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Petroleum and natural gas industries — Offshore production installations — Guidelines on tools and techniques for hazard identification and risk assessment

Industries du pétrole et du gaz naturel — Installations des plates-formes en mer — Lignes directrices relatives aux outils et techniques pour l'identification et l'évaluation des risques

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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International Standard ISO 17776 was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum and natural gas industries*, Subcommittee SC 6, *Processing equipment and systems*.

Annexes A, B, C and D of this International Standard are for information only.

Introduction

Oil and gas exploration and production activities have many hazards and hazardous events associated with them.

Different tools and techniques can be used to identify and assess hazards and risks, and it is important that the approach selected is appropriate to the particular circumstances.

This International Standard identifies some of the tools and techniques that may be used for this purpose in the offshore exploration and production industry and gives guidance on how they may be applied to particular activities. This International Standard incorporates advice and guidance given in other documents used in the industry, some of which are cited in the Bibliography.

This International Standard does not provide a detailed description of the practical application of the various tools and techniques, as this will need to be specifically developed to deal with particular circumstances. In many cases expert advice from competent practitioners will be required to effectively apply the tools and techniques described in this International Standard.

Petroleum and natural gas industries — Offshore production installations — Guidelines on tools and techniques for hazard identification and risk assessment

1 Scope

This International Standard describes some of the principal tools and techniques that are commonly used for the identification and assessment of hazards associated with offshore oil and gas exploration and production activities, including seismic and topographical surveys, drilling and well operations, field development, operations, decommissioning and disposal together with the necessary logistical support of each of these activities. It provides guidance on how these tools and techniques can be used to assist in development of strategies both to prevent hazardous events and to control and mitigate any events that may arise.

This International Standard is applicable to:

— fixed offshore structures;

— floating production, storage and off-take systems;

for the petroleum and natural gas industries.

This International Standard is not applicable to design and construction aspects of mobile offshore units that fall under the jurisdiction of the International Maritime Organization.

This International Standard is not intended to be used as part of certification criteria, and no defect in the management of risks should be inferred if any of the tools and techniques covered by this International Standard are not applied to an installation.

2 Terms, definitions and abbreviated terms

For the purpose of this International Standard, the following terms, definitions and abbreviated terms apply.

2.1 Terms and definitions

2.1.1
barrier
measure which reduces the probability of realizing a hazard's potential for harm and which reduces its consequence

NOTE Barriers may be physical (materials, protective devices, shields, segregation, etc.) or non-physical (procedures, inspection, training, drills, etc.).

2.1.2
control
⟨of hazards⟩ limiting the extent and/or duration of a hazardous event to prevent escalation

2.1.3
environment
surroundings in which an organization operates, including air, water, land, natural resources, flora, fauna, humans and their interrelation

2.1.4
environmental impact
any change to the environment, whether adverse or beneficial, wholly or partially resulting from an organization's activities, products or services

2.1.5
escalation
spread of the impact of a hazardous event to equipment or other areas, thereby causing an increase in the consequences of the event

2.1.6
event tree
event tree analysis
ETA
tree-like diagram used to determine alternative potential scenarios arising from a particular hazardous event

NOTE It can be used quantitatively to determine the probability or frequency of different consequences arising from the hazardous event.

2.1.7
fault tree
fault tree analysis
FTA
tree-like diagram based upon the application of "and/or" logic used to identify alternative sequences of hardware faults and human errors that result in system failures or hazardous events

NOTE When quantified, fault trees allow system-failure probability or frequency to be calculated.

2.1.8
functional requirements
minimum criteria which should be satisfied to meet the stated health, safety and environmental objectives

NOTE See 5.4.2 for further information.

2.1.9
hazard
potential source of harm

NOTE In the context of this International Standard, the potential harm may relate to human injury, damage to the environment, damage to property, or a combination of these.

2.1.10
hazards register
document providing a brief, but complete, overview of the identified hazards and the measures necessary to manage them

NOTE The hazards register also provides references to more detailed information relevant to a particular hazard.

2.1.11
hazardous event
incident which occurs when a hazard is realized

EXAMPLES Release of gas, fire, loss of buoyancy.

2.1.12
incident
accident
event or chain of events which cause, or could have caused, injury, illness and/or damage (loss) to assets, the environment or third parties

2.1.13
mitigation
limitation of the undesirable effects of a particular event

2.1.14
procedure
series of steps to be carried out in a logical order for a defined operation or in a given situation

2.1.15
risk
combination of the probability of an event and the consequences of the event

2.1.16
risk analysis
use of available information to identify hazards and to estimate risk

2.1.17
risk assessment
overall process of risk analysis and risk evaluation

2.1.18
risk evaluation
judgement, on the basis of risk analysis, of whether a risk is tolerable

2.1.19
screening criterion
target or standard used to judge the tolerability of an identified hazard or effect

NOTE See 5.3.2 for further information.

2.1.20
tolerable risk
risk which is accepted in a given context based on the current values of society

2.1.21
top event
particular hazardous event considered in the development of fault and event trees

2.2 Abbreviated terms

CBA cost-benefit analysis

CFD computational fluid dynamics

EERA escape, evacuation and rescue analysis

ESD emergency shutdown

ETA event tree analysis

FMEA failure modes and effects analysis

FTA fault tree analysis

HAZAN hazard analysis

HAZID hazard identification

HAZOP hazard and operability study

HEMP hazard effect and management process

HRA health risk assessment

HSE health, safety and environment

JHA job hazard analysis

LNG liquefied natural gas

LPG liquefied petroleum gas

P&ID process and instrument diagram

PHA preliminary hazard analysis

PEM physical effects modelling

QRA quantitative risk assessment

SAR search and rescue

SIL safety integrity level

3 Hazards and risk assessment concepts

Effective management systems are required to address the health and safety aspects of the activities undertaken by all companies associated with the offshore recovery of hydrocarbons[1)]. These management systems should be applied to all stages in the life cycle of an installation and to all related activities. Such a management system, which has been developed for environmental issues, is described in ISO 14001 [3] and the principles contained in this International Standard can also be applied to issues relating to health and safety.

One key element of effective management systems is a systematic approach to the identification of hazards and the assessment of the associated risk in order to provide information to aid decision-making on the need to introduce risk-reduction measures.

Risk-reduction measures should include those to prevent incidents (i.e. reduce the probability of occurrence), to control incidents (i.e. limit the extent and duration of a hazardous event) and to mitigate the effects (i.e. reduce the consequences). Preventive measures, such as using inherently safer designs and ensuring asset integrity, should be emphasized wherever practicable. Measures to recover from incidents should be provided based on risk assessment and should be developed taking into account possible failures of the control and mitigation measures. Based on the results of the evaluation, detailed health, safety and environmental objectives and functional requirements should be set at appropriate levels.

1) For example, operators should have an effective management system. Contractors should have either their own management system or conduct their activities consistently with the operator's management system.

ISO 13702 [2] introduced the concept of strategies, but stated that such strategies do not have to be separately documented as the relevant information may be included with other HSE information for an installation or may be contained in recognized codes and standards that are relevant to the operating location. Indeed there can be significant overlap between strategies and other HSE information, so that combining this information into one source is likely to assist the understanding by the people on the installation of how the various measures are integrated.

The results of the hazard identification and risk assessment activities and the decisions taken with respect to the need for, and role of, any measures required for risk reduction should be recorded in strategies.

Hazards identification and risk assessment involves a series of steps as described below.

a) **Step 1: Identification of the hazard,** based upon consideration of factors such as the physical and chemical properties of the fluids being handled, the arrangement of equipment, operating and maintenance procedures and processing conditions. External hazards such as ship collision, extreme environmental conditions, helicopter crash, etc. also need to be considered at this stage.

b) **Step 2: Assessment of the risk** arising from the hazards and consideration of its tolerability to personnel, the facility and the environment. This normally involves the identification of initiating events, identification of possible accident sequences, estimation of the probability of occurrence of accident sequences and assessment of the consequences. The acceptability of the estimated risk must then be judged based upon criteria appropriate to the particular situation.

c) **Step 3: Elimination or reduction of the risk** where this is deemed to be necessary. This involves identifying opportunities to reduce the probability and/or consequence of an accident.

These three generic steps are inherent in all the methods which are described in this International Standard.

In selecting the appropriate hazard identification and risk assessment tools and techniques, the nature and scale of the installation, the stage in the life cycle and experience of similar installations should all be considered. The level of effort devoted to hazard identification and risk assessment should be based on the anticipated level of risk, the novelty of the undertaking and any limitations in knowledge.

Where the more complex, structured review techniques are used, the uncertainties in the assumptions used must be appreciated and considered when assessing necessary risk-reduction measures. It is important that uncertainties in the assumptions are well documented and communicated to the personnel who are using the results of the hazards and risk assessment to assist in decision-making.

For new installations or activities it is important to identify hazards as early as possible, in order that sufficient time can be given to the study and evaluation of the hazard before determining the most appropriate solution to manage it. It is always easier to make modifications early in the design stage of a project, when changes can be made with minimal effect on cost and schedule.

Hazards and risk assessment can also be applied to existing facilities, but in some cases changes that would be justified during design may not be practicable for an existing facility. As an example, improvements in layout concepts may not be practicable for existing facilities. The work necessary in undertaking modifications to an existing facility in itself introduces an additional risk of an accident which needs to be considered.

Figure 1 shows approaches with differing levels of complexity that may be used for hazards and risk assessment.

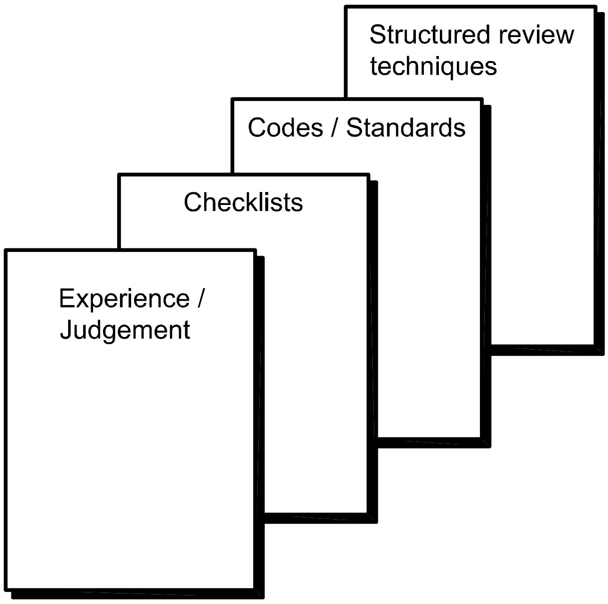

Figure 1 — Approaches to hazards and risk assessment

In many circumstances, the knowledge and expertise of experienced staff using a structured approach may be sufficient to manage risk.

Checklists are quick and easy to use, and can help determine whether design standards and practices are met and whether previously recognized hazards are properly addressed.

Where the experience gained by industry has been incorporated into codes and standards, a high level of safety can be achieved by checking for compliance with these standard practices in design, construction, operation and maintenance.

Structured review techniques can be used to identify and evaluate previously unforeseen hazards and unintended events that are not adequately addressed by the previous methods.

Further details are given in annex A.

4 Methods for hazard identification and risk assessment

4.1 Selection of methods

The level and extent of hazard identification and risk assessment activities vary depending on the scale of the installation and the stage in the installation life cycle when the identification and assessment process is undertaken. For example:

— complex installations, e.g. large production platforms incorporating complex facilities, drilling modules and large accommodation modules, are likely to require detailed studies to address hazardous events such as fires, explosions, ship collisions, structural damage, etc.;

— for simpler installations, e.g. wellhead platforms with limited process facilities, it may be possible to rely on application of recognized codes and standards as a suitable base which reflects industry experience for this type of facility;

— for installations which are a repeat of earlier designs, evaluations undertaken for the original design may be deemed sufficient to determine the measures needed to manage hazardous events;

— for installations in the early design phases, evaluations will necessarily be less detailed than those undertaken during later design phases, and will focus on design issues rather than management and procedural aspects. Any design criteria developed during these early stages need to be verified once the installation is operational.

Hazard identification and risk assessment activities may need to be reviewed and updated if significant new issues are identified or if there is significant change to the installation.

4.2 Role of experience/judgement

An often adequate approach is one in which the knowledge and expertise of staff, having appropriate experience, is used for hazard identification and assessment. This is particularly useful where the activity under consideration is similar to activities undertaken previously at the same or different locations. Practical staff experience gained in the field and feedback from hazardous events and near misses that have occurred is essential in this respect.

This approach on its own, however, is unlikely to be sufficient when dealing with novel or innovative systems and facilities, or where local conditions render previous experience invalid. For example, operating experience gained in benign tropical waters should not generally be used as the basis for evaluations of arctic installations.

4.3 Checklists

These are a useful way of ensuring that known hazards and threats have all been identified and assessed, although the use of checklists shall not be allowed to limit the scope of any review. Checklists are normally drawn up from standards and operational experience, and therefore focus on areas where the potential for mistakes is high or where problems have occurred in the past. Checklists are easy to apply and can be used at any stage in the project life cycle.

The checklist should be prepared by experienced personnel familiar with the design and operation of the facilities and with the company and industry standards and procedures. Checklists may be applied by less experienced personnel, although the effectiveness of the checklist technique is limited by the experience of the authors and the diligence of the users. However, they do not provide a creative format for the identification and evaluation of new hazards where experience is lacking.

Checklists should be reviewed and updated regularly to incorporate new experience by the company and industry, including the results from any accident or incident investigations.

Hazard registers from previous similar developments, which contain a record of hazards identified for that installation, are useful as a basis for checklists.

A checklist may be as detailed or as general as necessary, depending upon the specific application. It should be conscientiously applied, in order to evaluate whether standard procedures are being followed and to identify aspects that requires further attention. A checklist is generally the quickest and easiest method of hazards and risk assessment, and is very effective in the control of risk arising from standard, well understood hazards.

4.4 Codes and standards

Codes and standards reflect collective knowledge and experience, accumulated on the basis of company, national or international operations. These documents incorporate the lessons learned from previous designs, from hazards and risk assessment and from accident and incident investigations. They thus contain an inherent hazards and risk assessment, since the hazards have already been identified and the standard methods for their control and mitigation defined.

Information on hazards that may be contained in codes and standards is usually applicable to a particular type of operation. For example, the designer of a pressure vessel relief system can use a standard to find detailed guidance on the relief cases that should be considered. In some cases, compliance with prescriptive standards alone will reduce risks to a tolerable level. Similarly, the acceptability of emissions or discharges to the environment, or release of agents harmful to health, can be assessed by reference to environmental quality standards and occupational health exposure limits.

The use of checklists based upon the requirements laid out in codes and standards is a frequently used technique which is very effective in identifying compliance with industry standard practice and highlighting aspects which require further investigation.

4.5 Selection of structured review techniques

Where it is considered necessary to use hazards and risk assessment based upon structured review techniques, as described in annex B, the following guidelines may be used to select the appropriate method.

Identification of the main hazards is important in the early stages of a design, in order to allow design decisions to be made which reduce risk. HAZID and PHA may be useful to achieve this objective. If suitable information is available, preliminary QRA may be used at this stage and can make a contribution towards optimizing the platform layout. Sensitivity analyses, allowing the identification of parameters which have a significant effect on risk, often form a part of such assessments.

At later stages in a design, evaluation techniques, such as FMEA, FTA (2.1.7) and ETA (2.1.6), QRA and HAZOP may be found useful. Annex B presents information to input data for these techniques.

Evaluation of hazards and risks associated with construction tasks and operations, including inspection, testing and maintenance are effectively undertaken using techniques such as JHA and HAZOP, whilst FTA can sometimes be useful in identifying sequences or events which could give rise to a hazardous situation.

QRA should only be used when the input data are adequate to ensure that valid and robust results will be obtained. In most practical applications, there will be uncertainties in both the key parameters used and the QRA model itself. The effect of these uncertainties should be evaluated to confirm that they would not change the conclusion. Limitations in input data are likely to be less significant when QRA is being used to evaluate options, such as during concept selection.

QRA should only be undertaken by personnel with adequate skills and competencies. It is most important that the QRA model effectively reflects reality and thus those familiar with the facilities and their operation need to be involved in the evaluation. This is particularly true in relation to the preparation of input data and assumptions and the review of results from the evaluation.

All evaluation techniques provide results which are themselves subject to a range of uncertainty and consequently, the results should be compared with the judgement of experienced personnel.

Where there is felt to be potentially significant uncertainty in a key element of the evaluation, the use of alternative techniques should be investigated to validate results.

Usually the identification of hazards and the evaluation of risks are undertaken to reflect the situation at a particular point in time (e.g. construction activities, start-up of production, abandonment). Conditions on offshore installations are however dynamic, with changes in operating parameters such as pressure, temperature and produced fluids often being reflected in changed operating procedures and facilities. It is important therefore that the range of conditions for which the hazard identification and risk assessment are valid are clearly stated, and that the criteria triggering the need for re-evaluation are defined.

5 Risk management

5.1 General

5.1.1 Overview of risk management process

The process of identification of hazards and the assessment and control of risk is shown diagrammatically in Figure 2, which also illustrates the three steps described in clause 3.

After the relevant hazards have been identified, the risks arising from them are evaluated either qualitatively or, if appropriate, quantitatively. Risk-reducing measures should be introduced if the risks exceed any screening criteria, or if there are other reasonable measures that can be justified. Once the measures required to achieve a tolerable level of risk have been identified, the functional requirements of these measures should be defined.

The remainder of clause 5 provides more guidance on some of the important features of the risk management process.

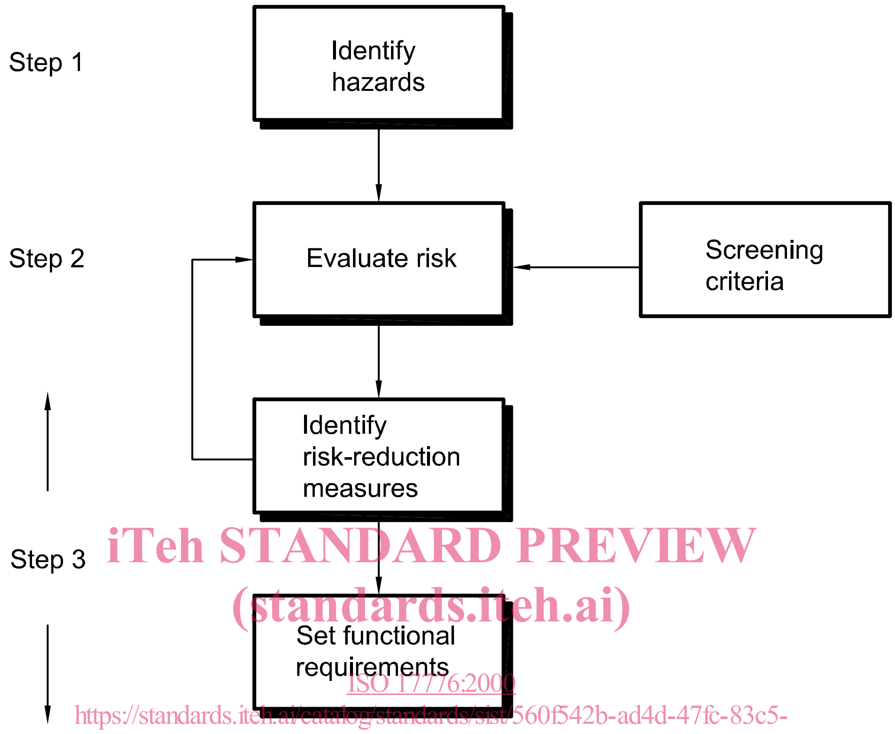

Figure 2 — The process of risk management

5.1.2 Organization and personnel

Hazards and risk assessment is normally performed by a team, but for some facilities or operations it may be undertaken by an individual. The effectiveness of a hazards and risk assessment depends on the skills, knowledge and efforts of the personnel undertaking the work.

The number of people involved and their range of experience should be determined by the size and complexity of the facility or operation being analysed. The identification of hazards and the subsequent evaluation of risk should be undertaken by personnel, or groups of personnel, who are both skilled in the techniques involved and knowledgeable about the design, operation and maintenance of the facilities under consideration.

The involvement, from an early stage, of work force representatives with “hands-on” experience has been shown to be particularly beneficial.

The effectiveness of any hazards and risk assessment is dependent upon careful planning and execution of the various tasks. Hazards and risk assessment should be started as early as possible, subject to the availability of the necessary information, in order that it may be a positive influence rather than a restrictive constraint on progress, requiring rework and additional cost.

5.1.3 Documentation

The key information and the decisions made in the identification and assessment of hazardous events should be documented in an ordered and comprehensive manner, for the benefit of both those that operate the installation and those who may be involved in subsequent changes.

