Position incidents during offshore loading with shuttle tankers on the Norwegian Continental shelf 2000-2011

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ABSTRACT

Since year 2000 there have been two collisions between shuttle tankers and facilities on the Norwegian continental shelf. In addition, there have been four near collision events and seven incidents related to loss of position, with varying degree of severity. The 13 cases will be briefly described. The paper will provide a review of the most common causes of the events.
The high number of incidents has caused several initiatives in the industry to get improvements. We will discuss the results from research activities, industry groups, and how PSA regulate the activity.

KEY WORDS:

Collisions; shuttle tankers; offloading; procedures; competence; software.

INTRODUCTION

This article

The paper is divided into four sections. The first section gives an overview of the present regulations and guidelines. The second provides a statistical overview of the collisions. The third section is a review of the events which from the authors point of view, is the most onerous since year 2000. The last section will discuss the needs for improvement.

Publications on collisions data

Data on shuttle tanker collisions on the Norwegian Continental shelf have previously been reported by Kvitrud (1994 and 2011) and PSA (2011). Several collisions on the UK continental shelf are reported by HSE (2001) including incidents up to October 2001. Since then, the shuttle tanker Loch Rannoch (130,031 dwt built 1998) had a collision with the Schiehallion FPSO in 2009 (Bevington, 2009).

Offshore loading systems in Norway

The following offshore loading systems are used or have been used in Norway:
* Tandem loading from FPSOs (Floating, Production, Storage and Offloading platforms) are used at the Balder, Jotun, Alvheim, Norne, Petrojarl 1, Petrojarl Varg and Åsgard A, and are planed from Skarv, Knarr and Goliat. Loading from FSUs (Floating, Storage, Unit platforms) are used at Åsgard C, Njord B and Navion Saga (at Volve).
* Loading from buoys as ALP (Articulated Loading Platform) or SPM (Single Point Mooring) were done from Statfjord C SPM from 1984 to about 2003, Statfjord A ALP from 1977 to about 1986, Statfjord B SPM from 1982 to about 1990, are done from Gullfaks SPM 1 from 1986 and Gullfaks SPM 2 from 1987.
* Draugen FLP (Floating Loading Platform) has been in use since 1993, but will be replaced in 2012.
* The UKOLS (Ugland-Kongsberg Offshore Loading System) at Statfjord OLS A has been in use since 1987 and Statfjord OLS B from 1990. Similar systems will be taken into service in 2012 at Draugen and Yme.
* STL (Submerged Turret Loading) or STP (Submerged Turret Production) are used several places. At Heidrun two buoys were installed in 1995. In addition the system is used at Åsgard C, Navion Saga at the Volve field, Alvheim and Njord B. The Single loading system (SLS) is to be used at the Yme field from 2012.
Most of the maritime activities related to offloading activities are monitored from the traffic control centre at Sandsli (Statoil).

REGULATIONS AND GUIDELINES ON SHUTTLE TANKERS

Regulations

Our first regulations to prevent collisions and avoid position incidents on shuttle tankers came in 2004, and were modified 1.1.2010.
PSA regulations apply to health, environment and safety in the petroleum activities. The Petroleum Activities Act section 2 defines the shuttle tankers role in the petroleum activity as:
* Petroleum activity = "…*but not including transport of petroleum in bulk by ship*".
* Facility = "... *but not ships that transport petroleum in bulk*".
* Production = "…*and shipment of petroleum for transport by ships*".

Consequently, our regulations only apply for the shuttle tankers during the loading at the field i.e. when the shuttle tanker is inside the safety zone. However, our technical regulations do not apply for the shuttle tanker.

The activity regulation (PSA et al, 2010) section 90 gives requirements on positioning: "*When carrying out maritime operations, the responsible party shall implement necessary measures so that those who participate in the operations, are not injured, and so that the probability of hazard and accident situations is reduced. Requirements shall be set for maintaining the position of vessels and facilities when conducting such operations, and criteria shall be set for start-up and interruption,…*"

Changes in our guidelines

In the 2010 edition of our guidelines to the activity regulation section 90, a set of changes and clarifications were introduced based on recent years of experience.

DP classes

Clarifications of the recommendations on equipment classes to different loading systems, were done in 2010. As an example, direct loading from fixed production platforms has been proposed, and clarifications have been necessary. The changes also limited some creative unsafe solutions.

In order to fulfil the requirements to maritime operations a set on equipment classes should be used for the shuttle tankers. The shuttle tankers should have an equipment class with reference to IMO/MSC (1994) circ. 645 guidelines as:

* Shuttle tanker loading from facilities handling hydrocarbons: DP class 2.

* Shuttle tanker loading from subsea loading and off-loading installations where the shuttle tanker is not moored or anchored to these installations: DP class 2.

* Shuttle tanker loading from subsea loading and off-loading installations where the shuttle tanker is moored or anchored to these installations DP class 1 or DP class 2. Class 1 if the distance between associated facility and shuttle tanker is 2.5 km or more, otherwise class 2.

* Loading operations from buoys: DP class 1.

Some systems, as the OLS system, had previously a recommendation of DP class 1. If the DP screen became "black", the DP operator could not know where the ship was in relation to the 0-point. The result can be hose damage and oil spill. As a consequence, DP class 2 is now the recommendation for loading from the OLS systems.

The FPSOs, FSUs and shuttle tankers cooperation

We recommend in the guidance to the activity regulation section 90:
* "*In order to maintain the position, floating production, storage and offloading facilities (FPSOs) and floating storage units (FSUs) that offload to shuttle tankers, should be equipped with directional control*." In this context it is important to note that we do not require a DP system.
* "*Floating vessel-shaped production and storage facilities should at all times know their own position and direction and the position and direction of nearby facilities and larger vessels".* The text is made to secure that the shuttle tanker positions and movements can be supervised, and get alarms or monitor presentation if the shuttle tanker position is out of control. The information about the position and movements should be given simultaneously to the crew on the shuttle tanker as well as on the FPSO or FSU.
* "*In loading operations where no hawser is being used, the shuttle tanker should be able to stop the loading automatically if the limits for distance or direction are exceeded, at the same time as emergency shutdown valves are being closed on the facility and on the vessel".* The reason for the text is solutions without use of hawser. The state of art for loading operations has been at a given tension in the hawser, to automatically stop loading and close the valves. The new text has been included, to get the same safety level independent of solutions.

The collision loads on FPSOs and FSUs

For the design of structures exposed to shuttle tanker collisions the facility regulation (PSA et al, 2010) section 11 on loads, load effects and resistance applies: "*The loads that can affect facilities or parts of facilities, shall be determined. Accidental loads and natural loads with an annual probability greater than or equal to* $1x10^{-4}$*, shall not result in loss of a main safety function*". Five main safety functions are described in Section 7, and one of them is "maintaining the capacity of load-bearing structures until the facility has been evacuated*".*

FPSOs and FSUs that follow the framework regulation section 3, shall comply with the regulations of the Norwegian Maritime Directorate, together with supplementary classification rules issued by Det Norske Veritas. In these cases a requirement to kinetic energy to be considered is normally not to be less than 14MJ. But in addition, the management regulation section 6 requires that the "*operator shall set acceptance criteria for major accident risk and environmental risk*". A 14 MJ collision was stipulated for a recent FPSO design, but according to our view it was not in compliance with our regulations. A value in the order of magnitude of 50-100MJ is in many cases more correct.

The shape of the stern of FPSOs and FSUs

OLF (2004) recommended: "*A slender stern may reduce collision damage and reduce the potential for collision*." The OLF updated report in 2008, states: *"Resent experience with the Njord B has confirmed the importance of a rounded stern and minimizing equipment located there."* Analysis on the Knarr FPSO demonstrate that the shape of the bow of the FPSO or FSU can have a significant impact on how much of the shuttle tankers collision energies have to be absorbed by the FPSO or FSU (Pettersen, 2010). If the hitting point on the FPSO or FSU is roughly within the centre 1/3 of the aft, the reduction of energy is minor, but if the hit point is on the outer 1/3 on both sides the collision energy is reduced significantly.

The NORSOK N-001 will in 2012 get a new text in chapter 7.10: "*due consideration shall be paid with regards to the shape of the stern of FPSOs/FSOs to minimize consequences in case of collision between FPSOs/FSOs and shuttle tankers during tandem offloading. A rounded or partly rounded stern shape is recommended*."

The safety for other ship activities

A change in the Activities Regulations § 30 (Safety clearance activities) is planned from 2013: "*When the tandem transfer of hydrocarbons from a FPSO or FSU to the shuttle tanker is in progress, there should be no other ship activities to or from the FPSO or FSU*". This text is expected to reduce the risk for the personnel on the ships if a collision or a near shuttle tanker collision event, occur.

A STATISTICAL OVERVIEW

Up to 2000, a large number of incidents and collisions occurred. Major research activities were performed, giving recommendations to prevent accidents. Many of the recommendations were implemented. The following five years (2001-2005) only one position incident was reported to us. We then got a new collision in 2006 followed by several incidents every year since (figure 1). To a large extent, the improvements made in 2000 have vanished. A similar pattern can be seen on all reported incidents from offshore shuttle tankers (figure 2), with a peak in 2008. In 2007 we also had a major oil spill at Statfjord A with 4.400 m^3 of oil (Leonhardsen et al, 2008).

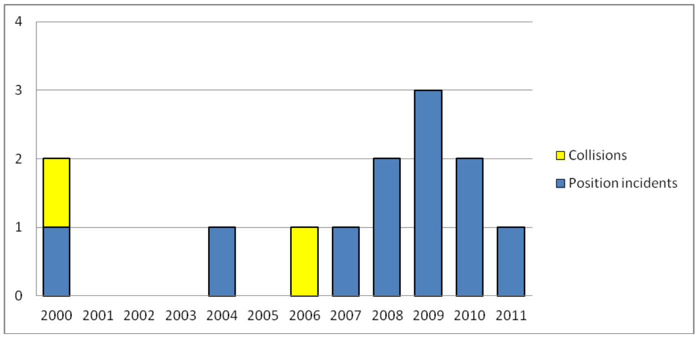

Figure 1: Collisions and position incidents reported in the period 2000-2011 from offshore shuttle tankers.

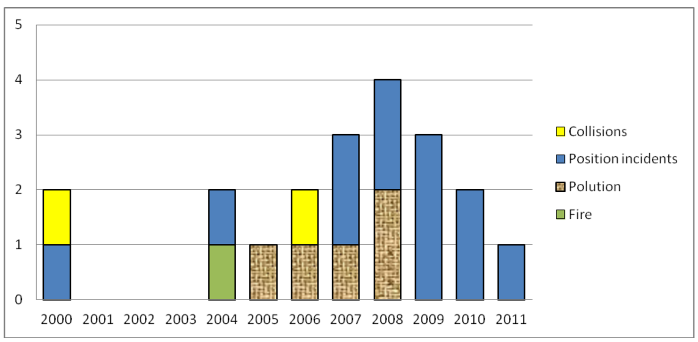

Figure 2: Reported number of collisions, position incidents, fires and pollution cases in the period 2000-2011 from offshore shuttle tankers.

The sizes of the colliding tankers since 1986 have varied between 154,000 dwt and 124,472 dwt. The tankers colliding had an average of 131,000 dwt. The tankers with reported incidents in the period 2000 to 2011 have about the same size, with an average of 130,500 dwt. The reason for the small differences in sizes goes back to when Statoil was the main user of offloading systems. Most tankers were designed according to the following requirements:

* 850 000 barrels as the "normal" load size, accepted by all buyers of the oil.

* The ships should be able to unload in Milford Haven in United Kingdom. They have a length limit of 265m, causing "all" vessels to be just below 265 m. All the named shuttle tankers in the article had DNV class.

The average age of the shuttle tanker when then collided was 3.5 years. The average age of the shuttle tankers near to collide was 9.7 years, and the average age of the shuttle tanker with position related incidents was 10.7 years. It is not possible to draw to firm conclusions since there are only two collisions, but it might be that new shuttle tankers are more exposed than the older, caused by new equipment not sufficiently tested and new teams. This conclusion can also be supported by the UK collision by Loch Rannoch in 2009. Even if the shuttle tanker was 11 years old, the collision occurred because of failures during commissioning of a new positioning reference system (Robertson, 2009).

Table 1: The years of build, when the incidents occurred, and the sizes of the shuttle tankers involved.

Shuttle tanker	**Built**	**Incidents**	**Size (dwt)**
Vigdis Knutsen	1993	2004	123423
Navion Norvegia	1995	2010	130596
Elisabeth Knutsen	1997	2009	124768
Stena Alexita	1998	2009	126955
Navion Hispania	1999	2006	126183
Sallie Knutsen (previously Knock Sallie)	1999	2000 and 2008	153617
Navion Anglia	1999	2008, 2009, 2010 and 2011	126749
Stena Sirita	1999	2000	124472
Stena Natalita	2001	2007	108073

THE COLLISIONS

All of the incidents the last decade have been subject to investigations by the vessel owner, the platform owner or the operator. The scope of investigation varied, dependent of the severity of the case.

There have been four collisions on the Norwegian Continental shelf before 2000: 23th January 1986 the tanker Polyviking (130,700 dwt) collided with Statfjord C loading buoy, June 9th 1986 the Polytraveller (125,690 dwt) collided with Statfjord-B-SPM, October 10th 1991 the Sarita (124,472 dwt) collided with the Gullfaks SPM 1 - buoy, January 17th 1992 the Evita (126,352 dwt) collided with Statfjord C-SPM buoy. For details confer Kvitrud (1994). The two collision accidents since 2000 are at March 5th 2000 Knock Sallie (154,000 dwt) collided with Norne FPSOs and Navion Hispania (126,183 dwt) collision with Njord B FSU November 13th 2006.

Knock Sallie collision with Norne FPSO in 2000

At March 5th 2000 the shuttle tanker Knock Sallie lost position after loading crude oil from Norne, and hit Norne on the starboard side aft. The accident occurred when Knock Sallie was disconnecting from Norne. The weather conditions were good with significant wave height of 2.9m. The collision energy was 31 MJ (Chen and Moan, 2005).

The investigation report (Statoil, 2000) highlighted the main causes as errors in the DP system or erroneous operation of the DP system, and late response from the crew. Even if there were several indications of errors, the manual control was not used before 58 seconds after the drive off had started. The shuttle tanker than had a velocity of 0.7 m/s, reduced to 0.6 m/s at the time of collision. The report also state: * The manning on the bridge was not according to procedure. * Training of personnel not performed according to procedures. * Lack of knowledge of the DP-system. * The data logger did not give the required alarms. * The testing of the system was too much on individual components and not the system. * Logic or programming errors in the DP system. * Unnecessary “position drop out” tests. * Erroneous calculation of the environmental loading in the DP system.

Navion Hispania collision with Njord B FSU in 2006

The accident happened when the shuttle tanker Navion Hispania got black-out when connecting to Njord Bravo. As a result, most propellers stopped. System errors led to escalation. Navion Hispania tried to avoid a collision, but hit Njord Bravo at a speed of 1.2 m/s (Teekay, 2006). Navion Hispania was damaged in the bow, while Njord Bravo was damaged in the aft. The collision energy was about 61 MJ. Statoil had a loss of about 250 million kroner in the collision (Næss, 2011).

The investigation report (Teekay, 2006) highlighted a total of 24 immediate causes for the incident. Some of the main causes of the accident according to the report were: * Excessive contamination of the fuel system. * Clogged Filters. * Inadequate knowledge of the Dynamic Positioning system. * Erroneous feedback in the control systems for propellers. * Incorrect signal wiring * DP maintained in "Autopos" mode even after severe thruster failures. * During the blackout there was a cacophony of alarms on the bridge. * Inadequate training in the DP failure modes. * Lack of compliance with procedures. * Error in procedures. * Inadequate maintenance. The conclusion related to the fuel quality has later been disputed (Næss, 2011).

NEAR COLLISION INCIDENTS

Near collision incidents have occurred in 2000, 2004, 2009 and 2010.

Stena Sirita at Jotun A FPSO in 2000

December 3rd 2000 Stena Sirita got problems with their DP system, near Jotun A. The minimum distance was 45m. Unfortunately, we do not have the investigation report in our archive.

Vigdis Knutsen at Njord B FSU in 2004

October 25th 2004 the dynamic positioning system on the shuttle tanker Vigdis Knutsen failed during the unloading at a distance of approximately 72m from Njord B. The weather conditions were good with Hs = 1.3 m. The DP operator wanted to change heading due to swell and current, and requested the FSU to change heading 10 degrees to port side in two steps. When the shuttle tanker changed heading, it increased speed ahead. ESD 1 was immediately activated and the DP operator was in standby for activating ESD 2. The DP system was activating high force in forward direction and the DP-operator therefore decided to change to manual DP-mode. The minimum distance between Vigdis Knutsen and Njord B was 26 meters (Teekay Norway, 2005).

The likely root cause (Teekay Norway, 2005) was the rapid change of headings, where the DP model was not stabilizing. This was in combination with non-optimal maximum thrust settings of the main propeller. The underlying causes according to Teekay were that they did not follow procedures on: * Prior to installation of any new equipment on shuttle tankers the shuttle tanker shall be supplied with all relevant installation and operation manuals. * After installation the supplier shall give operational instruction onboard and if necessary training courses.

Stena Alexita at Balder FPSO in 2009

The tanker stopped 75m from Balder, and the connection procedure was initiated at March 12th 2009. The Master then noticed a sudden increase in engine power and some surging. In addition, a "distance to DP-base too short" alarm and "drive-off" alarm were received. The Master decided to use manual control. He also, by mistake, selected "surge" & "yaw" (intention was sway & yaw) as DP controlled settings. As the shuttle tanker then started to move forward again, the Master found that the shuttle tanker was not responding to the joystick input as expected. The Master then switched to complete manual pitch control operation. Handles were placed in full astern, but there was no response on the starboard propeller pitch. Port propeller pitch worked as normal. The starboard propeller was then controlled by use of emergency pitch control. The distance to Balder was 34 meters before the shuttle tanker began to go astern.

The direct causes (Teekay and ExxonMobil, 2009) were: * Incorrect set-up (use) of equipment. * Incorrect use of equipment and incorrect settings when manoeuvring the shuttle tanker by joystick on DP. * Using defective tools. Handle had not been properly assembled or tested. Contributory causes were: * The person setting up the DP software for use was not aware that the default setting was set to "Transit" for this shuttle tanker. * The familiarization procedure with regards to DP equipment was not fully covering all aspects of DP-system set-up before loading. The root causes was inadequate procedures, lack of knowledge or inadequate leadership.

Navion Norvegia at Gullfaks SPM 2 in 2010

During loading at Gullfaks SPM 2 the shuttle tanker Navion Norvegia had to abort loading due to drive-off February 2nd 2010 (Teekay and Statoil, 2010). Due to erroneous Artemis position references, a restart of the reference systems was performed on location. Consequently the tanker moved against the loading buoy within seconds. The maximum speed was 0.5 m/s. Navion Norvegia reached a distance of 5m from the bow to the boom tip. The shuttle tanker performed ESD 1 and a controlled disconnection from the SPM 2. Some small damages to the loading hose were reported.

The immediate causes were (Teekay and Statoil, 2010): * An erroneous Artemis signal was activated as the position reference system. * The Artemis was wrongly configurated with 20 telegrams per second, while the DP system only read one telegram per second. Underlying causes were: * A drop out to re-align the reference systems, giving 10sec without any reference system available. * Lack of training. The shuttle tanker had only sporadically used Artemis due to the shuttle tankers operation pattern. * Did not follow the procedures with minimum two reference systems at any time.

INCIDENTS RELATED TO POSITION

To get a better understanding of the initiating events, we have review seven cases with position related incidents. There was also an incident at Jotun A FPSO related to the offloading. The messenger line (Ø25mm) came in to the thruster of the Jotun A FPSO during disconnection of the shuttle tanker. But we regard it as not directly relevant for the shuttle tanker. It is not described further below. We are uncertain if all the shuttle tanker incidents have been reported. The reported number of incidents is probably a lower bound value. Violation of reporting procedures have occurred. The malfunction and the degraded to DP Class 1, was initially not reported on one of the cases described below.

Stena Natalita at Jotun A FPSO in 2007

A DP incident occurred on Stena Natalita on August 5th 2007 during loading at Jotun FPSO (Teekay, 2007). When all position reference systems were lost, the DP officer took manually control. The shuttle tanker was kept steadily close to the ideal position (75m) from Jotun. To safeguard the situation ESD1 was activated. The shuttle tanker had not exceeded the ESD1 limit when activated. The loading operation was stopped for 30 minutes while the DP system was taken to Standby mode for rebuilding of the model and for the Position Reference System to be reset. After this all the systems were found working stable before the shuttle tanker was put back in DP mode. The loading operations were resumed.

The investigation (Teekay, 2007) concluded on the direct causes: * The loss of DP positioning reference systems was directly caused by incorrect Gyro heading. Further on the basic cause as: * Error on Gyro latitude and speed compensation caused faulty Gyro heading out put. * DP accepting incorrect Gyro Heading input. * GPS position failure (Navigation GPS). And root causes: * No barrier in the Gyro rejecting incorrect latitude and speed compensation. * The barrier in the DP for accepting deviation between calculated and measured heading was too wide. * GPS Position failure most likely caused by receiver interference.

Sallie Knutsen and Petrojarl 1 FPSO in 2008

During offloading to M / T "Sallie Knutsen" October 21th 2008, the hawser between Petrojarl 1 and "Sallie Knutsen" broke (Teekay Petrojarl, 2008). The wind increased suddenly and without warning from about 15 m/s to about 30 m/s. After a few minutes the wind speed decreased abruptly. The crane operator onboard Petrojarl 1 signalled that the hawser was broken. The ESD 1 button onboard Sally Knutsen was activated and the ESD 2 was activated soon after. The fracture surface of the hawser indicated a combination of mechanical damage and overload. The hawser may have been damaged before it broke. The significant wave height was about 3.5m.

The underlying causes (root causes) were identified as (Teekay Petrojarl, 2008): * Incomplete requirements for condition monitoring. * Inadequate control routine in the maintenance system. * Lack of expertise on visual inspection. * Lack of requirements for performance monitoring and recertification. • Inadequate updating of procedures. * Procedures were not updated. * Lack of consistency between documentation and reality. * The systems were likely under current standard. * Unclear guidelines for criticality. * The technical solutions were not fit for the operation. * Inadequate storage and procurement philosophy. * Several deviations from the governing documents.

Navion Anglia at Statfjord C in 2008

During loading November 29th 2008 from Statfjord C to Navion Anglia via the OLS-A, Navion Anglia lost the power on the starboard switch board and on the emergency switch board (Teekay and StatoilHydro, 2008). The dynamic positioning system lost update from the reference systems. An ESD 2 shut down was performed. The weather was good, with 10m/s wind and Hs of 2.8m.

The direct cause of the incident was not clearly identified (Teekay and StatoilHydro, 2008). Causes of the incidents were: * Low fuel system pressure leading to fuel starvation and variations in voltage and frequency supply. Restrictions in flow meters and fuel filters * Problems with the fuel quality can be a trigger, but the analysis did not confirm this. * The emergency generator failed to connect to the emergency switchboard due to faulty time delay. * Unstable power supply led to the DP system to lose all reference systems and gyros. * The ESD2 sequence could not be completed due to a stuck clutch.

Navion Anglia at Alvheim FPSO in 2009

Navion Anglia had only three of four engines running, when it arrived at Alvheim. A risk assessment concluded that Navion Anglia only needed three engines in operation to satisfy the DP2. During loading, an additional engine failed November 19th 2009. Navion Anglia still had all positioning systems operational. The loss of redundancy, reduced the classification from DP2 to DP1. The tanker was disconnected, and placed in a safe distance from the Alvheim FPSO (Marathon Petroleum, 2009).

After a restart at a safe distance from the FPSO, no faults were found. The test was performed for several hours. The tanker was hooked up again, and the engine stopped again. The same procedure was followed at a safe distance. The tanker sailed to shore in order to troubleshoot. The cause of the incidents was an earth fault on a sensor (Teekay, 2009).

Elisabeth Knutsen at Gullfaks A in 2009

During loading from SPM1 at Gullfaks A Elisabeth Knutsen got problems with the engine power November 13th 2009 (Statoil, 2009). A short circuit occurred, which tripped the secondary transformer breaker. The tripping triggered numbers of alarms. Fume emissions triggered the fire alarm indicating fire in the engine control room. Subsequent the loading was stopped by interrupting the telemetry signal. Three of four thrusters stopped; both stern thrusters and the forward bow thruster. The ESD I was activated and the bow loading system (BLS) sprinkler system was released. The shuttle tanker’s main engines were not affected by incident; hence they manoeuvred the shuttle tanker safely away from the loading buoy (Knutsen, 2009).

The causes of the incident were (Knutsen, 2009): * Short circuit and tripping of the port secondary transformer breaker. * Ballast vacuum pump was unintentionally in operation during de-ballasting. It was one of the consumers. * A thermo photography report in June 2007 found a hot spot on a circuit. The follow up and closing of observations was insufficient. The terminal block arrangement was not changed.

Navion Anglia at Statfjord A in 2010

On February 10th 2010 (Teekay, 2010) during the approach at Statfjord OLS A the shuttle tanker Navion Anglia experienced a pitch failure on the port main engine. When the pitch failure occurred, the shuttle tanker was connecting approximately 60m from the OLS A base. The shuttle tanker stayed in position during the DP events, with starboard main engine engaged. The shuttle tanker aborted the connection, laid the hose down according to normal procedures and retreated out in normal way.

The direct causes were (Teekay, 2010): * Machinery and equipment breakdown or failure * Equipment on electrical motor was worn out. The root causes were: * A faulty component. * Lack of maintenance inspection regime.

Navion Anglia at Åsgard A FPSO in 2011

During loading operation at Åsgard A February 12th 2011, Navion Anglia experienced a malfunction on a stepper motor causing the propeller to freeze in 10% pitch forward while the shuttle tanker position was controlled by DP (Teekay, 2011). It was not possible to operate, and normal condition could not be restored without further investigation. The controllable pitch propeller was deselected from DP and operated in emergency mode from the manual or main console on the bridge.

The direct cause (Teekay, 2011) was a machinery and equipment breakdown or failure. The root causes was inadequate design or inadequate scheduling of the inspection. Further there were violations of operational procedures.

INVESTIGATIONS OF COMMON CAUSES

Several investigations on common causes of collisions have been performed, and are briefly referred above. Our conclusions are given in the end.

Recommendations from Vinnem et al (2003)

Vinnem et al (2003) summarized the main conclusions from several research activities in Norway on shuttle tanker collision risk. The industry group recommended in brief:

Human and Organizational Factors
* The education and training program for DP operators should be kept current with the technology.
* The management systems on the shuttle tankers should be evaluated. All should have specific well-defined tasks and work as a team.
* Increase competence of FPSO personnel.
* The field specific emergency procedures should be better.
* The procedures should in more detail address the FPSO responsibilities.

Shuttle Tanker positioning system
* Reduce complexity of DP system Man-Machine Interface.
* Further development of 'Tandem loading' software.
* At least twin main propulsion systems and additional redundant thruster facilities. *But they don't specify how to combine this with "Reduce complexity"!*

Man-Machine Interface on Shuttle Tankers
* The status of thrusters should be observed together with other critical DP information as position references.
* Consider automatic thruster reversal when a minimum distance is reached.

FPSO features and interface with Shuttle Tanker
* Provide FPSOs with heading control.
* Increase thruster power on FPSOs.
* Provide FPSOs with surge control.
* Installation of visual pictures of both vessels on the FPSO.
These recommendations are too detailed to be included in our guidance, but several of them can obviously be included in industry standards.

Conclusions from Chen and Moan (2005)

Chen and Moan (2005) discuss how to reduce the crew's reaction time, and also discuss an increase in the separation distance between the FPSO and the shuttle tanker. The disadvantage of increased separation distance might be an increased collision velocity in case of a drive off. A large separation distance combined with an additional requirement of not having the direction of the shuttle tanker against the FPSO, will be tested at the Goliat field.

Conclusions from OLF (2008)

A team from the OLFs FPSO workgroup conducted interviews with shuttle tanker operators. Their safety relevant observations were:
1. There is a general concern about the availability and competence of maritime staff on board FPSOs.
2. There is a strong demand from shuttle tanker operators for a standard set of basic offloading procedures or guidelines.
3. There needs to be better oversight of the interfaces between offloading vessels and FPSO/FSOs.
To point 2, it is not PSAs role to regulate the activities in detail. However, we support this recommendation. The parties involved have to take the responsibility to reduce the risk related to the shuttle tankers. To point 2, the new PSA guidance from 2010 do to a large extent included this.

Conclusions from Kvitrud (2011)

Kvitrud (2011) investigated the most onerous collisions with visiting vessels, mainly supply vessels, on the Norwegian Continental shelf, and found the following causes as the most important:
a) The safety culture in the vessel industry is not good enough – procedures are not followed.
b) The vessels get more sophisticated technical equipment on the bridge, not all crew on the bridge are adequately trained to use it. The crew has too much confidence in the DP systems, and when errors occur the bridge crew are not sufficiently attentive to correct errors in time. The NWEA guidelines call for two persons on the bridge, but the authority levels on the bridge cause problems.
c) Equipment is not sufficiently adjusted to the needs of the users, and has inadequate barriers. A tendency is that the bridge equipment becomes more and more complex, and more difficult to use correctly.
d) The platform owners do not monitor the ships entering the safety zone sufficiently.

OUR INVESTIGATIONS

The accident and incident investigations have been performed by different personnel from investigations to investigation. This has several disadvantages and some advantages. The investigators have been mainly from the owners and managers of the shuttle tanker, but in several cases the oilfield operators have participated or done their own investigation.

An obvious question is why don't all the incidents end up in a collision? And are some of the root causes less severe than others?

We have grouped the causes as described in the investigations into categories and counted the number of causes in the tree groups – the collisions, the near collisions and the position incidents.

For the collision accidents lack of knowledge or training and software errors occur in both cases. For the near collision incidents software errors have occurred in all three cases. Lacks of knowledge or training together with not following procedures are found to be the causes for two of the three incidents. For the position incidents, equipment errors are dominating and are a part of the incident in six out of seven cases. Software errors and lack of maintenance is found for two of the incidents.

To get collisions or near collisions, the most common causes have been errors in the software in combination with unskilled personnel. Equipment errors or lack of maintenance can cause a problems, but normally not collisions.

PSA CONCLUSIONS

The parties in the industry are responsible for the safety of their own vessels and platforms. The Norwegian regulatory philosophy is based on the legislated expectation that those who conduct petroleum activities are responsible for complying with the requirements of the acts and regulations. Furthermore, the regulations require a management system that systematically ensures compliance at any time.

PSA give functional requirements in our regulations. It has further been necessary to give some additional recommendations.

PSA have for several years had meetings with the responsible for collisions and severe incidents. We produce annual updates on the statistics of collision events. In 2010 and 2011 several presentations have given by PSA requesting improvements. In January 2011 a press release requesting improvements in the industry was issued. A request is made to the Norwegian standardization organization to review the requirements in NORSOK N-003, and a similar is sent to DNV to review their DNV-OS-A101. During our handling of applications for consents we have emphasized to the operators aspects related to collisions.

Our review of the shuttle tanker incidents, confirm that many of the causes found for collisions with smaller vessels are valid also for shuttle tankers, as well as the conclusions found by the parties and investigators. As we see it, a disadvantage in most of the investigations is that they are performed by the owners of the shuttle tankers only, and the operators' roles are not investigated. Further some tankers are involved in several incidents, but this fact is not discussed in the investigation reports.

The most common causes for the shuttle tanker accidents and incidents investigated, as described above are:
a) The procedures and instructions are not followed.
b) The crew on the bridge are not adequately trained to use technical equipment on the bridge in emergency situations. The crew has too much confidence in the systems, and when errors occur, the crew are not sufficiently attentive or trained to correct errors in time.
c) Several incident investigations are pinpointing malfunction of equipment, due to errors in design, insufficient quality of the testing or commissioning. In a special category are software errors being the most common cause of the severe cases.
d) Some reports highlight inadequate maintenance systems, but it has a minor influence. The severity of incidents seems to be inverse proportional to the age of the colliding shuttle tankers.

From our point of view, high attention should be given to have well designed and tested systems before a shuttle tanker is taken into service and in service to have a good safety culture, competence and training.

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