MAJOR HAZARDS TO OFFSHORE PLATFORMS AND THE USE OF RISK ANALYSIS TO MINIMISE THEM

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1. INTRODUCTION

The winning of the gas and oil resources of the North Sea is a demanding and challenging activity requiring safe, proven and reliable equipment, if the costs in human terms are to remain within tolerable limits.

Nevertheless, as in all human activity accidents will occur, despite the best endeavors of all concerned. Such accidents may be of an every day kind, such as falling off ladders or being hit by objects dropped from above, or more serious, such as fires and explosions.

The purpose of this paper is to look at both these types of hazards. Firstly, to examine accidents and hazards that have occurred offshore in the past both of the everyday kind, and of the more severe kind involving major hazards, so as to pinpoint the areas of most risk to installation and to personnel. Second, to look at risk analysis methods currently in use in the North Sea to try to identify and to minimise major hazard risks at an early stage of design.

2. THE ACCIDENT RECORD

A reasonable historical record of accidents is publicly available for two areas of the world : the North Sea and the Gulf of Mexico. By examining the records for these two areas for each type of hazard, a picture can be built up of the relative significance of the risks.

Accidents can be classified in two different ways: either by the occurrence of types of accident, such as blowout, or by the distribution of fatalities amongst the accident types. Both classifications are considered here, and are discussed below.

2.1 Occurrence of Accident Types

The main types of major accident can be summarised as follows:

1) Fire and explosion

   a) topsides
   b) blowout
   c) risers

2) Toxic fumes

   a) topsides
   b) at sea level

3) Structural failures

   a) crane accidents
   b) ship collisions
   c) helicopter crashes
   d) design or repair defects
   e) excess environmental loading

4) Support function failures

   a) helicopter ditching
   b) diving accidents

These types are now discussed in more detail, at least for those ones where statistics are available.

2.1.1 Fires and Explosions Topsides

Table 1 shows an analysis of reported fires and explosions in the UK sector, based on submissions to the UK Department of Energy from UK Sector operators.

The table demonstrates the major contribution to minor fires from maintenance activities. The contribution to major fires can be seen to be from the utilities, not from the main process : glycol reboiler, vent stack, oily water system and maintenance activities.

Table 2 shows a comparable analysis for the US Gulf of Mexico. It is probably not so representative as the UK Sector table, since the reporting is not very comprehensive. It does, however, point up the importance of fires and explosions arising from the utilities. It also demonstrates that blowouts are a major risk contributor for the type of platforms common to the Gulf.

A further look in Table 3 at the "all equipment related" incidents gives a more detailed breakdown of the cause of the incident: gas compressors emerge as a major contributor to minor fires, whilst incidents involving pumps caused few accidents, but they were the most severe.

2.1.2 Blowouts

Blowouts have been frequently identified as the most significant major hazard specific to offshore platforms. On what is this conclusion based?

The answer is, regrettably, on rather poor information about a rather large number of blowouts.

There have been reports of some 45-60 blowouts reported to the US geological survey in the period 1956-1979, depending on the source of data. Basic analysis of these results show the following distribution by severity:

TABLE 4 : BREAKDOWN OF USA BLOWOUTS BY SEVERITY (Gulf of Mexico)

Type of Operation	Total	Severe	Damage	Minor	None	Lost	Sum
Mobile	3	1	1	4	6	1	16
Other drilling	3	1	-	5	-	2	11
Production	3	-	1	8	1	-	13
Unknown	1	-	-	1	2	-	4
Sum	10	2	2	18	9	9	44

There is, however, little back up detail on the cause, nature and development of the incidents. The example in Table 5 of some blowouts in 1980 shows the extent of the information that is generally available from the USA..

These numbers are also probably underestimates. In an interview in Offshore Magazine in 1979. 'Red' Adair was quoted as saying that there have been 215 blowouts worldwide in the previous 5 years; he had worked on 42 in the previous year.

In the UK sector, the estimate of the known number of blowouts varies from 3 to 9, depending on the source quoted. In relation to the total number of wells drilled, this is roughly in line with the number of blowouts in the Gulf of Mexico, suggesting a similar blowout 'frequency'.

2.1.3 Riser Leaks, Fires and Explosions

Leakage from risers can lead to a severe incident, particularly in cases where the sea line is long and carries a large inventory of gas.

In the UK Sector, the environmental conditions have given severe problems, but in only one case has this been recorded as leading to a major fire/explosion (Platform Alpha, 1975).

In the US Gulf of Mexico, analysis of USGS records indicates approximately 90 cases of riser leakage, of which 5 were major leaks. In many of these cases, fracture was due to wave impact in poor weather conditions, after the platform had been evacuated. There is only one recorded incident of a riser leakage leading directly to major platform damage.

2.1.4 Structural impact accidents

Accidents from dropped crane loads and supply ship impacts are expected events from the point of view of platform operation. Certainly there are frequent reports of their occurrence, generally resulting in limited damage.

Of most consequence is the potential for impact by passing vessels. So far no such accidents have been reported in the UK Sector, although some four incidents have been reported in the US, most notably that of the Txaco North Dakota. The figure below illustrates the position of the tanker after impact.

In the UK Sector, the hazards of such potential collision depend to a large extent on the location of the platform. Platforms near routes of high traffic intensity will be most exposed to risk, whilst those in areas of little traffic can expect a very low level of risk. A recent near miss occurred when the coastal tanker 'Wadhurst'was off course and narrowly missed the Rough platform, whilst travelling on one of the high traffic routes down the UK East coast.

2.2 Causes of Fatalities

Apart from the risk of a major incident occurring, a picture of the particular hazards involved can be gleaned from looking at the fatality record in the North Sea. Clearly this will reflect much more the common incidents than the major rare events, but the picture is nevertheless illustrative.

Tables 6 and 7 show the record of fatalities in the North Sea UK and Norwegian sectors respectively.

The tables highlight the fact that, apart from drilling operations, the dangers come primarily from cranes, diving, construction and helicopter operations : all operations concerned with the support of oil and gas production, rather than from the hazards of the process itself.

Since 1977, the picture has, of course, changed considerably with the loss of the Alexander Kielland, a loss which brings up a feature not yet brought out clearly: the additional hazards arising from mobile platforms.

2.3 Mobile Platforms

In the period 1955 to 1981, there were 47 total losses of mobile platforms. Additionally there were 45 major accidents causing damage over $1 million, and 67 minor accidents.

The causes of these accidents are shown in Table 8.

From this table the picture emerges that there are two prime accident types : blowout, and storm induced failure. Together these two accounted for over 50% of all the total losses. Recent tragedies have borne out this conclusion, with the loss of the Alexander Kielland, the Ocean Ranger and the Ron Tappemayer.

These incidents highlight the additional risks on board floating platforms. This is evident from the following table showing the rate of loss of rigs and platforms, as a function of the number of years of operation, for the Gulf of Mexico.

Installation	Loss rate (loss per rig years of operation)
Jack up	1:100
Semi submersible	1:200
Fixed platforms	1:900

[Note, however, that this table relates primarily to the early years of operation in the Gulf of Mexico].

3. USE OF RISK ANALYSIS IN MINIMISING THE HAZARDS

The survey above of what has happened in the past begs the question "So how can we use this for improved safety of operation?" The answer lies in two places. Firstly, in taking note of the circumstances of each accident and applying the lessons learned; this process goes on all the time in modifying designs in the light of accident investigations. Second, to use this historical record systematically in the design of new platforms; to identify those hazards most likely to occur and to concentrate the available safety effect on them. This, taken together with methods for identifying hazards not evident from the part, is the basis of risk analysis.

The basic steps are shown in Figure 1. Since the overall procedure is, however, fairly well known, the only step discussed here is the final one: that of using the results of feedback into the design, both in the concept design stage and at the detailed design stage.

3.1 Conceptual Design

The aim of this type of analysis is, by taking a 'broad brush' approach, to identify those areas of the operation that may have signficant hazardous effect, in terms of loss of life, and to rank these risks in terms of impact (quantified on the basis of probability of occurrence and consequential effects) on an order of magnitude basis.

The result of such a systematic identification of potential major hazards are fed back into the design process in four ways:

1) Appearance of major hazards may necessitate a change of concept in order to reduce their probability/consequence.

2) Ranking of the hazards, allowing emphasis to be concentrated on the most important hazards only.

3) During the identification and review of potential hazards, a number of important measures will be discussed for ensuring that, in the detailed engineering stage, the probability/consequences of major hazardous events are minimised.

4) Where alternative concepts are being considered, a comparison of the major hazard implications of each concept are an important element in the overall comparison.

It is clearly most important that a study of this type be done at the conceptual stage, so that the results can be fed into the design and/or operational procedures whilst there is still a large degree of flexibility about options in design that can be swayed by such safety considerations.

The main areas of feedback, those on major points of concept and hazard ranking, are discussed below.

3.1.1 Major Points of Concept

The feedback to the design process on major points of concept arises when the significance analysis of the hazardous events points out certain events as being of much greater importance than either the remaining events or similar events in comparable installations. The discussion of such events with the design team is likely to lead to changes of the concept in one of the following two areas:

i) Increased safety through layout.
ii) Increased safety through design.

Layout Depending on the type of event highlighted, the discussion of layout alterations may be at installation level, such as a gross recommendation to alter the location of the whole installation due to hazards from ship collision; at function level, to further separate areas such as drilling and process, or at equipment level, to alter the layout within, say, a particular module.

Design As far as possible, the aim of the study is to point out where greater safety needs to be built into the design. In many cases, a hazard is pointed out as being of greater significance in its present context than in the situations where it is more commonly encountered. Offshore, one of the most recurring examples of this is the hazard of direct impingement of jet fires on close neighbouring vessels. This hazard stands out more offshore, because of the lack of space dictates that reduction of fire hazards be achieved more by fire water deluge systems than by separation. Such deluge systems are unlikely to be very effective against direct jet flame impingement. The detailed identification and quantification reveals that, in order to reach the same level of safety as in the situation for which the item or system was first designed, an increased level of design safety is required.

In the case of the philosophies, such as for E.S.D. operations, gas detection, or process control, a detailed check at this stage, with perhaps some modifications resulting, will have ramifications the whole way through detailed engineering. In the case of design codes, the demonstration of a need to apply perhaps more stringent codes to certain items or systems, whilst still at the concept stage will save much time delay than if the matter is discoverd later in the project, and lead to a grater level of design safety. An example of such a case would be where pressure vessel codes need to be applied to particular sections/units of pipeline, in preference to the sometimes less stringent pipeline codes.

3.1.2 Ranking of Hazards

One of the most fruitful areas of feedback is the ability to give the designer an order of priority for minimising the hazards. Such a ranking saves considerable effort that may otherwise be expended in say, improving the performance of a safety system that is anyway extremely unlikely to be used, and allow the designer to focus on the likely cause of a particular hazard. The case of the hazards posed by a sea level fire is a good illustration of this.

3.2 Detailed Design

In this stage of design the main function of risk analysis is to look at ways in which the safety systems to be installed might fail, based on an analysis of the type of incident to be expected.

The outcomes of such analyses are many, but the following give a feeling for the kind of changes that may emerge:

a) Rerouting of pipes, cables, or communication links to minimise interruption during an incident.

b) Increasing the redundancy of critical items.

c) Modifying the design so as to give the simplest and most efficient maintenance.

d) Specifying performance critria to manufacturers for particular items.

e) Demonstrating the tasks most vulnerable to human error.

Current examples of its application are:

- in layout of cabling to and from a control room
- in the design of the ballasting system for a semisubmersible -
- in the layout of the flare header system, and
- in the design and laying of anchors and anchor chains from semi-submersibles.

4. CONCLUSIONS

The analysis of past incidents is a useful tool in guiding the safety of new platform design, particularly when combined with a systematic approach to ranking of all the hazards affecting a platform's integrity.

TABLE 1

ANALYSIS OF FIRS 6 EXPLOSIONS - NORTH SEA UK SECTOR 1975-1980

System	Minor		Moderate		Total
	Fires	Explosions	Fires	Explosions	
PRODUCTION					
Glycol reboiler	3	1	3		7
Compressor system	3	1			4
Gas turbine	5				5
Flare system	1				1
Vent stack			2		2
Control communications module	1				1
Filter box	1				1
Diesel day tank	1				1
Suction scrubber		1			1
Flowline drain valve	1				1
Pumps	1				1
Condensate flash exchanger	1				1
Oily water exchange separator	1		1		2
Chlorination cell assembly		1			1
Production separator	1				1
Containerised diesel oil machine	1				1
Miscellaneous	2				2
Assorted maintenance activities	18		1		19
Domestic area	8		1		9
	49	4	8	0	61
DRILLING					
Flopetrol tank				1	1
Shipping pumps mechanical seal drain	1				1
Mud room	1				1
CST gun	1				1
Chemical store	1				1
Diesel engines	1				1
Diesel generator module	1				1
Miscellaneous maintenance	2				2
Domestic	9				9
	17		1	1	18
CONSTRUCTION					
MISCELLANEOUS	17		4		21

TABLE 2

Number of fire and explosion incidents in the Gulf of Mexico 1956-1979

INITIAL EVENT	F I R E S A N D E X L O S I O N S						% pf 326 incidents
	CLASS OF DAMAGE						
	Platform loss	Major to platform	Major (local)	Minor	Minimal	Total	
Tanks leaks, intentional releases and venting	-	1	5	14	25	45	14
Electrical	-	-	2	3	3	8	2
Piping risers and valves - leaks and ruptures	-	1	9	25	33	68	21
Spills	-	1	-	4	3	8	2
All equipment related	1	1	5	61	65	133	41
Human error and non-hydrocarbon	-	-	1	14	9	24	7
Kicks and blowouts	4	4	4	2	-	14	4
Collisions	1	1	1	-	-	3	<1
Overload of lifting devices	-	1	-	-	-	1	<1
Unknown, not reported	3	3	6	5	5	22	7
TOTAL	9	13	33	128	143	326	100

TABLE 3

Number of fire and explosion incidents related to equipment (Gulf of Mexico)

Initial Event Equipment Type	Class of damage					
	Platform Loss	Major to Platform	Major (local)	Minor	Minimal	Total
Engines	-	-	-	4	8	12
Glycol Equipment	-	-	-	10	7	17
Generators/turbine generators	-	-	2	6	3	11
Gas Compressors	-	-	-	16	27	43
Line Heaters	-	-	1	2	2	5
Pumps and specified pump drivers	1	1	-	4	10	16
Other equipment	-	-	2	19	8	29

TABLE 4

ACCIDENTS TO MOBILE RIGS 1955-1981

Incident	Total losses	Major accidents ($1 million)	Minor accidents
Blowout, fire	14	9	10
Collision	0	2	26
Storm induced	12	8	19
Jacking mode	1	3	3
Moving	9	15	3
Preparing to move	3	0	1
Drilling	3	5	0
Unknown	4	3	5
	47	45	67

TABLE 5

Accidents connected with federal oil and gas operations in the outer continental shelf Gulf of Mexico.

BLOWOUTS

Area and block lease & Well No. Operator	Date and duration	Type accident, related depth	How controlled	Volume oil spilled (BBLS.)	Injuries, Fatalities, damage to property or environment
1. South Marsh Island BLK 281 OCS-G 2600 Placid	03-05-79 Fire-25 Hrs/BO-6 weeks	Blowout, Gas; Fire B/E/	Leaking valve allowed well to backflow		8 fatalities Rig a total loss omitted from 79 report
2. Galveston BLK 144 Plat A OCS-G 3374 Occidental	02-25-80	Blowout, Gas; master valve could not be closed	Well killed by pumping through wing-valve		
3. Ship shoal BLK 246 Plat B OCS-G 1027 CNG	03-24-80 1 day	Blowout, two master and one subsurface valves would not close	Pumping through wing-valve		Gas leakage through needle valve was reported blowing straight up 20' high
4. High Island BLK A-368 Plat A OCS-G 2433 Pennzoil Well No. A-3	03-24-80	Blowout, explosion, fire caused by shallow gas B/E/			6 fatalities 29 injuries extensive damage

B/ see also explosions and fires Table B
C/ see also pipeline leaks or breaks Table C
D/ see also significant pollution incidents Table D
E/ see also major accidents Table E

TABLE 6

	Pre-68	68	69	70	71	72	73	74	75	76	77	Σ
Construction	14*								2	4		20
Drilling		2			2	2		5	2	2	2	17
Production												
Maintenance			1			1				1	2	7
Diving	1				1	1	1	3	3+	6	2	18
Helicopters										1		1
Boats		5	1				1	3	1	1	1	13
Cranes	1	1	1	1			1	1	2	2	2	12
Domestic												

TABLE 7

Fatalities by location and activity on the Norwegian Continental Shelf
(Petroleum activity)

Location / Activity	Fixed platform	Mobile platform	Supply ships	Crane vessels/ barges	Pipe-laying vessels	Helicopters	Others	Total
Maintenance/ testing		2						2
Construction	10			1				11
Drilling		3						3
Production process								
Diving		5		1	1		1	8
Crane operations	4							4
Anchor handling			1					1
Transport to/from/ between locations			1		1	34		36
Emergency evacuation	3	6						9
Others	1		1	3	1		2	8
TOTAL	18	16	3	5	3	34	3	82