Drill-floor machinery and tubular-handling safety

Offshore Information Sheet No 2/2013

Contents

Purpose

Automation of drill-floor machinery and tubular-handling equipment has many advantages but it can introduce new hazards. Malfunctions of such machinery and equipment have a high potential for serious injury or fatality.

This information sheet provides guidance on managing risks in relation to drill-floor machinery and tubular-handling equipment, both existing and new. It applies both onshore in Great Britain and offshore on the United Kingdom's Continental Shelf (UKCS), wherever drilling or well work-over is undertaken in relation to the exploitation (including storage) of subterranean hydrocarbons.

It is aimed at anyone who has a role in managing the risks associated with drilling systems, specifically users, suppliers and system integrators (as defined in the Glossary).

Introduction

Following the Deepwater Horizon incident in the Gulf of Mexico in 2010, management of well control has been widely examined. However, the industry also needs to manage the associated drilling machinery and drilling machinery systems to ensure the safety of workers on the drill floor and related areas.

Complex machinery is increasingly used to assist in tubular handling, drilling and associated activities. However, while such equipment may eliminate certain types of incidents, it may also introduce new hazards arising from design/installation faults, equipment failure or operator error.

Collisions and other dangerous interactions may occur between equipment and workers, between equipment and structures, between different items of drill floor equipment or within the equipment itself. Such events often cause damage resulting in objects falling from height and presenting further hazards to drill floor personnel.

This Information Sheet promotes a systematic and holistic approach to managing drilling machinery system safety. A key feature of this is the implementation of safety management techniques and international standards that have been used successfully elsewhere in the hydrocarbon exploitation and machinery industries.

This information sheet promotes:

- the use of a systematic approach (eg HAZOP/HAZID, FMECA) to identify potentially dangerous interactions or occurrences and to identify suitable means for prevention or mitigation;
- the application of international machinery/control system standards in the design, integration and maintenance of drilling machinery and drilling machinery systems;
- a team approach to safety management with transparency and sharing of information;
- a clear definition of management responsibilities for functional safety particularly in suppliers' companies.

Advances in drill-floor technology have resulted in a greater reliance on electronic systems to implement safety-related functions. However, suppliers and users of drilling machinery and drilling machinery systems rarely carry out the sort of assessments which are routinely performed in other industries. In particular it is rare to find Safety Integrity Level (SIL) or machinery Performance Level (PL) assessments of the safety functions of drilling machinery and drilling machinery systems as advocated by standards such as IEC 61508, IEC 62061 and ISO 13849.

The principles in this information sheet may apply in other contexts where machinery is used to handle heavy loads (eg pipe-laying vessels, diving support vessels, heavy lift vessels).

This document has been prepared in consultation with drilling machinery system suppliers, integrators and users.

Duties

This document is based on the relevant GB and EU legal requirements. In particular, the following legal duties underlie this guidance.

Dutyholders

The Health and Safety at Work etc Act 1974 and its associated regulations mainly place duties on employers. Offshore, this includes installation owners, operators and contractors. Employees also have duties under the Act. Everyone has a part to play in ensuring healthy and safe conditions at work. Responsibility is placed mainly on the primary dutyholders, for example, operators of production installations and owners of non-production installations. They are in overall control of the installation and must co-ordinate the health and safety activities of all the companies and personnel present. See www.hse.gov.uk/offshore/guidance/entrants.pdf.

Suppliers

Suppliers have a duty to ensure, so far as is reasonably practicable, that the assembled drilling machinery system is designed and constructed so that it is safe. Suppliers have a duty to take the necessary steps to ensure that users are provided with adequate information about the intended use of the equipment and to ensure that users are supplied with all relevant revisions of such information. (Health and Safety at Work etc Act 1974, section 6)

Suppliers (including importers) of machinery to fixed offshore installations or to onshore facilities (and users who put machinery into service on fixed installations) have a duty to ensure the machinery meets the essential health and safety requirements as specified in the Supply of Machinery (Safety) Regulations 2008 (or equivalent legislation in other member states of the European Economic Area). These Regulations are the implementation in GB law of the EC Machinery Directive (2006/4/2/EC).

Users

Users have a duty to ensure that the complete drilling machinery system is fit for purpose (Provision and Use of Work Equipment Regulations, regulation 4) and a duty to ensure, so far as is reasonably practicable, that the complete drilling machinery system is safe. (Health and Safety at Work etc Act 1974, section 2)

Users who put together or import drilling machinery systems also take on the duties of a supplier. (Health and Safety at Work etc Act 1974, section 6)

Users have a duty to ensure, so far as is reasonably practicable, that the measures implemented to prevent injury arising from articles falling from, or being ejected from, drilling machinery systems are measures other than instruction, supervision and training and are part of a coherent overall accident prevention policy (Provision and Use of Work Equipment Regulations 1998, regulation 12, Management of Health and Safety at Work Regulations 1999, regulation 4).

Key actions

This information sheet identifies key actions for safety management of the drilling machinery system, but leaves the dutyholder to choose how they will be implemented.

Key actions for users

Users should implement the following safety management measures. Although these are listed as user actions, some will require information to be provided by the supplier.

Where a user assembles drilling equipment and/or tubular-handling equipment the user assumes the role of supplier or systems integrator and should implement the corresponding key actions.

- Identify potential dropped objects and machinery hazards and categorise risks associated with operation of drill floor machinery and tubular-handling equipment using methodologies such as collision and contention matrices, FMECA or FMEA, HAZOP, 'What-if analyses'.
- Where practicable eliminate hazards by redesign. For example, relocate passive equipment which might intrude upon the path of machinery.
- Assess the potential danger to people and plant and ensure that the safety preventative systems (both hardware and software) are robust and have the appropriate integrity to ensure risks are reduced to a level that is as low as is reasonably practicable (ALARP). Acceptable assessment methods include IEC 61508, ISO 13849, IEC 62061, DNV RP-D201 (software aspects) and ABS ISQM (software aspects).
- Implement appropriate hardware and software design measures in accordance with the relevant standards.
- Ensure that there is a safe, reliable and accurate method for drill floor measurements required by protective systems (such as zone management software) to be input into the protective logic. For a congested drill floor or a drilling system consisting of several items of machinery this might require the use of electronic measurement techniques.
- Ensure that there is a safe and sufficiently reliable means of verifying that each protective function operates as intended. It is likely that this will require redundancy of critical sensors. For systems comprising several pieces of machinery, an electronic system archive facility ('black box') may help.
- Ensure that on loss of power or distorted power supply waveforms (eg harmonic distortion or voltage dips) the mechanised movement stops and any raised/suspended items remain secure.
- Define the system boundaries and identify all interfaces with other systems and utilities including auxiliary systems such as telecoms, CCTV and reserve/back-up systems, eg emergency power, local operator stations, air reservoirs, standby hydraulic pumps.
- Ensure that appropriate management controls are in place so that equipment interlocks are not defeated or overridden unless:
  - an appropriate job-specific risk assessment has been undertaken and the specified risk controls are in place;
  - all other reasonable precautions have been taken;
  - the assessments and overrides are properly authorised and recorded;
  - the overrides are removed as soon as practicable;
  - the number of machines moved with overrides in place is minimised.
- Test, audit, monitor and review performance of the drill floor machinery and tubular-handling equipment. Monitoring and review should include investigation of incidents (including near misses), audit of the application of inhibits/overrides to the protective hardware and verification that the demands (eg numbers of alarms) on those who operate the machinery are reasonable. An electronic system archive device ('black box') can be very useful for reviewing and auditing each of these items.
- Review, manage and implement suppliers' new safety information including any changes to operation and maintenance manuals, safety and product bulletins.
- Review and manage change control of the complete drilling machinery system should prompt a review of the risk categorisation assessment and may require changes to the installed protection measures. Software systems require both version control and protection against unauthorised software modification and 'malware' such as viruses.

- Ensure that job safety analyses risk assessments, job plans and drill floor access diagrams (eg 'red zone' designations) are up to date and dynamic (ie allow for unplanned events).
- Have appropriate assurance and verification checks carried out by all parties.
- Ensure that safety-related interfaces between drillers and other operators of machinery are designed to good ergonomic principles.
- Ensure that all safety-related messages and indications to the operators of machinery are clear and unambiguous. This is particularly important if, for any protective function, it is not reasonably practicable to provide an automatic hardware protective function.
- Take extra precautions when troubleshooting or recovering from faulty operation. There may be additional hazards which require precautions beyond those employed in normal operation.
- Ensure appropriate training and competence for all of the drilling team covering the specific operations being carried out.
- Consider the key actions for suppliers below, and ensure that the appropriate information is obtained from the supplier.
- Define the roles and responsibilities of the user, supplier and system integrator(s).

Key actions for suppliers

- Provide users with the outcome of the drilling machinery system FMECA/FMEA or equivalent risk assessment, including details of any residual risks. This should detail where, when and how the equipment might give rise to danger, including during foreseeable fault conditions. It should also provide details of any critical maintenance activities necessary to maintain such risks at or below an acceptable level.
- Provide users with appropriate maintenance information including test and maintenance intervals. This information should be reviewed and any new or revised information sent to users if anything becomes known that gives rise to a serious risk to safety or health.
- Maintain a full history of the design and all modifications.
- Ensure the design of equipment is in accordance with relevant international standards. Provide evidence of conformity including certification and any special conditions such as limits of operation.
- Test equipment as far as possible to replicate operational conditions.
- Provide users with appropriate training in the operation of their equipment or system.
- Provide users with any other information necessary for them to undertake their key actions (above).
- There should be clear senior management responsibility for functional safety. This includes the design processes, methods and techniques that are employed to ensure, so far is as reasonably practicable, that equipment and/or systems as supplied to users is safe.

Key actions for system integrators

The role of system integrator involves aspects of both the supplier's role and the user's role. Accordingly, both key actions for suppliers and key actions for users may be applicable to a systems integrator.

Application of hazard identification techniques to drilling machinery systems

General

Several different techniques are available to identify hazards and operability problems, including include checklists, 'what-if analysis', collision/contention matrices, HAZOP, FMEA and fault tree analysis. Some techniques, such as checklists and 'what-if analysis,' can be used early in the system lifecycle when little detailed information is available. HAZOP and FMEA require more details of the drilling machinery system but produce more comprehensive information on the hazards.

It is important that the hazard identification process considers all the machinery together. Significant hazards may be missed if each item of equipment is considered in isolation.

Whichever combination of hazard identification techniques is used, suppliers' safety bulletins, operating and maintenance manuals should also be reviewed. Any warnings of danger or specific hazards should be considered carefully to ensure there are sufficient risk control measures in place during use of the machinery.

HAZOP

A HAZOP study involves an 'examination session' in which a multi-disciplinary team systematically examines all relevant aspects of a design. The examination is a creative process. It systematically uses a series of guide words/terms to prompt team members to envisage how a deviation from the design intent may occur and to identify the potential consequences. The examination is carried out with guidance from an experienced study leader whose role includes ensuring that the review is comprehensive (IEC 61882).

Originally HAZOP studies were applied in relation to process plant, however HAZOP's area of application has steadily widened. A key aspect for successful application of the technique is an appropriate choice of guide words/terms. Whereas guide words such as 'NO FLOW, 'MORE FLOW', 'LESS FLOW' are typically used in HAZOPs for the process industries guide words/terms such as 'TOO FAR', 'NOT FAR ENOUGH', 'TOO SLOW', 'TOO FAST', 'RELEASED' ,'NOT RELEASED' might be more relevant to machinery.

Sometimes a serious hazard may involve the interaction between several parts of a system. In such cases there may be a need for more detailed study using techniques such as fault tree and event tree analysis. As with any hazard identification technique there can be no guarantee that HAZOP by itself will identify all potential hazards or operability problems.

FMEA

A failure modes and effects analysis (FMEA) is a procedure in systems engineering for the analysis of potential failure modes within the system. An FMEA will assist a team to identify potential failure modes on equipment or processes. The FMEA process forces a review of functions and functional requirements, it also serves as a form of system design review. Failure modes are any errors or defects in a process, design, or item, especially those that affect the intended function of the product and/or process, and can be potential or actual. Effects analysis refers to studying the consequences of those failures.

FMECA

FMECA extends an FMEA by including a criticality analysis, which is used to chart the probability of failure modes against the severity of their consequences. The result highlights failure modes with relatively high probability and severity of consequences, allowing remedial effort to be directed where it will produce the greatest value.

The FMECA technique shares some features with HAZOP. It uses guidewords/terms to propose possible component failures and investigates the consequences of each failure on the system as a whole. However, whereas HAZOP is a system-centred approach which proposes deviations from design intent, FMECA is component centred. FMECA is thus unidirectional, working from cause to consequence to criticality.

A drill floor machinery system will contain many components and a comprehensive application of FMECA in general will be very labour intensive. With respect to this guidance a key goal of the FMECA for a drilling machinery system should be to ensure that any single line component with a significant safety role is identified and the severity and probability of a possible failure is analysed. Wherever practicable any such single line dependency should be eliminated. Analysis of the system should not only cover specific items of equipment but should cover the interaction of different items of equipment and the effects of how a failure on one piece of equipment may affect another.

Collision matrices

A collision matrix is a simple, high level, pictorial approach to identifying potential interactions between different movable items. The collision matrix contains a row for each item of movable plant on the drill floor and a row for the structure (derrick etc). It also contains a column for each item of movable plant and also a column for the structure. Where the paths of equipment could intersect or collide a numbered cross is placed in the matrix. The numbered cross provides an index against which the protective barriers to prevent the collision can be listed.

For a simple drill floor, with limited mechanisation and no congestion, the identification of mechanised movements which could cause collisions may be relatively easy. For crowded and more mechanised drilling areas the identification of potential collision scenarios may be assisted by software tools to accurately determine the extent of the volumes occupied by the various items of equipment as they move in their operational paths.

Movable equipment should be considered in its most general sense and could, for example, include items such as hinged doors for hydraulic units. Consideration should also be given to the potential for equipment to collide with itself or its own load.

Contention matrices

These are very similar to collision matrices except the interaction to be identified is the possibility of two items of machinery pulling in opposing directions on a single item of plant (eg draw works and pipe-handling equipment pulling on a stand of drill pipe).

Safety function specification

For each hazard, the means of controlling or reducing the risk of harm should be determined. These might include, for example, interlocks, brakes and/or work procedures.

There is a legal requirement (Provision and Use of Work Equipment Regulations, regulation 12) that, so far as is reasonably practicable, the means of controlling or reducing risk should be built into the equipment, rather than relying on training or procedures, ie safe by design. So engineered measures such as interlocks or barriers should be employed whenever practicable. Procedural measures such as management of restricted access areas ('red zones') can also play an important part.

Where risk control or risk reduction depends on an active control system, such as speed control or an interlock, then this is referred to as a 'safety function'. Safety functions should be specified in terms of both the functionality (what the function should do, or not do, to prevent a hazardous situation, including any requirements for speed or sequence of operation) and integrity (a measure of the required likelihood of the safety function being properly carried out).

Clear specification of safety functions (including constraints) is vital for software based systems. The relevant international standards for machinery control systems, IEC 62061 and ISO 13849, detail how the integrity requirement should be specified in terms of Safety Integrity Level (SIL) or Performance Level (PL). These standards also detail how the required SIL or PL is determined by a process of risk assessment based on how the machinery is used.

Design, implementation and integration

The machinery control system should be designed, implemented and integrated so that it is capable of carrying out the required safety functions in accordance with the safety function specification. Hardware reliability (including electrical, electronic, mechanical and hydraulic elements) and software integrity should be adequate in accordance with the SIL or PL for each safety function.

IEC 62061 and ISO 13849 specify design requirements for both hardware and software. If these requirements are met it can be assumed that the design will fulfil the relevant requirements of the Supply of Machinery (Safety) Regulations 2008, as is required for machinery being supplied to fixed installations on the UKCS and onshore in GB.

Examples of incidents

The following examples illustrate the consequences of failure to properly implement key actions described in this offshore information sheet. The examples relate to incidents reported to, or investigated by, HSE. The potential for serious injury in most of the incidents was very high. In most cases there were deficiencies in the implementation of more than one key action, but for simplicity the number of deficiencies listed here has been restricted.

Example 1 Interaction of pipe-racker and its load

Failing: Inadequate hazard identification

A pipe-racker was being used to manipulate a non-standard load. A task risk assessment identified the awkward nature of the load but recommended use of a spotter on the drill floor. While carrying the load the arms of the pipe-racker were retracted. The load damaged an attachment to the central column of the pipe-racker, but no objects fell. The arms were subsequently extended and an object fell in the vicinity of the spotter.

Example 2 Interaction of draw works and passive plant

Failing: Inadequate hazard identification/inadequate elimination of hazards by design

A hydraulic panel with hinged doors was installed high in the derrick. In windy conditions the panel doors swung open. The top-drive assembly collided with a door causing the door to fall to the drill floor

Example 3 Failure to implement safety alert

Failing: Inadequate review of supplier information (safety bulletins)

A safety alert to rectify a software problem was issued by an equipment supplier. A user failed to implement the safety alert. Several years later there was an incident in which two people were seriously hurt. Implementation of the safety alert would have prevented the incident.

Example 4 Contention between draw works and pipe-racker

Failing: Inadequate hazard identification

A pipe-racker was holding a stand of drill pipe. The draw-works attempted to lift the stand. A jaw of the pipe-racker fractured and fell to the drill floor.

Example 5 Dependence of collision avoidance on a single sensor

Failing: Inadequate hazard identification and inadequate means to verify equipment performance

The top-drive assembly design incorporated a single sensor for measurement of the top drive assembly position. The corresponding FMECA had concluded that a stand-alone system failure of the sensor could not lead to a dangerous collision. However the top-drive was installed on a drill floor with several items of mechanised drill floor machinery including a pipe-racker. There was a collision between the pipe-racker and the top-drive assembly resulting in several dropped objects. It was subsequently found that the single sensor had failed.

Example 6 Free swinging short stand

Failing: Inadequate hazard identification

A drill ship with extensive drill floor machinery used a monkey arm to guide pipe while it was being lifted by the top drive assembly. When a short stand of pipe was being lifted it completely exited the monkey arm guide and swing freely over the drill floor.

Example 7 Two drill centres

Failing: Inadequate hazard identification

A drill ship utilised two drill centres. The installation procedures permitted the personnel for both drill centres to work with active drilling machinery systems both in front of them and behind them.

Example 8 Lack of resilience to power cut

Failing: Inadequate hazard identification

An articulated crane for moving drill pipe was stationary with load for 30 minutes. A time-out had been installed in the crane software so that after 30 minutes of being stationary the hydraulic unit for the crane was shutdown. A few seconds thereafter the drill pipe fell to deck. There was a small hydraulic leak at one of the claws being used to support the pipe. In the absence of hydraulic power the pressure decreased in a way that led to rotation of the jaw sufficiently for the load to drop.

Example 9 Additional equipment

Failing: Lack of review and update to the hazard identification.

A collision matrix was used to identify potential collisions on a floating drilling unit. The client oil company changed and a new stabbing board was added. The hazard identification was not reviewed. Subsequently there was a collision between top drive assembly and the new stabbing board.

Example 10 Monkey-board substructure ignored

Failing: Inadequate hazard identification

A collision matrix was used to identify potential collisions for a relatively simple configuration of drilling equipment. The substructure beneath the monkey-board was not considered. Three years later the link tilt collided with the monkey-board substructure resulting in an object falling to the drill floor.

Example 11 Inadequate monitoring and review of equipment performance

Failing: Inadequate monitoring of system performance

An incident occurred in which a stand of pipe fell onto the drillers' shack. There were suggestions that the associated tubular-handling equipment had made unrequested movements, but there was no historical archive to show what commands had been made by those operating the equipment and no record of equipment positions.

Example 12 Software management

Failing: Inadequate change control

An audit of the drilling machinery system control computers on a floating drilling rig found forty-eight software viruses in the system, the average processor load was greater than 80% compared to the intent of approximately 15%. There was occasional 'freezing' of the driller's screen

Example 13 Ergonomic matters

Failing: Design was not according to good ergonomic principles

A driller was wearing headphones to communicate with the operator of the pipe-handling machine. He was engaging the magnetic brake with one hand and the dynamic brake with the other. The driller saw personnel on the drill floor and wanted to verbally warn them of the danger. The driller released the magnetic brake to grasp the drill floor public address (PA) microphone. In executing this manoeuvre he moved his knee to initiate the PA. As a consequence the dynamic brake moved into neutral and a 98 kg object fell to the drill floor.

Example 14 Ambiguous warning/alarm

Failing: Inadequate checks on the intelligibility of messages

The message 'brake on fault' was presented to the driller. The driller interpreted the message to mean the brake had been applied. In fact it had not and the top-drive assembly was being held in position by the draw-works.

Example 15 Incompatible pipe diameter and finger board spacing

Failing: Inadequate hazard identification and inadequate change control

On a semi-submersible drilling installation the finger board latch spacing was intended for 7-inch casing. The rig motion and the weight of the stand caused adjustable latches to splay enough for 1 stand of 6–5/8 inch landing string to come out of the slot into which it had been racked. The stand fell across the derrick.

Glossary

black box an electronic data recording device that records extensive data relevant to the use of safety-related equipment. To be of value for a drilling machinery system the recorded data should include times and nature of override commands to the protection systems, time and nature of commands to the machinery and regular timed records of all sensor values.

drilling machinery system the term includes rig or vessel mechanical equipment involved with drilling or tubular handling, including all control systems, control system software and operator interfaces required to operate the mechanical equipment.

integrator a company which assembles items of mechanised drill floor equipment to produce a drilling machinery system, or part of such a system. An integrator may be a supplier of the individual items of equipment, a user or a third party.

single line component a component whose will result in a dangerous failure of drilling equipment or the drilling machinery system.

supplier a company which supplies individual items of machinery (eg pipe handler or cherry picker), or supplies a complete drilling machinery system.

use any activity which involves the drilling machinery system, when it is installed on the rig or installation. Such activity includes normal operation, setting, testing and maintenance.

user the company with control over the use of the drilling machinery system. The user may be a rig/installation operator or owner company.

Regulations and standards

Note: Where a reference is undated the most recent version should be consulted.

Note: IEC, ISO and EN standards are published in the UK by BSI as BS IEC, BS ISO or BS EN documents.

Health and Safety at Work etc Act 1974

Provision and Use of Work Equipment Regulations 1998

Supply of Machinery (Safety) Regulations 2008

Lifting Operations Lifting Equipment Regulations 1998

IEC 62061 *Safety of machinery – Functional safety of safety-related electrical, electronic and programmable electronic control systems*

EN 1037 *Safety of machinery: Prevention of unexpected start up*

ISO 13849 *Safety of machinery – Safety-related parts of control systems (2 parts)*

IEC 60812 *Analysis techniques for system reliability – Procedure for failure mode and effects analysis (FMEA)*

IEC 61508 *Functional safety of electrical/electronic/ programmable electronic safety-related systems (7 parts)*

ISO 12100 *Safety of machinery (2 parts)*

ISO 13535 *Petroleum and natural gas industries. Drilling and production equipment. Hoisting equipment*

IEC 61882 *Hazard and operability studies (HAZOP studies) – Application guide*

IEC 60812 *Analysis techniques for system reliability - Procedure for failure mode and effects analysis (FMEA)*

Successful health and safety management HSG65 (Second edition) HSE Books 1997 ISBN 978 0 7176 1276 5 www.hse.gov.uk/pubns/books/HSG65.htm

Technical guidance on the safe use of lifting equipment offshore HSG221 (Second edition) HSE Books 2007 ISBN 978 0 7176 6229 6 www.hse.gov.uk/pubns/books/HSG221.htm

Out of control: Why control systems go wrong and how to prevent failure HSG238 (Second edition) HSE Books 2003 ISBN 978 0 7176 2192 7 www.hse.gov.uk/pubns/books/HSG238.htm

Interlocks for drill floor machinery OSD Safety Notice: 02/2006 HSE 2006

Integrated Software Dependent Systems, Det Norske Veritas AS,
Recommended Practice, DNV-RP-D201
Offshore Standard, DNV-OS-D203

Guide for Integrated Software Quality Management ABS 0185 American Bureau of Shipping

Recommended guidelines for the use of restricted access areas (red zones)
Dropped Object Prevention Scheme (DROPS)

Further information

Any queries relating to this notice should be addressed to:

osd3admin@hse.gsi.gov.uk

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www.hse.gov.uk/offshore/infosheets/is_index.htm

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