ABSTRACT

Technological advances continue to be made in the offshore oil and gas exploration, drilling and production industries. This is in part due to the quest to explore reserves in deeper waters and to perform more efficient offshore operations. As a result, offshore facilities are being designed incorporating non-traditional arrangements and unconventional technology. In facilitating the development and implementation of regulations, classification societies have a key role to play in ensuring that the safety standards associated with these unique facilities are maintained.

As with all other marine vessels, standard designs of offshore facilities are well served by traditional prescriptive regulations. These regulations are based on proven engineering concepts, historical performance data and lessons learned from previous incidents. Unconventional designs do not have the associated historical performance data and as a result, their design verification must be based on engineering first-principles.

Practical examples are presented in this paper to illustrate the role of classification societies in verifying safe design on both traditional and novel offshore facilities. The prescriptive, performance and risk-based approaches to regulatory compliance are discussed and practical examples are presented to illustrate the holistic approach to the design verification process.

INTRODUCTION

Classification societies have long been established as having a key role to play in the maritime industry with the origins of the first society traced back to 1760. Throughout the eighteenth and nineteenth centuries, classification societies developed and became recognized as providing a critical third-party verification service to the shipping industry. As a result, when the offshore oil and gas industries emerged in the twentieth century, classification societies were the obvious organizations to become involved in the development and implementation of safety regulations.

As the offshore industry continues to develop and evolve, more sophisticated technologies are being utilized with drilling and production operations moving into increasingly deeper waters. As a result, the need for classification societies to provide third party verification in the current environment remains as critical as their role in verifying safe design was at the time of their origins in the eighteenth century.

OVERVIEW OF CLASSIFICATION SOCIETIES

To begin, it is appropriate to explain the role of marine classification in the current offshore industry and briefly discuss the classification process.

Classification societies provide for self-regulation of the marine industry. As independent organizations they have no commercial interests related to the design, building, ownership, operation, management, or repair of vessels. As a result their primary focus is associated with the development of standards to ensure the seaworthiness of vessels is maintained.

The principal activities of classification societies are:

- Develop rules and guides with industry participation to establish minimum acceptable standards for the design of marine vessels.
- Provide preliminary planning and advice regarding compliance with classification and regulatory requirements to designers, vessel owners and operators during the conceptual stage of a project.
- Conduct design review of documents and drawings to verify the design of a vessel complies with the applicable classification society rules.
- Act on behalf of flag states. In such a capacity, a classification society works under a country’s maritime authority, to verify compliance with international regulations. Currently over one
hundred and seventy flag states authorize ABS (American Bureau of Shipping) to act in this capacity.

- Complete surveys during the construction of a vessel to verify it is being fabricated in accordance with the approved drawings and in-line with good marine practice.
- Survey the installation of the sub-sea foundations, anchoring systems, mooring arrangements, hull structure and topsides deck modules for offshore facilities which have a fixed location.
- Complete periodic surveys over the life of a vessel to ensure that the appropriate level of safety is being maintained.

As represented in Figure 1, the activities of classification societies are based around the safety of life, property and the natural environment.

**Figure 1:** Key classification society activities

Most classification societies reflect their corporate objectives regarding the achievement of safety within their mission statement. ABS’s corporate objectives are “to serve the public interest as well as the needs of our clients by promoting the security of life, property and the natural environment….”

Having provided an overview of classification societies, we will now review the approaches used to attain regulatory compliance for an offshore facility. We will specifically review the prescriptive, performance and risk-based format for regulations.

**PRESCRIPTIVE REGULATORY REGIME**

Under the prescriptive regulatory regime, direct application of rules and regulations is required. In this approach, regulations for the hull of the vessel are based on the established principles of naval architecture and marine engineering. The regulations for a vessel’s support systems are based on other applicable engineering principles. As an example, requirements for on-board firefighting systems are developed based on well-established mechanical engineering concepts. Similarly, the requirements regarding the safety of electrical systems are established based on electrical engineering principles directly applied to power systems, communications, navigation systems and the fire detection and alarm systems.

An example of a prescriptive requirement related to fire safety would be within the International Maritime Organization’s Code for the Construction and Equipment of Mobile Offshore Drilling Units Regulation 9.1 [1989 MODU Code]. The Code requires that a galley onboard a Mobile Offshore Drilling Unit, classified as a high risk service space, be separated from an accommodation space by a boundary with an ‘A-0’ level of fire integrity. Such a boundary is defined as a division capable of preventing the passage of flame and smoke for a one hour period. Using established construction standards, a four millimeter thick steel bulkhead would satisfy this requirement.

Such a regulation clearly outlines that the minimum standard of construction to be attained is ‘A-0’. As a result, a designer can demonstrate compliance with a minimum design standard by simply following the IMO MODU Code requirements and installing a steel bulkhead of the required thickness. Since the designer need only follow the code requirements, no appreciation of the hazards present or any understanding of the principles of fire engineering is required on the design team.

In cases where a designer seeks an exemption from the requirement, a detailed engineering analysis is required. Since the prescriptive regulation does not explicitly outline the true performance objective of the regulation, the classification societies must apply engineering judgment to determine the intent of the requirement and to verify that the alternative arrangements appropriately address the potential hazards.

As demonstrated by the generally decreasing trend of marine causalities over recent years, the prescriptive-based regime has been successful. Regulations based on a prescriptive approach are however subject to the following criticisms:

- Resources may be expended to mitigate small or non-existent risks, in order to satisfy a regulation. Often these resources could be more effectively used to address other, more significant risks onboard the vessel.
- Regulations are often created in the aftermath of accidents. As a result, prescriptive regulations are typically reactive rather than proactive in nature.
- The review of novel arrangements can present challenges due to the absence of applicable regulations and the lack of previous historical experience.

The requirements from the International Maritime Organization, classification societies and flag states are generally based on the traditional prescriptive-based approach. However over the last decade many have evolved to include alternative approaches to attain regulatory compliance.
PERFORMANCE-BASED REGULATORY REGIME

Regulations based on performance criteria are an alternative to the traditional prescriptive-based regulatory scheme. Under this approach, the design is required to satisfy functional requirements rather than specific standards of design and construction. As an example, a performance regulation may state “the objective of this requirement is to safeguard occupants while they are evacuating from the vessel in the event of a fire.” As a result, the design team is left with the freedom to develop arrangements to satisfy the performance characteristics without being bound to a strict prescriptive requirement. In this example, items that would need to be considered would include:

(a) the location of occupants to determine their potential exposure to fire conditions
(b) the location of escape routes to determine the likelihood that the occupants can escape
(c) the tenability limits, such as smoke obscuration levels, gas layer temperatures and the height of the smoke layer anticipated within the compartment in the event of a fire.

After considering all of these conditions, the design team, in conjunction with the applicable classification society and relevant regulatory bodies, would decide the appropriate level of protection to be provided. In addition, an agreement would be reached regarding the methods to use for documenting compliance.

The performance-based approach permits the design team to address the unique hazards present onboard a facility. As a result, the design is no longer constrained by rigid prescriptive regulations. The approach permits the use of alternative materials and novel techniques provided they achieve an acceptable level of safety for personnel, assets and the environment. If managed correctly, a performance-based approach can offer savings over a prescriptive approach. Under the former category only those hazards which need to be addressed are those which are present onboard the facility, whereas the prescriptive regime necessitates the expenditure of resources on a list of hazards, irregardless of their applicability to the specific vessel.

Use of a performance-based approach does however require a significant commitment from each of the stakeholders involved in the project. It also requires additional technical knowledge and often takes longer to complete than the prescriptive approach.

RISK-BASED REGULATORY REGIME

A risk-based design is an alternative to the prescriptive or performance-based regulatory regime. Under such an approach, the hazards and potential consequences of unwanted events associated with an offshore facility are firstly identified and presented in a structured format. The expected frequency of each event is then determined based on historical data and expert judgment. With this information the data can then be analyzed to identify those risks which need to be mitigated and to select the most appropriate risk-reduction approach. The steps involved in a risk-based approach are outlined in Figure 2.

![Figure 2: Simplified risk-based approach](image)

A risk-based approach is particularly well suited to a technology driven industry, where vessel designs are being created well in advance of the development of prescriptive or performance-based regulations. Considerable background knowledge and expertise is required from those involved in the engineering design and approval process.

The initial step, requiring the identification of potential hazards onboard a facility, while seemingly simple requires considerable professional judgment. All hazards need to be recognized during this step. This consists of those which are known, those which are known but their effects are not totally understood and those which have not yet been identified. Since complete information is not available for the two latter categories, appropriate tolerances need to be considered.

Overall, risk-based methods provide a proactive systematic approach to assist in the identification and categorization of potential risk. Sound management and decision-making permits this information to be used as a tool in the design and regulatory compliance process.

An example incorporating a risk-based approach would be the requirements applied to the design of high pressure hydrocarbon storage vessels. The design of the mechanical
components is based on prescriptive regulations to ensure adequate strength at elevated temperatures while the fire protection requirements will be developed from a risk-based approach. The hydrocarbon inventory within the vessel, the reliability of the mechanical components, likelihood of a leak, and potential ignition sources would all be evaluated and considered during the application of the risk-based approach. Based on the findings of the analysis, the appropriate fire protection would be selected and provided for the vessel.

A shortage of valid reliability performance data can be a challenge associated with a risk-based regulatory regime. Since such data is critical to the decision making process, the absence of valid data can be a significant restriction to this approach. In addition under both a qualitative and quantitative approach, acceptance criteria setting out a tolerable level of risk has to be established against which the result of the assessment can be measured. The acceptable level of risk needs to be determined during the initial stages of the project with input from both the designers and regulators.

**PRACTICAL EXAMPLES OF CLASSIFICATION SOCIETY INVOLVEMENT**

The following are practical examples of classification societies’ involvement in establishing and verifying safe design onboard offshore oil and gas facilities:

(i) Development of rules as a result of lessons learned from maritime casualties

As previously noted, many prescriptive regulations in the maritime industry, as with other industries, are enacted as a direct result of lessons learned from casualties or near-miss events. A review of the historical development of classification society rules indicates many examples of rule changes brought about as a result of marine casualties. Some key examples in the offshore industry are:

**SEDCO 135B** – This semi-submersible drilling unit broke up while under tow in the South China Sea in 1965 with the loss of thirteen people onboard. The incident created the impetus for the development of the 1968 ABS Rules for Building and Classing Offshore Mobile Drilling Units [1968 ABS OMDU Rules], including requirements for intact and damage stability, the first such rules for offshore drilling vessels. Further development resulted in the publication on the international level of the International Maritime Organization’s 1979 MODU Code [1979 IMO MODU Code].

**ALEXANDER KIELAND** – This semi-submersible drilling unit capsized after the loss of a column in the Norwegian Sector of the North Sea in 1980 with the loss of one hundred and twenty three people onboard. The incident was attributed to a fatigue crack in the area of a hydrophone sensor in one of the leg bracings. The incident brought about requirements for a leak detection system, redundancy analysis in the design and a more focused review of vessels over their service life. In addition, the use of enhanced fatigue analysis and the introduction of risk-based surveys were a direct result of this incident. These items are now found in all classification society rules and international regulations.

**PETROBRAS P-36** – This vessel was built in 1995 as a drilling semi-submersible, and was later converted to a production platform for use by Petrobras. The conversion included incorporating a crude oil storage tank into one of the columns. In March 2001, while operating in the Roncador Field, off the coast of Brazil, a series of explosions onboard resulted in eleven fatalities along with structural damage to the aft column and pontoon, allowing water to enter the vessel. Despite salvage efforts, the water entry could not be stopped and the vessel sank. As a result of the incident, more attention is now paid to designs which incorporate process equipment within the hull of a vessel.

By learning from previous incidents and modifying the existing prescriptive regulations, future vessel designs should have a higher degree of inherent safety.

(ii) Facility layout

The size, weight and distribution of weight on an offshore facility have a significant impact on the motions and marine performance of the structure. For facilities such as Tension Leg Platforms (TLP’s) and Spar’s, which have their main deck structure located well over one hundred feet above water level, changes in these items can have particularly acute effects on the vessels center of gravity, adversely affecting the vessels marine performance characteristics.

As a result, limiting the size and weight of a facility and strictly controlling the distribution of weight is often critical to achieving the optimum marine performance. Such weight control can be difficult given the considerable size and weight of drilling and production equipment.

In contrast to the weight control efforts, many of the features which result in an enhanced level of safety onboard require the size and weight of the facility to be increased. Examples of these are the spatial separation of personnel from hazards and the installation of firewalls to separate personnel from potential fire hazards. As a result, there are often competing interests with regard to marine performance and safe design.

The sections below outline some of the hazards onboard an offshore facility and present some of the key considerations needed to address the safety concerns.

With regard to hazards, offshore oil and gas drilling and production facilities are subject to many of the same concerns as found on traditional ships including fires associated with deckhouse activities and combustion engines, marine collisions and the effects of inclement weather conditions. In addition, both offshore facilities and traditional vessels are often located in remote areas with
limited opportunities for finding a safe place of refuge and with a low likelihood of receiving immediate assistance from external sources in event of an incident onboard. In addition to these concerns, offshore facilities are subject to hazards associated with frequent helicopter operations, potential gas release hazards associated with drilling operations and fire and explosion hazards associated with hydrocarbon production and storage activities.

The location and separation of the hazards from the personnel on board and the separation of fuel sources from potential ignition sources is of critical importance. Key items which are required to be considered in the layout of drilling and production facilities include:

- **Location of personnel and their associated primary and secondary egress routes**
  In contrast to a traditional vessel, an offshore facility requires personnel intervention on many potentially hazardous activities. For example, a drilling unit requires drilling and support personnel to work on the drill floor area. Similarly, a production facility requires periodic inspection and maintenance operations on the production decks. Due to the presence of personnel in the high risk areas, the lay-out of primary and secondary egress routes on offshore facilities are of critical importance.

- **Location of lifesaving and firefighting equipment**
  Since as noted above, personnel on an offshore facility are likely to be located in a range of areas, the location and distribution of lifesaving and firefighting equipment onboard the facility requires careful consideration. The arrangement should be such that personnel in all working areas of the facility have the means to locate and operate firefighting and lifesaving equipment.

- **Location of potential fire and explosion hazards**
  The early identification of fire and explosion hazards during the design phase of a project allows many of them to be eliminated. Where this is not possible, mitigation strategies such as passive and active fire protection measures can be implemented.

- **Prevailing environmental conditions**
  Since an offshore facility may remain on the same location for a prolonged period of time, consideration of the prevailing environmental conditions at the time of initial design is of considerable importance. The potential consequences of a gas or oil leak on the personnel, the facility and the environment can be minimized by due consideration of the prevailing wind and current directions.

- **Location and design of living quarters**
  Unlike traditional trading vessels which have their deckhouse located on a single block integral to the ship structure, the living quarters on offshore facilities are typically standalone buildings located on the open deck. The location of these buildings and their associated egress routes require careful consideration to ensure the personnel onboard have adequate protection in the event of a fire or explosion incident.

  - **Blowdown procedures for reducing the facilities hydrocarbon fuel inventory**
    In the event of an incident onboard, many offshore facilities incorporate blowdown procedures into their emergency plans. Under such plans, the hydrocarbon inventory onboard a facility is released typically through venting to a flare stack, thereby reducing the quantity of hydrocarbon fuel onboard the facility to become involved in a fire. As a consequence of the high volume of gas burned, high temperatures develop that can be harmful to personnel, structures and other equipment. Special attention needs to be paid to the location of flares in relation to the process equipment, living quarters and helicopter landing facilities.

- **Location of potential ignition sources**
  Ignition sources must be identified and protected to prevent ignition in the event of a hydrocarbon leak.

In the ideal scenario all hazards would be eliminated from a facility during the design phase of the project however, due to the nature of activities onboard an offshore facility, such goals are not achievable. As a result, appropriate mitigation measures and operating safeguards are required onboard to insure that the potential hazards do not materialize.

ABS addresses the review of the facility layout through a combination of prescriptive and performance-based requirements. These include prescriptive rules such as the requirement to provide fire integrity to the forward face of the accommodation block to resist a hydrocarbon fuelled fire or the requirement for a firewall to be provided around topsides mounted wellheads. In addition, some aspects of the facility layout are addressed within the ABS Rules based on performance requirements. An example in this regard would be the requirements for egress routes to be provided giving due regard to the hazards present. Since no prescriptive arrangements are specified, the designer is free to select arrangements that suit the overall facility layout provided that the underlying performance characteristics of providing usable escape routes are satisfied.

By considering the holistic aspects of the facility, and addressing the requirements in terms of both strict prescriptive requirements and performance-based requirements, the intent is that all aspects of safe design are considered and appropriate design features implemented.
(iii) Lifeboat launching arrangements

Prescriptive regulations for lifesaving appliances are generally based on traditional ship-shaped vessels involved in “typical” marine operations. When the regulations are applied to offshore production facilities which incorporate unique hull designs including Spars, Tension Leg Platforms and semi-submersibles, such regulations are not always applicable. By way of example, some codes require lifeboat arrangements to be such that lifeboats can be launched when the vessel sustains a list of twenty degrees or a trim of ten degrees. Such a requirement is directly applicable to a traditional trading vessel in which limiting the trim to ten degrees has merit. Such requirements however do not correlate well to offshore production facilities fabricated with a circular hull and square topsides.

Lifeboat placement and location on offshore facilities needs to be considered to ensure sufficient redundancy in the available lifesaving apparatus. Challenges to be addressed include the elevation of the decks above sea level, the location of fire and explosion hazards on the deck and the anticipated motions of the facility. In addition to consideration of the lifeboat, protection is also required for the personnel mustering on embarkation stations prior to the lifeboat launching. Depending on the proximity of fire hazards areas, additional structural fire protection may be warranted.

Classification societies can bring together stability engineers, fire and life safety personnel and human behavior experts to assist in determining the optimum location of equipment. By considering the unique characteristics of arrangements onboard offshore facilities, lifesaving equipment can be arranged to satisfy the intent of the regulations and more importantly provide a critical means of escape in the event of an incident onboard the facility.

(iv) Risk-based inspection.

As with other marine vessels, offshore facilities are complex structures that are expected to operate throughout their life cycle, often in harsh and demanding marine environments. Continual exposure to these environmental forces can result in high rates of degradation including corrosion and cracking due to fatigue.

Frequent monitoring and inspection of offshore facilities is crucial to determine the early effects of degradation and to give an opportunity to take remedial action where appropriate. Given the physical size and technical complexity of offshore facilities, it is however generally only feasible to periodically inspect a small proportion of the overall structure. Additionally, since some portions of offshore facilities are normally inaccessible, the opportunities for inspection are reduced. To address the challenge of using the available inspection opportunities most efficiently, risk-based inspection methods are recognized as an optional approach.

In this process, the areas, frequency and methods of inspection are determined based on historical data and expert opinion. As a result, the areas where degradation and failures are most likely to occur can be subject to the most frequent and stringent inspection, thereby maximizing the efficiency of the inspection resources and increasing the likelihood of early detection of an impending failure.

SUMMARY

Classification societies have a key function to play in ensuring safety onboard offshore oil and gas production facilities. Their role in the development and implementation of requirements whether in the form of prescriptive, performance or risk-based approaches is critical to continued safe design. This is particularly important when the pace of technological innovations continues to develop.

As engineering personnel within offshore owner and operating companies are decreasing, the expertise within classification societies is increasingly being relied upon to offer third party verification. Through practical examples, this paper has illustrated the role of classification societies in verifying safe design on offshore oil and gas facilities.

REFERENCES

ABS Rules for Building and Classing Offshore Mobile Drilling Units, 1968, American Bureau of Shipping, Houston, TX, Houston, TX, USA.
