 +6 +8

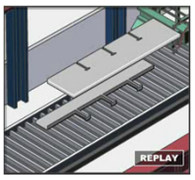
* Reference: DSME

Design
(Basic/Detailed/Production)

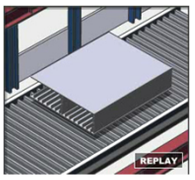
Construction period of 300K VLCC
(on December 2006)

Key Event	Duration
Contract	-6 months
S/C or W/C*	Base date
K/L	+3 months
L/C	+6 months
D/L	+8 months
Total	14 months

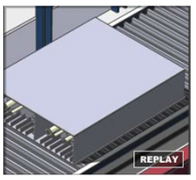
* W/C: Work Commence. Starting date when S/C is made.



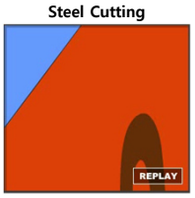
Steel Cutting



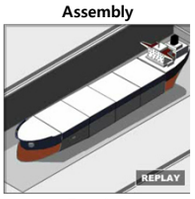
Assembly



Outfitting



Painting



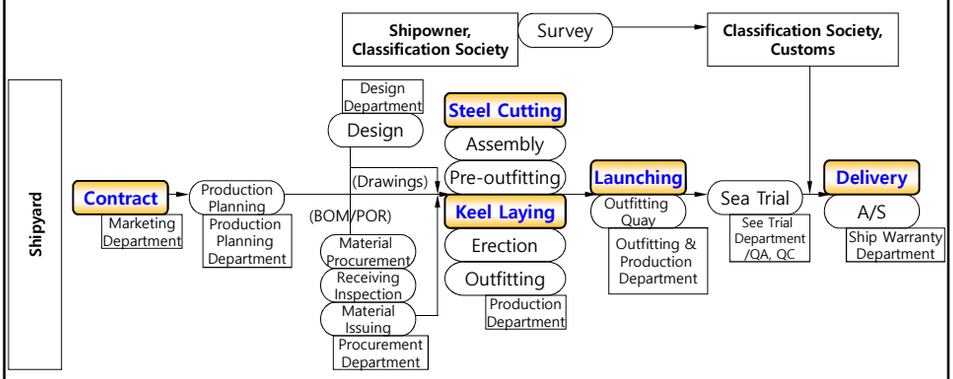
Erection

Launching

Construction Procedures of a Ship (Detailed)

선박 건조 절차(상세)

: 5 key events of construction procedures



선주, 검사 기관, 선급협회, 선급협회 관행 설계 부서 강재 절단 설계 조립 (도면) 선행 의장 진수 인도 생산 계약 계획 의장 해상 시운전 (BOM/POR) 용골 거치 A/S 영업 부서 생산 부서 부두 해상 시운전 부서 선박 보증 계획 부서 자재 조달 탑재 의장 및 QA/QC 부서 생산 부서 자재 입고 의장 부서 검사 생산 자재 부서 출고 조달 부서

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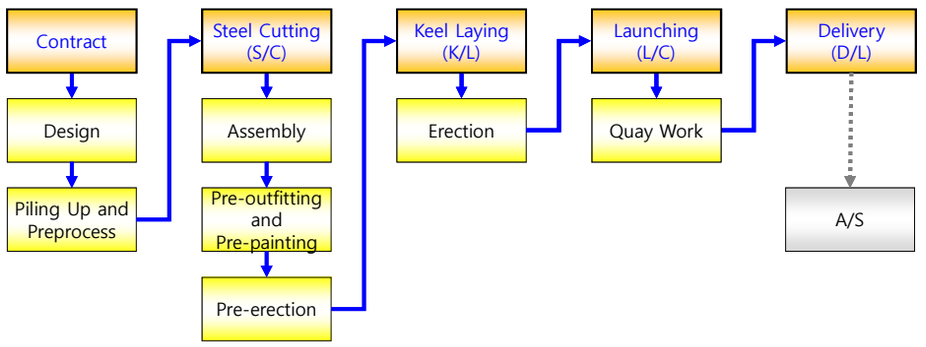
* BOM: Bill Of Material, POR: Purchase Order Request, QA: Quality Assurance, QC: Quality Control

Construction Procedures of a Ship (Detailed)

선박 건조 절차(상세)



강재 절단 용골 거치 진수 인도 계약 (S/C) (K/L) (L/C) (D/L) 설계 조립 탑재 안벽 작업 선행 의장 적층 및 및 A/S 전처리 선행 도장 선행 탑재

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41

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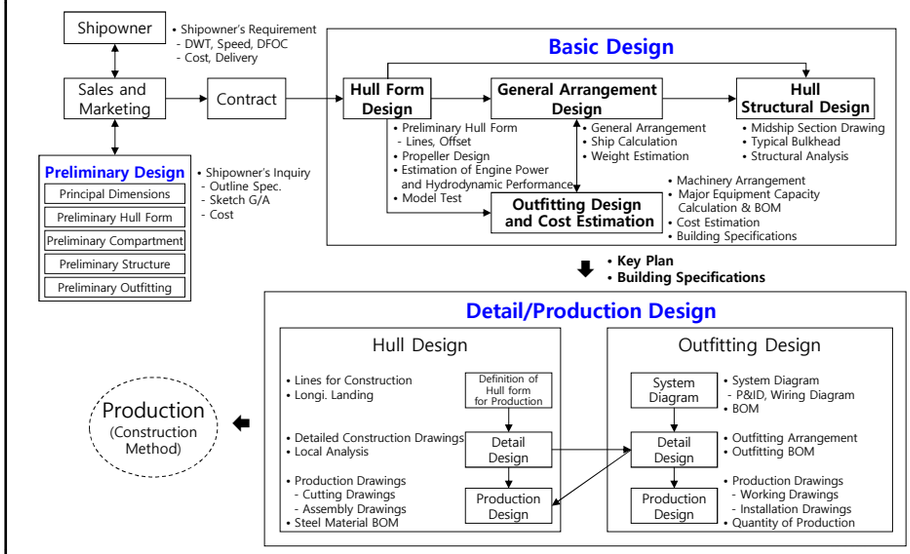
Design

설계

Ship Design Process

Overview

선박 설계 절차 개요



선주 • 선주 요구사항 DWT, 속도, DFOC 기본 설계 비용, 인도 영업 및 마케팅 • 선형 설계 • 일반 배치 설계 • 선체 계약 설계 • 구조 설계 예비 선형 • 일반 배치 • 중앙 단면도 선도, 오프셋 • 선박 계산 • 표준 격벽 프로펠러 설계 • 중량 추정 • 구조 해석 선주 문의 • 기관 출력 추정 초기 설계 기관 배치 개략 사양 및 유체역학적 성능 주요 치수 • 주요 장비 용량 개략 일반 배치도 • 모형 시험 의장 설계 계산 및 BOM 예비 선형 - 비용 및 비용 추정 • 비용 추정 건조 사양서 예비 구획 예비 구조 • 기준선도 건조 사양서 예비 의장 상세/생산 설계 선체 설계 • 의장 설계 건조용 선도 • 시스템 정의 • 시스템 계통도 종방향 배치도 - P&ID, 배선도 상세 건조 도면 • 의장 배치 생산 도면 • 생산 도면 절단 도면 - 작업 도면 • 생산 • 생산 조립 도면 - 설치 도면 • 설계 • 설계 강재 BOM • 생산 수량

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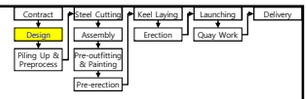
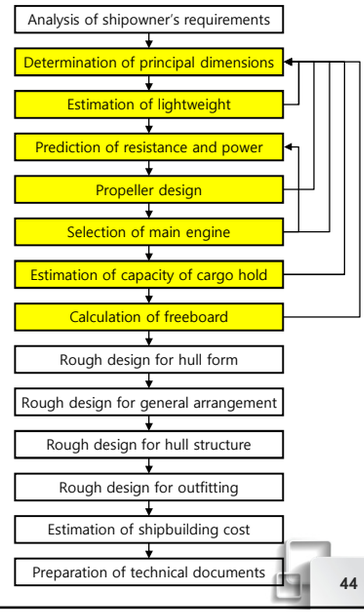
43

Preliminary Design

Determination of Ship's Principal Dimensions



- **Given**
  - **Deadweight (DWT)**
  - **Cargo hold capacity (V_{CH})**
  - **Service speed (V_s)**
  - **Daily Fuel Oil Consumption ($DFOC$)**
  - **Endurance**
  - **…**
- **Find**
  - L, B, D, T, C_B



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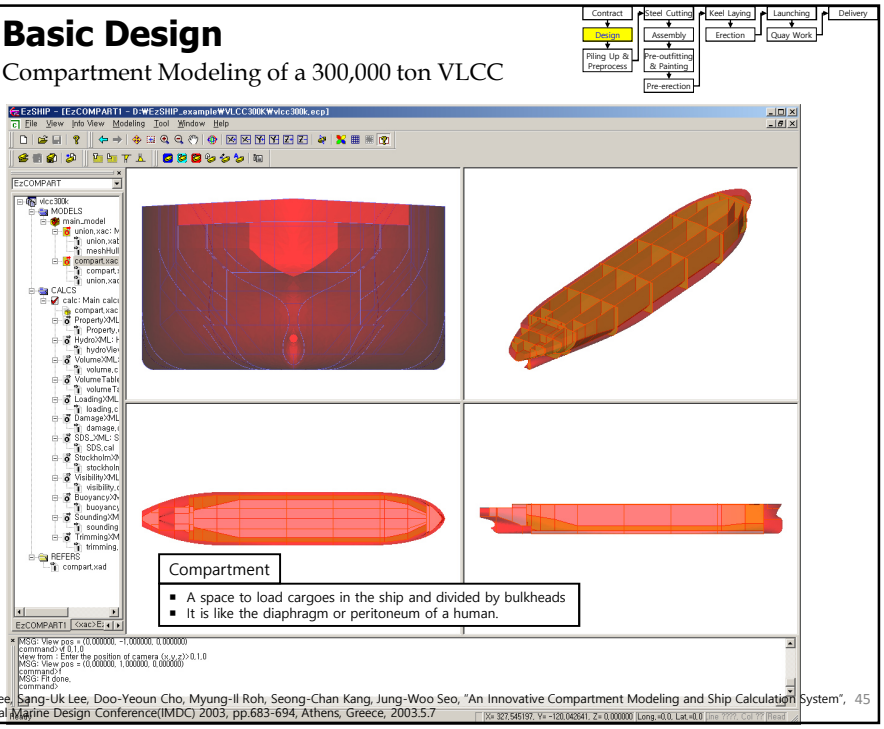
선주 요구사항 분석이 주어짐 화물창 용량 추정값을 구함

Basic Design

Compartment Modeling of a 300,000 ton VLCC

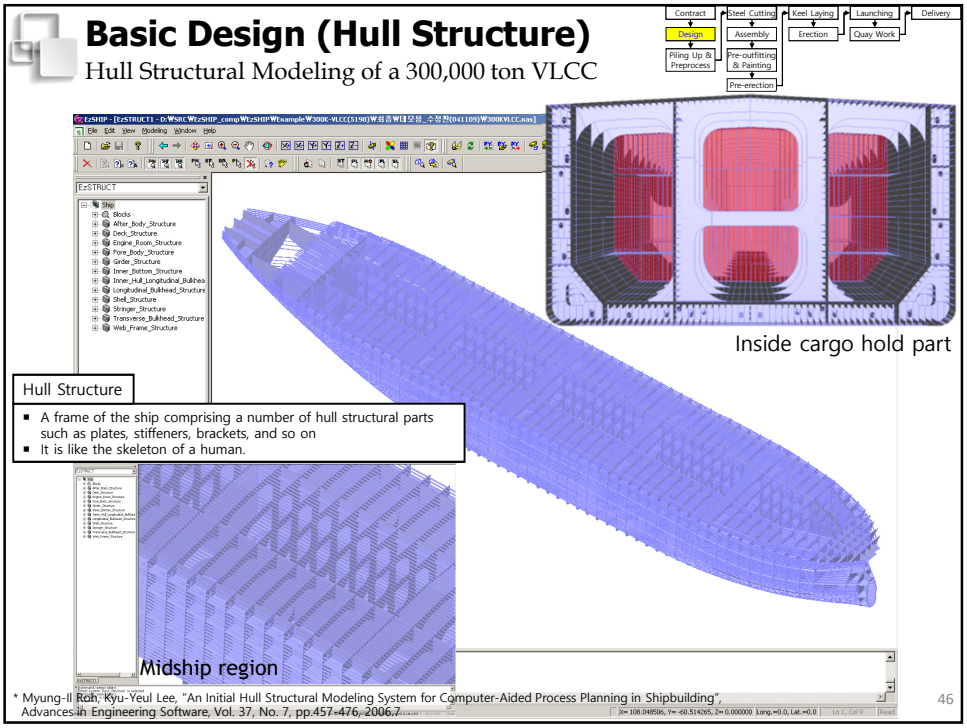


* Kyu-Yeul Lee, Sang-Uk Lee, Doo-Yeoun Cho, Myung-Il Roh, Seong-Chan Kang, Jung-Woo Seo, "An Innovative Compartment Modeling and Ship Calculation System", International Marine Design Conference(IMDC) 2003, pp.683-694, Athens, Greece, 2003.5.7

45

Basic Design (Hull Structure)

Hull Structural Modeling of a 300,000 ton VLCC



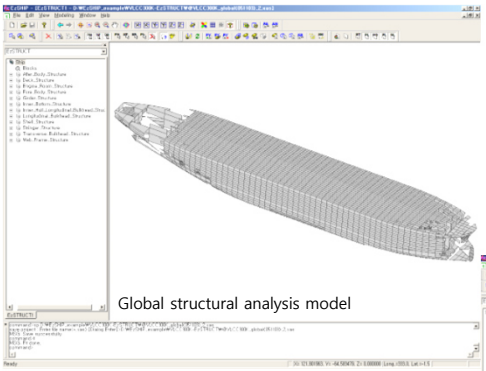
* Myung-Il Roh, Kyu-Yeul Lee, "An Initial Hull Structural Modeling System for Computer-Aided Process Planning in Shipbuilding", Advances in Engineering Software, Vol. 37, No. 7, pp.457-476, 2006.7

46

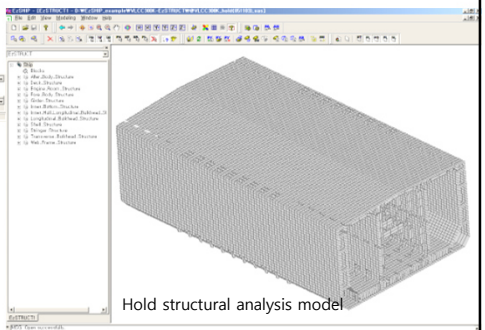
Basic Design (Hull Structure)

Structural Analysis Modeling of a 300,000 ton VLCC

Contract → Steel Cutting → Keel Laying → Launching → Delivery
Design → Assembly → Erection → Quay Work
Piling Up & Preprocess → Pre-outfitting & Painting → Pre-erection



Global structural analysis model



Hold structural analysis model

Structural Analysis

- A task to assess structural strength of a ship
- It is normally based on finite element method.

* Myung-Il Roh, Kyu-Yeul Lee, Woo-Young Choi, Seong-Jin Yoo, "Improvement of Ship Design Practice Using a 3D CAD Model of a Hull Structure", Robotics and Computer-Integrated Manufacturing Journal(SCIE/IF:0.699), 2006.10.16

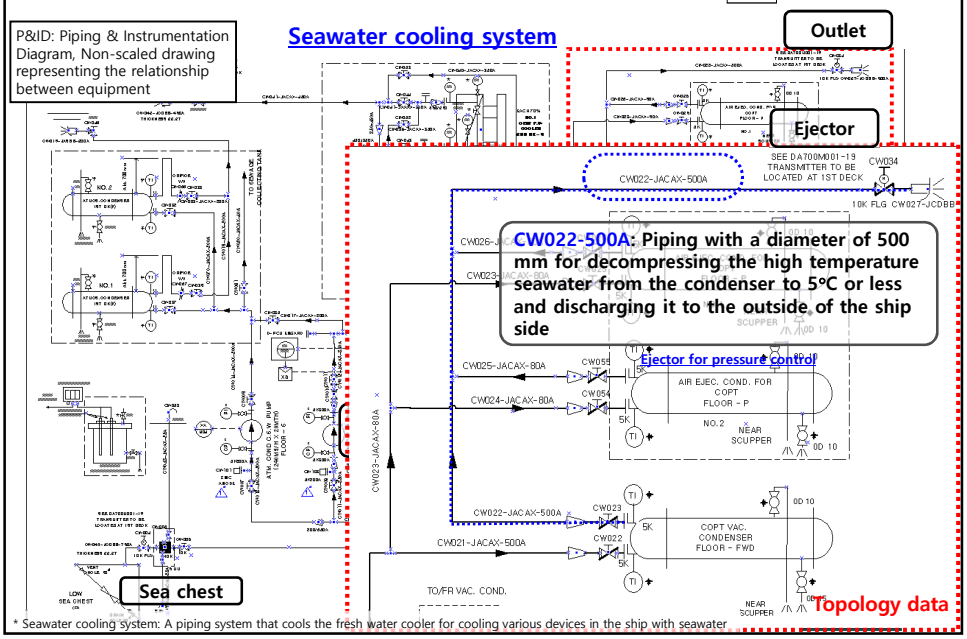
47

Basic Design (Pipe Outfitting)

P&ID (Piping and Instrument Diagram)

Contract → Steel Cutting → Keel Laying → Launching → Delivery
Design → Assembly → Erection → Quay Work
Piling Up & Preprocess → Pre-outfitting & Painting → Pre-erection

P&ID: Piping & Instrumentation Diagram, Non-scaled drawing representing the relationship between equipment



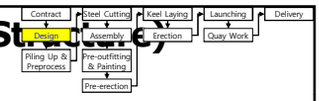
CW022-500A: Piping with a diameter of 500 mm for decompressing the high temperature seawater from the condenser to 5°C or less and discharging it to the outside of the ship side

* Seawater cooling system: A piping system that cools the fresh water cooler for cooling various devices in the ship with seawater

Detail/Production Design (Hull Structure)

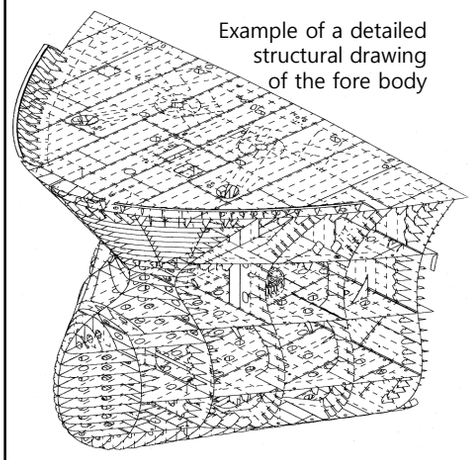
Result of Detailed/Production Design

상세/생산 설계(선체 구조)

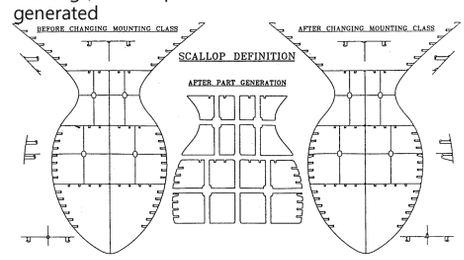


Detail design: the stage which detailed specification and performance are determined, and detailed drawings for each system are generated

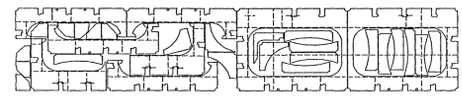
Example of a detailed structural drawing of the fore body



Production design: the stage which production drawings (cutting, nesting, piece, and installation drawings) for the production of each block are generated



Example of a cutting drawing



Example of a nesting drawing

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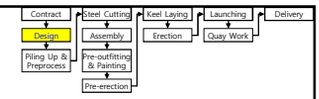
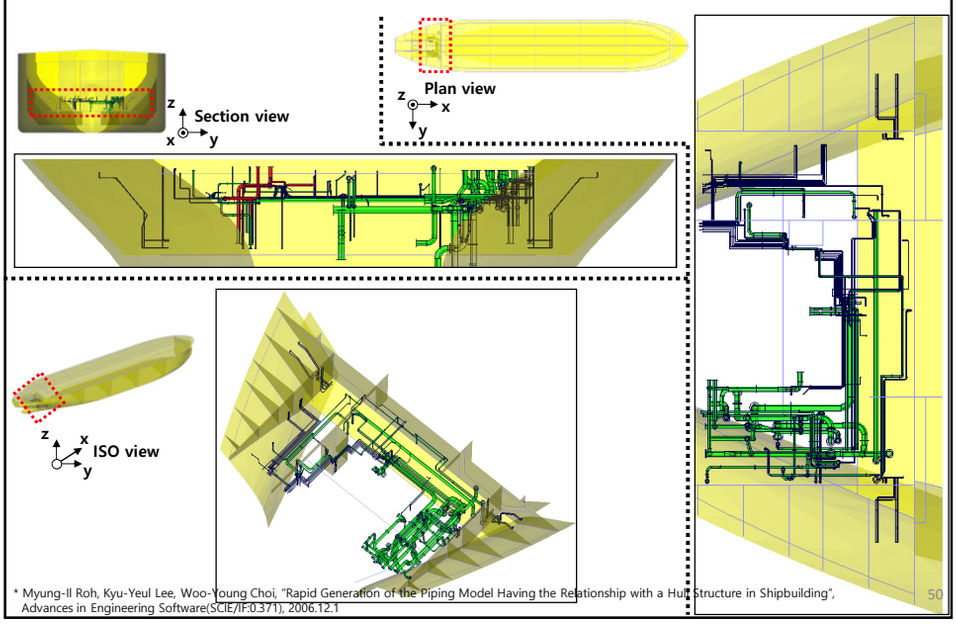
49

상세 설계: 상세 도면(각 시스템의 절단, 네스팅, 부재 및 설치 상세 도면)이 생성되는 단계이다. 생산 설계: 생산 사양과 성능이 결정되고 각 블록의 생산을 위한 도면이 생성된다. 선수부 상세 구조 도면의 예 절단 도면의 예 네스팅 도면의 예

Detail Design (Pipe Outfitting)

Pipe Modeling of a 300,000 ton VLCC





* Myung-Il Roh, Kyu-Yeul Lee, Woo-Young Choi, "Rapid Generation of the Piping Model Having the Relationship with a Hull Structure in Shipbuilding", Advances in Engineering Software(SCIE/IF:0.371), 2006.12.1

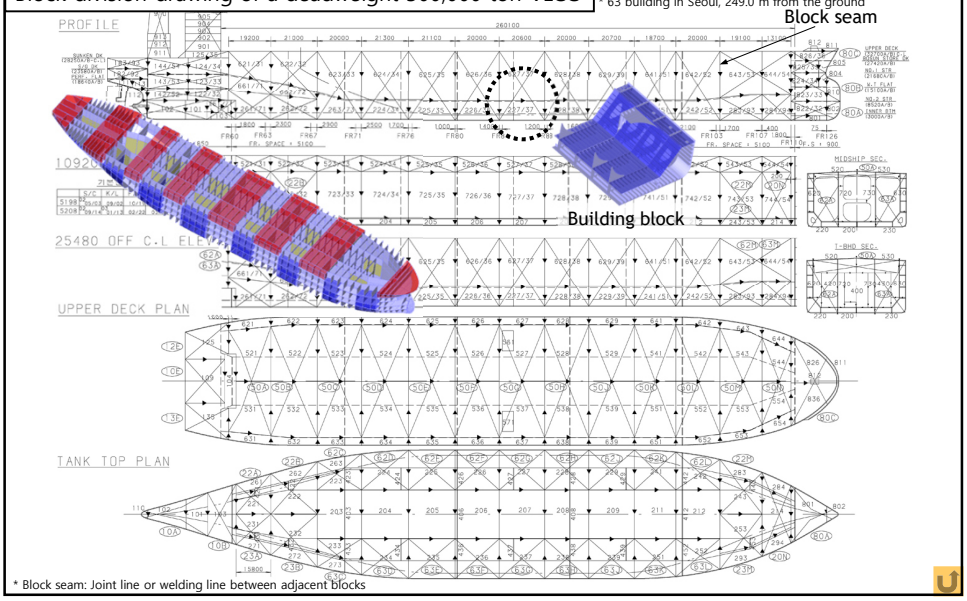
50

Block Division (Production Planning)

Contract → Design → Piling Up & Preprocess → Steel Cutting → Assembly → Pre-outfitting & Painting → Pre-erection → Keel Laying → Erection → Launching → Quay Work → Delivery

Block division drawing of a deadweight 300,000 ton VLCC

* Deadweight 300,000 ton VLCC, L: 320.0 m, B: 58.0 m, D: 31.2 m, 3 soccer fields can be located on the deck.
* 63 building in Seoul, 249.0 m from the ground



* Block seam: Joint line or welding line between adjacent blocks

Piling Up and Preprocess of Steel Material

강재 적치 및 전처리

Piling Up and Preprocess of Steel Plate

Contract | Steel Cutting | Keel Laying | Launching | Delivery
Design | Assembly | Erection | Quay Work
Piling Up & Preprocess | Pre-outfitting & Painting
Pre-erection

Piling Up of Steel Material

강재 적치 및 전처리

- **Steel material consists of plates and section steels, which have the shape of a bar.**

강재는 판재와 막대 형태의 형강으로 구성된다.

- **Piling up: Process of transporting steel material purchased from steel companies to sea or land and storing it in a stockyard**

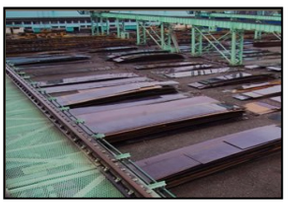
적치: 제철소에서 구매한 강재를 해상 또는 육상으로 운송하여 야적장에 보관하는 공정

- **Grouping: Process of sorting steel material according to the specification and production schedule of each ship, and then supplying it to the preprocess shop**

그룹화: 각 선박의 사양과 생산 일정에 따라 강재를 분류한 후 전처리 공장에 공급하는 공정

- **Piling up method: "Using Pallet"**

적치 방법: "팔레트 사용"


Types of section steels

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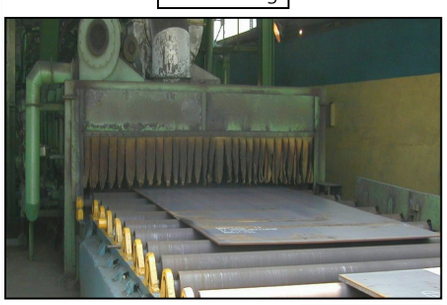
Piling Up and Preprocess of Steel Plate

Contract | Steel Cutting | Keel Laying | Launching | Delivery
Design | Assembly | Erection | Quay Work
Piling Up & Preprocess | Pre-outfitting & Painting
Pre-erection

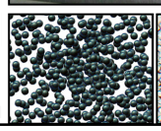
Preprocess of Steel Material

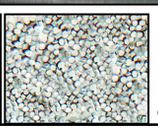
- **Process for removing the rust on the surface of steel material to improve the adhesion of paint and to prevent rust through shot blasting and shop priming**
  - **Shot blasting: Task to remove rust and mill scale by shooting abrasive (shot ball, cut wire, etc.) to the surface of steel material at high speed**
  - **Shop priming: Task to paint shop primer on steel material after shot blasting is completed to prevent rust during the manufacturing/assembly process**

Shot blasting | Shop priming




Types of shots


Shot ball


Cut wire

* Mill scale: A thin, black layer of metal oxide on the surface when heating the metal in the atmosphere

Piling Up and Preprocess of Steel
Marking

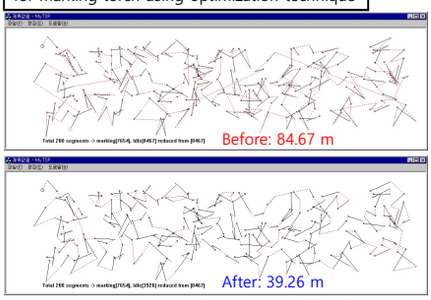
Contract | Steel Cutting | Keel Laying | Launching | Delivery
Design | Assembly | Erection | Quay Work
Piling Up & Preprocess | Pre-outfitting & Painting | Pre-erection

강재 적재 및 전처리

- **Marking: Marking lines and symbols for cutting, bending, and assembly processes**

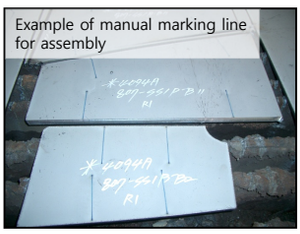
마킹: 절단, 굽힘 및 조립 공정을 위한 선과 기호를 표시한다

Example of path generation system for marking torch using optimization technique

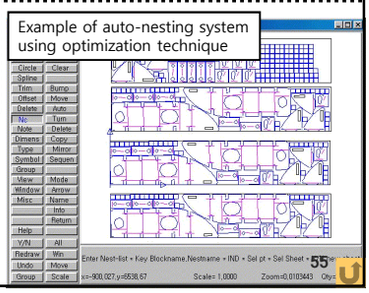


➡ How can we minimize the trajectory of marking torch in the NC (Numerical Control) marking?
➡ Example of application of optimization technique

Example of manual marking line for assembly



Example of auto-nesting system using optimization technique



* Nesting: Process to minimize the remnants of the steel sheet that are cut and cut by rotating the member pieces in order to use the standard steel sheet most effectively
➡ How can we automatically obtain the nesting result that maximizes the yield (the ratio of the area of the steel sheet to the area of the standard steel sheet)?
➡ Another application of the optimization technique

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Steel Cutting (S/C)

강재 절단(S/C)

Steel Cutting (S/C)

- **Cutting: Process for cutting steel along the marking line to obtain a member of the desired shape**

절단: 원하는 형상의 부재를 얻기 위해 마킹선을 따라 강재를 절단하는 공정

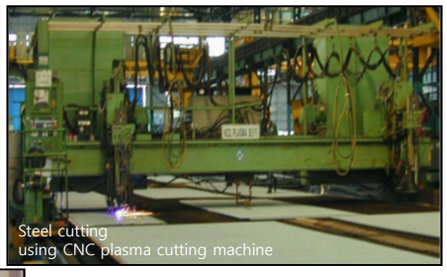
- **Steel Cutting (S/C) or Work Commencement (W/C): Steel cutting for the first time (called groundbreaking ceremony)**

강재 절단(S/C) 또는 작업 착수(W/C): 최초로 실시하는 강재 절단(기공식이라고 함)

- **Cutting methods: Gas cutting, Plasma cutting, Laser cutting, Edge milling, etc.**

절단 방법: 가스 절단, 플라스마 절단, 레이저 절단, 가장자리 밀링 등

Steel cutting
using CNC flame cutting machine



Steel cutting
using CNC plasma cutting machine

Steel cutting using edge milling machine
(Hyundai Samho Heavy Industries)

- Gas cutting: When the steel is heated to a temperature (800-900°C) at which the oxidation reaction is likely to occur, an exothermic reaction occurs and iron oxide is formed. At this time, cut the plate by supplying high-pressure oxygen.
- Plasma cutting: When an electric arc discharge occurs in air, hydrogen, gas, etc., the gas is partially plasmaized. It is shrunk by a thermophysical method so that the maximum temperature reaches 20,000-30,000°C. Using it, dissolve and blow the steel with high-pressure gas.
- Laser cutting: Melt locally by injecting the light after amplifying and densifying it and by blowing the steel out with high-pressure gas, and cut the steel
- Edge milling: Still cutting using industrial diamond

* CNC: Computer Numerical Control

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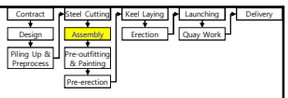
Assembly

조립

Assembly

Sub-assembly/Assembly



- **Sub-assembly**

소조립

- **Process for manufacturing a small-sized part constituting a block**

블록을 구성하는 소형 부품을 제작하는 공정

- **Assembly**

조립

- **Process for assembling sub-assembly blocks to make a large block**

소조립 블록을 조립하여 대형 블록을 만드는 공정

- **A process in which about 60% or more of the shipbuilding workload is processed**

조선 작업량의 약 60% 이상이 수행되는 공정이다

- **Depending on the shape of the block, it can be classified into the panel block process and the curved block process.**

블록의 형상에 따라 패널 블록 공정과 곡면 블록 공정으로 분류할 수 있다.

- **Panel block**

패널 블록

- × **Approximately 80% of the total assembly**

전체 조립의 약 80%

- × **The shape of the blocks and inner parts is relatively simple, and an automation system is employed.**

블록과 내부 부품의 형상이 비교적 단순하며, 자동화 시스템을 사용한다.

- × **Matrix (Egg Box) method, Line welder method, Slit method, Piece by piece method**

매트릭스(에그박스) 방식, 라인 용접법, 슬릿 방식, 개별 조립법

- **Curbed block**

곡면 블록

- × **Approximately 20% of the total assembly**

전체 조립의 약 20%

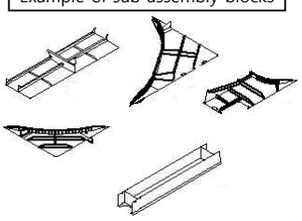
- × **It is challenging to implement an automation system due to the diverse shapes and complexities of the blocks.**

블록의 형상과 복잡성이 다양하여 자동화 시스템을 구현하기 어렵다.

- × **Line welder method, Piece by piece method**

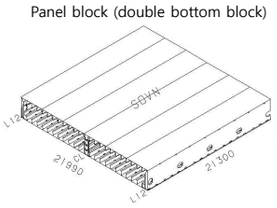
라인 용접법, 개별 조립법

Example of sub assembly blocks

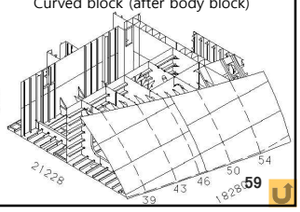


Example of assembly blocks

Panel block (double bottom block)



Curved block (after body block)



59

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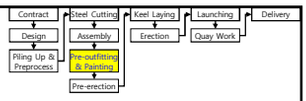
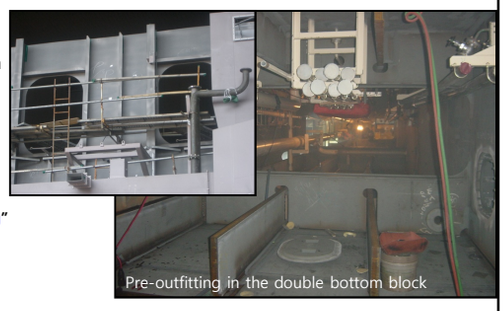
Pre-outfitting and Pre-painting

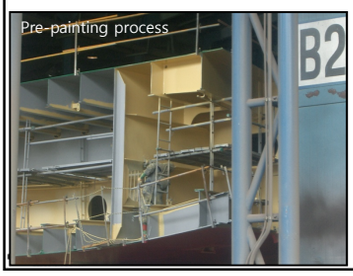
선행 의장 및 선행 도장

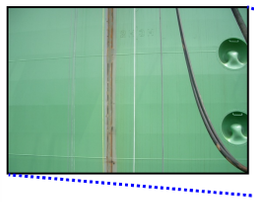
Pre-outfitting and Pre-painting

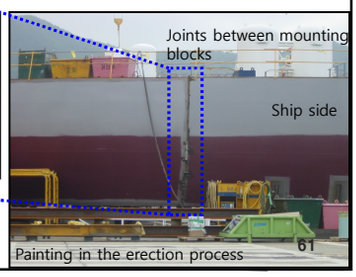


- **Pre-outfitting**
  - **Process for hastening the installation of outfitting (piping, ducts, etc.) to avoid congestion in the latter part of the construction period**
  - **Categorized into block outfitting, unit outfitting, and erection outfitting**
- **Pre-painting**
  - **Painting in the preprocess of steel material: "Shop priming"**
  - **Painting in the assembly process: "Pre-painting"**
    - **Perform block preprocess before preceding pre-painting**
  - **Painting in the erection process: "Erection painting"**
    - **Perform additional preprocess and painting work on joints between mounting blocks**


Pre-outfitting in the double bottom block

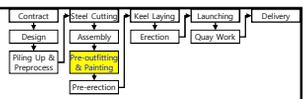






61

Block Preprocess



- **Process of removing the rust on the surface of the plate during the assembly process, before the preceding painting, to improve the adhesion of the paint**

도장 전에 조립 과정에서 판 표면의 녹을 제거하여 도료의 부착력을 향상시키는 공정

- **Consisting of blasting, air blowing, and grit recovery**

블라스팅, 에어 블로잉 및 그릿 회수로 구성된다

- **Blasting: Removing rust by spraying a small piece of iron (grit) onto the plate**

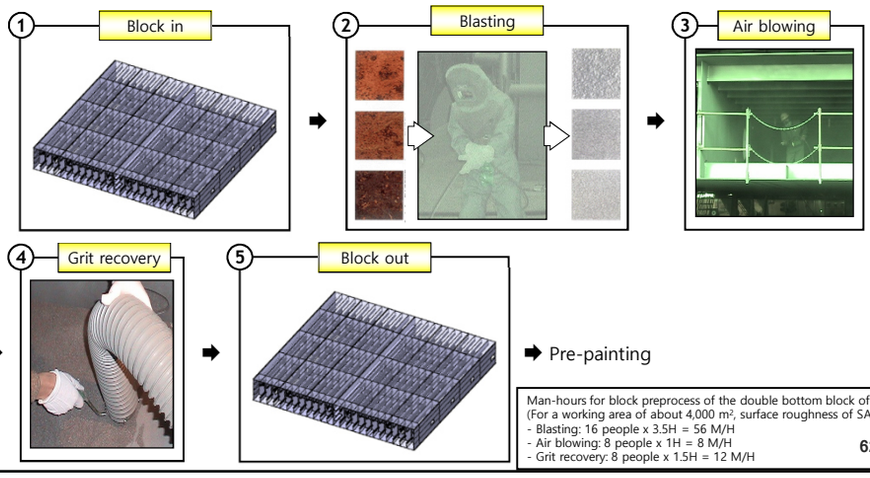
블라스팅: 판에 작은 철 조각(그릿)을 분사하여 녹을 제거하는 작업

- **Air blowing: Drop grit on the top of a stiffener to the floor using air**

에어 블로잉: 공기를 사용하여 보강재 상부의 그릿을 바닥으로 떨어뜨리는 작업

- **Grit recovery: Collecting grit, dust, etc. on the floor**

그릿 회수: 바닥의 그릿, 먼지 등을 수거하는 작업



Man-hours for block preprocess of the double bottom block of VLCC
(For a working area of about 4,000 m², surface roughness of SA2.5)
- Blasting: 16 people x 3.5H = 56 M/H
- Air blowing: 8 people x 1H = 8 M/H
- Grit recovery: 8 people x 1.5H = 12 M/H

62

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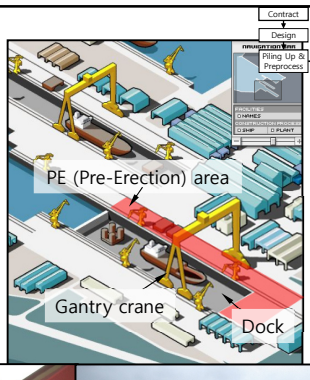
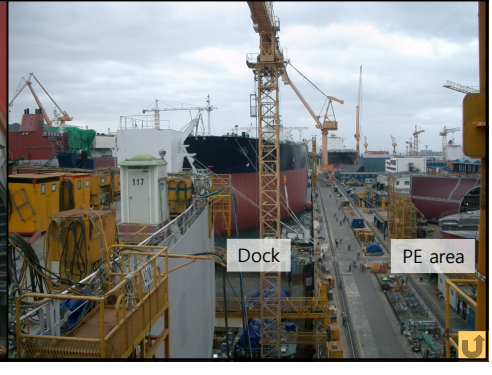
Pre-erection

탑재 전

Pre-erection

- **An intermediate process between the assembly and erection processes to increase erection efficiency**
- **This process makes "one large PE (Pre-Erection) block" by combining two or more hull blocks and outfitting near the dock**





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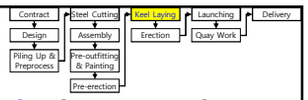
Keel Laying (K/L)

용골 거치(K/L)

Keel Laying (K/L)



- **The event when the first block is erected on the dock. That means the starting point of block erection.**

첫 번째 블록을 도크에서 탑재하는 시점이다. 즉, 블록 탑재의 시작점이다.

- **At this time, put several supports under the ship to support the ship's weight**

이때 선박을 지지하기 위해 선박 아래에 여러 지지대를 설치한다.

Support

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66

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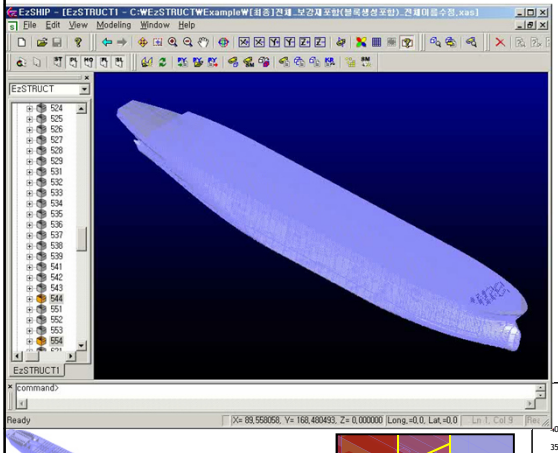
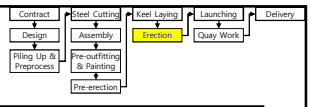
Erection

탑재

Block Erection Simulation

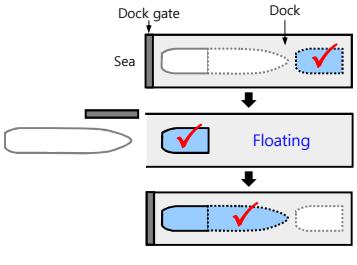
Semi-tandem Construction Method

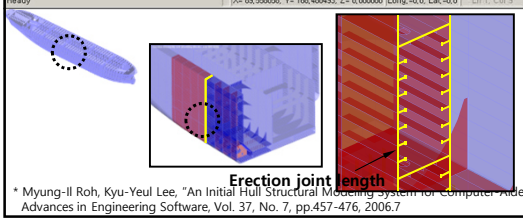


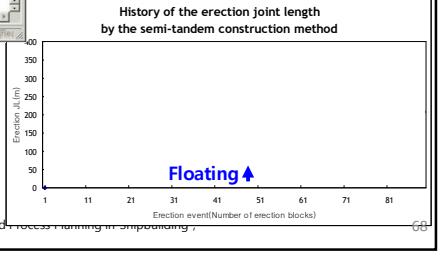


Semi-tandem Construction Method

➡ Construct a complete ship and another ship's after body together in the dock







* Myung-Il Roh, Kyu-Yeul Lee, "An Initial Hull Structural Modeling System for Computer Aided Process Planning in Shipbuilding", Advances in Engineering Software, Vol. 37, No. 7, pp.457-476, 2006.7

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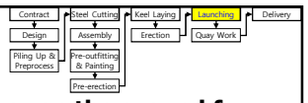
Launching (L/C)

진수(L/C)

Launching (L/C)



- **Process for launching a ship that is dry in the dock or on the ground for the first time after various tests**

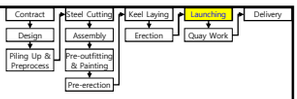
각종 시험을 거친 선박을 도크 또는 육상에서 처음 진수하는 공정

- **The date is approximately 12 months prior to the contract date.**

그 날짜는 계약일보다 약 12개월 앞선다.

Launching

Ground Launching Method of HHI and STX



- **Building a ship on land rather than a dock**

도크가 아닌 육상에서 선박 건조

- **In October 2004, Hyundai Heavy Industries was the first in the world to succeed.**

2004년 10월, Hyundai Heavy Industries가 세계 최초로 성공했다.

- **Overall procedures of the ground launching method**

육상 진수 방식의 전반적인 절차

1. Complete the erection of a ship on land

1. 육상에서 선박의 탑재를 완료한다.

2. Two barges are placed next to the land area.

2. 육상 구역 옆에 바지선 2척을 배치한다.

3. The ship is pulled over the barge ("Load Out") using the principle of submarine in Germany and the principle of the mobile system developed by Switzerland

4. Move a barge carrying the ship to the deep sea

5. The barge sinks below the surface of the water.

6. Finish the launch of the ship

71 71

* Reference: Hyundai Heavy Industries

3. 독일의 잠수함 원리를 이용하여 선박을 바지선 위로 끌어올리는("Load Out") 작업과

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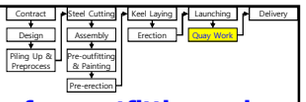
Quay Work

안벽 작업

Quay Work

Outfitting/Painting

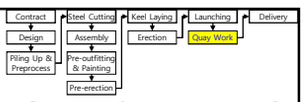


- **After launching the ship, put her on the quay and perform outfitting and painting to complete her.**

73

Quay Work

Sea Trial



- **The testing phase of the ship is designed to measure her performance and general seaworthiness.**

선박의 시험 단계는 선박의 성능과 전반적인 감항성을 측정하기 위해 수행한다.

- **It is typically the final phase of construction and takes place on open water, lasting from a few hours to several days.**

이는 일반적으로 건조의 마지막 단계로, 수상에서 수행되며 몇 시간에서 수일간 지속된다.

- **The ship's speed, maneuverability, equipment, and safety features are usually evaluated.**

일반적으로 선박의 속력, 조종성, 장비 및 안전 기능을 평가한다.

- **Typical trials: speed trial, crash stop, endurance, maneuvering trials, seakeeping**

일반적인 시험: 속력 시험, 급정지 시험, 내구성 시험, 조종 시험,

74

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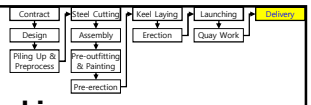
Delivery (D/L)

인도(D/L)

Delivery (D/L)

Naming Ceremony and Delivery



- **Process for naming the ship and delivering her to a ship owner**

Naming Ceremony of FPSO (Floating Production Storage, and Off-loading unit)

76

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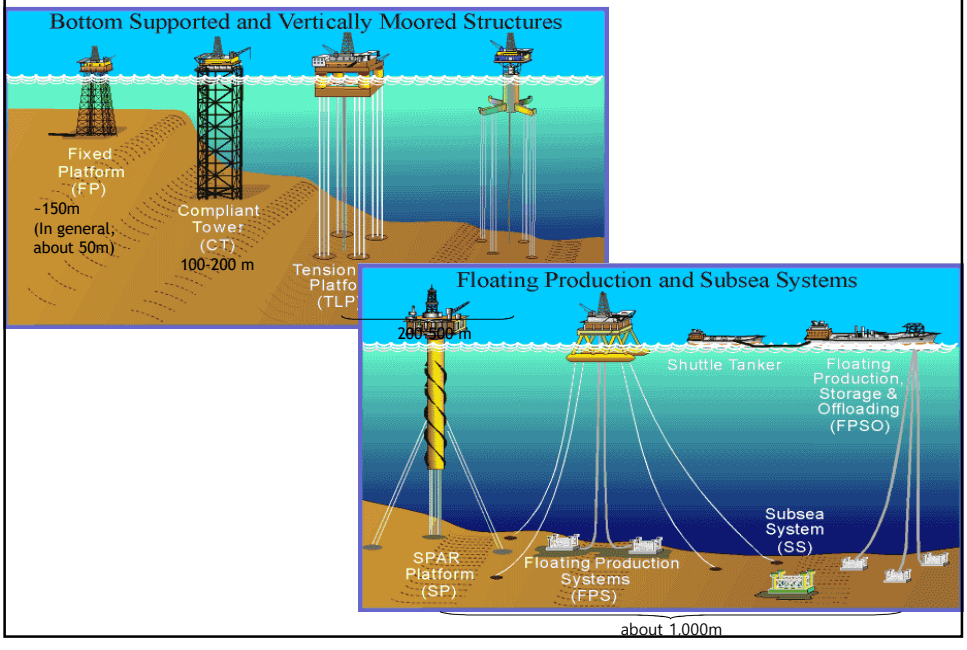
Offshore Structure Design

해양 구조물 설계

Offshore Structures for Oil and Gas Development



FPSO for the Development of Deep Sea

Floating, Production, Storage, and Offloading unit

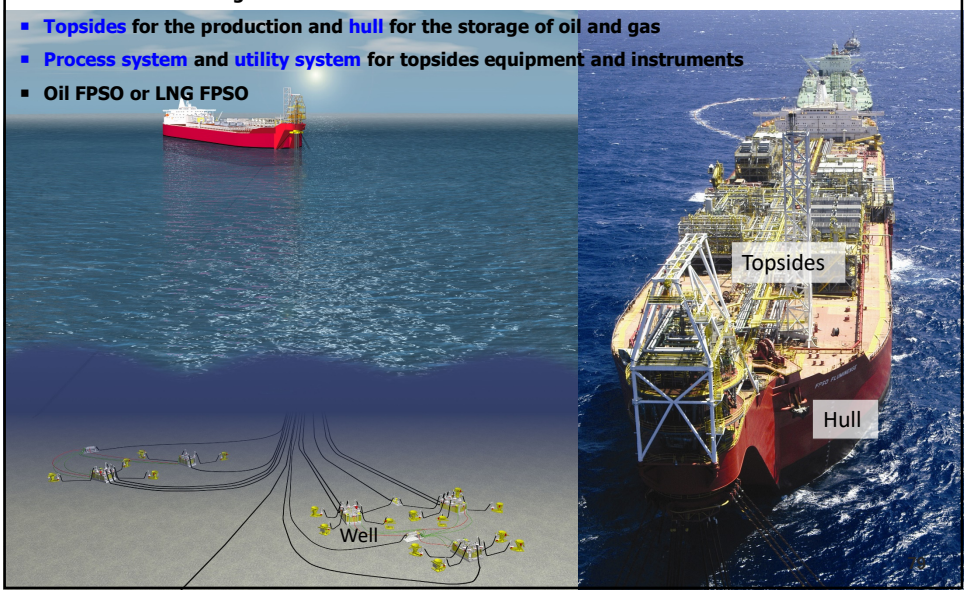
심해 개발을 위한 FPSO

- **Offshore structure for separating the well stream into oil, gas, and water**

유정 생산 유체를 석유, 가스 및 물로 분리하는 해양 구조물

and then transferring them to onshore

- **Topsides for the production and hull for the storage of oil and gas**
- **Process system and utility system for topsides equipment and instruments**
- **Oil FPSO or 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 → Crude Oil → Refining → Petroleum → Distillation & Fractionation

- Gasoline C7~C10
- Kerosene C10~C16
- Light Oil C16~C20
- Heavy Oil C20~C25
- Asphalt C25~C30
- Pitch

→ Heavy Components

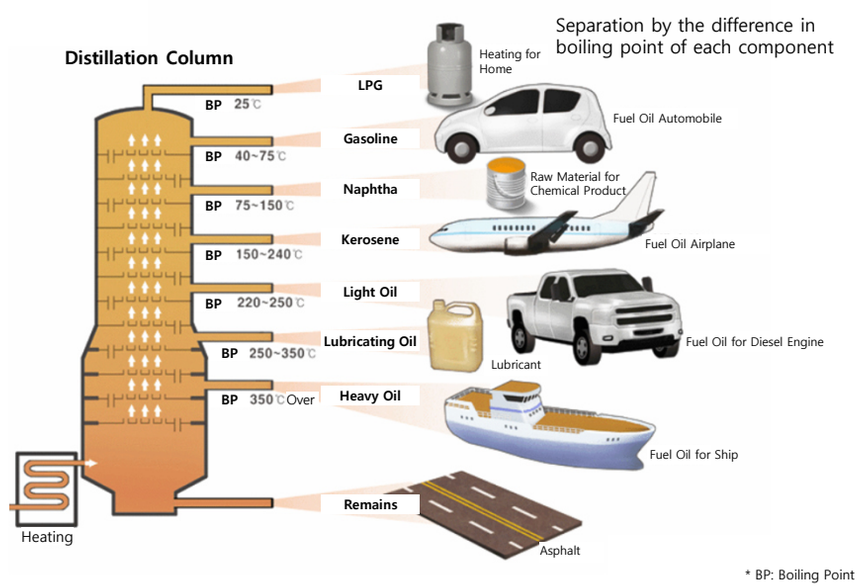
Gas → Refining → Dehydrated Gas → Refrigeration

- LNG C1 (CH_4)
- NGL C2
- LPG C3, C4
- Condensate C5, C6

→ Light Components

80

[Reference] Distillation and Fractionation of Oil

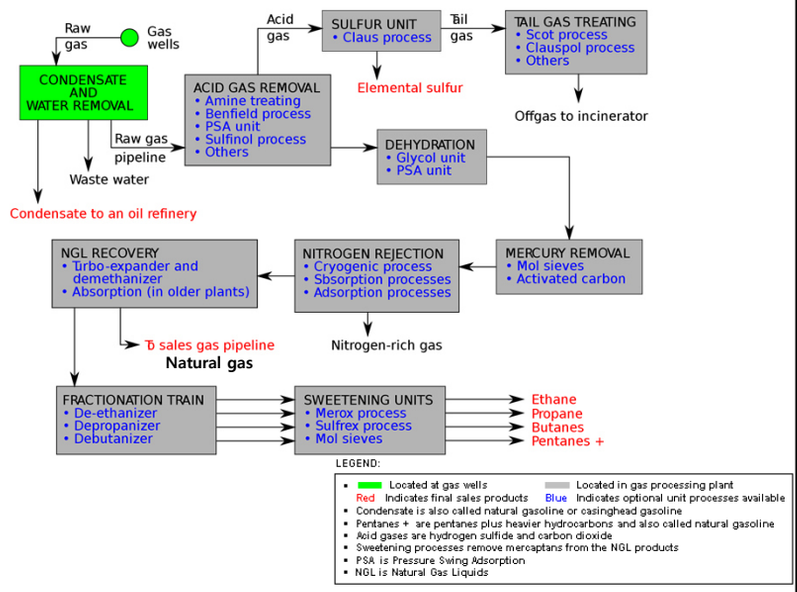


* Reference: http://doopedia.co.kr

* 참고: http://doopedia.co.kr

[Reference] Processing of Raw Natural Gas

[참고] 원료 천연가스 처리



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

* 참고: http://en.wikipedia.org

Natural Gas (NG)

▪ Natural Gas

천연가스

- **Hydrocarbon gas mixture consisting primarily of methane (CH_4)**

주로 메탄(CH4)으로 구성된 탄화수소 가스 혼합물

- **Clean energy for preventing environmental pollution**

환경 오염을 방지하기 위한 청정 에너지

➡ **Used for all fields of home, commerce, transportation, industry, etc.**

가정, 상업, 운송, 산업 등 모든 분야에 사용된다

- **Providing about 25% of energy consumption of the world**

세계 에너지 소비량의 약 25%를 공급한다

➡ **It will be continuously increased.**

지속적으로 증가할 것이다.

▪ Special Features

대기압에서 -162 C로 액화된다

- **Liquefied at -162°C under atmospheric pressure**

대기압에서 -162 C로 액화된다

➡ **Liquefied Natural Gas (LNG)**

액화하면 부피가 1/600이 된다.

- **When liquefied, the volume becomes 1/600.**

액화하면 부피가 1/600이 된다

➡ **Reason why we carry NG as LNG**

천연가스의 세계 매장량(2014년)

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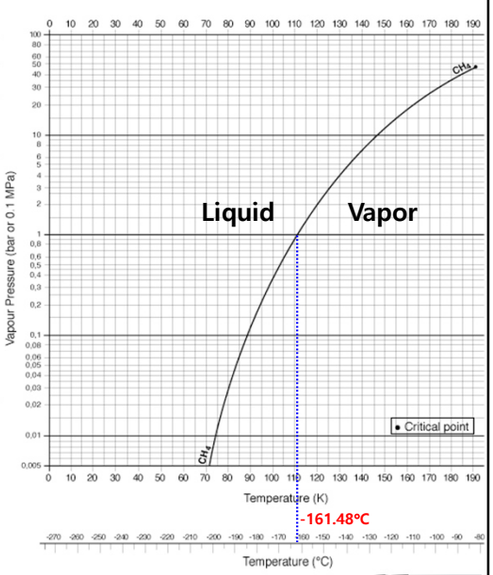
83

[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



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84

Worldwide Reserves of Natural Gas (2014)

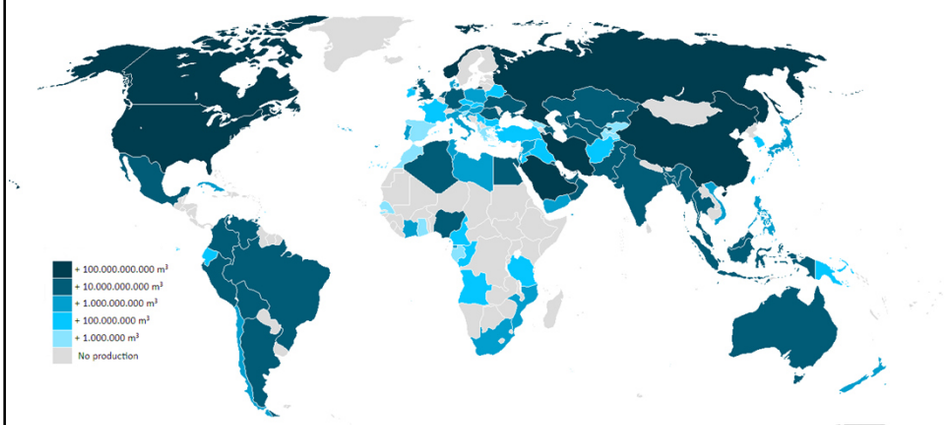
전 세계 천연가스 매장량 (2014)

- **The reserves are not biased towards the Middle East and are distributed worldwide, with a very large amount.**

매장량은 중동에 편중되어 있지 않으며 전 세계에 매우 많은 양이 분포되어 있다.

- **The development field moves from near the sea to far beyond the sea.**

개발 지역은 해안 인근에서 훨씬 먼 곳으로 이동한다

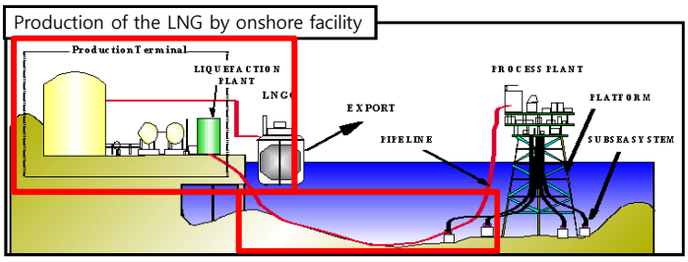


sydlab * Reference: http://en.wikipedia.org

85

Concept of LNG FPSO

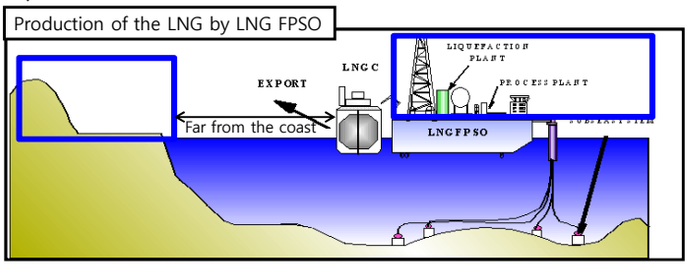
Production of the LNG by onshore facility



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

The LNG FPSO is a floating vessel equipped with a production facility, liquefaction facility, storage tanks, an offloading system for LNG, and a turret system.

Production of the LNG by LNG FPSO



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

86

[Article] The World's First LNG FPSO

Shell decides to move forward with groundbreaking LNG FPSO.

[기사] 세계 최초의 LNG FPSO Shell이 획기적인 LNG FPSO를 추진하기로 결정한다.

- **Shell, the world's largest oil company, is now ready to start construction of what will be the world's first LNG FPSO ("Prelude"), in a shipyard, Samsung Heavy Industries, in South Korea.**

세계 최대 석유 회사인 Shell은 이제 대한민국의 조선소 Samsung Heavy Industries에서 세계 최초의 LNG FPSO("Prelude")가 될 선박의 건조를 시작할 준비를 마쳤다.

- **LNG FPSO cools the temperature of the natural gas (NG) from 27°C to -162°C, causing it to shrink in volume by a factor of 600.**

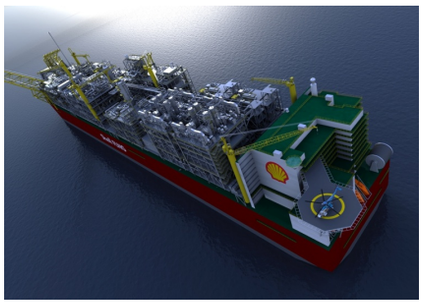
LNG FPSO는 천연가스(NG)의 온도를 27°C에서 -162°C로 낮춰 부피를 600배 줄인다.

- **The liquefaction process system for LNG is the most important system of the LNG FPSO.**

LNG의 액화 공정 시스템은 LNG FPSO의 가장 중요한 시스템이다.

- **Remark: It was delivered in 2017, and the purchase price is estimated to be approximately 10.8-12.6B$.**

참고: 2017년에 인도되었으며, 구매 가격은 약 10.8~12.6B$로 추정된다.



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* MTPA: Million Ton Per Annual
* Reference: [Article] Yonhapnews, Shell decides to move forward with groundbreaking floating LNG, 2011.5.20

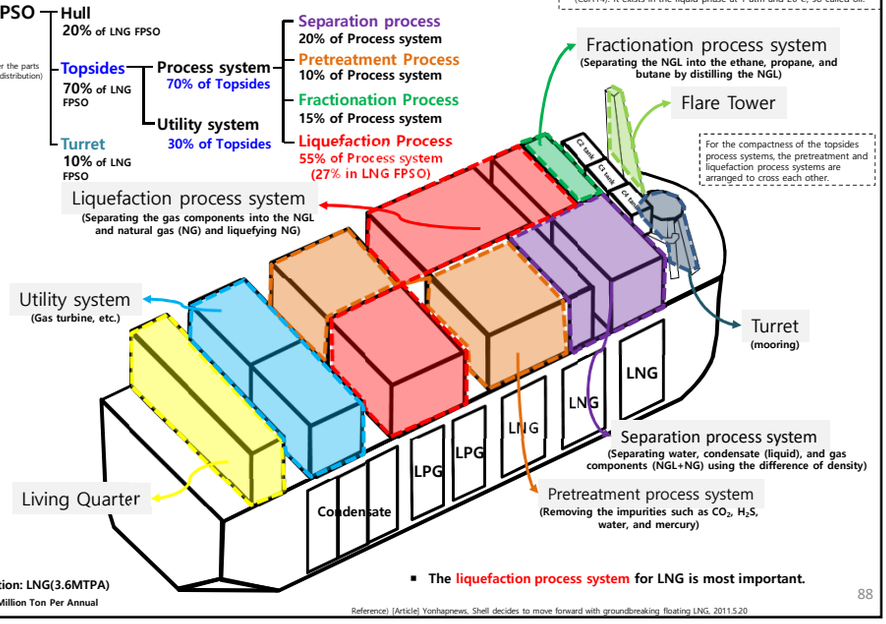
87

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.**

88

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

Topsides Process System of LNG

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

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 in density

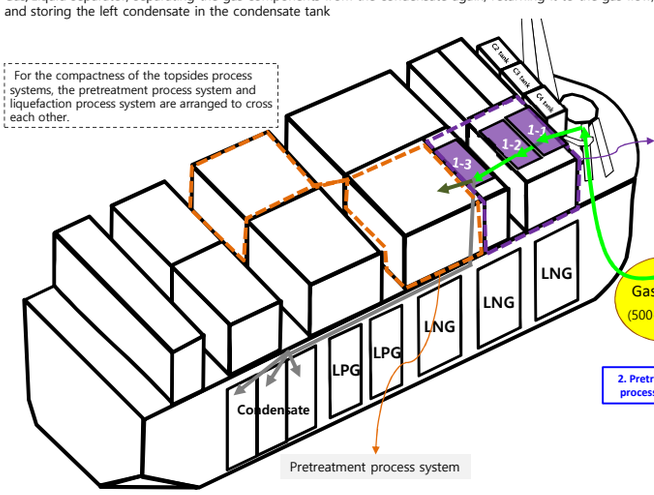
1-3. Stabilizer: Since a part of the gas components is not separated from the condensate completely in the

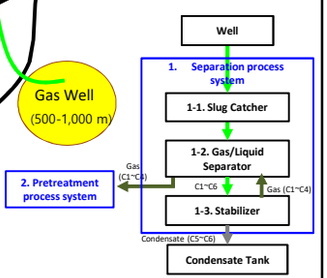
: Condensate + NGL+ NG
: Condensate (C5~C6)
: NGL + NG

LNG FPSO의 톱사이드 공정 시스템 (1/3) 1-2. 기체/액체 분리기: 물, 응축액(액체) 및 기체 성분(NGL+NG)을 분리한다 밀도 차이를 이용한다 1-3.

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.





Gas Well (500-1,000 m)

89

안정화기: NGL + NG 기체/액체 분리기에서 기체 성분의 일부가 응축액으로부터 완전히 분리되지 않으므로, 응축액에서 기체 성분을 다시 분리하여 기체 흐름으로 되돌린다.

Topsides Process System of LNG

- NG (Natural Gas): Main component is methane (CH4).
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- Condensate: Main components are Pentane (C5H12) and Hexane (C6H14). It exists in the liquid phase at 1 atm and 20°C, so-called oil.

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 beings

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

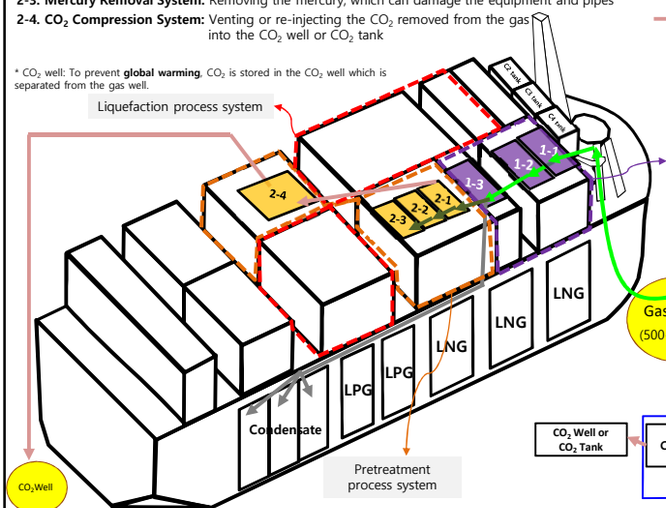
2-3. Mercury Removal System: Removing the mercury, which can damage the equipment and pipes

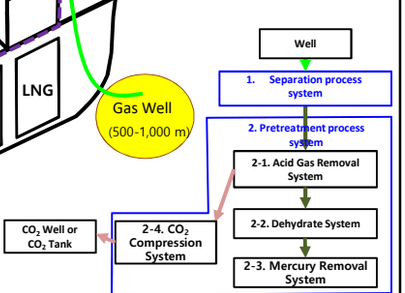
2-4. CO_2 Compression System: Venting or re-injecting the CO_2 removed from the gas into the CO_2 well or CO_2 tank

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

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

Liquefaction process system





Gas Well (500-1,000 m)

90

LNG FPSO의 톱사이드 공정 시스템 (2/3) 2-1. 산성 가스 제거 시스템: 재료에 부식성을 유발하는 산성 가스(H2S, CO2)를 제거하는 시스템 인체에 유독한 산성 가스(H2S, CO2)를 제거한다 2-2. 탈수 시스템: 얼음을 형성할 수 있는 물을 제거한다 2-3. 수은 제거 시스템: 장비와 배관을 손상시킬 수 있는 수은을 제거한다 2-4. CO2 압축 시스템: 가스에서 제거한 CO2를 배출하거나 CO2 CO2 유정 또는 CO2 탱크로 주입한다 액화 공정 시스템 분리 공정 시스템 유정 1. LNG 분리 공정 시스템 가스정 LNG 2. 전처리 공정 (500-1,000 m) LNG 시스템 2-1. 산성 가스 제거 LPG 시스템 LPG 2-2. 탈수 시스템 응축액 2-4. CO2 CO2 유정 또는 CO2 탱크 압축 시스템 전처리 2-3. 수은 제거 CO2 유정 공정 시스템 시스템

Topsides Process System of LNG

- NG (Natural Gas): Main component is methane (CH4).
- **LPG (Liquefied Petroleum Gas):** Main components are propane (C3H8) and butane (C4H10).
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- 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 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 the 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 (-161.5C°, 60 bar) to the atmospheric pressure (1-2 bar)

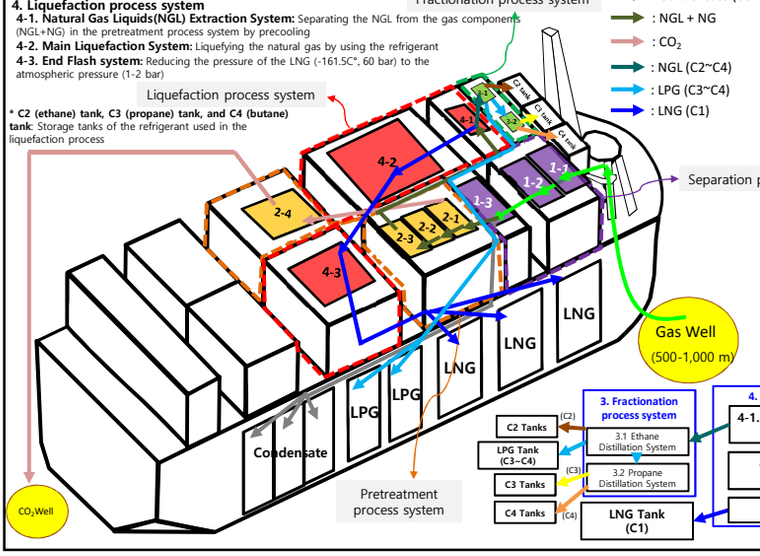
* **C2 (ethane) tank, C3 (propane) tank, and C4 (butane) tank**: Storage tanks of the refrigerant used in the liquefaction process

: Condensate + NGL+ NG
: Condensate (C5~C6)
: NGL + NG
: CO_2
: NGL (C2~C4)
: LPG (C3~C4)
: LNG (C1)

Natural gas composition:

Components	Natural gas(mol %)
Nitrogen	6.0
Methane	**83.2**
Ethane	7.1
Propane	2.25
i-Butane	0.40
n-Butane	0.60
i-Pentane	0.12
n-Pentane	0.33

: NG composition for maximizing the amount of methane and satisfying the required the heating value of NG



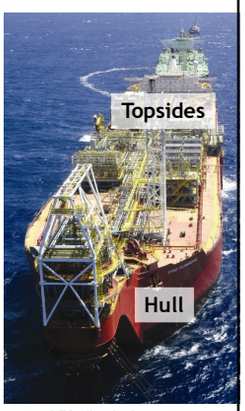
Gas Well (500-1,000 m)

Well
1. Separation process system
2. Pretreatment process system
3. Fractionation process system
4. Liquefaction process system
4-1. Natural Gas Liquids (NGL) Extraction System
4-2. Main Liquefaction System
4-3. End Flash system
3.1 Ethane Distillation System
3.2 Propane Distillation System
C2 Tanks (C2)
LPG Tank (C3~C4)
C3 Tanks (C3)
C4 Tanks (C4)
LNG Tank (C1)

92

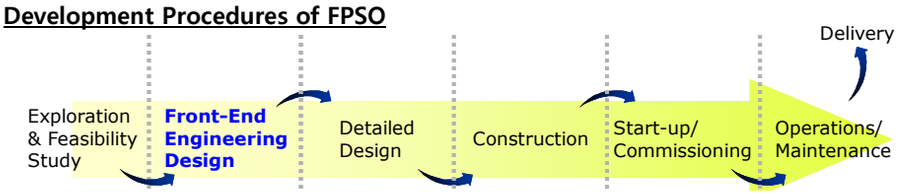
Development Procedures of FPSO and Importance of FEED

- **Topsides FEED(Initial or Basic Design): Estimation of building cost, total weight, and layout of topsides by determining specifications of all systems according to the 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 structure.**



FPSO 개발 절차와 FEED의 중요성 탑사이드 FEED(초기 또는 기본 설계): 발주자의 요구사항에 따라 모든 시스템의 사양을 결정하여 탑사이드의 건조 비용, 총중량 및 배치를 산정한다. 발주자의 요구사항에 따라 모든 시스템의 사양을 결정한다 우리 조선소는 상세 설계 또는 생산 이후의 업무만 담당한다. 탑사이드 FEED의 경우, 선체 해양 구조물 1기당 약 10~20M$의 비용으로 외국 설계 회사에 의존한다.

Development Procedures of FPSO



FPSO 개발 절차 인도 탐사 프런트엔드 상세 설계·시운전·운영·타당성 조사·엔지니어링·건조 탑사이드 공정 및 해양 구조물의 설계·시운전·유지보수 연구 설계 절차

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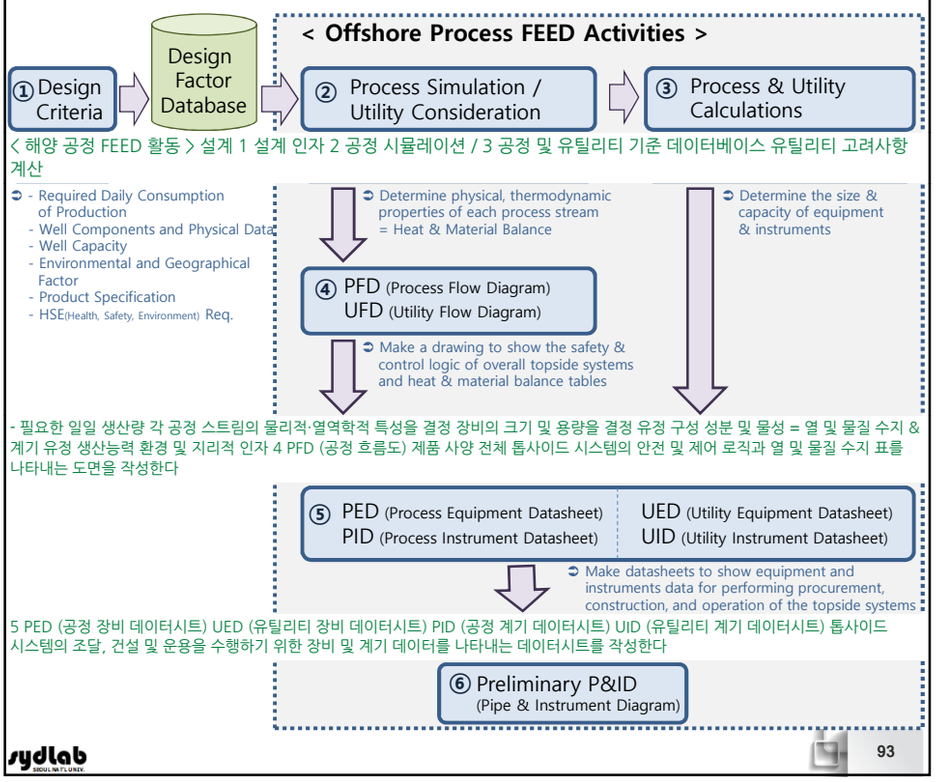
92

Procedures of Topsides Process FEED of Offshore Structures

해양 구조물 톱사이드 공정 FEED 절차



< 해양 공정 FEED 활동 > 설계 1 설계 인자 2 공정 시뮬레이션 / 3 공정 및 유틸리티 기준 데이터베이스 유틸리티 고려사항 계산

- 필요한 일일 생산량 각 공정 스트림의 물리적·열역학적 특성을 결정 장비의 크기 및 용량을 결정 유정 구성 성분 및 물성 = 열 및 물질 수지 & 계기 유정 생산능력 환경 및 지리적 인자 4 PFD (공정 흐름도) 제품 사양 전체 톱사이드 시스템의 안전 및 제어 로직과 열 및 물질 수지 표를 나타내는 도면을 작성한다

5 PED (공정 장비 데이터시트) UED (유틸리티 장비 데이터시트) PID (공정 계기 데이터시트) UID (유틸리티 계기 데이터시트) 톱사이드 시스템의 조달, 건설 및 운용을 수행하기 위한 장비 및 계기 데이터를 나타내는 데이터시트를 작성한다

6 예비 P&ID (배관 및 계기 다이어그램)

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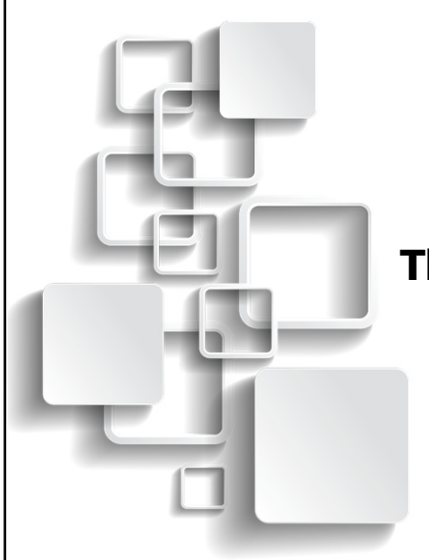

Thank you.

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