



GUIDANCE NOTES ON

ACCIDENTAL LOAD ANALYSIS AND DESIGN FOR OFFSHORE STRUCTURES

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**American Bureau of Shipping
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the State of New York 1862**

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Foreword

These Guidance Notes address the process of identifying, and assessing the effects of, structural loads arising from accidental events. An essential element in the determination of accidental loads in these Guidance Notes is the use of risk based assessment techniques.

The traditional approach to accident induced structural loads is the use of prescriptive criteria that are said to be primarily derived from experience and studies done for similar situations. Prescriptive criteria may be stated in terms of loading scenarios that may give specific load or pressure magnitudes, directions, durations, area of pressure application, etc. Alternatively some prescriptive criteria may be stated in terms of presumed accident consequences; such as, the loss of a major bracing member, extents of accidental collision penetration and flooding, missing mooring components, etc.

Over at least the last decade, there has been greater recognition of the use of risk based procedures to replace or support the prescriptive criteria. For example in ABS Classification criteria for Mobile Offshore Drilling Units and Floating Production Installations [see 1-1-3/5 of the *Rules for Building and Classing Floating Production Installations (FPI Rules)* and 1-1-4/13 of the *Rules for Building and Classing Mobile Offshore Drilling Units (MODU Rules)*] risk based evaluations are permitted to establish alternatives to the usual criteria given in the Guide and Rules. For new or novel situations, and structural types; the accidental load criteria may state primary reliance on the risk based accidental load determination; for example see the 2-2/3 *Guide for Building and Classing Floating Offshore Liquefied Gas Terminals (FLGT Guide)*.

With the use of risk based criteria, these Guidance Notes are meant to provide an overview of the approach that can be used to identify and assess the effects of accidental structural loads arising from four hazards (i.e., dropped objects, vessel collision, fire and blast). The given methodologies should be adapted to accidental structural loads arising from other hazards as specified in the Classification criteria of a particular type of offshore installation or MODU.

Users are cautioned that Regulatory bodies having jurisdiction over the offshore installation or unit may require the use of prescriptive accidental loads criteria. Accordingly, it is the responsibility of the Owner to discuss with the applicable authorities the acceptance of alternatives based on risk evaluations.

These Guidance Notes become effective on the first day of the month of publication.

Users are advised to check periodically on the ABS website www.eagle.org to verify that this version of these Guidance Notes is the most current.

We welcome your feedback. Comments or suggestions can be sent electronically by email to rsd@eagle.org.

GUIDANCE NOTES ON

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SECTION 1 Introduction

1 General

These Guidance Notes provide an overview of the process for identifying and assessing a variety of accidental loading scenarios that can be experienced by offshore oil and gas facilities with an emphasis on minimizing health and safety, environment, and facility risks. While a wide range of potential accidents exists, the focus here is on key events that can affect the structural performance of the facility, namely ship collisions, dropped objects, fires, and blast loadings. The same conceptual process can be used with other accidental loading scenarios, such as the survival of permanent mooring systems under extreme environmental conditions. The guidance highlights activities associated with the assessment including:

- i) Accidental loading scenario hazard evaluation overview
- ii) Ship collision hazards
- iii) Dropped object hazards
- iv) Fire hazards
- v) Blast hazards

These Guidance Notes are not intended to serve as a design or assessment standard, but rather to highlight the primary activities relating to accidental loading assessment to promote more efficient and safer design and operation of the facility.

3 Design Philosophy for Accidental Loading

Accidents are defined as unintended events that arise during the course of installing, operating, or decommissioning an offshore oil and gas facility. The purpose of assessing accidental loadings is to understand the extent of initial damage and verify that the accident does not escalate in terms of personnel health and safety, environmental concerns, or facility damage (i.e., financial consequences). Escalation of the accident occurs when the local failure causes a chain of additional cascading events. For instance, a fire may impinge on a primary structural member resulting in its failure. While this may prove to be a financial consequence to the facility in terms of the member repair, an escalation of additional members failing may raise the event to include a subsequent global collapse with potential loss of life or significant environmental release.

Unlike design loadings where elastic behavior is expected, the accidental loading assessments may consider the structure well into the plastic (inelastic) regime. The sheer magnitude of the accident makes requiring an elastic response impractical in most cases given the low likelihood of the event occurring. The acceptance criteria for the events will need to be modified to reflect the acceptability of these high strains and large deflections during the event provided that the damage is such that the event does not escalate.

The process for assessing accidental loadings follows the standard hazard risk assessment method for the oil and gas industry that incorporates traditional hazard identification methods and existing structural assessment methods. First, a preliminary risk assessment examines the potential for accidental loading based on evaluating the risk exposure that includes both the likelihood of the accident and its consequence. A detailed accidental hazard risk assessment is then performed, if required. The events identified during the preliminary risk assessment are categorized so that low level risk and extremely low likelihood events are removed from further consideration based on the Owner's risk tolerance. A refined assessment is then performed on the remaining accidents with the intention to either conclude sufficient structural capacity or operational constraints exist to reduce the risk (i.e., advanced analysis reduces the level of conservatism present in the initial risk assessment), or highlight mitigation activities that can successfully mitigate the risk exposure.

SECTION 2 Accidental Loading Hazard Evaluation Overview

1 General

The accidental loading scenario hazard evaluation defines potential accidents that may occur to the facility during its life from installation to decommissioning and assesses the corresponding risk exposure. For the purposes of these Guidance Notes, an accident is defined as a scenario involving a ship collision, dropped object, fire, or blast that introduces risk to personnel, the environment, or the facility.

Fundamentally, there are two basic approaches to addressing the hazards faced by an offshore facility: hazard control and predictive hazard evaluation (API RP 14J). Hazard control requires that the facility is designed and operated in a manner consistent with Industry standard practices. While not explicitly stating as such, this approach has a built-in hazard analysis component as industry standard practices evolve to promote the safe operations of many facilities and reflect prior hazard analyses and incident investigations. Typically, a simple checklist approach is utilized to verify standard practices are maintained from design and throughout the service life of the facility. Predictive hazard evaluation provides a method to address asset-specific hazards that may be outside of the coverage of hazard control via standards compliance. The steps involved in a predictive hazard analysis are: identify pertinent hazards, evaluate the risk exposure for each hazard, and mitigate the likelihood and/or consequences associated with each event.

These Guidance Notes do not address the hazard control by utilizing industry standard practices. It is assumed that standard practices are adhered to at all phases of the facility's design and operation. The focus on the accidental loading scenario identification study is in the execution of a predictive hazard evaluation of the proposed accidents.

The proposed accidental loading scenario evaluation process is structured in accordance with a traditional risk assessment where an initial hazard identification defines potential accidents that may occur to the facility during its life from installation to decommissioning and then the corresponding risk exposure is developed based on likelihood and consequence for each event. The process is idealized as three distinct activities: develop an accidental hazard risk assessment plan, perform a preliminary risk assessment, and perform a detailed risk assessment as warranted, as shown in Section 2, Figure 1. The process begins with the definition of the hazard risk assessment method, which focuses on defining the types of accidents considered (in this case, ship collisions, dropped objects, fire, and blast), definition of the governing standards driving the evaluation, and the risk assessment guidance (including the risk matrix definition common for all hazards). Once the method is defined, the second step involves the preliminary risk assessment for specific accidents as shown in Section 2, Figure 2. Accidental hazard identification defines the events including a detailed description (accident type, loading characteristics, and safeguards present) after which an assessment is performed to determine the associated likelihood and consequence from which a preliminary risk characterization can be determined. The detailed accidental hazard risk assessment presented in Section 2, Figure 3 utilizes information from the preliminary risk assessment to determine if the risk exposure is acceptable or if additional assessment or accident mitigations are required.

When identifying potential accidental hazards, these Guidance Notes neglect joint events where one accident type escalates into another. For instance, a dropped object evaluation only considers the structural damage associated with the impact event and will not address the potential escalation into a fire or blast event. It is assumed that the initial hazard identification effort will highlight potential joint events for further highly specialized study where loading and structural damage reflect the joint event.

The remainder of this Section presents a high-level process for identifying and characterizing accidents and the assessment approach. Details pertaining to the execution of the hazard identification and assessment activities for a given type of accident are given in Sections 3 through 6.

FIGURE 1
Idealization of Three Distinct Activities in the Accidental Hazard Evaluation Process

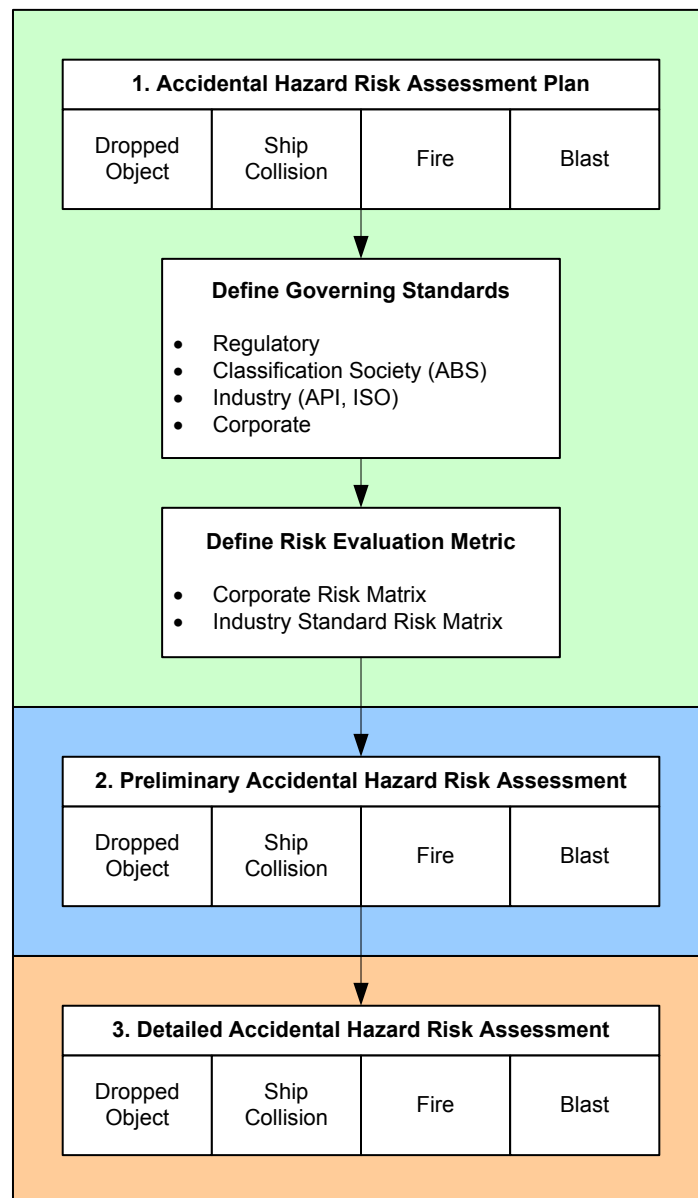


FIGURE 2
Overview of the Preliminary Accidental Hazard Risk Assessment Process

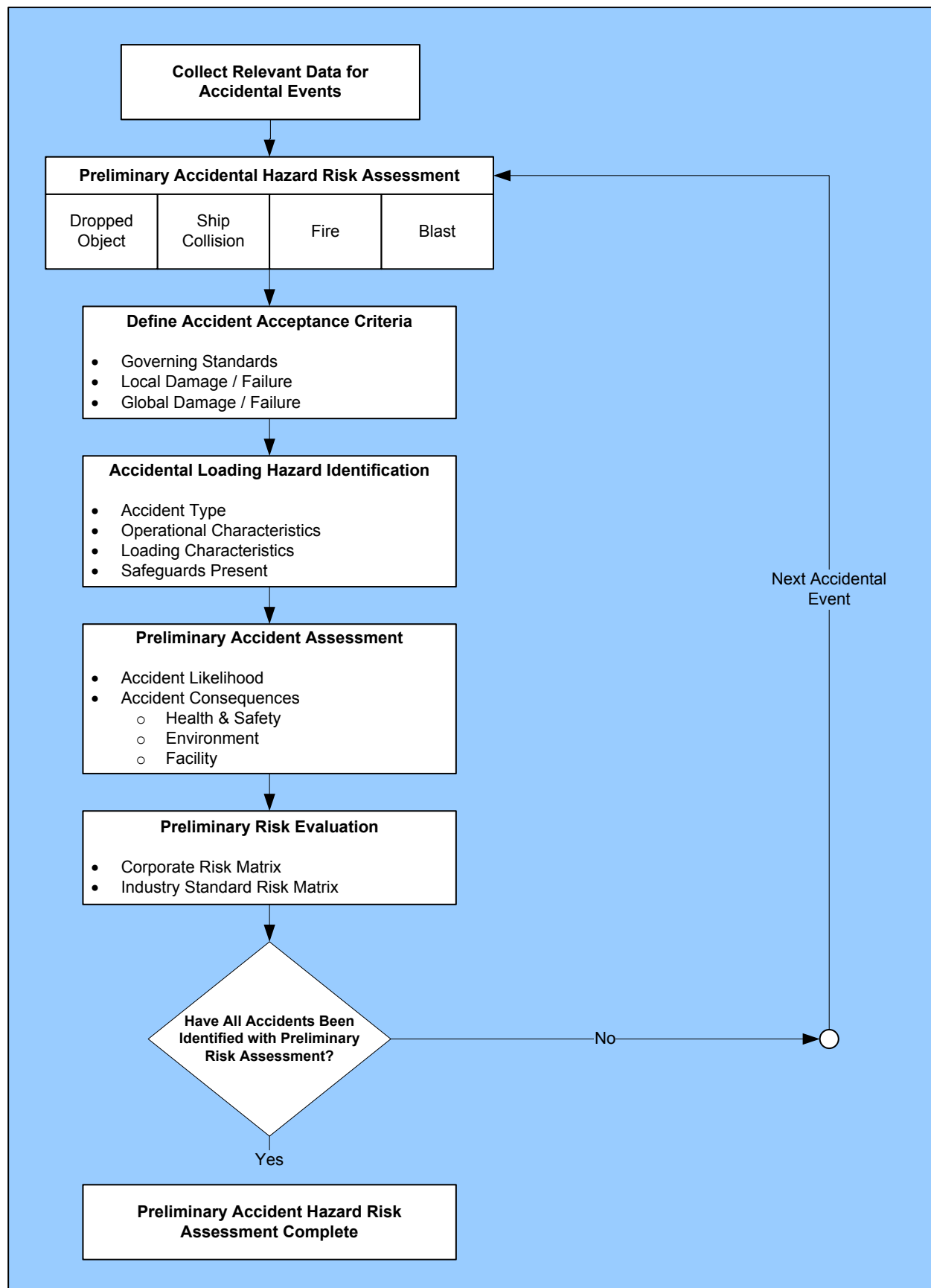
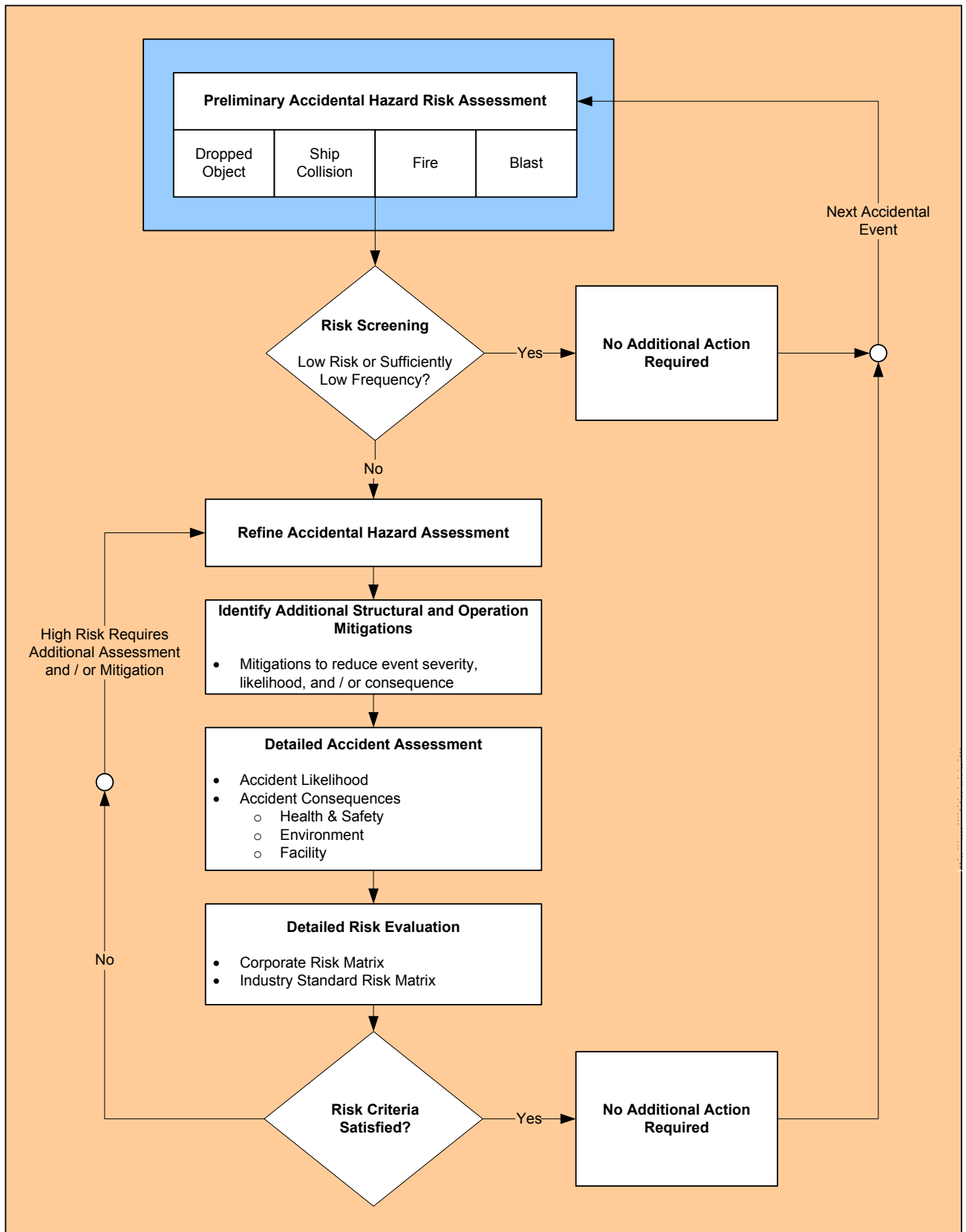


FIGURE 3
Overview of the Detailed Accidental Hazard Risk Assessment Process



1.1 Existing Standards for Reference

- API RP 14J Recommended Practice for Design and Hazards Analysis for Offshore Production Facilities [2007]
- ISO 19901-3 Petroleum and natural gas industries – Specific requirements for offshore structures – Part 3: Topsides structure [2010]
- API RP 2FB Recommended Practice for the Design of Offshore Facilities Against Fire and Blast Loading [2006]
- API RP 2A-WSD Recommended Practice for Planning, Designing, and Constructing Fixed Offshore Platforms – Working Stress Design: Section 18, Fire, Blast, and Accidental Loading [2008]
- ABS (1) Guidance Notes on Risk Assessment Applications for the Marine and Offshore Oil and Gas Industries [2000]
- ABS (2) Guidance Notes on Review and Approval of Novel Concepts [2003]
- ABS (3) Guide for Risk Evaluations for the Classification of Marine-Related Facilities [2003]

3 Hazard Evaluation Process

The hazard evaluation assesses the accidental risk exposure for a facility. The timing of the hazard evaluation process for a new asset ranges from project feasibility studies through preliminary design to detailed design (an existing facility can only perform hazard evaluation during operations). The detail present in the hazard evaluation gradually increases through the life of the facility (high-level information during feasibility studies to accurate and specific information during the detailed design and execution phases). As shown in Section 2, Figure 1, the accidental hazard evaluation process is composed of three primary steps: accidental hazard risk assessment plan, preliminary risk assessment, and detailed risk assessment. Details pertinent to these three steps are presented in the following Paragraphs.

3.1 Accidental Hazard Risk Assessment Plan

The definition of the accidental hazard risk assessment plan provides the framework for performing all accident hazard evaluations for an offshore oil and gas facility. It is intended to define the scope of hazards considered, identify pertinent governing standards, and specify a common risk matrix.

The scope of accidental hazards considered by these Guidance Notes is: ship collision, dropped object, fire, and blast scenarios. At a minimum, a facility should consider these. However, additional potential accidents should be addressed as appropriate on a facility-by-facility basis.

The governing evaluation standards are intended to cover the hazard identification, accident assessment (including both accident likelihood and consequences), and subsequent risk evaluation processes. The standards will be derived from regulatory requirements, classification society Rules and Guides, industry recommended practices, and Owner practices. Once identified, any deviation from the governing standards would necessitate formal documentation highlighting the variation and its impact on the hazard evaluation.

The final piece of the risk assessment plan is in the specification of a risk matrix that will be utilized by all the evaluations. The source of the risk matrix could either be an Owner-defined matrix or a generic industry standard matrix (e.g., ISO 19901-3). Regardless of its source, the risk matrix will have at a minimum:

- Sufficient granularity in both consequence and likelihood to capture potential accidental hazard risk and differentiate between events
- Clearly defined health and safety, environmental, and financial consequences
- Clearly defined risk levels with acceptability (e.g., no additional mitigation required or requires immediate mitigation prior to resuming operations)

Note that the hazard identification method and risk matrix selected for use during the hazard identification should be reviewed by ABS prior to initiating the identification process if they will be requested to assess the hazard evaluation effort.

The risk evaluations done during the preliminary and detailed risk assessment phases will utilize pre-defined risk exposure levels. For example, three risk levels may be defined by the Owner:

- (1) Low risk: Insignificant/minimal risk (eliminate from further consideration)
- (2) Medium risk: Risk can be shown to be acceptable provided additional potential mitigations are included based on cost-benefit assessment
- (3) High risk: Risk requires additional mitigation to reduce the consequence or likelihood

In addition to the three risk levels, an additional threshold for events having an “improbable” likelihood may be defined by the owner such that events with lower frequency do not require evaluation.

The definition of the evaluation method will be clearly documented so as to capture:

- i) Scope of accidental hazard evaluation
- ii) Identification of governing standards for structural analyses of each accident type and risk assessments
- iii) Definition of the risk matrix to be used for all accidental hazard assessments

3.3 Preliminary Accidental Hazard Risk Assessment

The preliminary accident risk assessment process is comprised of four key activities: definition of accident acceptance criteria, accidental loading hazard identification, preliminary accident assessment (likelihood and consequence), and preliminary risk evaluation.

3.3.1 Acceptance Criteria Definition

The structural performance acceptance criteria for each accident type should be defined by the owner based on existing regulatory, classification society, and corporate guidance so that the appropriate risk levels for health and safety, environment, and facility are maintained during and after the accident event. The acceptance criteria should address each potential damage mechanism faced by the structure. In general, the accidents considered will tend to induce large deformations and deflections well beyond the limits associated with traditional design standards. As such, it is incumbent on owners to clearly define the acceptance criteria so that all potential damage mechanisms as considered including:

- i) Structural member failure (primary and secondary structural members)
 - Yielding
 - Buckling
 - Formation of plastic hinges
 - Excessive deformation
 - Connection failures (i.e., connections fail prior to member capacity)
- ii) Global structural failure
 - Hull girder collapse (ship-shaped floating facility)
 - Damaged stability (fixed and floating facilities)
 - Immediately following the accident
 - Stability until repair (e.g., capacity exceeds required return period event)
 - Structural collapse (topsides)
- iii) Safety critical elements
 - Fire/blast walls exceed design criteria
 - Escape routes and muster areas are impinged during/after the event
 - Containment equipment (e.g., pressure vessels and risers) fail under accidental loading

It is anticipated that the precise definition of the acceptance criteria will be related to the analysis method utilized to assess the accident with more robust analysis methods utilizing higher acceptance criteria.

3.3.2 Accidental Loading Hazard Identification

The hazard identification process will be similar regardless of type of hazard considered (dropped object, collision, fire, or blast). The identification process will utilize one or more standard hazard identification methods to define the accident and its preliminary risk exposure (ABS (1) and API RP 14J) including, but not limited to those identified in Section 2, Table 1.

Each method or combination of methods has a place in the hazard identification process over the life of the facility so it is important that the analysts select accordingly. As many of these methods are qualitative in nature, especially early in the design process, it is critical that a qualified and diverse staff be utilized to thoroughly detail the potential accidents.

3.3.3 Preliminary Accident Assessment

A preliminary accident assessment evaluates both the likelihood and consequences associated with each event identified during the hazard identification process. During this assessment, the structural response to the accident will be evaluated in light of the acceptance criteria previously defined given facility-specific information (e.g., structural configuration and material properties). This response will in turn provide direct input into the specification of both the likelihood and consequences for each event.

3.3.4 Preliminary Risk Evaluation

A preliminary risk is evaluated for each event based on the likelihood and consequences developed during the accident assessment phase. The resulting risk exposure will identify key events to be examined in subsequent detailed assessment. Ideally for consistency, the same risk matrix should be utilized for all accidental loading scenarios as well as other design and operational aspects of the facility.

3.3.5 Preliminary Risk Evaluation

The output for the preliminary accidental hazard risk assessment process includes:

- i) Detailed descriptions of and basis for each accident including event type, location, and intensity (e.g., type of vessel anticipated for a ship collision, energy of dropped object, flame geometry and duration, and blast overpressure and duration at different locations)
- ii) Safeguards present (e.g., design margins, operations, and active/passive safeguards present)
- iii) Acceptance criteria assumed during evaluation
- iv) Preliminary likelihood, consequence, and risk evaluation

TABLE 1
Overview of the Accidental Hazard Identification Methods

<i>Hazard Identification Methods</i>	<i>Summary of Method</i>	<i>More Common Uses</i>	<i>Example</i>
What-if analysis	What-if analysis is a brainstorming approach that uses loosely structured questioning to (1) postulate potential upsets that may result in mishaps or system performance problems and (2) ensure that appropriate safeguards against those problems are in place.	- Generally applicable to any type of system, process or activity (especially when pertinent checklists of loss prevention requirements or best practices exist). - Most often used when the use of other more systematic methods (e.g., FMEA and HAZOP analysis) is not practical.	“What happens if an off-loading vessel loses station keeping capabilities during an offloading operation?” The results provide insight into subsequent activities (e.g., bow of a full offloading vessel collides with lightened FPSO at given velocity), highlighting potential mitigations.
Hazard and operability (HAZOP) analysis	The HAZOP analysis technique is an inductive approach that uses a systematic process (using special guide words) for (1) postulating deviations from design intents for sections of systems and (2) ensuring that appropriate safeguards are in place to help prevent system performance problems.	Primarily used for identifying safety hazards and operability problems of continuous process systems (especially fluid and thermal systems). Also used to review procedures and other sequential operations.	A HAZOP is convened to assess risk exposure of crane operations. Attention will be paid to structural failures of the crane (from the crane pedestal to the boom) and rigging (straps/chains, shackles, and lifting points). Potential failure of each topic will be considered.
Failure modes and effects analyses (FMEA)	FMEA is an inductive reasoning approach that is best suited to reviews of mechanical and electrical hardware systems. The FMEA technique (1) considers how the failure modes of each system component can result in system performance problems and (2) ensures that appropriate safeguards against such problems are in place. A quantitative version of FMEA is known as failure modes, effects and criticality analysis (FMECA).	- Primarily used for reviews of mechanical and electrical systems (e.g., fire suppression systems, vessel steering/propulsion systems). - Often used to develop and optimize planned maintenance and equipment inspection plans. - Sometimes used to gather information for troubleshooting systems.	FMEA is performed on the gas detection system. A single gas detector head is assumed to fail in the vicinity of a gas leak. The analysis would consider the effect of losing a detector on the overall deluge system efficiency (i.e., volume and density of gas released prior to the impaired system detecting the release).
Fault tree analysis (FTA)	FTA is a deductive analysis technique that graphically models (using Boolean logic) how logical relationships between equipment failures, human errors and external events can combine to cause specific mishaps of interest.	- Generally applicable for almost every type of analysis application, but most effectively used to address the fundamental causes of specific system failures dominated by relatively complex combinations of events. - Often used for complex electronic, control or communication systems.	A pool fire initiates on deck from product leaking from a crack in a cargo piping valve. The FTA would consider failures contributing to the release as well as the effectiveness of the active and passive fire protection systems.
Event tree analysis (ETA)	ETA is an inductive analysis technique that graphically models (using decision trees) the possible outcomes of an initiating event capable of producing a mishap of interest.	- Generally applicable for almost every type of analysis application, but most effectively used to address possible outcomes of initiating events for which multiple safeguards (lines of assurance) are in place as protective features. - Often used for analysis of vessel movement mishaps and propagation of fire/explosions or toxic releases.	A trading vessel enters the vicinity of the facility and loses steering and/or propulsion. The ETA would trace the sequence of events associated with the stricken vessel striking the facility.

3.5 Detailed Accidental Hazard Risk Assessment

The detailed accidental hazard risk assessment considers two primary steps: an initial event screening and a refined hazard assessment. The progression of the detailed accidental hazard risk assessment shown in Section 2, Figure 3 relates activities to the anticipated risk and consequence levels for a given event (note that this assumes the Owner specifies low, medium and high risk levels during risk matrix definition):

- i) If low risk is present or if the event frequency is sufficiently low, then no additional action is required.
- ii) Additional detailed hazard assessment should be performed on the high and medium risk events to either reduce the predicted risk via more refined (less conservative) modeling or identify additional mitigators.
- iii) If medium risk is obtained using the refined assessment and all reasonable safety barriers are present (i.e., all mitigations are present except those identified as being grossly disproportionate in expense, time or effort relative to the reduction in risk they afford), then no additional action is required.
- iv) If high risk is present, then additional detailed assessment and mitigation evaluations should be pursued until medium or low risk is obtained.

Once the risk for the current event has been reduced to acceptable limits, the process is repeated with the next event from the hazard identification.

The specific details regarding the detailed hazard assessment procedures for each of the key accidents of ship collision, dropped objects, fire, and blast are detailed in Sections 3 through 6, respectively.

The detailed accidental hazard risk assessment will be documented in a manner similar to that with the preliminary assessment. The primary distinctions are that the detailed assessment will not include specifics on the hazard identifications but may include multiple analyses of each accident.

3.7 Documentation

The documentation requirements for the accidental hazard evaluation are highlighted in Section 2, Table 2. Three activities are defined:

1. Accidental hazard risk assessment plan
2. Preliminary accidental hazard risk assessment
3. Detailed accidental hazard risk assessment

Where ABS is requested to review the accidental hazard evaluation, each of these activities should be submitted to ABS prior to proceeding to subsequent activities. For activities 2 and 3 (preliminary and detailed accidental hazard risk assessments, respectively), it is assumed that the individual hazard types (ship collision, dropped objects, fire, and blast) will be evaluated separately. In this case, the detailed risk assessment for a given hazard type (e.g., fire) only requires that its preliminary risk assessment has been reviewed by ABS. It should be noted that the elements presented in the preliminary and detailed accidental hazard risk assessment deliverables (2 and 3) are generic. Details pertaining to a specific hazard identification and assessment deliverables are provided in Sections 3 through 6.

TABLE 2
Overview of Accidental Hazard Evaluation Documentation Requirements

1. Accidental Hazard Risk Assessment Plan		
Description	Overview of the method to evaluate potential accidental loadings pertinent to the facility	
<i>Includes</i>	<i>Examples</i>	<i>Detailed In *</i>
Hazards to be considered	Ship collisions, dropped objects, fire, and blast events	2/1
Pertinent governing standards for each hazard type	ABS standards, industry standards (API, ISO), or Owner standards	X/1.1
Risk matrix to be utilized during evaluation	Industry standards (API, ISO) or Owner standard	2/3.1
2. Preliminary Accidental Hazard Risk Assessment*		
Description	Accidental hazard identification process for each hazard type considered	
<i>Includes</i>	<i>Examples</i>	<i>Detailed In *</i>
Hazard identification process utilized for each hazard type	Hazard operability analysis, failure modes and effects analysis, and fault tree analysis	2/3.3
Pertinent governing standards for hazard type	ABS standards, industry standards (API, ISO), or Owner standards	X/1.1
Acceptance criteria definition	Definition of local acceptance criteria (e.g., deflection and stresses) and global acceptance criteria (e.g., collapse and facility stability)	X/3.1
Personnel involved in the identification process	Personnel with diverse experience capable of identifying potential accidents and their likelihood and consequence	2/3.3.3
Accidental event definition (magnitude, location, and safeguards present)	Ship collision would include the vessel type (supply operations or drifting vessel), facility and colliding vessel characteristics (mass, hull shape/form, safety barriers), collision specifications (velocity, approach angle, contact location, environmental conditions, and applied loading)	X/3.3
Preliminary risk evaluation based on likelihood and consequence	Based on event definition and acceptance criteria, a preliminary risk assessment is developed based on the experiences and judgment of the hazard identification personnel (most likely qualitative risk assessment)	2/3.1
3. Detailed Accidental Hazard Risk Assessment *		
Description	Accidental hazard assessment process for each hazard type considered	
<i>Includes</i>	<i>Examples</i>	<i>Detailed In *</i>
Acceptance criteria definition	Definition of local acceptance criteria (e.g., deflection and stresses) and global acceptance criteria (e.g., collapse and facility stability)	X/3.1
Detailed description of the accidental loading	Reference that developed during the hazard identification activity	X/3.3
Pertinent governing standards for hazard type	ABS standards, industry standards (API, ISO), or Owner standards	X/1.1
Assessment method and results	Assessment method may involve sequentially more complicated assessment processes to reduce the conservatism present A fire assessment may initiate with a zone method (screening analysis) then proceed to a linear-elastic method (strength-level analysis) and nonlinear, elastic-plastic method (ductility-level analysis) Results presented would, at a minimum, provide sufficient information to address the selected acceptance criteria	X/3.5
Proposed additional structural and operational mitigations (if required)	Dropped object mitigations may include adjusting the general arrangement of critical equipment, restricting crane operations, and increased structural protection	X/3.7
Detailed risk exposure	Risk assessment process utilizing updated likelihood and consequence (refined assessment and additional mitigations)	2/3.1

* Reference nomenclature is "X/Y.Z" where X is the Section for each hazard and Y.Z is corresponding Subsection or Paragraph. For brevity, the use of "X" references discussion on ship collision (Section 3), dropped objects (Section 4), fire (Section 5), and blast (Section 6). If only a single section is appropriate, "X" is replaced by a Section number.