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Report

Lift incidents in the drilling area on offshore units

Description of incidents and causes

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ABSTRACT

The objective of the present study has been to give a detailed description of lifting incidents in the drilling area. The main focus have been the drawwork and specially designed lifting devices (e.g. elevators), but the study should also identify:

- Which types of lifting devices in the drilling area that represents a large contribution to the incidents
- Direct (triggering) and indirect causes for the incidents

The study shows that the moving part of the derrick equipment providing drilling and handling of drillstring, riser and tubing can be associated with 28% of the incidents. Heavy duty cranes and also elevators are also related to a significant part of the incidents (21% and 14%, respectively).

In a major part of the incidents the lifted objects (mostly pipes) either:

- fall because they are released from the grip, support or guide, or
- collide due to erroneous manoeuvre, mostly in confined spaces.

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1 Background

Lifting operations is an activity that is over represented with regards to personal injuries and material damage. The industry and the Norwegian Petroleum Safety Authority (PSA) have worked systematically and with success during the last decades to reduce the number of incidents. A present PSA initiative is to gain knowledge about causes of incidents related to lifting and other material handling activity in the drilling area.

Incidents related to offshore cranes (during the periods 1994-1999 [1] and 2000-2004 [2]) have been studied previously, and for the period 2005-2010 a follow-up study was performed, where the scope was widened also to include lifting in the drilling area and all other lifting activity in the petroleum sector [3].

One main result from this study is shown in Figure 1, which gives the number of serious (red and yellow) incidents for each year. The incidents are sorted on:

- Installation type (permanently located or movable)
- Main equipment and location:
  - Use of offshore crane
  - Handling of pipes and other load objects on pipe deck and in the drilling area

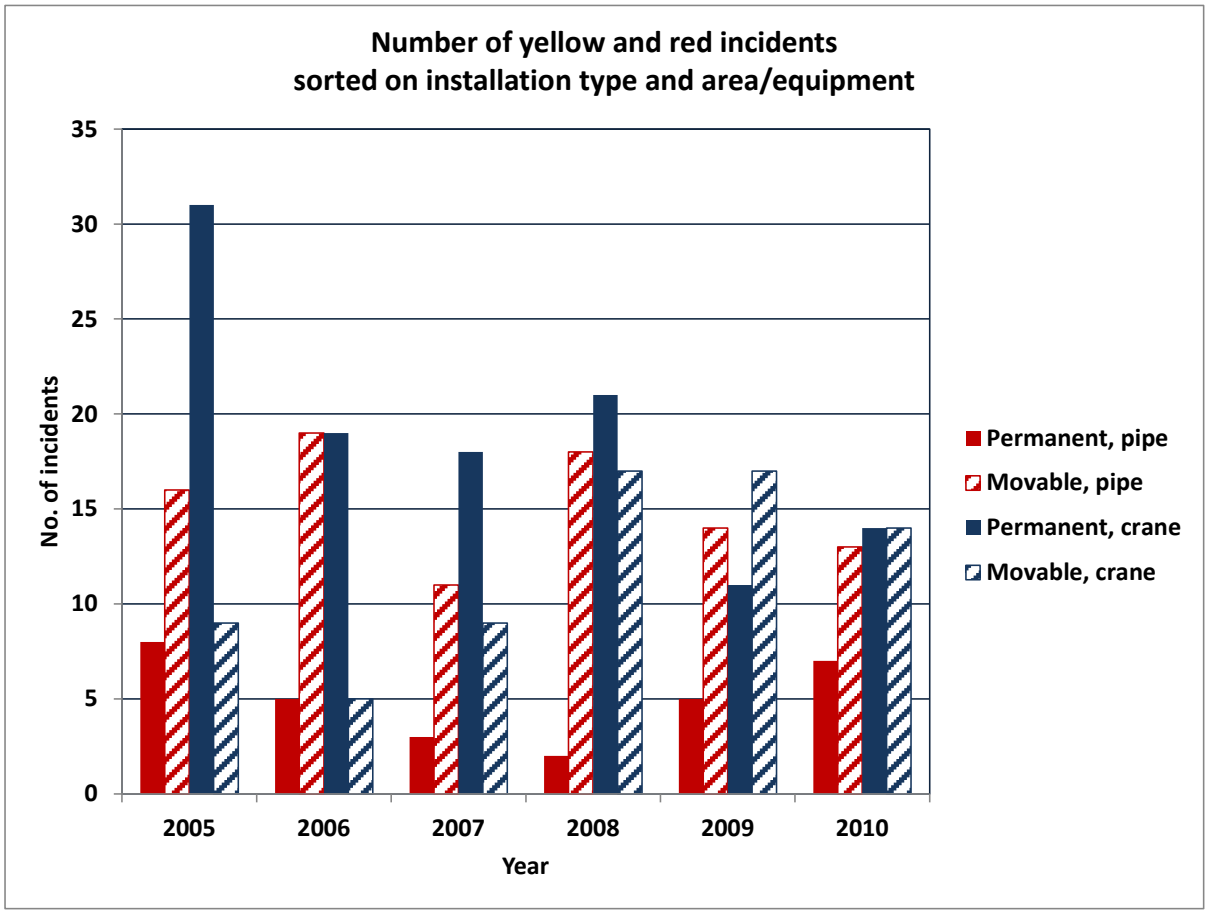


Figure 1 Trend of lifting incidents 2005 – 2010 [3]

1.1 Scope of study

The objective of the present study has been to give a detailed description of lifting incidents in the drilling area. The main focus should be the drawwork and specially designed lifting devices (e.g. elevators), but the study should also as far as possible identify:

- Which types of lifting devices in the drilling area that represents a large contribution to the incidents?
- What types of incidents are reported?
- Direct (triggering) and indirect causes for the incidents

The study have used a previously established data base with links to incident reports [3], supplemented with additional information from operators and contractors.

The goal of the study is to learn about the underlying causes of incidents involving lifting activities in the drilling area, in order to prevent future incidents and improve the level of safety in the industry.

1.2 Received reports

Altogether previously received reports from 139 lifting incidents in the drilling area 2005 – 2010 have been studied. An analysis of these incidents is documented in [3].
In addition received reports from 112 incidents in the drilling area during 2011 – 2013 have been studied and systematized.

2 Summary

Received reports from 251 unwanted lifting incidents related to lifting or material transport in the drilling area since 2005 have been studied and systematized.

The aim of the study has been to find:

- **How** the incidents have occurred, involving
- **Which** equipment, and
- **Why** (i.e. triggering and indirect causes)

For each incident also the **severity** potential has been evaluated. Number of incidents, sorted by severity:

Red:	Serious injury, permanent disablement or fatal, large material damage	72	(29%)
Yellow:	Injury demanding medical treatment. Considerable material damage, >50000 US$	119	(47%)
Green:	From no damage/injury to first aid injury without sick leave	60	(24%)

The study shows that the moving part of the derrick equipment providing drilling and handling of drillstring, riser and tubing can be associated with 71 of the incidents. Heavy duty cranes and also elevators are also related to a significant part of the incidents (53 and 35, respectively).

The stationary derrick equipment (heave compensators and tensioners), lighter handling equipment and winches used to control the lifted objects are less related to serious incidents.

The most commonly registered incident types are:

- Grip, clamp or support error, causing the lifted object to fall.
- Impact damage during manoeuver, mostly in small spaces
- Other falling objects, comprising nuts, washers or bolts, or parts of the lifted object or parts of the lifting equipment.
- Error in normal function or control system.

The first two types of incidents constitute slightly more than 50% of the total number of incidents, of which the three most exposed groups of equipment (heavy derrick equipment, elevator and cranes) alone represent around 30%, equally divided between grip failure and manoeuvre incidents.

The most frequently indicated direct, triggering causes for the incidents:

Human related causes:

H1: Lack of concentration, not deliberate error action
H2: Erroneous action due to wrong interpretation of situation or risk.

Technical related causes:

T1: Inadequate design, e.g. deficiencies in ergonomics, wrong dimension, or with unintended release or lock. Modifications with incomplete testing or without updated manuals / documentation has also been defined in this group of causes
T2: Inadequate condition due to deterioration from wear and tear, corrosion or physical damage. Most of the equipment has a hard work load and is exposed to salt, water and vibration. Often inadequate maintenance is reported as indirect cause.

The most frequently indicated indirect causes:

Organizational causes:	O3:	Insufficient planning or risk assessment
	O4:	Inadequate management and control for safety

3 Introduction

3.1 Activity and equipment in the drilling area

3.1.1 General description

The length of a drillstring used for offshore drilling can easily exceed 5000 meters. It consists of 10-14 meter (31 or 46 foot) long sections of drill pipe. From the drilling vessel drilling fluid (mud) is lead through the drill string down to the drill head, for lubrication and to transport rock material up through the hole, outside the drill string. During the last part of the drilling program the rotating drillstring is run inside a drilling riser through the water column. The three main purposes of the riser:

- To control the well pressure
- To lead return drill mud up to the mud system on board, for analysis, cleaning and recycling
- To protect the rotating drillstring

The drill string and the riser are carried by heavy equipment (drawwork with compensator or tensioner) that compensates for the vessel motion due to waves.

For various reasons the entire drillstring may be pulled stepwise out of the well during the drill programme. The drill pipe sections are then disconnected and transferred to an intermediate storage area where they stand vertical in a ("fingerboard") rack until they again are transferred to the drilling centre, re-connected and lowered to continue the drilling process. Figure 2 gives an overview over the area.

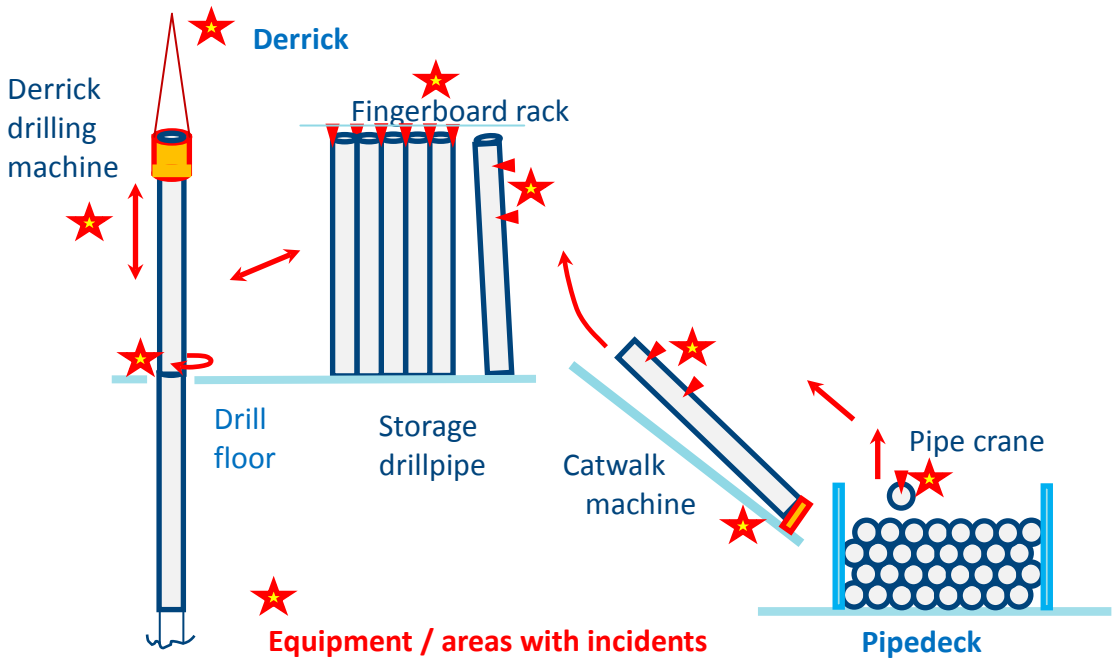


Figure 2 **Overview over the drilling area and the transport of pipe from storage area on the pipe deck to the drill floor.**

During the drilling program also tubes are deployed into the wells by use of specialised tubing running tools, in order to isolate the drill hole from the surrounding soil or bedrock.

The activity in the drilling area on offshore platforms thus comprises busy handling of the drill pipe sections, riser and tubing sections and heavy units, such as a blowout preventer (BOP) or seabed valve unit (e.g. Xmas tree). The lifting or handling equipment is either manually operated cranes and winches, or mechanised lifting and handling units. These units can be remotely controlled by operators and they may have automatic functions.

3.1.2 Equipment

The incident reports will often identify the location of the incident and which equipment that was involved. However, different names are used for the same or similar equipment and even brand names are used. The classification made in this study may thus contain interpretation errors. The equipment found to be associated with lifting incidents is sketched in Figure 3. Examples of specialized equipment are found in Figure 4 and Figure 5.

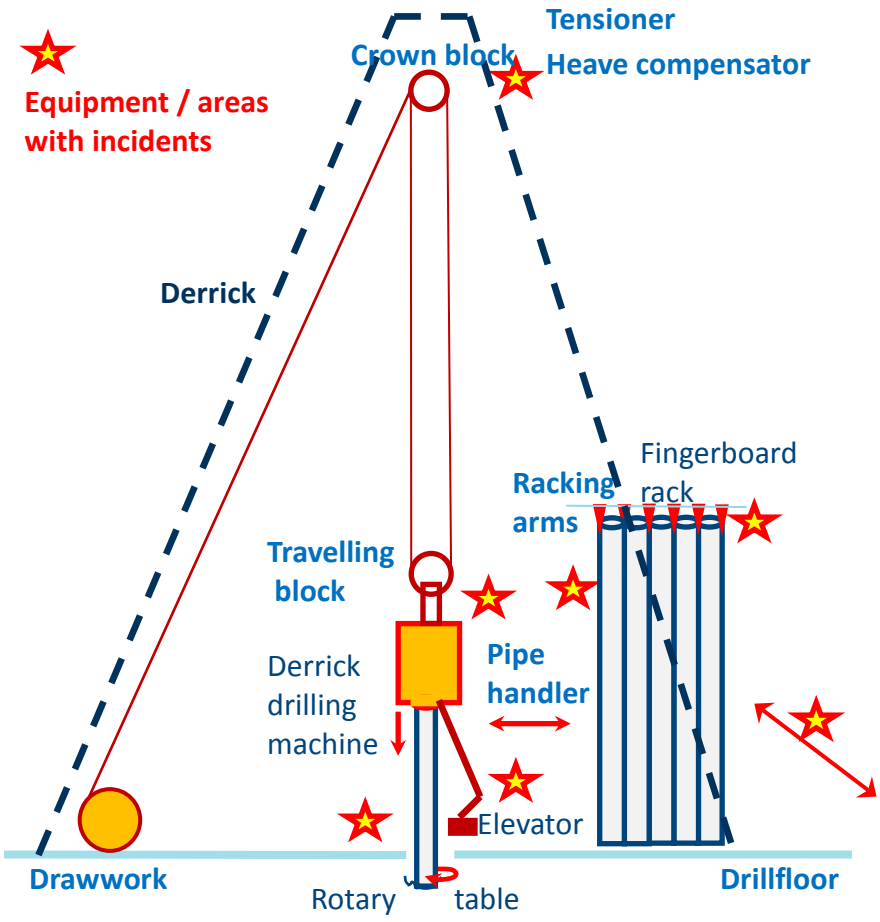


Figure 3 Overview in the drilling area, indicating handling equipment and intermediate pipe storage.

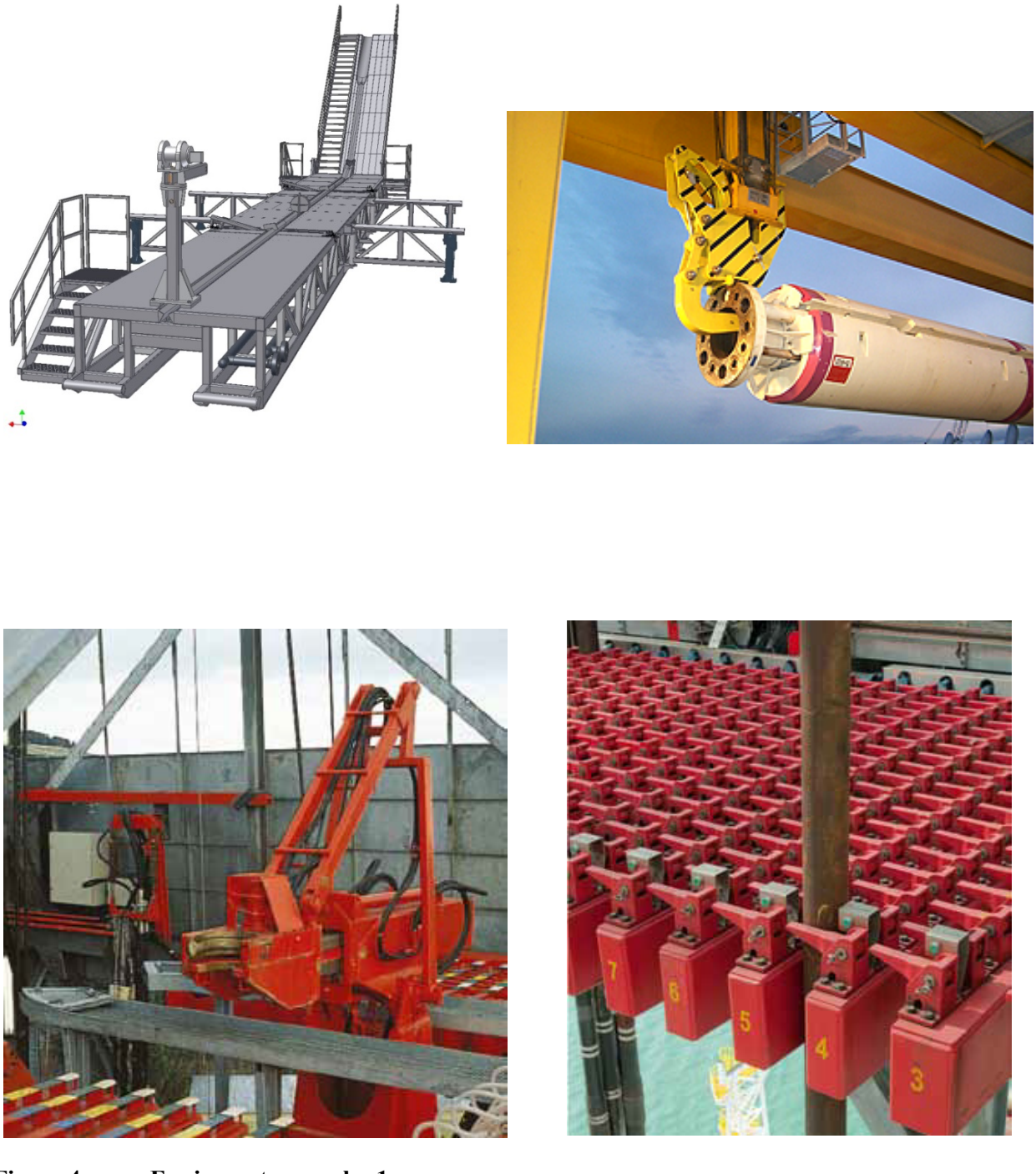


Figure 4 Equipment examples 1

Upper left: Catwalk machine (tubular feeding machine, TFM)
Upper right: Marine riser handling system
Lower left: Upper racking arm, URA
Lower right: Fingerboard rack

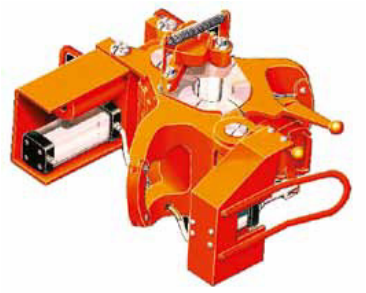


Figure 5 Equipment examples 2

Left, from top: Top drive / Swivel / Casing running tool / Elevator
Right, from top: Drillstring compensator / Derrick drilling machine

4 Method of Analysis

The received incident reports have been systemized, aimed at finding:

How incidents have occurred, involving
Which equipment in the drilling area.

For each incident also the

Severity potential and the
Direct (triggering) and indirect **causes** have been evaluated

4.1 Description of incidents

The present study focus is put on the activity and equipment in the drilling area. Therefore it has been considered useful to describe the incidents instead of the immediate result. As an example the descriptions "falling object" or "impact" can both describe the result of various incidents, directly related to either the handling equipment or the load. The following classification is selected to describe *what* has been observed:

Table 1 Identified failure types

Grip failure (mechanical grippers or magnetic yoke fails)	G
Rigging /guiding/ securing failure (in racks or TFM)	R
Loose bolts/nut/washer falling	B
Other object falling	O
Load (component) failure, loose load part falls	L
Hydraulic hose torn off or fails	H
Other failure in lift equipment	X
Wire failure	W
Small clearances, narrow space,	S
Manual manoeuvre failure	M
Functional or control system failure in lifting device	FC

These incident types have been defined into the following six groups:

Table 2 Defined groups of failure types

Grip/rigging failure	G+R
Falling small objects	B+O
Part of load or equipment falls	L+H+X
Wire failure	W
Manoeuvres, impact in narrow spaces	S+M
Functional or control system failure	FC

There have been two reasons for aggregating the related equipment and failure types into groups:

1. The incident reports do often not identify the equipment and describe the incident clearly, so an interpretation has been necessary. All interpretations may contain uncertainties.
2. The grouping is decided, also to increase confidence from few observations.

4.2 Involved equipment

The equipment found to be associated with lifting incidents are listed with a brief explanation in Table 3. An overview over standard equipment in the drilling area, taken from [4], is found in Appendix A.

Table 3 Equipment associated with lifting incidents in the drilling area.

Area:	Name / ID	Explanation / description	
Derrick	Main drive	TD: Top drive, all derrick equipment that holds the drillstring DW: Drawwork, winch that moves DDM vertically DDM: Derrick drilling machine (rotates the drill string)	
	Compensator	HC: Heave Compensator CMC: Crown Mounted Compensator	Move the lifting system in the derrick (TD, DDM) to compensate for vertical wave induced motion.
		MRT :Marine Riser Tensioner	Holds the marine riser at (nearly) constant tension, compensating for wave induced motion
Storage area	Pipe handler	F: Finger board, rack equipment for storing standing drillpipes MA: Manipulating Arm, RA: Racking Arm, equipment for lifting pipes to, from or into the storage racks VPH :Vertical Pipe Handler, for lifting pipes between storage and drilling area.	
Drill floor	Lift accessory	Elevator: Unit used when connecting or disconnecting drillstring segments. Grips around the string and lowers or lifts. Running tools for casing (CRT) and tubing hanger (THRT).	
Pipe deck to drill floor	Pipe feed	TFM Tubular Feeding Machine, HTV: Horizontal to Vertical handler, Eagle and Catwalk machine are all names for a conveyor transport and handling system, from the pipe deck up to the drilling area	
Drill area	BOP crane	Crane or tower for lifting and skidding the BOP or other heavy units	
	Tugger winch	Wires and winches used to control pendulum motion of a suspended load, or to pull it to desired position	
	Cranes (other)	Other crane or lifting device. In some of the reports the crane type was not clearly defined. Some cranes in this group should possibly be put into the group 'BOP crane'.	
	Unspec.	Unspecified equipment, and slips in the rotary table	

4.3 Classification of causes

The term "cause" is here interpreted as various probable explanations for *why* the incidents took place. This is the traditional interpretation.

The same classification of causes for an incident has been used as in previous analyses, ref. [1], [2] and [3]:

Triggering or direct causes:	H - Causes related to human actions
	T – Causes related to technical design or condition (wear and tear)
Underlying or indirect causes:	O – Causes related to organization and management

The classification groups are defined in Table 4.

Table 4 Triggering and underlying causes for unwanted incidents

Triggering / direct causes		Underlying / indirect causes	
H1	Lack of concentration, not deliberate error action	O1	Lack of competence or training, risk not understood
H2	Erroneous action due to wrong interpretation of situation or risk	O2	Procedure quality or existence. Manuals lacking or not updated
H3	Inadequate communication	O3	Insufficient planning or risk assessment
H4	Deliberate breach of procedure	O4	Inadequate management and control for safety
		O5	Inadequate maintenance
T1	Inadequate technical design / function	O6	Inadequate priority from the management
T2	Technical condition (wear and tear)	O7	Adverse work environment (wind, motion, visibility, space)

4.4 Weighting of causes

For each incident at least one triggering cause and at least one indirect cause have been assigned. For each group of equipment the total number of assigned direct or indirect causes may be larger than the number of incidents related to that equipment group. In order to be able to compare the incidents related to different equipment, a normalization or weighting has been made:

Assume that:

Ni is the number of incidents related to the equipment where cause number i has been given
Nc is the total number of causes assigned to the incidents related to the equipment
Nn is the number of incidents related to the equipment

Then the normalized or weighted number of cause number i for the equipment is:

$N(wi) = Ni * Nn / Nc$

Direct and indirect causes are treated separately.

4.5 Classification of severity

The severity classification is made based on the potential consequence that the incident could have under 'slightly changed circumstances'. From some of the companies we have received synergy reports containing severity assessment classified by color code, which we have followed. For incidents without such classification the potential severity has been classified as follows (irrespective of potential recurrence frequency):

GREEN:	From no damage/injury to first aid injury without sick leave
YELLOW:	Injury demanding medical treatment. Considerable material damage, >50000 US$
RED:	Serious injury, permanent disablement or fatal, large material damage

The estimation and classification of material damage has been tentative.

5 Results

Altogether reports from 251 unwanted incidents related to lifting or material transport in the drilling area have been studied, with potential severity:

Red:	72	(29%)
Yellow:	119	(47%)
Green:	60	(24%)

The potential severity and the causes of the incidents are presented more detailed in the following sections.

5.1 Severity of the reported incidents

The total number of incidents related to the different groups of lifting and handling equipment is shown in Figure 6. The division into severity classes is also shown. It appears that the moving part of the derrick equipment, the heavy duty cranes and the elevators can be associated with a dominating part of the incidents. The stationary derrick equipment (heave compensators and tensioners), the lighter handling equipment and winches used to control the lifted objects are less related to serious incidents.

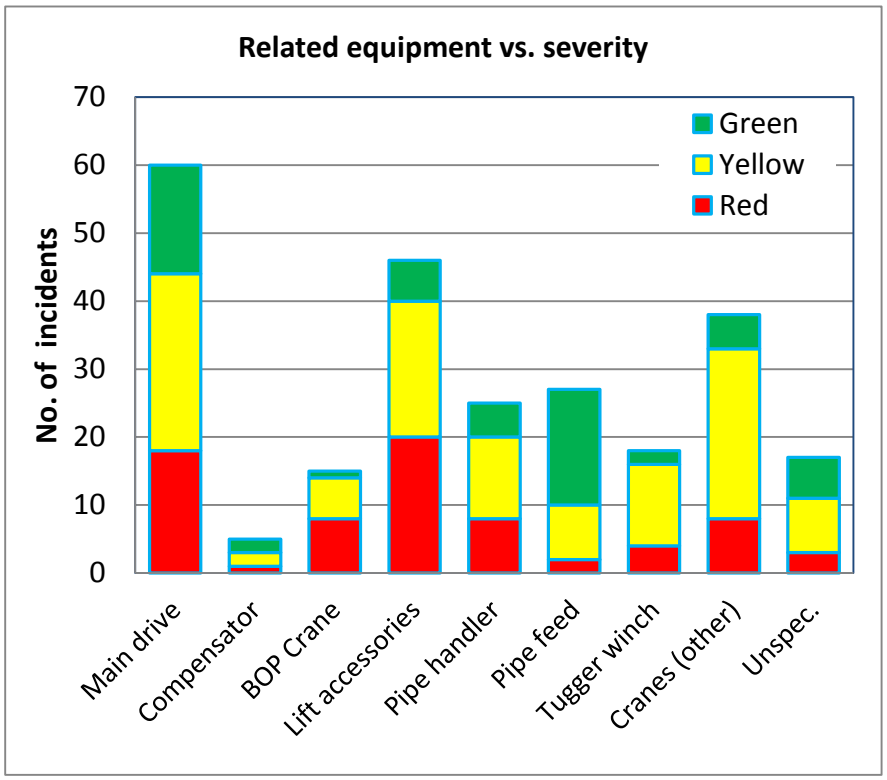


Figure 6 Potential severity of incidents related to various equipment defined in Table 3.

Alternatively Figure 7 shows tentatively the distribution of red, yellow and green incidents for each group of equipment. It appears that the potential consequences if incidents related to the following equipment tend to be more severe:

- Heavy duty equipment in the derrick providing drilling and handling of drillstring, riser and tubing
- BOP crane
- Lift accessories (elevator and running tools)
- Pipe transport system from the pipe deck.

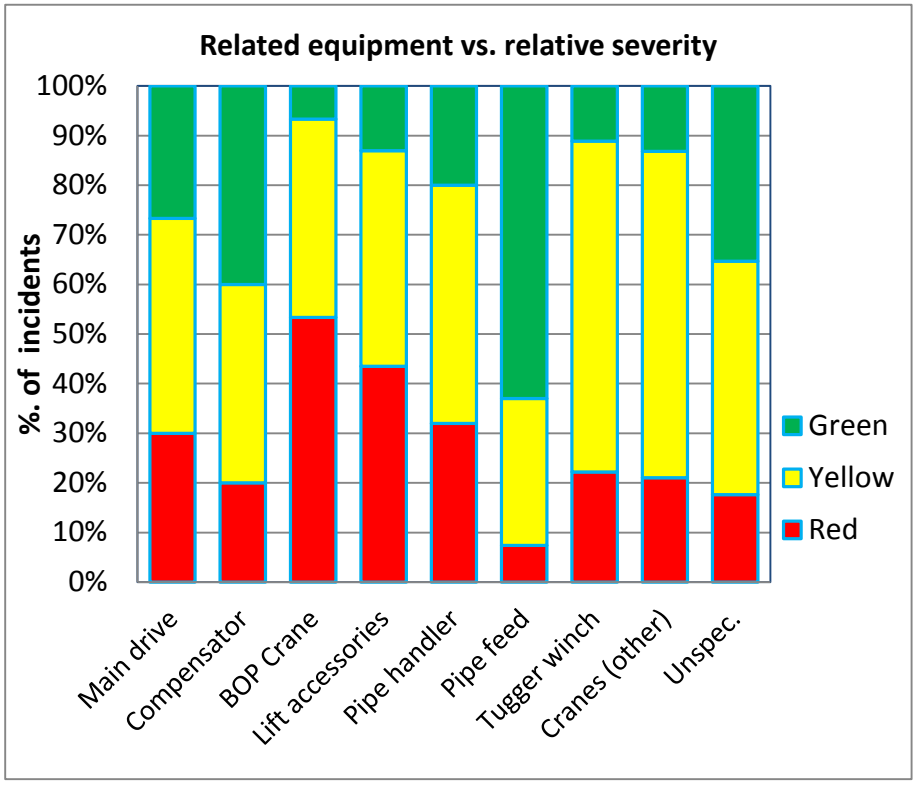
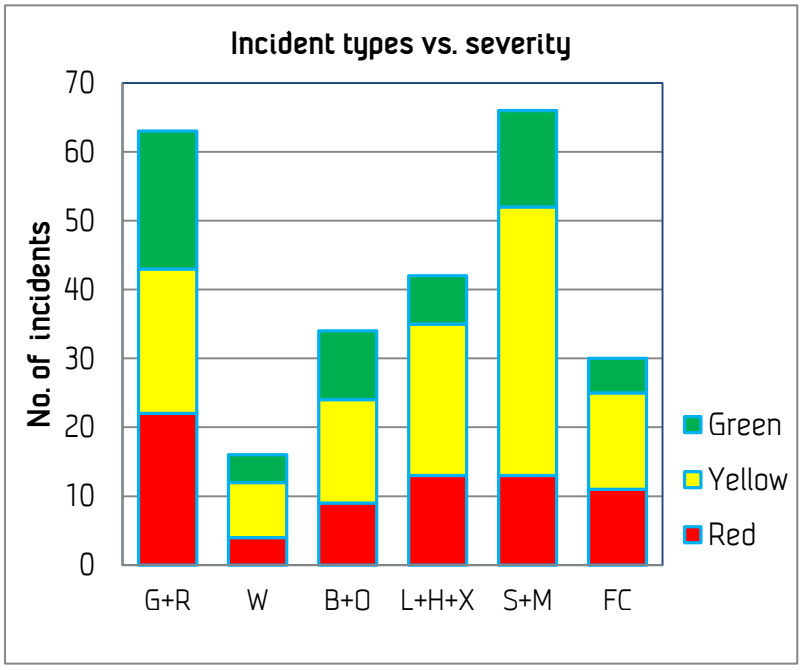


Figure 7 Relative severity of incidents related to various equipment.

The number of incidents and their severity versus the classified types of incidents is shown in Figure 8. It appears that in a major part of the incidents the lifted objects (mostly pipes) either fall because they are released from the grip, support or guide (G+R), or collide due to erroneous manoeuvre, most probably in confined spaces (S+M).

These two types of incidents constitute slightly more than 50% of the total number of incidents, of which the three most exposed groups of equipment (heavy derrick equipment, elevator and cranes) alone represent around 30%, equally divided between gripper (G+R) and impact (S+M) incidents.



G+R: Grip/ rigging
Falling objects:
B+O: Small objects
L+H+X: Part of load or equipment
W: Wire failure
S+M: Maneuver, narrow space
FC: Failure of function or control system
(c.f. Table 1-3)

Figure 8 Potential severity of the various types of incidents

5.2 Identified causes

The total percentage of registered direct and indirect causes for all incidents are summarised in Figure 9. The graph shows that the following causes are often found:

Human related causes:	H1, H2	(Unconscious, lack of concentration, deliberate errors)
Technical causes:	T1, T2	(design, ergonomics, wear and tear)
Organizational causes:	O3, O4	(work planning, work management and control

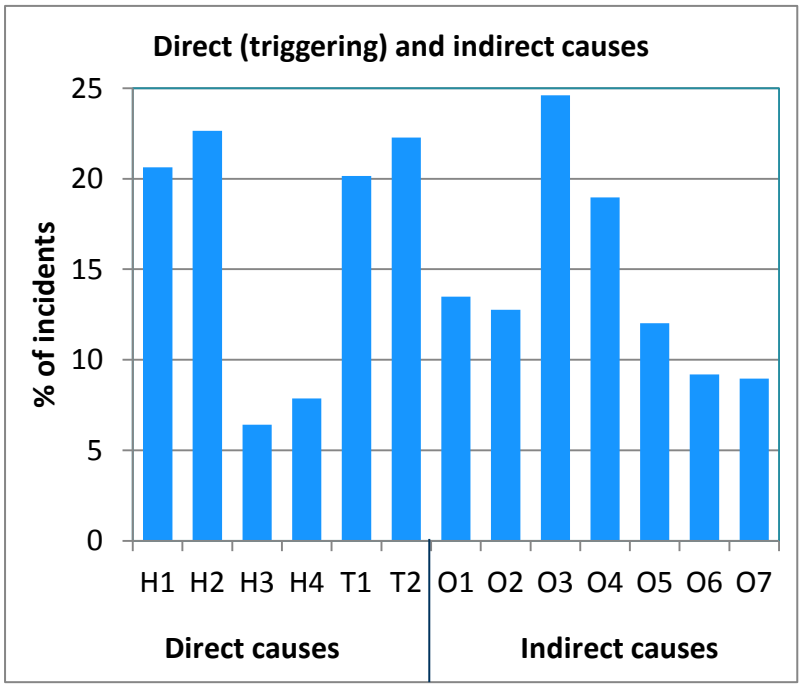


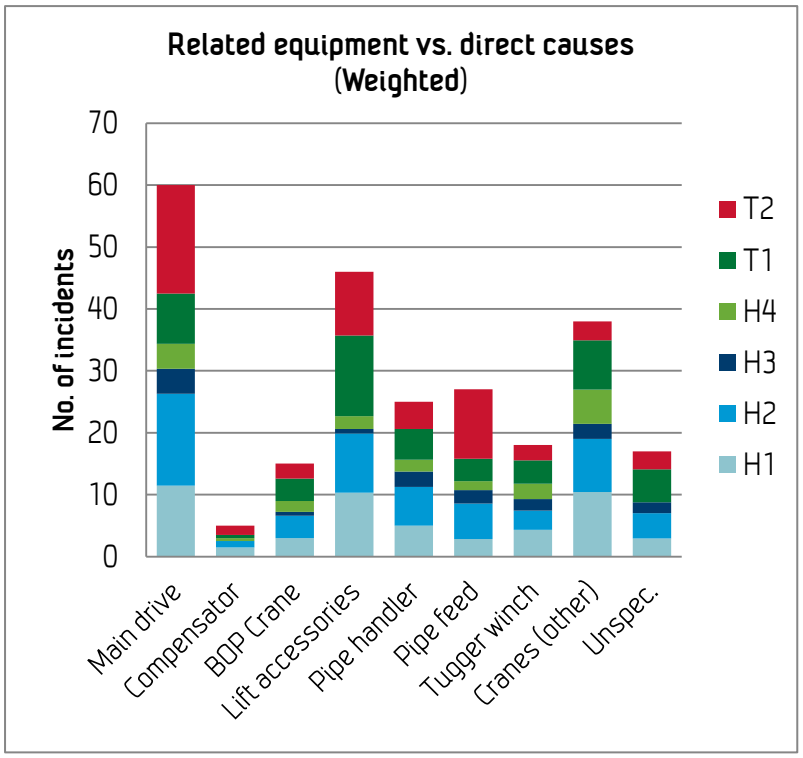
Figure 9 Direct and indirect causes, in % of all incidents

The incidents are now sorted according to involved equipment. The direct, triggering causes are shown in Figure 10 and the indirect causes in Figure 11.

The human causes related to lack of concentration or understanding of risk (H1, H2) and the technical causes (T1, T2) contribute to a major part of the direct causes to the incidents. This is particularly evident for equipment that is frequently or nearly continuously used, exposed to vibrations and salt.

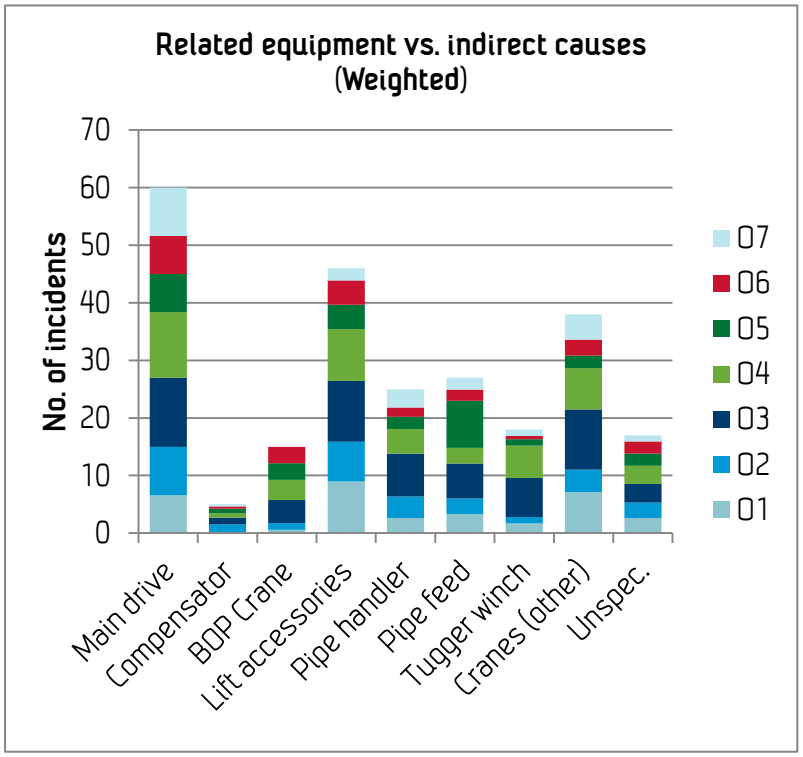
The incidents sorted according to type of incidents are similarly shown in Figure 12 and Figure 13. As expected, the human related causes H1 and H2 are important for the manoeuvre and handling errors (S+M and G+R). Frequently mentioned indirect causes of these incidents are O1 (lack of competence), O3 and O4 (unsatisfactory planning and management / control).

Unsatisfactory technical condition explains incidents involving dropped small objects (B+O) and functional errors in the handling system (FC). Improper design is identified as important direct cause for the many incidents where pipes are released from handling clamps or magnetic lifters (G+R). Inadequate maintenance (O5) is often reported as indirect cause whenever wear and tear (T2) is assigned as direct cause.



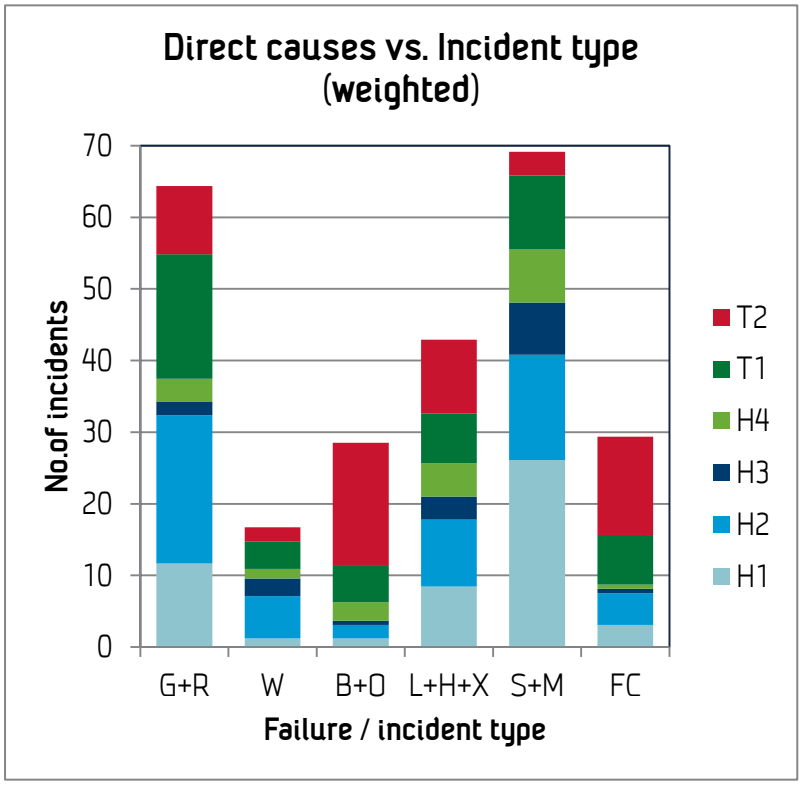
H1 *Lack of concentration*
H2 *Wrong, deliberate action*
H3 *Communication*
H4 *Breach of procedures*
T1 *Improper design*
T2 *Technical, wear and tear*

Figure 10 **Direct causes vs. involved equipment**



O1 *Lack of competence*
O2 *Procedure, manuals*
O3 *Work planning*
O4 *Work management*
O5 *Maintenance*
O6 *Management HSE focus*
O7 *External conditions*

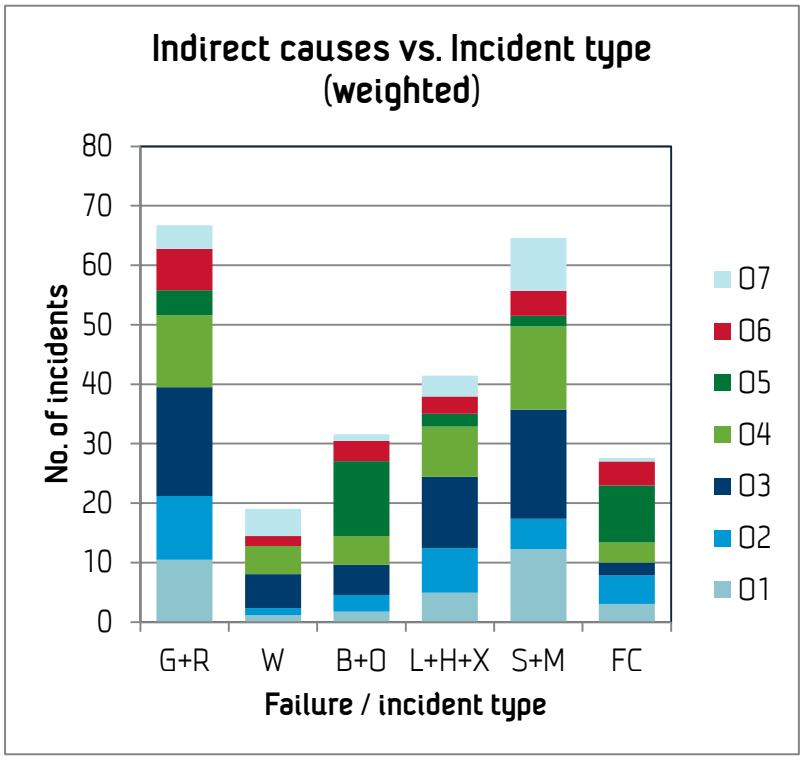
Figure 11 **Indirect causes vs. involved equipment**



G+R: Grip/support
Falling objects:
B+O: Small objects
L+H+X: Part of load or equipment
W: Wire failure
S+M: Maneuver, narrow space
FC:Failure in function or control system
(c.f. Table 1-3)

H1	*Lack of concentration*
H2	*Wrong, deliberate action*
H3	*Communication*
H4	*Breach of procedures*
T1	*Improper design*
T2	*Technical, wear and tear*

Figure 12 Direct causes vs. incident types



O1	*Lack of competence*
O2	*Procedure, manuals*
O3	*Work planning*
O4	*Work management*
O5	*Maintenance*
O6	*Management HSE focus*
O7	*External conditions*

Figure 13 Indirect causes vs. incident types

5.3 Equipment, incident types and technical causes

In the present continuous effort to reduce the risk level, it can be of interest to have a documentation of:

Which equipment is related to what types of incidents?
Can the incidents be explained by technical inadequacy?

An overview intended to somewhat clarify these questions are given in the following.

Derrick equipment (drawwork, top drive, derrick drilling machine):
A total of 60 incidents. Technical causes given in 38 cases.
Various falling objects constituted 20 incidents,
10 of these are explained by corrosion, wear and tear, 3 by inadequate design
Damage during manoeuver in small spaces constituted 15 incidents,
3 of these are explained by inadequate design, 3 by wear and tear
Errors in basic function or safety control device constituted 12 incidents
5 of these were explained by wear and tear.
Inadequate testing after repair reported in 1-2 cases

Motion compensators (heave compensators, marine riser tensioner):
A total of 5 incidents. Too few incidents for confident conclusions
2 cases described as functional errors due to inadequate maintenance

BOP crane:
A total of 15 incidents. Technical causes given in 10 cases.
Function or control errors constituted 5 incidents, and wire failure 2 incidents. 3 of the function control errors are explained by inadequate ergonomics
Various falling objects are reported for 4 incidents, caused by wear and tear

Lifting accessories (elevators, running tools for tubing hanger or riser):
A total of 46 incidents. Technical causes given in 34 cases.
Grip / clamp errors constituted 27 Incidents
15 of these explained by inadequate design
8 of these explained by wear and tear.
Various falling objects constituted 11 incidents,
7 of these are explained by wear and tear (inadequate maintenance)
Damage during manoeuver in small spaces constituted 8 incidents,
2 of these are explained by inadequate design

Pipe handling equipment (vertical pipe handler, racker equipment, manipulator arms):
A total of 27 incidents. Technical causes given in 20 cases.
Various falling objects constituted 10 incidents,
9 of these are explained by corrosion, wear and tear (inadequate maintenance)
Grip / clamp / support errors constituted 8 Incidents
Physical causes are inadequate design and wear and tear (number not conclusive)

Pipe feeding equipment from pipe deck to drill floor (tubular feeding machine, catwalk machine etc.):
A total of 25 incidents. Technical causes given in 15 cases.
Grip / clamp errors constituted 7 Incidents
4 of these explained by inadequate design
Various falling objects constituted 6 incidents,
3 of these are explained by wear and tear
Damage during manoeuver in small spaces constituted 5 incidents,
One is explained by wear and tear
Function errors constituted 5 Incidents
2 of these explained by inadequate design, 3 by wear and tear

Tugger winches (for maneuver assistance):
A total of 18 incidents. Technical causes given in 10 cases.
Various falling objects constituted 6 incidents
3 of these are explained by wear and tear
Damage during maneuver in small spaces was identified in 9 incidents
5 of these are explained by inadequate design / ergonomics

Other cranes (traverse cranes / carriages etc.):
A total of 38 incidents. Technical causes given in 18 cases.
Grip / clamp errors constituted 9 Incidents
4 of these are explained by inadequate design / ergonomics
Various falling objects constituted 8 incidents,
4 of these are explained by inadequate design, and 2 by wear and tear
Erroneous maneuver (in small space) was identified in 17 incidents
4 of these are explained by inadequate design / ergonomics

Other equipment:
A total of 17 incidents. Technical causes given in 14 cases
Inadequate design reported in 9 cases, wear and tear in 5 cases.

6 References

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Scandpower Risk Management AS Rapport nr. 33.790.007 R1, 9. Juni 2005

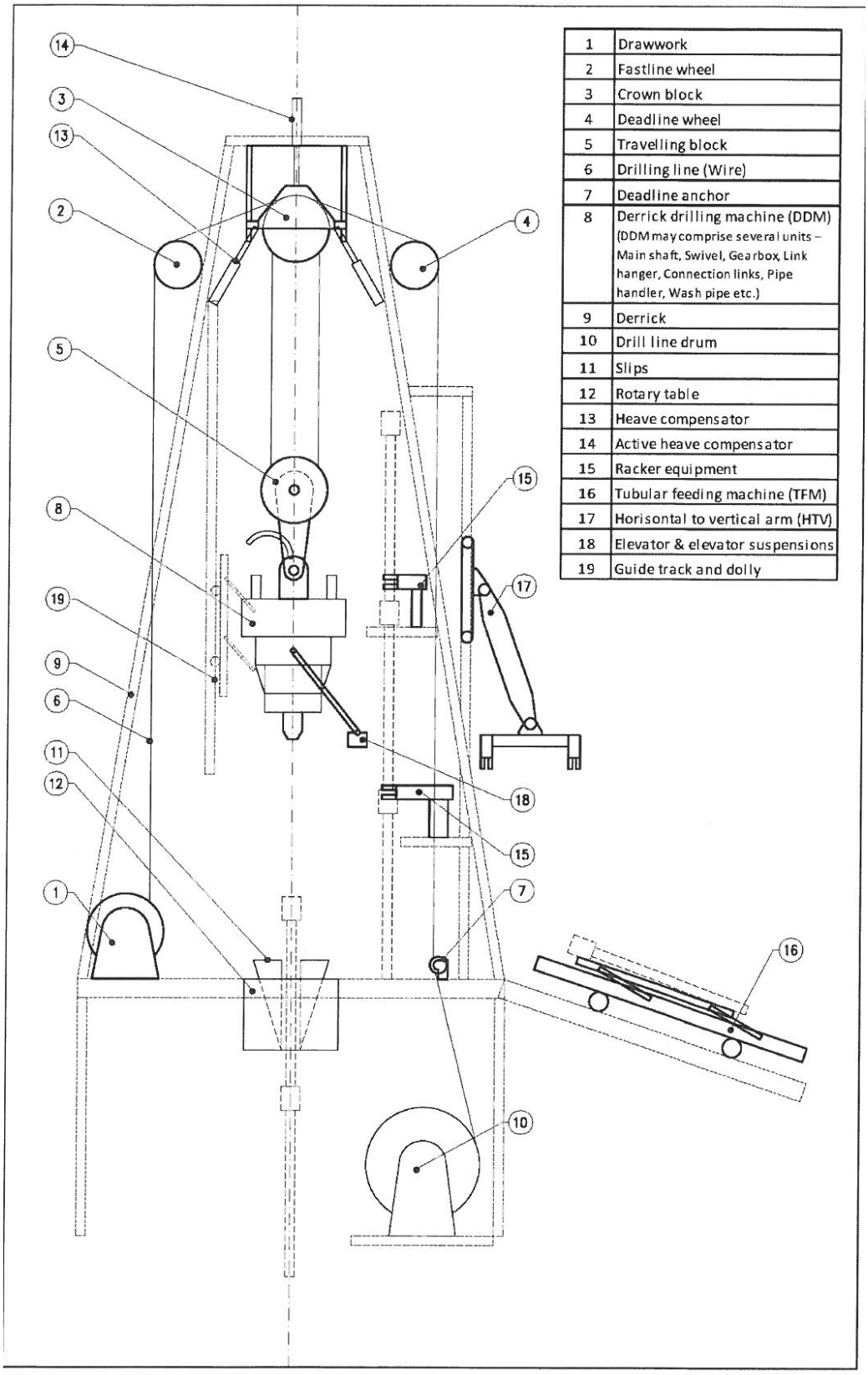
[3] Analyse av årsakssammmenhenger til uønskede løftehendelser

Fase 3 – Perioden 2005 – 2010
Marintek rapport nr. MT58 F12-027 / 580285.00.01. Februar 2012

[4] NORSOK Standard R-002 Lifting equipment

Draft Edition 2. June 2011, Standards Norway

Appendix A Drilling rig equipment (from NORSOK Standard R-002)



1	Drawwork
2	Fastline wheel
3	Crown block
4	Deadline wheel
5	Travelling block
6	Drilling line (Wire)
7	Deadline anchor
8	Derrick drilling machine (DDM) (DDM may comprise several units – Main shaft, Swivel, Gearbox, Link hanger, Connection links, Pipe handler, Wash pipe etc.)
9	Derrick
10	Drill line drum
11	Slips
12	Rotary table
13	Heave compensator
14	Active heave compensator
15	Racker equipment
16	Tubular feeding machine (TFM)
17	Horisontal to vertical arm (HTV)
18	Elevator & elevator suspensions
19	Guide track and dolly

Appendix B Summary of incident causes

Equipment		Direct causes						Indirect causes							Consequence		
	Incident	**H1**	**H2**	**H3**	**H4**	**T1**	**T2**	**O1**	**O2**	**O3**	**O4**	**O5**	**O6**	**O7**	**R**	**Y**	**G**
Main drive	G+R	2	4				1	2		4	3			1	1	1	3
	W		5		1	2	2	1	1	5	5			4	1	5	2
	B+O				1	1	5		2	1	2	3	1	1	2	3	2
TD+DW+DDM	L+H+X	3	5	2	2	2	5	2	5	4	2		3	5	5	6	2
	S+M	10	6	4	2	3	3	3	3	5	5	2	4	2	4	7	4
	FC	2	2			4	10	3	3	1	2	6	3	1	5	4	3
	SUM	**17**	**22**	**6**	**6**	**12**	**26**	**11**	**14**	**20**	**19**	**11**	**11**	**14**	**18**	**26**	**16**
	Incident	**H1**	**H2**	**H3**	**H4**	**T1**	**T2**	**O1**	**O2**	**O3**	**O4**	**O5**	**O6**	**O7**	**R**	**Y**	**G**
Compensators	G+R																
	W																
HC+CMC+MRT	B+O						1		1		1		1				1
	L+H+X																
	S+M	2	1		1				1	2	1			1		1	1
	FC	1	1			1	2		2	1		2			1	1	
	SUM	**3**	**2**	**0**	**1**	**1**	**3**	**0**	**4**	**3**	**2**	**2**	**1**	**1**	**1**	**2**	**2**
	Incident	**H1**	**H2**	**H3**	**H4**	**T1**	**T2**	**O1**	**O2**	**O3**	**O4**	**O5**	**O6**	**O7**	**R**	**Y**	**G**
BOP Crane	G+R		1			1			1				1		1		
	W	1	1			2			1		1		2		1	1	
	B+O						2				1	2	1		2		
	L+H+X	1	1				1			2	1	1			1		1
	S+M	2	1	1	2					3	1				1	2	
	FC	1	2		1	3	1	1		2	2	2	1		2	3	
	SUM	**5**	**6**	**1**	**3**	**6**	**4**	**1**	**2**	**7**	**6**	**5**	**5**	**0**	**8**	**6**	**1**

Equipment		Direct causes						Indirect causes							Consequence		
	Incident	**H1**	**H2**	**H3**	**H4**	**T1**	**T2**	**O1**	**O2**	**O3**	**O4**	**O5**	**O6**	**O7**	**R**	**Y**	**G**
Lift accessories	G+R	6	10	1	1	15	8	9	10	12	10	3	8	2	14	9	4
	W																
Elevator +	B+O				1		2				1	2				2	
Running tools	L+H+X	4	2			2	5	3	2	5	3	3		1	4	4	1
	S+M	5	2		1	2		5	1	3	3			1	2	5	1
	FC																
	SUM	**15**	**14**	**1**	**3**	**19**	**15**	**17**	**13**	**20**	**17**	**8**	**8**	**4**	**20**	**20**	**6**
	Incident	**H1**	**H2**	**H3**	**H4**	**T1**	**T2**	**O1**	**O2**	**O3**	**O4**	**O5**	**O6**	**O7**	**R**	**Y**	**G**
Pipe handling	G+R	1					3					2		1			3
	W																
VPH+Racker	B+O					1	4		1			4				1	3
equipment	L+H+X		2		1		2		1	3	1					2	1
	S+M		1	1		1		1	1	1	1		1	1		1	2
	FC						1					1				1	
	SUM	**1**	**3**	**1**	**1**	**2**	**10**	**1**	**3**	**4**	**2**	**7**	**1**	**2**	**0**	**5**	**9**
	Incident	**H1**	**H2**	**H3**	**H4**	**T1**	**T2**	**O1**	**O2**	**O3**	**O4**	**O5**	**O6**	**O7**	**R**	**Y**	**G**
Pipe feed	G+R	1	6			4			2	6	3		1		4	3	
	W			1		1	1			1				2			2
TFM+HTV+CW	B+O						1					1				1	
+Eagle	L+H+X	2	2	1	2	1	2	2	2	5	1		1		1	3	1
	S+M	4	1	1	1			3		2	2			4	1	3	1
	FC	1	1	1		2	3		3		2	3	1		2	2	1
	SUM	**8**	**10**	**4**	**3**	**8**	**7**	**5**	**7**	**14**	**8**	**4**	**3**	**6**	**8**	**12**	**5**

Equipment		Direct causes						Indirect causes							Consequence		
	Incident	H1	H2	H3	H4	T1	T2	O1	O2	O3	O4	O5	O6	O7	R	Y	G
Finger board +	G+R	1	3	1	1	1		2		3	2	1				1	4
Manipulating arm	W																
	B+O		1			2	3	1		1		3	2		2		2
	L+H+X																
F+MA	S+M	2		1						1				1		1	1
	FC		1				2	1	1			1				1	1
	SUM	**3**	**5**	**2**	**1**	**3**	**5**	**4**	**1**	**5**	**2**	**5**	**2**	**1**	**2**	**3**	**8**
	Incident	H1	H2	H3	H4	T1	T2	O1	O2	O3	O4	O5	O6	O7	R	Y	G
Tugger W	G+R																
	W	1		1	1	1				1	2				1	1	
	B+O						3			2		2			1	1	1
	L+H+X	1		1	2						3					3	
	S+M	5	5	1	1	5		3	2	9	5			2	2	6	1
	FC						1						1			1	
	SUM	**7**	**5**	**3**	**4**	**6**	**4**	**3**	**2**	**12**	**10**	**2**	**1**	**2**	**4**	**12**	**2**
	Incident	H1	H2	H3	H4	T1	T2	O1	O2	O3	O4	O5	O6	O7	R	Y	G
Cranes (other)	G+R	3	6		3	4		2	4	7	2		1	3	1	5	3
	W		3	2				1		3			1	2	1	1	
	B+O	1	1		2		2	2		2	2	1			1	3	
	L+H+X	2				4		2	2	1	2				1	3	
	S+M	11	4	2	4	4	2	6	1	6	7	1	2	3	3	12	2
	FC					1	1					2	1		1	1	
	SUM	**17**	**14**	**4**	**9**	**13**	**5**	**13**	**7**	**19**	**13**	**4**	**5**	**8**	**8**	**25**	**5**
	Incident	H1	H2	H3	H4	T1	T2	O1	O2	O3	O4	O5	O6	O7	R	Y	G
U (unspec,	G+R	4	2	1		2	2	4	3	1	2	1	2		1	2	3
other, slips)	W																
	B+O	1	1	1		4	3		1	3	2	3	1	1	1	4	1
	L+H+X		2	1		2			1	1	2		1		1	1	1
	S+M		2			1		1		1				1		1	1
	FC																
	SUM	**5**	**7**	**3**	**0**	**9**	**5**	**5**	**5**	**6**	**6**	**4**	**4**	**2**	**3**	**8**	**6**