Abstract

Risk based verification methods are being utilized more frequently in the offshore industry as a means of managing and confirming that an acceptable level of safety has been attained in the design and fabrication of production systems. In an effort to integrate this risk based approach with Classification and certification activities, a new process has been developed to obtain risk based Classification of production systems in lieu of the application of prescriptive Classification Rules. The information presented in this paper is based upon practical experience as well as ABS Guides and Guidance Notes on the application of risk assessment for Classification.

The fundamental concept of a risk based Classification approach is the development of a risk assessment to understand the risk contributions of each component within the scope, and then use this information to develop an installation specific Classification plan. The application of this plan will shift efforts in Classification activities (design reviews and surveys) towards the identified critical equipment.

This paper addresses the advantages of Classification through risk based verification as well as general methodologies employed from FEED through construction and commissioning. This procedure constitutes an innovative approach to the Classification of offshore installations, which is tailored to the specific design features of each installation, as opposed to the typical prescriptive rules which apply to all installations of a certain type.

The methodology described in this paper has been successfully implemented. Application of this methodology results in a reduction of the number of components to be reviewed by Class, shifting efforts towards the safety critical equipment.

Introduction

Class Societies have always implicitly considered risk and incorporated risk mitigation principles in their Rules. This has been accomplished in many ways throughout the history of maritime Classification. Most improvements and updates to the Rules throughout the years have been based upon reactions to accidents and failures. By learning from the experiences of the maritime industry, Rules are added and updated with the intention of mitigating Risk in the future. In the more recent history of Classification Societies (30-40 years) a more organized collection of information and analysis of failure trends had led to further refinement of the Rules. This analysis is commonly performed by utilizing techniques common to many standard risk analysis methodologies. The next logical step is to begin utilizing these methodologies as the basis of Classification alone as opposed to using them to create and improve upon prescriptive Rules.

In 2004, ABS began providing Classification of production facilities through Risk Based Verification (RBV) in lieu of utilizing prescriptive Rules and Guides. Beginning with the FEED phase of engineering design and continuing through construction, ABS has been involved in development and Approval of risk tolerance criteria and performance standards for equipment and systems. This involvement allows for a large degree of flexibility toward methods of verifying the safe design and construction production facilities.

A significant effort was made to coordinate the RBV scheme for Classification with the QC activities of the FPSO owner and builder. This synchronization provides all parties (owner, builder, Class Society) with the advantage of each others cooperation and experience.
Experience has shown that Classification of production facilities through RBV can be performed successfully. While prescriptive Classification methods are still the norm, the potential of Class through RBV has been made evident. Risk based verification provides a “project specific” approach to Classification of production facilities that ensures that the significant risks to the facility have been sufficiently mitigated or eliminated.

**Definitions**

**Major Accident Event**
An accident that has the potential to cause substantial consequences. Substantial consequences are defined as any one of the following:

- Personnel Safety: at least one death or multiple serious personal injuries
- Environment: a single release of more that 100 bbls of oil or chemicals to the environment.
- Facility: loss of asset and/or loss of production resulting in a loss in excess US$50,000,000

Examples of major accident events are:
- Fire, explosion or release of a dangerous substance
- A helicopter collision
- Diving accidents
- Major structural damage of the installation
- Loss of stability

**Safety Critical Element**
Any structure, plant, equipment, system, subsystem or component part:

- whose failure could cause or contribute substantially to a Major Accident Event and which is considered essential for the safety and integrity of the installation, or
- which is intended to prevent or limit the effect of a Major Incident, or
- used to detect, control or mitigate upon occurrence of a Major Incident.

**Risk Assessment**
An integrated array of analytical techniques (e.g. reliability, availability & maintainability engineering, statistics, decision theory, systems engineering and human behavior) that can successfully integrate diverse aspects of design and operation in order to identify hazards, analyze accident scenarios and assess risk.

**Performance Standards**
A statement in qualitative or quantitative terms of the performance required of a Critical Element, and which is used as a basis of verification throughout the life cycle of the installation. It is established in terms of its:

- Functionality (What the equipment can do?)
- Reliability (Will the equipment do it?)
- Availability (Will the equipment be ready to do it when required?)
- Survivability (Will the equipment keep on going for as long as it is needed?)
- Interaction/Dependency (Will the equipment operation be affected by any other factors?)

**Availability**
Availability of a system or equipment is the probability that it is not in a failed state at a point in time.

**Reliability**
Reliability is a probability of desired performance over time in a specified condition e.g. machinery or system reliability, structural reliability, human reliability.

**Verification**
A verification is a continuous and systematic process by which the SCEs are checked and examined to ensure that they conform to the standards (Performance Standards) which define their operability.

**Written Scheme of Verification**
Written Scheme of Verification (WSV) is often termed the Written Scheme of Examination (WSE), or quite simply Verification Scheme. The Scheme documents the examination tasks for each requirement within each Performance Standard. The Verification Scheme produced would have to, in order to be regarded as a suitable written scheme, give assurance that the SCEs:

- Are suitable and fit for purpose.
- Remain in good repair and condition.

**Process for Classification through RBV**
The risk associated with an asset or a system can be assessed in relation to different levels and a verification process can be used to manage such risk. Such a process is termed Risk Based Verification (RBV). Through a RBV process, work effort and resources can be optimized thus leading to improvements in effectiveness. Clearly a risk assessment is the key in conducting a RBV while the findings from the examination of quality management systems, documents and production activities are important.

As mentioned before, ABS has developed a methodology for Classification of offshore installations using a risk based verification approach. This section gives an overview of this procedure. Figure 1 shows the main steps in this procedure, including flow of information and parties responsible for development.
Step 1: Safety Critical Elements
The objective of this step is to identify the safety critical elements within the scope of the design to be Classed. There are a number of tasks that need to be performed for this step, as described below.

Define Asset Hierarchy
The first step in a risk based verification process of offshore installations is to define the asset hierarchy. This includes a detailed description of asset in terms of functionality, capacity, operational requirements etc. Such a description may need to be given at different indenture levels (ie. system level, subsystem level etc.).

Identify Major Accident Event
The approach to system selection and setting of Performance Standards is to establish a clear link between hazard, risk and the appropriate risk reducing measures. The risk reducing measures can be likelihood of incident occurrence (prevention) as well as control of consequence (mitigation). The risk based verification approach requires an initial risk ranking exercise of hazards identified in suitable studies. Using this approach allows hazards considered comparatively trivial to be separated from major hazards so that attention can be focused on the most significant hazards.

The identification of major accident events can be performed through a Hazard Identification (HAZID) exercise. A HAZID is a structured method for the identification of hazards, threats and consequences. Hazard identification aims at identifying and generating a selected list of hazards specific to the design under review. Hazard identification uses brainstorming techniques involving a small group of experienced and suitably qualified personnel from various disciplines to identify and analyze hazards. Engineering judgment and past experience as well as the information in the risk assessment are required to carry out hazard identification and screening.

Using the definition of Major Accident Events (MAE), a HAZID exercise can produce the list of MAE. The following is a typical list of Major Accident Events for an offshore installation:

- Blow-out
- Mooring / Station Holding Failure
- Dropped Objects
- Ship Collision
- Explosion
- Structural Failure
- Fire
- Towing Incidents
- Helicopter Crash
- Toxic Release
- Loss of Stability
- Major Mechanical Failure

Identify Safety Critical Elements
Once the MAEs are identified, SCEs are defined as those items of equipment or structures whose failure could lead to, or whose purpose is to prevent or limit the consequences of a Major Accident Event. In addition to using the HAZID information to identify SCEs, the following should be considered as complementary sources for such purpose:

- Review of related risk assessments/safety cases
- Review of related documentation and other supporting studies
- Asset walk downs
- Review meetings

The final list of SCEs should be documented, including the selection process followed for their identification.

Step 2: Performance Standards
For each of the SCEs identified, performance of the elements or sub-elements has to be considered and defined, and the so called Performance Standards shall be set.

The Performance Standards should be described in terms of:

- Functionality (what the system must do)
- Reliability and Availability (how ready and capable)
- Survivability (will continue to function when required, under accident conditions)
- Interactions and dependencies (assure supporting systems are adequate)

Performance standards can be qualitative and/or quantitative. When Performance Standards are qualitative, descriptive words for each element can be used. Where sufficient information is available for a quantitative Performance Standard to be set, then it can be readily incorporated.
The key to being able to set meaningful Performance Standards for a system/element is to have a clear and concise statement of the role of the system, based on an understanding of the suitability of the system for use in managing the specific hazard and knowledge of the range of applicability of the system concerned. These functional statements will be used as the foundation for defining the other elements of the Performance Standard for the system.

**Step 3: Class Verification**
This step consists of the formal review by ABS of the list of identified Safety Critical Elements and the defined Performance Standards. Any comments by ABS are to be resolved with agreement of all parties involved: shipyard, operator and class.

**Step 4: Verification Scheme**
In this step, verification tasks are identified in order to verify that the previously defined performance standards for safety critical elements are achieved. Once reviewed and agreed upon, this scheme will become the “risk-based Classification rules” for the design to be classed.

While all defined safety critical elements are required to comply with the stated performance standards, the verification scheme designed by ABS utilizes the concept of safety criticality to define the level of effort for Classification review purposes of safety critical elements. This recognizes that all elements defined as safety critical are not necessarily equally critical, and therefore ABS involvement in the Classification process will be dependent on the assigned risk level. As explained before, the definition of a SCE is based on the severity of possible consequences and the role it plays in hazard management should there be a failure of that element. In addition to this and for the purpose of using a verification scheme for Classification purposes, all SCEs are further classified into three groups based on a risk level. The methodology to determine safety critical levels for each SCE includes an assessment of the following four factors:

1) The applicable failure modes of the safety critical element
2) The likelihood ranking (qualitative) of the major accident event that involves the failure of the SCE
3) The consequence ranking (qualitative) of the major accident event
4) Whether the function of the SCE is to mitigate a major accident event

Based on the above, a safety criticality level (1, 2 or 3) is assigned to each SCE, so that they can be ranked according to the degree of safety criticality associated with them.

The purpose of estimating Safety Criticality is to provide an input to the asset’s Classification requirements to ensure that Classification efforts are efficiently allocated based on the significance of the major accident events and the role of the SCEs in contributing to risk-reduction.

Table 1 below shows an example of the Classification involvement that was generically chosen for each SCE, depending on the safety critically level assigned to each.

<table>
<thead>
<tr>
<th>Safety Criticality Level</th>
<th>Class Involvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>Certificate of Compliance to Appropriate Standard – No surveyor attendance required.</td>
</tr>
<tr>
<td>Level 2</td>
<td>Certificate of Compliance to Appropriate Standard – Attendance for inspection of completed component and FAT</td>
</tr>
<tr>
<td>Level 3</td>
<td>Full Plan Review, Surveyor Attendance during Fabrication and FAT</td>
</tr>
</tbody>
</table>

Table 1

A Verification Scheme is expected to identify errors or defects in areas such as specification, selection of appropriate Performance Standards, design, construction or maintenance of elements which have been identified as safety-critical, so that appropriate preventive or remedial action can be taken.

The output of this step is a set of tables outlining the Classification requirements for the safety critical elements as derived through the risk based verification scheme.

**Step 5: Verification Scheme Review**
Once Safety Critical Elements are identified, Performance Standards are defined, and a mutually agreed Verification Scheme has been produced, ABS performs a final review. This review focuses on the following:

- Agreement that all SCEs have been identified
- Arrangements are in place to verify that their performance will be achieved
- Remain suitable to prevent/mitigate the hazards as intended

Any disagreements on any of the above items will require a tripartite meeting so that all parties involved can arrive to an agreement. If any modifications are made, the procedure should iterate back to the corresponding step (Figure 1), and update the documents as appropriate, including a new review by ABS.

**Step 6: Class Assignment**
ABS uses the agreed Verification Scheme to conduct the design engineering review, including surveying
activities, in order to assign Classification. In this step, ABS verifies that the SCEs meets the standards stipulated in the scheme, and assess any deficiencies.

For system/components that were not identified as SCEs, ABS will not conduct a formal Classification review. Technical design review and class survey is not required for these systems/components. Instead, these systems/components area expected to comply with appropriate recognized industry standards, and verification of such will be accomplished through Audits.

Experience in Application of Risk Based Classification

Risk Based Verification is utilized as a means of determining that a level of safety equivalent to that of Classification has been attained without applying the available prescriptive Rules. By employing a “verification scheme” approach to RBV, we are able to clearly define steps to this process. This greatly aids in defining the RBV schedule, such as determining “hold points” for design, construction, and verification.

Experience has taught us that properly managing the verification scheme process is at least as important as the verification activities themselves. The following sections outline some of the facets of ABS’s experiences in utilizing this process of Classification through RBV.

Safety Critical Elements

As previously described, the first step in utilizing this approach is defining the overall performance criteria for the facility. Aspects such as acceptable down time, injury and mortality rates, acceptable financial or property loss and environmental impact must be agreed upon by all parties. The parties in agreement must include, at a minimum, the owner, the builder and the Class Society.

These performance standards can then be used to define the safety critical elements of the production facility. The safety critical elements can be identified by using various methods. Risk tools such as QRA, HAZID, HazOp, and/or FMEA are suitable for this purpose. Safety critical elements can also be established through other considerations such as design basis or deterministic insights.

Consideration needs to be given to the level to which the safety critical elements are individually identified. While it is valid to consider “the hydrocarbon train” a safety critical element, the team must recognize that this is a system made up of multiple components. Many of these components may require different degrees of verification based upon their inherent risk toward their surroundings. While both components of “the hydrocarbon train”, an HP gas scrubber and an LP separator pose significantly different risks. Another example of this could be as follows in Table 2.

<table>
<thead>
<tr>
<th>Prescriptive Class Rules</th>
<th>Verification Activity</th>
<th>Safety Criticality Level</th>
<th>Verification Activity</th>
<th>Risk Based Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure Vessel per ABS Facilities Guide 3-3/17</td>
<td>Full Plan Review, Surveyor Attendance during Fabrication and FAT</td>
<td>SCL1</td>
<td>Provide Vendors Certificate of Compliance to Appropriate Standard</td>
<td>Full Plan Review, Surveyor Attendance during Fabrication and FAT</td>
</tr>
<tr>
<td>Pressure Vessel per ABS Facilities Guide 3-3/17</td>
<td>Full Plan Review, Surveyor Attendance during Fabrication and FAT</td>
<td>SCL3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2

Another aspect that will have a major impact on identifying the safety critical elements is defining the scope of the production facility that is being considered for Class through RBV. All systems and equipment whose failure or malfunction would have a direct impact on the facilities’ ability to meet its performance criteria should be included. For example, a seawater cooling pump may not directly contact produced hydrocarbons, but if its failure would take a critical produced gas cooler out of service, it should be considered as within scope of the safety critical elements.

Performance Standards

Performance standards may be established in terms of functionality, reliability, survivability and/or interaction/dependency. These performance standards can be as simple as a fire detection system being required to function properly or as complicated as quantifying the efficiency and availability of a piece of equipment. Regardless, these performance standards must be clearly defined and agreed upon by all parties.

A key aspect of developing meaningful performance standards is understanding the system/equipment’s role as part of the facility. Many times, considering the full “downstream” effect of an SCE malfunction/failure is quite difficult. The most useful tool in verifying the all necessary performance aspect has been addressed is analysis of the HazOp of the facility design. By verifying that the performance standards address each of failure modes identified as needing mitigation, you can be reasonably sure that interaction/dependency issues have been addressed.
Class Verification
At this stage of the process, it becomes the Class Society’s task to review and Approve the safety critical elements and their performance standards. This review serves to verify that the level of performance being required of the facility meets the intent of Class and provides an equivalent level of safety to that established by the prescriptive requirements. Provided the Class Society was included as an equal partner in the first stages of this process, this Approval should be a simple function of documenting the procedure up to this point. If the safety critical elements and their performance standards have been defined prior to including the Class Society in this process, their Approval can be a cumbersome, time consuming exercise.

Any aspects of the safety critical elements or the performance standards deemed by ABS to require revision or improvement will be raised as quickly as possible to the project team. Resolution of these issues needs to be approached as a team effort. All parties must be in agreement with any revisions made. This can be a delicate exercise based upon the need to balance the necessary performance of the facility with any impact to schedule and cost. This reinforces the need to complete this phase of the scheme as early as possible in an effort to give the builder the opportunity adjust and purchase orders or specification accordingly.

Verification Scheme
Once Approval of the safety critical elements and their performance standards has been obtained, a means of verifying that these performance standards are met needs to be established. A list of verification activities for each safety critical element should be created. The verification activities will also need to be submitted for review and Approval by the Classification society. These verification activities commonly refer to verifying compliance with industrial (API, ASME, NACE...) or project specific specifications. The verification activities need to consider the design and construction/commissioning aspects of the safety critical elements. As the design and procurement phases of the project progress, it is advantageous to develop a detailed schedule for all verification activities. This allows for an execution plan to be agreed upon. It also assures that all parties are provided the opportunity to participate in any design review or testing as determined to be necessary.

As indicated in Table 2, the assignment of safety criticality levels for each element can greatly impact the overall verification effort. The assignment of safety criticality levels can be one of the more challenging aspects of the scheme. This is most commonly due to the differing perspectives of each member of the team. This challenge is best mitigated by maintaining focus on the likelihood and consequence rankings developed for each accident event and how the subject equipment’s failure/malfunction could impact these events.

Verification Scheme Review/Class Assignment
At this point in the scheme, ABS essentially assumes its usual roll of verification agent. The only difference in ABS’ activities at this point is that instead of applying its prescriptive Rules, ABS is applying the verification scheme developed for the project. For items not identified as safety critical elements, the roll of the ABS engineer or surveyor is limited. It is the builder’s responsibility to manage the documentation provided by the equipment/system vendors and make these documents available to the surveyor. The surveyor will audit this documentation on a limited basis to verify that the equipment/systems comply with appropriate recognized standards.

Advantages and Drawbacks of Classification through Risk Based Verification
When considering whether to use risk based verification as a means of Classing a production facility, certain aspects of the approach should be considered. There are many advantages to utilizing this approach that should be weighed against the factors that could serve to hinder the process.

The most obvious advantage is that RBV clearly identifies the critical components of the production facility. While these safety critical elements could also be identified through an ordinary HAZID exercise, incorporating this identification into the Classification process serves two functions. Firstly, the experience and training of the ABS surveyors and engineers can be applied to the identification of SCEs. This assures that the failure modes normally considered applicable by Class are voiced in the earliest phases of the project. Secondly, it allows the ABS to allocate its resources to the areas of greatest need, right from the start of the project.

By their nature, prescriptive Rules are written in a generic manner to attempt to account for all types of failure modes encompassing a variety of designs. However for some designs, these generic Rules could drive the efforts of the Class Society toward aspects of the facility that may not be safety critical for that specific design. By concentrating its efforts on the specific elements of the facility that have been determined to be safety critical, the ABS is able to provide the most efficient and effective input to the project.

The increased scrutiny of the safety critical elements effectively provides a greater asset protection as well as an improved efficiency of the facility. Commonly the design is modified in its early stages with the intention of reducing the number of safety critical elements. These modifications are commonly either more reliable
or back-up equipment added to eliminate or reduce the likelihood of single points of failure.

A key component of Classification through risk based verification is the analysis done in the early stages of the design. Many times, the basic design phase of the facility is complete prior to a contract being signed with a Classification Society. Completing early stage RBV activities without the participation of the Class Society can lead to long term consequences relating to scope and scale of the safety critical elements. This is most evident in cases where the contract with the builder is signed based upon specifications created prior to including the Class Society in the RBV process. For the RBV Classification approach to function efficiently, the early, most important stages of the RBV process must include at least the three key parties: the owner, the builder and the Class Society.

A lack of commitment to the RBV process by any of the key parties can lead to considerable confusion when establishing the verification activities for the equipment and systems. The impact of any ambiguity or disagreement relating to the verification activities or performance standards will most greatly impact the builder. One of the most difficult aspects of utilizing this RBV-based process is the flexible nature of the verification scheme impacts equipment procurement. Most builders are able to estimate workload and base contract quotations on previous experience constructing similar facilities. If the RBV scheme determines that particular builder furnished equipment need be subjected to non-standard verification activities or performance standards, there can be a significant impact to procurement activities. This impact is even more significant on longer lead items that may require purchase orders to be issued before the verification activities are scheduled to be completed. This only goes to reinforce the fact the most significant key to a successful RBV Classification project is complete cooperation between all parties involved. Examples of this cooperation can be as simple as inviting all parties to any meeting related to the verification scheme or as complex as an in depth review of the detailed project schedule to confirm the builder is provided the opportunity to properly define equipment specification for their purchase orders for equipment.

**Conclusion**

Classification through risk based verification has proven itself a viable option in today’s regulatory environment. Technological advances and innovative approaches to risk management push design and construction towards the limits of the capabilities of prescriptive Rules. The ability of the ABS to respond to the needs of industry and provide a highly responsive service necessitates a more flexible approach to Classification methods. The inherent flexibility of the RBV methodology provides a means of Classification that is project specific and customer focused.

The availability of risk based Classification provides industry with an alternative to the traditional prescriptive Classification environment. The concentration of Classification resources on safety critical elements results in a more “project specific” risk reduction for the facility. This ever improving efficiency can only serve to aid the mission of the ABS and industry stakeholders to promote the security of life, property and the natural environment.

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**References**