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AN INTRODUCTION TO THE OFFSHORE BASICS

– Fire safety of a drillship, Drilling Rig Unit (DRU)

TURUN AMMATTIKORKEAKOULU
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AN INTRODUCTION TO THE OFFSHORE BASICS

The purpose of this Bachelor's thesis was to study the basics that ship designers should know when moving from the familiar ship design duties to the unfamiliar offshore industry. The thesis was carried out as an assignment of Foreship Ltd. This thesis uses the term offshore to refer to oil and gas drilling only. In Finland several ship design and engineering companies have also expanded their activities to the offshore field, of which only a few designers have previous experience. Designers have attuned to the rules and regulations related to ships but the rules of offshore design are derived from a different rule book. In the thesis offshore as a definition is explained. Also different rig and vessel types are presented as well as the greatest offshore operators. Additionally, different offshore rules and their regulators are introduced in the thesis.

In the actual study part the fire safety rules of passenger ships were compared to drillships defined by two different rule books. SOLAS and MODU Code both by International Maritime Organization were applied in the comparison. The differences were illustrated with help of comparison drawings and tables made according to the above-mentioned rule books. The requirements of fire insulation were presented in the comparison.

Even with a brief examination, significant differences can be detected between ship design and offshore design. The functional requirements of vessels under consideration are very different from each other and therefore, the safety requirements vary significantly in some cases. There are a lot of new pointers in this thesis that a traditional ship designer can utilize when moving to a new design area. The study could be expanded by comparing national regulations and standards. The field is very broad because, in addition to the rule books, almost every country applies their own national regulations and standards to their design projects.

KEYWORDS:

shipbuilding, marine engineering, fire safety, oil drilling, gas drilling, oilfields

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JOHDATUS OFFSHOREN PERUSTEISIIN

Tämän insinöörityön tarkoituksena on tutkia tärkeitä perusasioita, joita laivansuunnittelijoiden tulisi tuntea siirtyessään tutuista laivansuunnittelutehtävistä tuntemattomalle offshore-alalle. Työ toteutetaan Foreship Oy:n tehtävänantona. Offshore sisältää tässä työssä merellä tapahtuvan öljyn- ja kaasunporauksen. Useat laivansuunnittelutoimistot Suomessa ovat laajentaneet toimintaansa myös offshore-alalle, josta harvalla suunnittelijalla on aiempaa kokemusta. Suunnittelijat ovat tottuneet laivoja koskeviin sääntöihin ja ohjeistuksiin, mutta offshore-suunnittelun säännöt tulevat eri sääntökirjasta. Työssä selitetään offshore-käsite, esitellään lautta- ja alustyyppejä ja suurimpia offshore-alueita ja -toimijoita. Työssä tehdään selkoa erilaisista offshore-säännöistä ja niiden valvojista.

Varsinaisessa tutkimusosassa tutkitaan kahden sääntökirjan määräämiä paloturvallisuussääntöjä matkustajalaivojen ja porauslaivojen välillä. Vertailuun sovelletaan International Maritime Organizationin laatimia SOLAS- ja MODU Code -säännöstöjä. Eroavaisuuksia havainnollistetaan muun muassa edellä mainittujen sääntökirjojen avulla tehdyillä vertailukuvilla ja -taulukoilla, joissa esitetään porauslaivan paloeristysvaatimusten eroja.

Suppeallakin tarkastelulla havaitaan merkittäviä eroja laivansuunnittelussa ja offshore-suunnittelussa. Vertailtavien alusten toimintavaatimukset ovat kuitenkin niin erilaiset, että turvallisuusvaatimukset vaihtelevat joissakin tilanteissa merkittävästikin. Uusia asioita perinteiselle laivansuunnittelijalle ilmenee paljon, jolloin tämä työ antaa suunnittelijalle hyvän pohjan uuden suunnittelualan valtaamiselle. Tutkimusta voitaisiin laajentaa ottamalla vertailuun erilaisia maakohtaisia säännöstöjä ja standardeja. Aihealue on erittäin laaja, koska lähestulkoon kaikki valtiot soveltavat edellä mainittujen sääntökirjojen lisäksi omia kansallisia ohjeistuksia ja standardeja suunnitteluprojekteissaan.

ASIASANAT:

laivanrakennus, paloturvallisuus, öljynporaus, kaasunporaus, öljykentät

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LIST OF ABBREVIATIONS (OR) SYMBOLS

Barrel	Unit of volume for petroleum. 159 litres.
BLEVE	Boiling liquid expanding vapor explosion
DRU	Drilling Rig Unit
EEBD	Emergency escape breathing device
FSS Code	International Code for Fire Safety Systems
FTP Code	International Code for Application of Fire Test Procedures
GOM	the Gulf of Mexico
GT	Gross Tonnage
ILO	International Labour Organization
IMO	International Maritime Organization
IOC	International Oil Company
SOLAS	Safety of Life at Sea
MODU Code (MC)	Code for the construction and equipment of mobile offshore drilling units
NOC	National Oil Company
OGP	International Association of Oil & Gas Producers

1 INTRODUCTION

This material is intended for ship designers who are entering from the familiar ship design to the new field of offshore technology. Ship designers have practises that they have used for many years. Nowadays several ship design and engineering companies are developing their activities and are expanding to other marine sectors, for example offshore sector. This is why designers have to use a new approach what comes to design. The crossover might not be painless because the offshore field, its regulations and practises are different. Designers have to consider new points in their design projects. For many designers the whole area is new and the knowledge of offshore basics is minor.

The designer has to start from the basics including offshore as a definition, the main types of offshore structures, main offshore fields, the major offshore operators and main regulations. Without the knowledge of these basics, design work will be difficult and the probability of faulty design might increase. Working with oil and flammable gases sets a high demand on safety in the offshore working environment.

Ship designers have to face daily a variety of challenges in their regular design projects. Offshore design gives fire safety a special attention. Ship design contains oil fires and gas explosions in the fire safety rules of tankers but on the oil platforms fire safety is more complex.

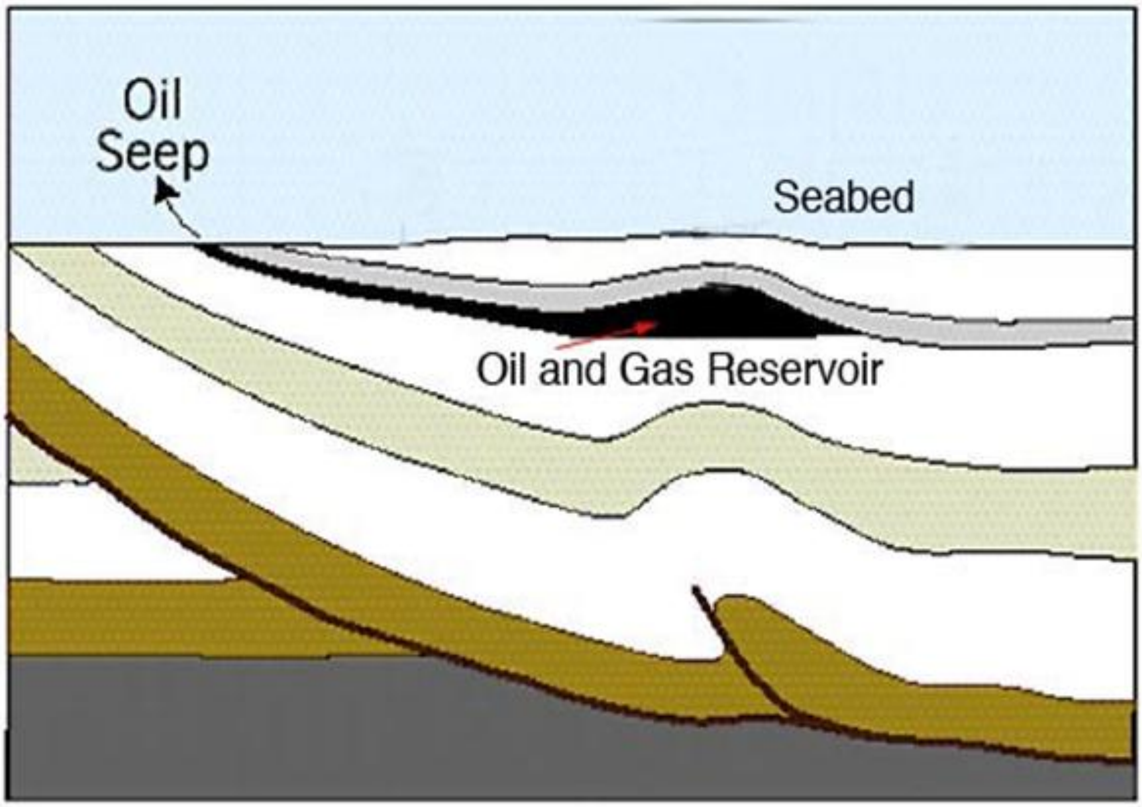
The objective of the thesis is to serve as a new compact information package for a designer who starts in the offshore design sector. The work was performed in cooperation with a ship design company Foreship Ltd. Foreship is a well-known and highly respected independent ship design and engineering company providing a broad range of services to the shipping industry (Foreship.com 2014).

Foreship has the need for this kind of research. All designers will study this information package before they start working on a new offshore project. The offshore concept is very broad and therefore, the thesis covers offshore only from the point of view of oil and gas drilling. Especially offshore structures with an accommodation area and the requirement for interior outfitting are presented. A structure working in accommodation mode is essentially acting as an offshore hotel. An offshore accommodation can be equipped for a variety of situations.

In the beginning the basics of offshore are presented but at the end the focus is on fire safety and fire integrity. This is because Foreship is specialized in interior outfitting where fire safety is one of the main parts of design. Ship design has its own regulations, which are derived from a book called SOLAS. IMO SOLAS is the best friend of the ship designer. In the offshore design, regulations are different and MODU Code regulates them. In the thesis these two regulation books are compared in the section of fire safety. The reader is expected to understand the contents of SOLAS before studying this work. To illustrate the differences, an example of Structural Fire Protection Plan is shown by these two design methods.

2 OFFSHORE (OIL AND GAS) AS A DEFINITION

Offshore refers to energy activity located at a distance from the shore. Offshore is a broad concept and therefore in this thesis offshore refers to oil and gas drilling only. Wind energy is outside the scope of the thesis. Offshore refers to drilling of oil and gas reservoirs away from the seabed. Oil and gas is drilled with help of different offshore structures, for example rigs and vessels. Offshore drilling is a process where a borehole is drilled through the seabed. Petroleum and natural gas is located below the bedrock, which makes it difficult to extract them. A limited amount of inland oil has driven oil industry to the seas to find more oil deposits. There are high financial markets in the offshore industry and that is why much money is being invested in new offshore structures all around the world.



Picture 1. Oil and gas reservoir (OilPrice.com 2014).

3 THE MAIN TYPES OF OFFSHORE STRUCTURES

Offshore structures are constructed for many different purposes worldwide. The structures are expensive to construct but there is an opportunity to have significant financial profit. The construction process demands a lot of expertise from the designers because the offshore regulations set high standards for the building process. Working with oil and gas is always dangerous and the risks are higher than in normal marine structures such as ships. Different offshore structures are designed for various water depths. Petroleum can be drilled up to 3, 000 meters (Lake, Larry W. Mitchell, Robert F; 2007, 589).

Classification of water depths (DNV, Arild Rogne. 2013, 9):

< 300 meters – Shallow water

< 1500 meters – Deep water

> 1500 meters – Ultra deep water

Offshore structures are classified to rigs and vessels. Offshore oil rigs (also known as platforms) must service safely for over 25 years. Difficult sea conditions with salt water set challenges to the rigs and it is crucial to consider the circumstances as peak loads created by storm winds and waves. The structures are made of various grades of steel and the platforms are the tallest structures on the earth (Sadeghi 2008, 67). Their massive weight demands special transportation methods on the sea.

“Offshore construction, with its many current opportunities and its tremendous demands and challenges, is emerging as one of the most exciting fields of engineering practice, one which will test human-kind's ability to rise to new heights of skill and courage” (Ramakrishnan. 2008, 2).

Some offshore structures are classified as “Mobile Offshore Drilling Units”. SOLAS specifies MODU as a vessel capable of engaging in drilling operations for the exploration for or the exploitation of resources beneath the seabed (SOLAS IX/1, MODU Code 2009 para 1.3.40).

3.1 Rigs

Offshore rigs, also known as platforms are massive structures which are built for oil and gas drilling out of the seabed. Platforms are equipped with storages where the oil can be reserved before it is transported to refineries. Several people are working on the rigs and usually there are accommodation areas for them. Depending on the requirement, rigs can be fixed to the seabed or can be floating with anchors and wires.

Table 1. Offshore Rig Fleet by Rig Type (Rigzone 2014).

Rig Type	Rig Fleet (rigs)	% Utilization
Drill Barge	49	53.1 %
Drillship	168	52.4 %
Inland Barge	13	18.6 %
Jack-up	637	59.0 %
Platform Rig	249	54.2 %
Semi-sub	246	72.0 %

Fixed platform/ Fixed steel structure

In shallow waters, it is possible to attach an offshore platform directly to the seabed with the use of legs. Steel is the most common material of the legs and they are fixed to the seabed with piles. The main benefit of the fixed rigs is stability as they are attached to the seabed. There are spaces for drilling, production facilities and accommodation area on the fixed platform. This type of rig is not suitable for extremely deep water as the length of the legs is a restrictive factor. Ordinarily, these types of platforms can be installed in water depths up to 520 meters (1,700 ft) (Maritime Connector 2014).

Tension Leg Platform (TLP)

These platforms are operated in deep waters. They are floating platforms and their long, flexible tension legs are attached to the seabed and the legs are self-adjusting. These legs allow lateral movement with little vertical movement. TLP structures can be installed in water depths up to 2100 meters (7000 ft) (Hilyard 2012, 108 & Maritime-Connector.com 2014).

Compliant towers (CT)

These types of platforms are fixed structures but they use narrower and flexible towers of concrete and steel. CT structures are designed to sustain high lateral forces. Compliant towers are capable of operating in water depths ranging from 450 to 900 meters (1,500 to 3,000 ft) (Hilyard 2012, 109 &Maritime-Connector.com 2014).

FPSO

FPSO (Floating production, storage and offloading system) is a major floating production system. FPSO structures can be operated either as floating semi-submersible rigs or drillships. An FPSO is designed to receive petroleum from the nearby oil platforms or Subsea Systems (SS), process it and store oil. From the FPSO, oil is transferred to a tanker which will transport oil to the ports. FPSOs can be operated in water depths ranging from 450 to 1800 meters (1,500 to 6,000 ft) (Leffler et al. 2011, 190-195 & Maritime Connector 2014).

Jack-up rig

The jack-up rig is an oil rig that it is suitable for drilling in water depths up to 120 meters (400 ft). Jack-ups are categorized to two main types; the independent-leg type with normally three legs with a lattice construction, and the mat type where the legs are attached to a very large mat that rests on the seabed. Both types have a hull. They are floating in their location, lowering their legs to the seabed, and jacking the hull out of the water to the required elevation. The advantage of the jack-up design is that it offers a steady and relatively movement-free platform in the drilling position and starts operation quickly and easily (Lake, Larry W. Mitchell, Robert F; 2007, 609) (Hilyard 2012, 100).

Semi-Submersible Platform

Semi-Submersible platforms (SSR) are floating structures that include pontoons and columns. They are the most popular drilling platforms, because they can be moved from one place to another. The large anchors or the dynamic positioning system hold the positioning of the rig. These types of platforms can be used in water depths up to 3000 meters (10,000 ft). (Maritime-Connector.com 2014), (Leffler et al. 2011, 106-107).

Sea Star Platform

These rigs are a more massive solution of the semi-submersible structure. They do not have anchors or the dynamic positioning system because these rigs are attached to the seabed by flexible steel legs. The operation depth is from 150 to 1100 meters (500 to 3,500 ft). (Maritime-Connector.com 2014)

SPAR Platforms

One of the major offshore rig types is called a SPAR. The platform is built above a tall cylinder that is designed to be underwater in vertical position below the platform. SPAR platforms have a better stability than Tension Leg Platforms, because SPARs are attached to the seabed with mooring lines. SPAR platforms are capable of operating in water depths ranging from 600 to 3000 meters (2,000 to 10,000 ft) (Hilyard. 2012, 112).

3.2 Vessels

Offshore vessels are designed to service in various tasks associated with the offshore drilling. The main tasks are transporting workforce, goods and equipment from port to platform. Some vessels can also be used as offshore platforms that operate in deep oceans (Maritime-Connector.com, 2014). A drillship is a good example of this.

Platform Supply Vessel

Crew and all kind of cargo are transported to the platforms with help of these vessels. There are tanks for cement, mud, drilling fluids, potable and nonpotable water and fuel below the deck. The deck is suitable for cargo such as drill pipes and tubing. In case of emergency situations, PSVs are usually equipped with firefighting equipment. The length of the vessels varies from 20 to 110 meters. Dynamic positioning prevents collisions toward the platforms (Leffler et al. 2011, 314-315).

Drillship

These vessels have a ship-shaped design and they are fitted with drilling equipment. The dynamic positioning system keeps them stable at the sea and drillships can change the drilling site quickly. Because of this mobility, drillships are more expensive to construct than semi-submersibles. In the fore of the ship there is an accommodation area for the crew. Drillships can be operated in water depth up to 3700 meters (12,000 ft) (Leffler et al. 2011, 107).

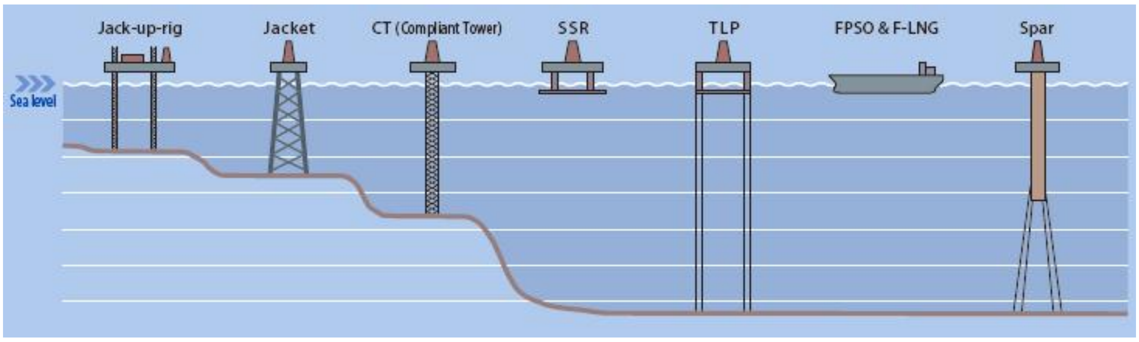
Picture 2. Drillship (gCaptain 2014).

Anchor Handling Tug Supply (AHTS)

AHTS vessels are designed to operate beside the oil platform. They tow the anchors to location and anchor them up. Plenty of equipment is transported to the oil rigs by these vessels. AHTS vessels vary from Platform Supply Vessels as they are fitted with winches for towing and anchor handling (Leffler et al. 2011, 316-317).

Offshore Barges

Offshore Barges are suitable for a variety of offshore tasks. These vessels are equipped with heavy lifting cranes and firefighting system. Moreover, Offshore Barges can serve accommodation for the workforce beside the platform. The length of the typical offshore barge varies between 80 and 160 meters (Ramakrishnan. 2008, 11-12).



Picture 3. Offshore structures (Kobelco 2014).

4 MAJOR OFFSHORE FIELDS

The main offshore fields are spread all over the world but the top three largest offshore oil areas are located in the Persian Gulf. This is the result of oil drilling activity since the 1950s. Also, on the other side of the world there are significant offshore areas. Santos Basin off the coast of Brazil is a giant oil field and the development is extensive. Kashagan field, in the North Caspian Sea, is the largest area outside the Middle East. Other large fields are the Gulf of Mexico and the North Sea.

Picture 4. The major offshore fields (Baker Hughes 2012).

The Persian Gulf

The Persian Gulf has the three largest offshore fields in the world. Safaniya in Saudi Arabia is the largest one and it is owned and operated by Saudi Aramco. The total reserve of oil is more than 36 billion barrels.

The second largest field is located in the United Arab Emirates and it is called Upper Zakum. It is owned and operated by a joint enterprise called Zakum Development Company (Abu Dhabi National Oil Company 60%, ExxonMobil

28% and Japan Oil Development Company 12%). The estimated reserve of oil is up to 21 billion barrels.

In the shallow waters of Saudi Arabia there is an oil field called Manifa. It is the third largest in the world. The total reserve of oil is more than 13 billion barrels (Forbes 2013).

The Caspian Sea

The largest offshore field outside the Middle East is in Kazakhstan, Kashagan. There are up to 35 billion barrels of oil in total and the estimated reserve of oil is around nine billion barrels. It was discovered in 2000 and it has been operated by KMG, Eni, ExxonMobil, Shell, Total, ConocoPhillips and INPEX. The production is expected to increase almost tenfold by 2021 (Offshore Technology, 4/2013).

The coast of Brazil

In the Santos Basin, Brazil the Lula field (earlier the Tupi field) is located, which is a major offshore oil area. The main operator of the field is Petrobras that owns 65% of it. The other eminent owners are BG Group and Galp Energia. The approximated recoverable oil reserve is about 6.5 billion barrels. The field was discovered in 2007 and the production began in 2010 (Offshore Technology, 4/2013).

The Gulf of Mexico

The Gulf of Mexico is an area steeped in the tradition of offshore oil drilling. The offshore activity is originated from the 1930s when the state of Louisiana founded its first offshore field. The coasts of Alabama, Louisiana, Mississippi and Texas are the main source of oil in the United States (Leffler et al. 2011, 49).

The North Sea

The North Sea is a large offshore field in Europe and it is operated by Norway, the Netherlands, the United Kingdom, Germany and Denmark. Norway is the largest oil producer in Europe and the second largest natural gas exporter in the world. Norway has the largest oil reserves in Western Europe. According to The Oil and Gas Journal (January 1), the proven oil reserve of Norway is 5.3 billion barrels. Statoil is the major operator in the North Sea and it controls 80 % of Norway's oil and gas production. In the North Sea the circumstances set challenges for designers with the low temperatures in comparison to the other offshore areas in the world (The Oil and Gas Journal 1/2012).

West Africa

The offshore operations of West Africa are concentrated to the coast of Niger, Angola and Congo. The oil exploration was originated in the early 1960s, when plenty of shallow water oil fields were brought to production at the coast of West Africa. Oil discoveries are in water depths greater than 300 meters, and therefore, the high quality offshore equipment are used in the coast of West Africa as in the Gulf of Mexico and Brazil. West Africa is one of the most rapidly expanding exploration and production area in the world (Leffler et al. 2011, 60).

Arctic Ocean

Offshore industry has also expanded to the challenging Arctic Ocean where the circumstances set challenges for drilling. The reason for expanding is the number of undiscovered oil and gas resources. In 2008 the United States Geological Survey estimated that over 20 % of the world's oil and gas might be in the Arctic area (Federation of American Scientists 2009, 15). The largest exploration areas are in Atlantic Canada, Alaska, Norway and Russia (Ramakrishnan 2008, 88-89). Ice class is required for offshore drilling units operating in those areas.

Asia, Southeast

Currently Southeast Asia is one of the most active offshore areas in the world. Malaysia dominates the offshore infrastructure of the region but China, Japan and Vietnam are also significant players in the field. According to Infield Systems' “Offshore Asia Oil and Gas Market Report to 2017”, the Asian market is expected to increase over 50% in offshore oil and gas in the next five years. The Malaysian national oil company Petronas and Chinese NOC, CNOOC, are important operators (Infield 2014).

Table 2. Top 10 countries for proved oil reserves, 2013 (U.S. Energy Information Administration, Oil & Gas Journal 2014).

Country	**Billion barrels**
Venezuela	297.6
Saudi Arabia	267.9
Canada	173.1
Iran	154.6
Iraq	141.4
Kuwait	104.0
United Arab Emirates	97.8
Russia	80.0
Libya	48.0
Nigeria	37.2

Note: In 2012, the United States ranked 12th in the world with 26.5 billion barrels.

Table 3. Top 10 Oil Producers, 2012 (U.S. Energy Information Administration, Oil & Gas Journal 2014).

Country	**Thousand Barrels per Day**
Saudi Arabia	11,726
United States	11,111
Russia	10,397
China	4,372
Canada	3,856
Iran	3,589

United Arab Emirates	3,213
Iraq	2,987
Mexico	2,936
Kuwait	2,797

Note: In 2012 Brazil ranked 11th and Norway 14th.

Table 4. Offshore Rig Fleet by Region (Rigzone 2014).

Region Name	**Rig Fleet**	**% Utilization**
Africa - West	91	77.8 %
Asia - Caspian	31	67.7 %
Asia - Far East	175	22.3 %
Asia - South East	188	54.3 %
Europe - North Sea	180	95.0 %
Mid East- Persian Gulf	133	73.7 %
N. America - Mexico	87	57.5 %
N. America - US GOM	224	37.5 %
S. America - Brazil	116	72.4 %
S. America - Venezuela	48	52.1 %

5 MAJOR OFFSHORE OPERATORS

Offshore business is a growing industry and due to the reduction of inland oil drilling significant offshore actors are extending their operations from mainland to offshore. There are plenty of offshore centers in the world and every major company is operating at the seas. These companies are significant employers to their closest nations. The success in the offshore industry has had a significant effect on some countries. Natural resources have enriched the local economy. Norway is a good example for this.

The oil operators have a high revenue and they are ranked among the greatest companies in the world. The World's Biggest Public Companies list (Forbes 2013, Global 2000 Leading Companies) have six oil operators in the top 20. ExxonMobil is ranked the fifth. Royal Dutch Shell (7th) and Chevron (13th) are also major companies in the world. Saudi Aramco is not on the list but it is the most valuable company in the world (Forbes 2010). Ross McCracken from Platts says that Asia-Pacific energy companies have improved their relative position in comparison to earlier (Businessinsider.com 2014).

Table 5. Offshore operator comparison (Forbes 5/2013 & RigZone.com).

Operator Name	Country	Rig Fleet	Profits	Market Value
Saudi Aramco	Saudi Arabia	48	$311.1B	$1245.0B
Pemex	Mexico	48	$26.1B	$415.7B
ExxonMobil	USA	16	$44.9B	$400.4B
ONGC	India	40	$3.8B	$315.3B
Chevron	USA	35	$26.2B	$232.5B
Royal Dutch Shell	Netherlands	43	$26.6B	$213.1B
BP	UK	37	$11.6B	$130.4B
Total	France	36	$14.1B	$115.5B
Petrobras	Brazil	78	$11.0B	$120.7B
CNOOC	China	24	$10.1B	$84.3B
ENI	Italy	17	$10.0B	$86.3B
Statoil	Norway	36	$12.4B	$78.1B
Conoco Phillips	USA	17	$8.4B	$72.1B

6 THE MAIN OFFSHORE RULES AND REGULATIONS

As all design, also offshore is regulated with a great variety of regulations. Ship designers are used to the IMO (International Maritime Organization) and its SOLAS regulations in their design projects but in offshore design new regulations have to be considered. The various offshore codes guide the designer in the same areas as in ship design. The IMO has a particular guide to offshore design called MODU Code (Code for the Construction and Equipment of Mobile Offshore Drilling Unit).

Offshore has expanded all over the world, thus there are country-specific differences in design. National regulators have standards for materials, equipment, systems and structures for the offshore petroleum industry. Several coast guards have their own input when it comes to safety. Coastguards monitor maritime security at the seas. Major guardians are the US Coast Guard, the Canadian Coast Guard and the Chinese Coast Guard.

The projects of the North Sea are the most common in Finland. Therefore, the regulations of Norway are an important factor. PSA Regulations and its standards are important in the petroleum field and therefore these should be understood.

In the end, there are eleven classification societies that belong to the International Association of Classification Societies. The three major players are DNV-GL, American Bureau of Shipping (ABS) and Lloyd's Register.

6.1 The International Maritime Organization (IMO)

The IMO is a specialized agency of the United Nations which administers international maritime security and prevents marine pollution from ships. The IMO has developed and adopted international regulations and standards for seafarers. The IMO is comprised of 170 member states (IMO 2014). The most important offshore rules come from the IMO's SOLAS and MODU Code.

SOLAS

The International Convention for the Safety of Life at Sea (SOLAS) is an international maritime safety convention. The main duty of the treaty is to regulate minimum standards for the construction, equipment and operation of structures, compatible with their safety. The SOLAS is viewed as the most important safety treaty when it comes to merchant ships. The flag states are responsible for ensuring that vessels under their flags are qualified for the requirements of the SOLAS. The SOLAS has specified offshore in chapter IX.

MODU Code

MODU Code was written to give an international standard for mobile offshore drilling units of new construction. This will simplify the international movement and operation of structures and ensure an adequate safety level for structures, and for personnel on board, equivalent to that required by the SOLAS (IMO MODU Code 2009, preamble).

“The purpose of the code is to recommend design criteria, construction standards and other safety measures for mobile offshore drilling units so as to minimize the risk to such units, to the personnel on board and to the environment.”(MODU Code 2009, Chapter 1.1).

6.2 Classification: International Association of Classification Societies (IACS)

As mentioned, all offshore structures have to be classified by a classification society and have the registration certificates of compliance to the rules and regulations. The purpose of MODU classification is to verify the structural strength and integrity of the MODU’s hull, and the reliability and function of all equipment and outfittings (IACS 2014, Classification Societies- their key role, 3). The customer decides which classification society will be used. The classification societies have normally private ownership and have a goal to make profit (Petrowiki, 2014). The classification societies work closely with design companies and governments. The IACS is comprised of eleven societies and the members are:

- American Bureau of Shipping (ABS)
- Bureau Veritas (BV)
- China Classification of Shipping (CCS)
- The Croatian Register of Shipping (CRS)
- Det Norske Veritas- Germanicher Lloyd (DNV-GL)
- Indian Register of Shipping (IRS)
- Korean Register of Shipping (KRS)
- Lloyd’s Register (LR)
- Nippon Kaiji Kyokai (NK)
- Polish Register of Shipping (PRS)
- Registro Italiano Navale (RINA)
- Russian Maritime Register of Shipping (RS)

However the primary societies are American Bureau of Shipping, DNV-GL and Lloyd’s Register of Shipping. According to Petrowiki, it is very rare to see a MODU that is not classified by one of these three primary societies (Petrowiki, 2014).

6.3 Coastal Authority Standards, Codes and Regulations

The coast guards have to be considered because they are a powerful decision-maker in international maritime matters. They are in charge of national maritime safety and security.

By law they have the following duties (United States Coast Guard 2014):

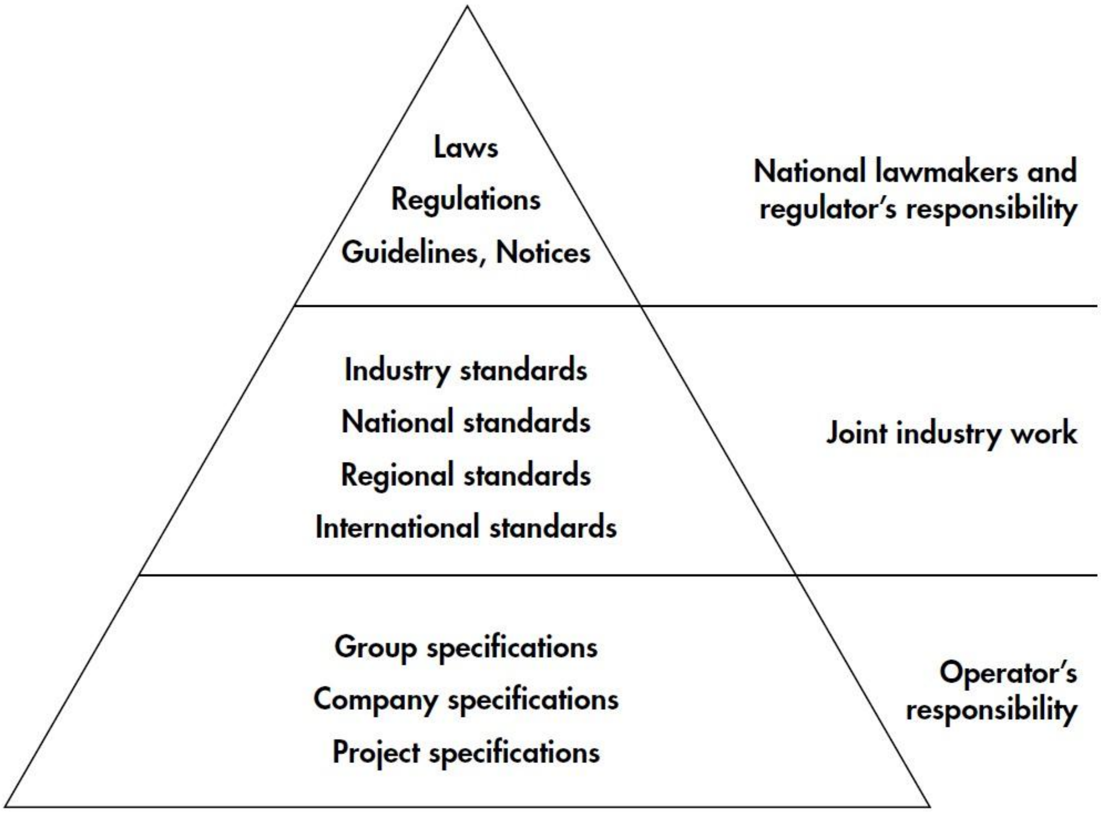
- ports, waterways, and coastal security,
- drug interdiction,
- aids to navigation,
- search and rescue,
- living marine resources,
- marine safety,
- defense readiness,
- migrant interdiction,

- marine environmental protection,
- ice operations, and
- other law enforcement.

The national coast guard has to give its permission to use a vessel in their territory. If the permission is not given, the vessel must be modified or it has to operate somewhere else.

6.4 National regulators

Offshore regulations are usually set by national regulators, with a few international exceptions such as the ILO and IMO. Most of the regulators use standards in specifying their schemes, regulations, guidelines or other regulatory documents. The hierarchy of these different offshore documents is shown in Picture 5.



Picture 5. The hierarchy of documents (International Association of Oil & Gas Producers 2010, 3)

The OGP mentions that the oil and gas industry and regulators are not able to work effectively without using the standards listed below (International Association of Oil & Gas Producers 2010, 2)

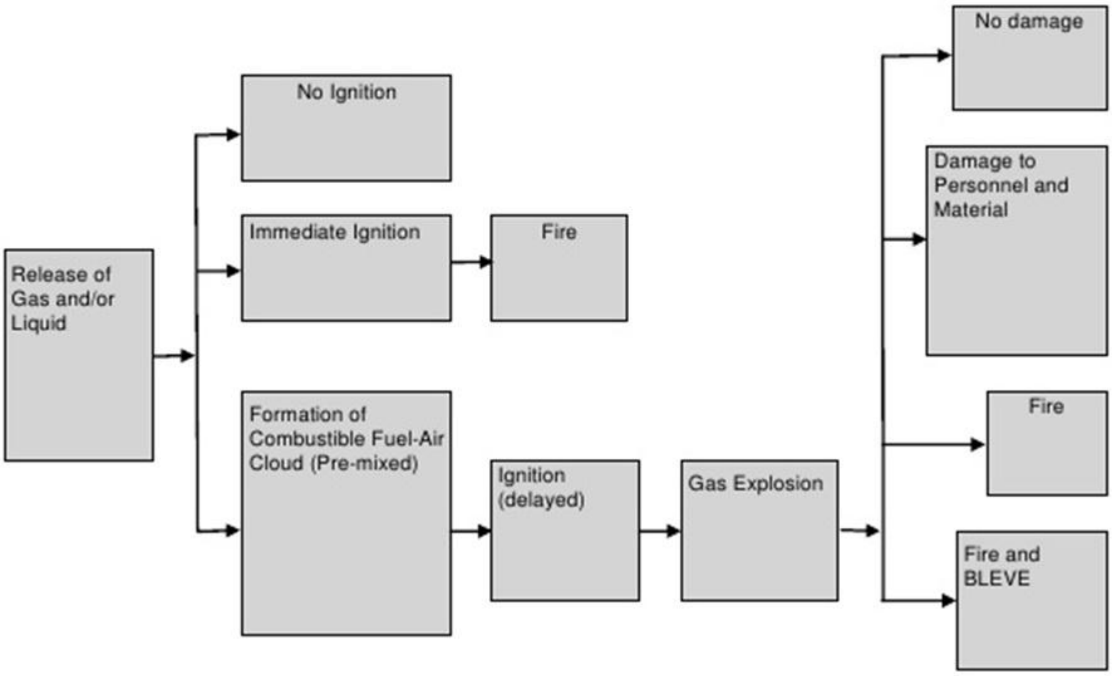
- Canada
  - Canada-Nova Scotia Offshore Petroleum Board (CNSOPB)
  - Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB)
  - National Energy Board (NEB)
- China National Offshore Oil Company (CNOOC), China
- Danish Energy Agency (DEA), Denmark
- Department of Labour (DoL), New Zealand
- Department of Mineral Fuels (DMF), Thailand
- Ministerodello Sviluppo Economico (MES), Italy
- National Agency of Petroleum, Natural Gas and Biofuels (ANP), Brazil
- National Offshore Petroleum Safety Authority (NOPSA), Australia
- Oil Industry Safety Directorate (OISD), India
- Petroleum Safety Authority (PSA), Norway
- Russia
  - The Ministry of Natural Resources of the Russian Federation (MNR)
  - The Ministry of Industry and Energy of the Russian Federation (Minpromenergo)
- State Supervision of Mines (SODM), The Netherlands
- UK Health and Safety Executive (HSE), UK
- United States represented by:
- US Coast Guard (USCG)
- US Minerals Management Service (US MMS)

7 COMPARISON: FIRE SAFETY, MODU CODE VS. SOLAS

The fire safety objectives of the SOLAS are to

- prevent the occurrence of fire and explosions,
- reduce the risk to life caused by fire,
- reduce the risk of damage caused by fire to the ship, its cargo and the environment,
- contain, control and suppress fire and explosions in the compartment of origin,
- provide adequate and readily accessible means of escape for passengers and crew.

As mentioned previously, mobile offshore drilling unit design is based on the rules of the MODU Code. It is unfamiliar to the ship designer who is entering the offshore world because the ship designer is used to the SOLAS regulations in his design projects. The following pages will discuss the differences between the MODU Code and SOLAS. The exact objective of this chapter is to present fire safety and fire integrity differences between the IMO MODU Code and SOLAS. In the SOLAS, the rules of a passenger ship (carrying more than 36 passengers) are used as a comparison material. Passenger ship was selected because it is familiar to the designers of Foreship Ltd. The fire safety design of a passenger ship has the most difference when compared to the corresponding offshore drilling units. Only the chapters of the MODU Code, which are different from those of the SOLAS, are presented. Many sections of the MODU Code are identical to the SOLAS, thus they are not included. The example vessel used in this case is a drillship.



Picture 6. Fire and explosion scenarios. (Torgeir Moan, Safety of Offshore Structures, 28, Norwegian University of Science and Technology).

7.1 Structural fire protection

In offshore construction the same methods as in ship construction are used when it comes to fire integrity. Bulkheads and decks are insulated with various class standards. As in the SOLAS, every space is categorized and numbered, and accordingly, the right insulation is selected and installed. “Structural fire protection details, materials and methods of construction should be in accordance with the FTP Code, as applicable, and SOLAS regulations II-2/5.3 and II-2/6, as applied to cargo ships.” (MODU CODE, 9.2)

Fire integrity of bulkheads and decks

1. The spaces are categorized differently in the MODUs and hazardous areas are specified in the MODU Code. This is explained by the fact that passenger ships do not have hazardous situations as the MODUs.
2. The category numbering is different between the SOLAS and MODU Code. Some spaces are named differently, and therefore, numbering is applied in some cases.

Table 6. The category numbering of fire integrity.

Space	**MODU Code**	**SOLAS**
Control stations	1	1
Corridors	2	3
Accommodation spaces	3	6
Stairways	4	2
Service spaces (low risk)	5	7
Machinery spaces of category A	6	12
Other machinery spaces	7	10, 11
Service spaces (high risk)	9	13
Open decks	10	5
Sanitary and similar spaces	11	9

3. The minimum fire integrity of bulkheads and decks is not described in the same way in the MODU Code as in the SOLAS. Both have similar tables but the requirements are different for fire integrity of bulkheads (or decks) separating adjacent spaces. The appendices exemplify how the design of fire integrity differs in these two fields. The main difference concerns offshore accommodation area which faces towards and is within 30 meters from an oil drilling place (MC 9.2.4.). Exterior boundaries of superstructures and deckhouses enclosing accommodation have to be designed and constructed according to “A-60” standard, because of fire and explosion risk.

   Even if the tables of both rule books look similar at the first sight, the first thing to do is to disregard the SOLAS table”. The MODUs and tankers have similar requirements concerning fire integrity but other ship types will be designed with different provisions.

Fire integrity of bulkheads separating adjacent spaces

Fire integrity tables in rule books are comprehensive and therefore only the main differences concerning the deck of the drillship are shown. To visualize the fire safety and fire integrity differences between the MODU Code and the SOLAS, an example picture of the Structural Fire Integrity Plan was made by these two methods. The pictures were designed with help of the MODU Code (Chapter 9) and the SOLAS (Chapter II-2). Examples of Structural Fire Integrity Plans are presented in the appendices. Interesting and tangible results are seen in these drawings. The main differences of the fire integrity of bulkheads separating adjacent spaces are shown in the following table.

Table 7. Fire integrity of bulkheads.

Adjacent spaces	MODU Code	SOLAS
Accommodation/ Corridor	B-0	B-15
Accommodation/ Accommodation	C	B-0
Stairways/ Accommodation	A-0	A-15
Stairways/ Corridor	A-0	B-15
Open deck/ Accommodation	*	A-0
Open deck/ Corridor	*	A-0
Open deck/ Stairways	*	A-0

* The division should be of steel or equivalent material, but need not to be of A-class.

As Table 7 shows, stricter requirements are demanded in the SOLAS. This might be explained by the fact that there are passengers. Safety is the most important matter on passenger ships. It should be noted that A-class is required between the stairways and corridor in the MODU Code.

Fire integrity of decks separating adjacent spaces

The required insulations of decks also differ between the two rule books under consideration. Some differences have been listed as follows.

Table 8. Fire integrity of decks.

Space below/ Space above	MODU Code	SOLAS
Accommodation/ Control station	A-60	A-60
Accommodation/ Corridor	A-0	A-15
Accommodation/ Accommodation	*	A-15
Accommodation/ Open deck	*	A-0
Corridor/ Accommodation	*	A-15
Corridor/ Corridor	*	A-0
Corridor/ Open deck	*	A-0
Open deck/ Open deck	-	-
Stairways/ Open deck	*	A-0
Stairways/ Stairways	*	A-0

* The division should be of steel or equivalent material, but need not to be of A-class.

7.2 Protection of accommodation spaces, service spaces and control stations

In the SOLAS hazardous areas are not presented much but in the MODU Code mentions that accommodation spaces, control stations and service spaces should not be located adjacent to hazardous areas. This is very understandable because the risks are so high in hazardous areas. When the accommodation area has to be constructed near the hazardous area, reliable engineering evaluation is needed to ensure the adequate safety level. (MC 9.3.1)

Ducts in hazardous areas are something that have to be considered. Ducts serving hazardous areas, galleys and machinery spaces should not pass through accommodation spaces, control spaces and service spaces. Smoke spreading in these areas can be prevented by the solution mentioned above. The MODU's operation is subject to the working condition of the critical areas. This sets challenges to the designer but the Administration can give opportunities to circumvent these provisions (except for the ducts passing through hazardous areas), providing that some conditions are filled. These terms are represented in the MODU Code (9.3.16).

7.3 Means of escape

In ship design there are many rules regarding the means of escape. The MODU Code is simpler in this sector because most people are normally employed on the MODUs. Unlike passenger ships, the design of the MODUs has an easier opportunity for special provisions by the Administration. Passengers on ships are visitors who are not conscious of the spaces and escape routes. Therefore, the escape design of the ships has to be accounted for carefully.

The rules mentioned in the MODU Code are almost similar to those of the SOLAS but the major difference concerns dead-end corridors. The SOLAS (p.247) requires that a part of a corridor has a depth not exceeding its width. The MODU Code (9.4.1.3) allows dead-end corridors up to seven meters in length. This remarkable difference is a result of people operating on the vessel. This kind of dead-end corridor on a passenger ship would cause a panic in an emergency situation.

The other difference concerns ladders. In the SOLAS it is mentioned that escape ladders should be of steel, but the MODU Code allows other equivalent material as well (MC 9.4.2).

7.4 Emergency escape breathing devices

According to the SOLAS (3.4.2 p.251), all ships shall carry at least two emergency escape breathing devices within the accommodation spaces. There should be two EEBDs in each main vertical zone in all passenger (36+) ships. Such reference was not in the MODU Code (9.6), but both should comply with the FSS Code.

The MODU Code covers the requirements of the EEBDs in machinery spaces instead of the accommodation areas etc. The following requirements are represented in the MODU Code (9.6.2).

In the machinery spaces of category A containing internal combustion machinery used for the main propulsion, the EEBDs should be positioned as follows.

- One (1) EEBD in the engine control room, if located within the machinery space.
- One (1) EEBD in workshop areas. If there is, however, a direct access to an escape way from the workshop, an EEBD is not required.
- One (1) EEBD on each deck or platform level near the escape ladder constituting the second means of escape from the machinery space (the other means being an enclosed escape trunk or watertight door at the lower level of the space).
- Alternatively, a different number or location may be determined by the Administration taking into consideration the layout and dimensions or the normal manning of the space.

For the machinery spaces of category A other than those containing internal combustion machinery used for the main propulsion, one (1) EEBD should, as a minimum, be provided on each deck or platform level near the escape ladder constituting the second means of escape from the space (the other means being an enclosed escape trunk or watertight door at the lower level of the space).

For other machinery spaces, the number and location of EEBDs are to be determined by the Administration. (MC 9.6)

7.5 Fire pumps, fire mains, hydrants and hoses

In the MODUs at least two independently driven fire pumps should be provided (MC2009 9.7.1). On passenger ships (SOLAS p. 229, 2.2.2) either at least two (less than 4000 gross tonnages) or at least three independently driven fire pumps (4000 GT and upwards) should be provided. A larger structure requires more pumping capacity.

The pressure at all hydrants should be at least (MC2009 9.7.5, SOLAS 2004 p.229):

- Offshore units: 0,35 N/mm^2
- Passenger ships (GT<4000): 0,30 N/mm^2
- Passenger ships (GT>4000): 0,40 N/mm^2

Fire hoses in the MODUs should be of material approved by the Administration but the fire hoses of the ships should be non-perishable material (SOLAS p.231 2.3.1.1). The SOLAS requires that every fire hose should be provided with a nozzle and the necessary couplings. The MODU Code (9.7.20) requires that as well but the nozzles have to be dual-purpose ones.

At least one international shore connection is needed in the offshore unit. The requirement is the same on passenger ships (GT>500) but smaller ships do not need it.

7.6 Portable fire extinguishers in accommodation, service and working spaces

This section is covered briefly in the MODU Code and the SOLAS and the rules are in accordance with the FSS Code, which is outside the scope of the thesis. The type of spaces are categorized completely differently and therefore it is impossible to compare the recommended number of fire extinguishers. However, the MODU Code has a suggestive table (MC 9-3) where the recommended number and distribution of additional portable extinguishers are shown.

7.7 Provisions for helicopter facilities

The SOLAS mentions that close to the helideck the following should be included;

1. At least two dry powder extinguishers with a total capacity of not less than 45 kg. In addition to the SOLAS, the MODU Code demands that they should be not less than 9 kg each (9.16.4.1).

2. The SOLAS requires a lift line of 5 mm diameter and 15 m in length. The MODU Code requires 30 m of the line (9.16.4.7.11).
3. The MODU Code requires a crowbar for immediate use in a fire situation. The SOLAS does not require it (9.16.4.7.11).

The need for the crowbar might be explained by the fact that the MODUs have much activity on open decks. Dangerous situations in offshore duties demand more powerful instruments. On the other hand, the lack of the crowbar on passenger ships is understandable involving safety questions. Passengers might use it as a striking weapon.

On the strength of the SOLAS, drainage facilities in the way of helidecks should be constructed of steel. The MODU Code allows other arrangements providing equivalent fire safety (9.16.5.1).

7.8 Operational readiness and maintenance

The SOLAS and MODU Code are nearly identical in this area but gas detection and alarm systems are included in the MODU Code. The maintenance plan should include in addition to the requirements of the SOLAS

1. portable hydrogen sulphide gas detection monitoring devices,
2. portable flammable gas and oxygen monitoring devices, and
3. gas detection and alarm systems (2009 MODU Code, 9.19.4; SOLAS 2004, 2.2.3 page 258).

8 CONCLUSION

Offshore is a broad concept, which makes it challenging to explore the field precisely in the current thesis. Nevertheless, this study provides a practical package for the designer who is entering the unfamiliar design area.

With narrow interpretation, notable differences between ship design and offshore design can be noticed. The functional requirements of vessels in comparison are so different that safety requirements vary significantly. There are a lot of new points for a traditional ship designer in which case the study of the thesis gives the basics for taking over offshore design.

The study can be improved and continued by selecting more rule books for comparison. In principle, all points are discussed in a general way. National rules and standards should be considered in such cases. The situation is complex because almost all countries are applying the instructions of the foregoing rule books with their own national rules and standards in their design projects. It would be best to choose a specific design area for a research subject.

The thesis is intended to serve as a guide when Foreship is tutoring its upcoming offshore designers. The guide can be easily expanded with a new design area and related issues.

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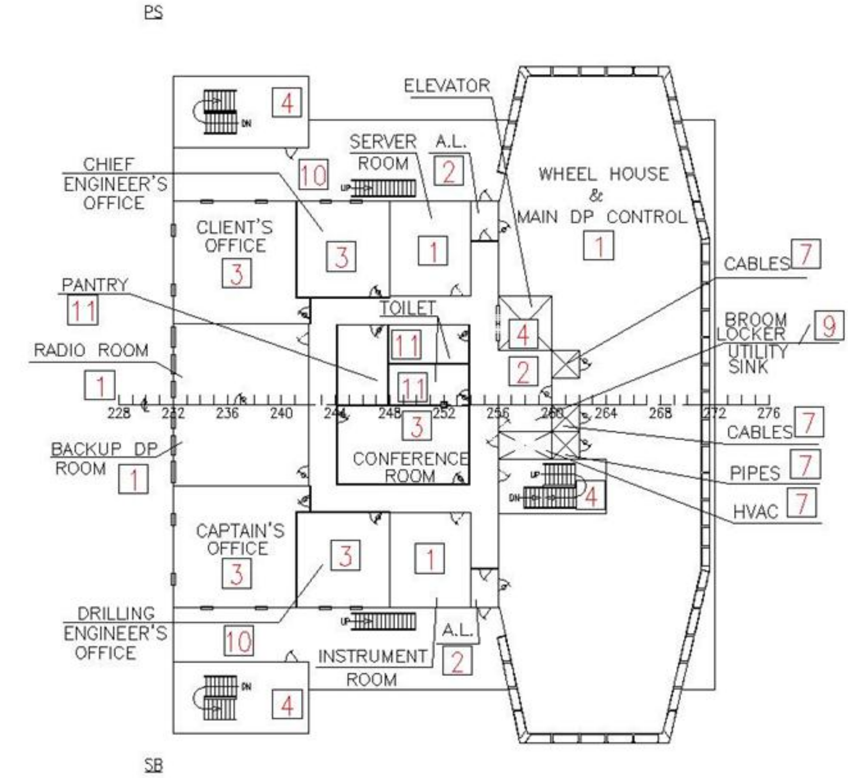
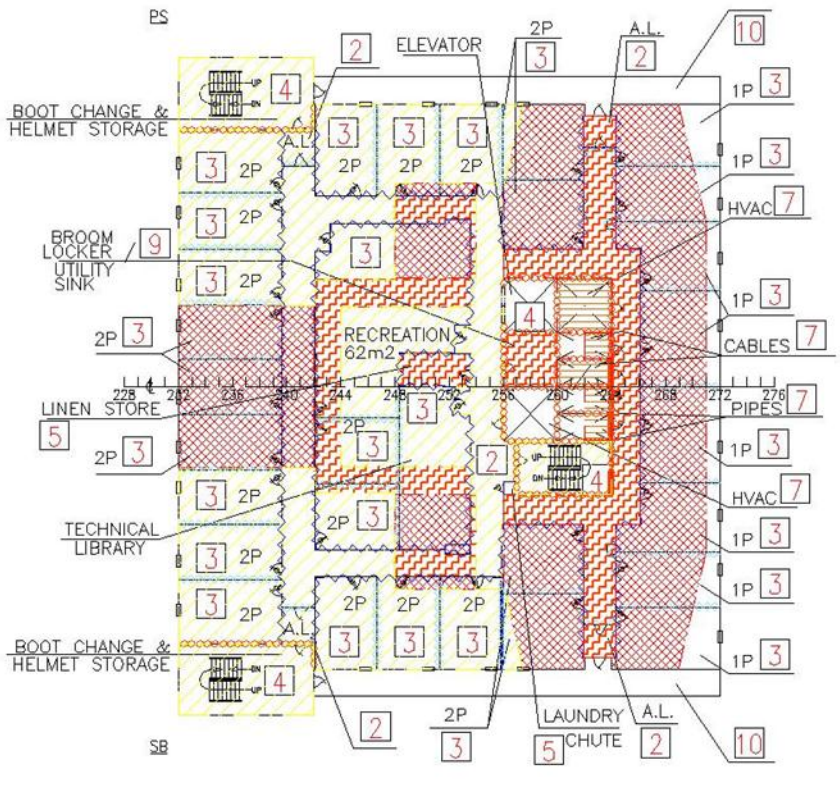


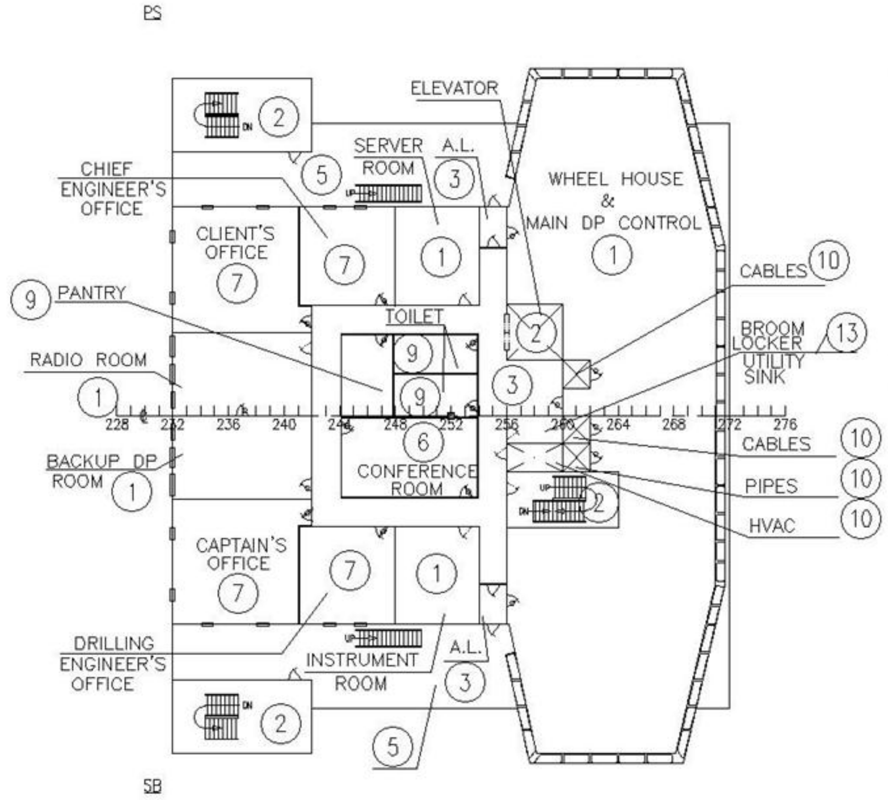
INSULATION CONSTRUCTION	INSULATION SYMBOL FOR DECKS	INSULATION SYMBOL FOR BULKHEADS
A-60		
A-30		
A-15		
A-0		
B-15		
B-0		
C		
		Steel deck or equivalent, but not to be of A-class

DECK ABOVE
FOR REFERENCE



MODEL DECK

MODU CODE Version



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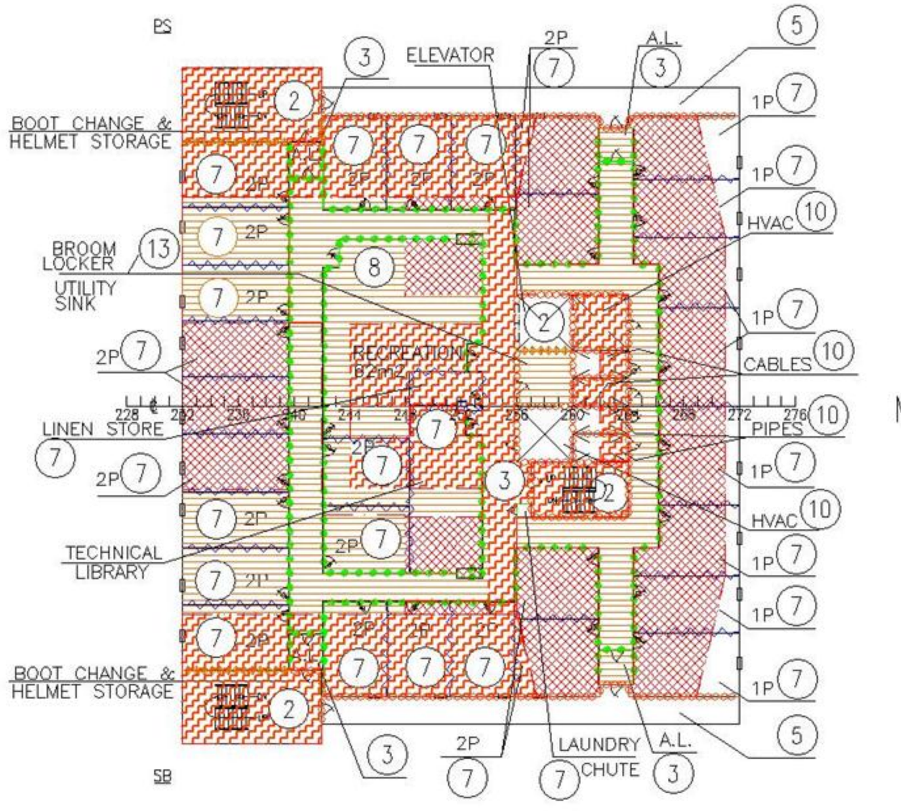

MODEL DECK

SOLAS Version

LEGEND

☐ CATEGORY OF SPACE ACCORDING TO MODU CODE, Ch 9

1. CONTROL STATIONS
2. CORRIDORS
3. ACCOMMODATION SPACES EXCEPT CORRIDORS & STAIRWAYS
4. STAIRWAYS OR EQUIVALENT
5. SERVICE AREA'S (LOW RISK)
6. MACHINERY SPACE OF CATEGORY "A"
7. OTHER MACHINERY SPACES
8. HAZARDOUS AREA'S
9. SERVICE AREA'S (HIGH RISK)
10. OPEN DECK
11. SANITARY AND SIMILAR SPACES

LEGEND

◯ CATEGORY OF SPACE ACCORDING TO SOLAS, Ch II–2

1. CONTROL STATIONS
2. STAIRWAYS
3. CORRIDORS
4. EVACUATION STATIONS AND EXTERNAL ESCAPE ROUTES
5. OPEN DECK SPACES
6. ACCOMMODATION SPACES OF MINOR FIRE RISK
7. ACCOMMODATION SPACES OF MODERATE FIRE RISK
8. ACCOMMODATION SPACES OF GREATER FIRE RISK
9. SANITARY AND SIMILAR SPACES
10. TANKS, VOIDS AND AUXILIARY MACHINERY SPACES HAVING LITTLE OR NO FIRE RISK
11. AUXILIARY MACHINERY SPACES, CARGO SPACES, CARGO AND OTHER OIL TANKS AND OTHER SIMILAR SPACES OF MODERATE FIRE RISK
12. MACHINERY SPACES AND MAIN GALLEYS
13. STATE–ROOMS, WORKSHOPS, PANTRIES ETC.
14. OTHER SPACES IN WHICH FLAMMABLE LIQUIDS ARE STOWED