Proceedings of the Tenth (2000) International Offshore and Polar Engineering Conference
Seattle, USA, May 28-June 2, 2000

ISBN 1-880653-46-X (Set); ISBN 1-880653-47-8 (Vol. 1); ISSN 1098-6189 (Set)

Green Water on Norwegian Production Ships

Gerhard Ersdal and Arne Kvitrud
Norwegian Petroleum Directorate
Stavanger, Norway

ABSTRACT

Green water events have made local damage on Norwegian production ships in sea states significantly lower than the 100-year sea states. These incidents have occurred both in the bow area, amidships and aft. Both analyses and model testing demonstrate a significant amount of green water on the deck structures in the 100-year wave situations. There is no general agreement on how to calculate the waves entering the deck of the ship, nor how well the wave height and the freeboard exceedance are correlated. The model tests show a large scatter when relating green water wave height and the corresponding freeboard exceedance.

Significant modifications have been made on the production ships, such as raised forecastle and installation of wave-breaking walls. Operational restrictions have also been introduced, including restrictions to personnel access in green water zones and storage limitations.

This paper describes the Norwegian requirements to air gap and green water. A description of the five production ships in Norway and the green water incidents are included. The status of the methods for evaluating the green water phenomenon as well as precautions taken to prevent further incidents, are also described.

INTRODUCTION

This paper presents some considerations related to green water on production ships as seen from the Norwegian Petroleum Directorate. The data and analyses presented in this paper is collected by the Norwegian Petroleum Directorate from the work performed by the operators of production ships Statoil, Saga (Hydro) and Esso.

Green water is defined as the solid water which is coming on the deck of a ship in large waves. Compared to white water, which is a mixture of air and water (foam or spray), green water refers to a more compact mass of water, often in the form of a water washing along and across the deck (Standing 1997).

There are at present five production ships on the Norwegian continental shelf. Four of these five ships have experienced damage due to green water on topside equipment according to reports from the operators of these ships.

Fixed installations like jackets and concrete gravity based structures have been designed with an generous air-gap. Topside equipment has thus been located with a large clearance to waves. On traditional tankers, however, green water has been accepted and equipment have been designed to withstand the green water loading. As the first ship-shaped installations were designed, the phenomenon of green water was partly ignored, partly underestimated in the design and layout of topside equipment. This is probably due to the traditions from previous topside deck design, and due to lack of communication between the ship designers and the topside designers. I.e. in model tests performed at early stages, the green water was not as such considered to be a significant problem. This is partly due to the fact that the model tests did not include the most critical sea states with respect to green water loading. These seastates are not equal to the sea states governing the mooring system design. Green water must, nevertheless, be regarded as a well-known phenomenon, due to the many years of experience with tankers.

New analyses and model testing have recently been performed for most of the production ships, and these analyses show that green water is a potential problem for all of them, including those two that have recently been installed. Different reasonable actions have been implemented to prevent green water damages. These actions can be divided into two main groups:

- Physical protection like raised forecastle, wave breaking walls or local reinforcement of equipment and structures,
- operational restrictions like reduced draft, change in static trim and restrictions with respect to personnel in green water zones.

NORWEGIAN REGULATORY REQUIREMENTS

In 1977 the Norwegian Petroleum Directorate's (NPD) regulations required an air gap. At present NPD have no requirements to air gap as such for any type of structures.

The present NPD requirements are restricted to actions and resistance and not to the occurrence of waves at various levels. The NPD regulations describe that loads in the ultimate limit state (ULS) and the serviceability limit state controls should be checked with an annual probability of 10^{-2}, and in the accidental limit state control (ALS) with an annual probability of 10^{-4}. These waves may hit the deck structure. In ULS they should not cause damage, the platform should be capable of full operation after an incident. The waves should not hit areas where people can be hurt. Imposing restrictions for personnel in certain areas can solve this last requirement. In the ALS the total safety of the platform should not be jeopardised, personnel should have the possibility to be safely evacuated, and no major pollution should occur.

It is important for the regulators to make rules that do not give technical benefits or disadvantages to specific concepts. The NPD regulations are to our best knowledge independent of concept and state requirements to the function of the installation in extreme weather conditions.

Waves hitting deck structures have been observed for different types of structures on the Norwegian Continental Shelf. Local damages have been experienced on jacket-, semi- and ship-type of structures. This paper only describes the efforts made which are related to green water on ship-type structures.

NORNE

The Norne ship has been on location in the Haltenbanken region (66°N 8°E) since 1997. A list of relevant data for the ship with regards to green water is given in table 1.

Green water incidents

The ship has experienced a couple of green water events during a few proceeding days (Eidissen, 1998). The event were especially severe on March 19th 1998, when green water was experienced on the main deck at the aft part of the ship at starboard side of the vessel, i.e. the leeward side. The crew reported that they had the impression that the waves were "turning around" on the leeward side hitting the area aft of amidships (Buchner and Wilde, 1998). Minor damages on fire equipment storage and a crane were registered. The ship was almost fully loaded. The freeboard was about 8 m. The minimum freeboard when fully loaded is 6.3 m.

The sea state at the time of the incidents (19.3.98) was approximately H_s=7.5 m and T_P=13 s. The waves were measured by wave radar. Current was not measured. The mean wave direction was 5-15 degrees with respect to the ship's heading.

Description of analyses and model tests

Prior to the incident, model tests were performed for the maximum significant wave height with related peak periods (16-18 sec). These periods were outside the area expected to be most critical with respect to green water (10-14 sec).

After the incident on the Norne ship, Statoil and MARIN performed independent calculations. The analyses are based on the same theory, but performed with different software and methods. The short-term wave statistics were based on a 100-year joint probability contour line (H_s and T_p) as shown in figure 3. Both analyses indicate freeboard exceedance both aft of amidships as well as for the bow.

Statoil (Vestbøstad 1999) calculated the loads and the hydrodynamics using the linear diffraction analysis program Wadam. The air gap calculated by TFPOP (Ude et. al. 1996) was used to calculate the transfer functions and the statistics of the relative position of the wave compared with the ship for the entire length of the ship. The analysis is believed to be most accurate at midship and less accurate at the bow and at the stern. Non-linearities in the incoming wave are accounted for in the Wadam model by the use of Stokes 2nd order theory.

MARIN (Eidissen, 17.2.1999) calculated the Norne ship using a linear theory 3-dimensional panel program (DIFFRAC) and the program GreenLab to account for non-linearities.

The two analyses showed the same trends, but a straightforward comparison is not possible, since MARIN used other wave situations and an other geometry than Statoil. Both analyses and model tests were performed at full draft (100% storage) in the 100 year wave condition using the Torsethaugen spectra (Torsethaugen, 1996) with H_s=11 m – 12.8 m and T_P=11 s – 13 s.

SINTEF Marintek in Norway performed model tests in October 1998 and March 1999. In the model tests approximately 4 m green water was measured on the poop deck, whereas on the Norne ship the freeboard is 9.8 m. This is not regarded as a problem for the Norne ship as the equipment in this area is not sensitive to green water. One special phenomenon arose in the model testing, however it was related to a situation were the simulation produced a group of large waves. Three waves succeeded each other, gradually increasing with the largest at the end. In the entire model testing, this test gave the largest amount of green water, even if the wave height was less than the 100-year condition.

The model test in March 1999 included a comparison between the existing bow structure and an increased bow height. The frequency of green water incidents in a 100 year storm was reduced from 20 per hour to 2.3 per hour with a 5 m increased bow height. The water pressures on the living quarter was also reduced (Eidissen, 12.05.99).

Statoil has concluded (Mosbergvik, 1999):

- a 100-year green water incident in the bow area on a fully loaded ship will have serious consequences for the living quarter and equipment and must be avoided by increasing the bow height by 5 m. This can be obtained by either decreasing loading capacity and retaining a static trim during winter season or by increasing the forecastle,
- a 100-year green water incident on the tank deck at midship on a fully loaded ship will lead to material damages halting production, but it is not regarded as a hazard to the safety of the ship and the safety of the personnel onboard.

Description of green water mitigation

Statoil has concluded (Mosbergvik, 1999) that a storage limitation (maximum 71% storage) and a static trim angle of 1° will be required during the winter season. This gives a draft at midship of 15.5 m and a freeboard of 9.5 m. The ship has an all year restriction on personnel on the tank deck and in the process area when $H_s > 6$ m (Eidissen, 20.11.98). Wave breaking walls between tank deck and process deck have been installed on the starboard and on the port side.

The limitation to the storing capacity and the static trim were effective from the winter 1998-99. In this period no green water events were observed. The restrictions to storage lead to loss of production and additional costs, as the off-loading cannot be performed in an optimal manner.

ÅSGARD A

The production ship at Åsgard A has been on location in the Haltenbanken region (65°N 7°E) since 1998. The ship is in general similar to the Norne ship, but the bow was increased by 4.7 m late in the project to account for green water. A list of relevant data for the ship with regards to green water is given in table 1.

Green water incidents

At February 13th and 14th in 1999 weather damage was observed (Bowitz, 1999). Statoil reported at February 13th at 24.00 hours that the significant wave height was 7 – 8 m, and wind speed was 31 m/s (10 min mean). Statoil has not reported the wave period. The Miros radar at Heidrun measured approximately 7 m significant wave height and a Tp of approximately 12 sec at this time (personal information from Knut Iden). The events occurred in a situation when the ship was high in the sea, with a midship freeboard of 10.1 m compared to the minimum freeboard of 6.6 m. The ship rolled 3-4 degrees and had a maximum heave at the helicopter deck of 19.5m. The wave direction compared with the direction of the ship was 5 to 15 degrees with respect to the port side of the ship's heading.

Damages on the following equipment were registered on Åsgard A (Bowitz, 1999):

- glass fibre boxes for fire equipment storage on tank deck (15 m from the ship side),
- steel cabinets for deluge stations on tank deck,
- 3" piping to fire hydrant,
- steel cabinet for VOC compressor,
- rails from tank deck to process deck,
- cable trays.

The incident occurred at tank deck at midship.

Description of analysis and model tests

MARIN performed the analysis using a linear theory 3-dimensional panel program (DIFFRAC) and the program GreenLab to account for non-linearities (Buchner and de Wilde, 1998). The short-term wave statistics were based on a 100-year joint probability contour line (H_s and T_p) as shown in figure 3. The analysis indicates freeboard exceedance both aft of amidships and at the bow. The analysis and model tests were performed at full draft (100% storage) in the 100 year wave condition using the Torsethaugen spectra (Torsethaugen, 1996) with H_s=11 m – 12.8 m and T_P=11 s – 13 s).

Model tests have not been performed for the Åsgard A ship, due to its similarities to the Norne ship. The results from the Norne model tests together with the MARIN calculations have been used for the evaluation of the Åsgard A ship.

The correlation between the analysis for Åsgard A and the model testing for Norne for freeboard and green water was good, but the calculated loads were higher than the model test results (Bowitz, 1999).

Statoil has concluded (Mosbergvik, 1999):

- a 100-year green water incident at the bow area on a fully loaded ship will not lead to damage on the living quarter or equipment,
- a 100-year green water incident on the tank deck at midship on a fully loaded ship will lead to large material damages halting production, but it is not regarded as a hazard to the safety of the ship nor the personnel onboard.

Description of green water mitigation

Statoil has decided (Mosbergvik, 1999) to install a wave breaker wall on starboard side on both the tank deck and on the process deck in order to reduce risk of damage to equipment. The stipulated weight of the wall will be 80 tons.

VARG B

The production ship at Varg has been on location in the North Sea (58°N 2°E) since 1998. A list of relevant data for the ship with regards to green water is given in table 1.

Green water incidents

Saga (Kverneland, 1999) reported wave damages to the Varg B ship during a period of harsh weather on February 5th and 6th 1999. The sea state in this period was reported to be 8 – 9 m significant wave height with 12 – 13 seconds peak period. The wave measurements are from Sleipner. The wave damage caused the loss of a life buoy, a fire equipment storage locker teared from the connections and minor damages to cable gates. All these items were located at midship. Due to the weather forecast, all personnel were removed from lower deck. "Sea spray" was observed in this situation.

The most critical event so far on the Norwegian sector, occurred at the Varg field the January 29th 2000. Hydro (Ljosland, 2000) reported damages to the Petrojarl Varg ship during a storm on fore ship, midship and aft ship. The significant wave height is estimated to about 12.5 m, and the peak period is estimated to 14.5 s at the time of the incident (personal information from Knut Iden). The available hindcast data for WINCH point (Latitude 57.99N, longitude 1.78E) close to the Varg field is shown in figure 1 together with the H_s-T_p design curves with the annual probability of exceedance of 10^{-1} and 10^{-2} for the Varg field. The estimated seastate is close to a 10 year situation. The incident occurred when the ship was close to fully loaded with a static trim of a little less than 1 degree.

The following damages was reported on fore ship:

- water ingress into a common room on deck 8 due to a broken window in the living quarter
- fire hose cabinet missing
- cabling and cabling gates where damaged
- walkway deformed

The following damages was reported in the living quarter:

- water ingress and ceiling fallen down in deck 9
- severe damage to inventory, ceiling, cablegates and electronic equipment at deck 8
- water in corridor at deck 7
- water in storage room on deck 6
- water on deck in traforoom on deck 4

The following damages was reported midship:

- safety equipment as fire hose cabinets, deluge cabinets, line gas sensors, life buoys and safety signboards missing or damaged.
- mechanical embarkment ladder found with minor structural damage
- cable gates twisted / damaged at several locations
- some protecting plates near walkways missing
- lightning fixtures twisted / damaged and waterfilled
- phone boxes damaged

The following damages was reported aft:

- liferaft missing
- rope ladder missing
- hand rail starboard side at flare tower damaged

Description of performed analysis and model tests

Model testing was performed in 1996. Measurements were made for wave crests at the bow and wave pressure at the living quarter in the front part of the ship (Sandberg, 1999). In 1999 an analysis of green water on the deck was done. A linear diffraction program was used. The freeboard exceedance was corrected based on the results from the JIP. The analysis gave a significant amount of green water on the deck structure in a 100 year wave situation. 8 – 9 m exceedance of the bow was experienced. According to the calculations the incidents should start with Tp at 8 – 9 seconds. At midship the freeboard could be exceeded by 4-5 m. The motion analysis fitted well to the movements observed from the model tests.

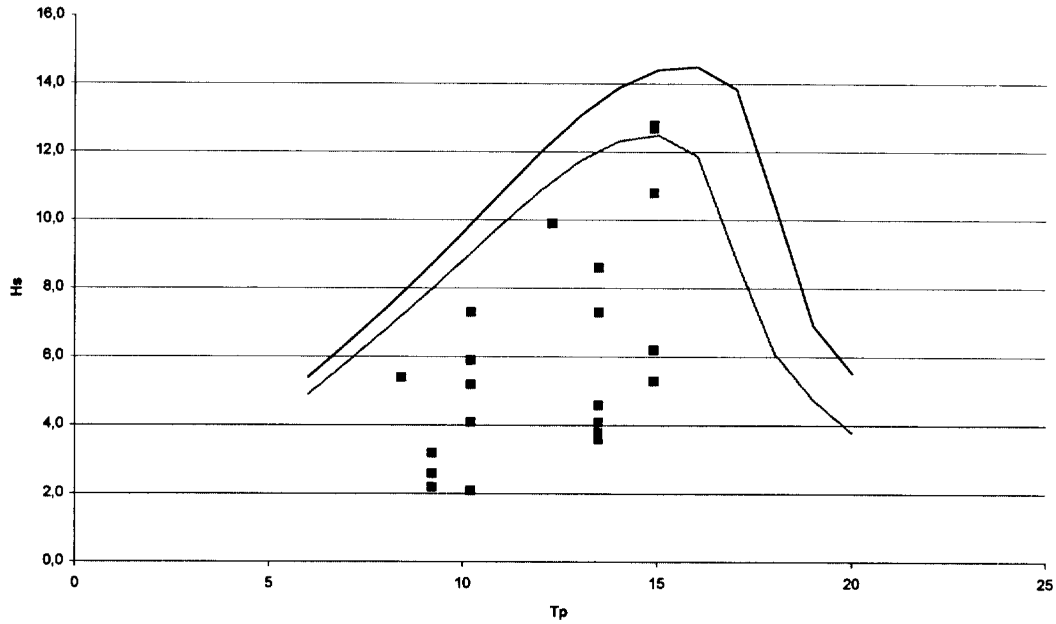

Figure 1, The $H_s - T_p$ design curves with the annual probability of exceedance of 10^{-1} and 10^{-2} for the Varg field. The hindcast data from nearby locations (Latitude 57.99N, longitude 1.78E) for January 29th 2000 is also included. The data is produced using WINCH hindcast model at DNMI. The data is not calibrated.

The analysis of the waves on the deck was done by using the program GreenLab. Local forces on the living quarter and on the support of the helideck gave higher loads than the design values. Compared with the model testing the analysis overestimated the pressure on the deck structures.

A new model test was performed in a 1:55 scale in 1999 at Marintek (Nygaard, 1999). The test consisted of a limited number of wave groups, selected from a regular simulation as a wave groups leading to large amounts of green water or large slam on living quarter. These wave groups was repeated 20-40 times. The results of these repeated wave groups gave a large scatter in results. A maximum water velocity of 14 m/s in a height of 4 m was found at midship (Børve, 1999). Different modifications was tested and compared to the as is situation. Figure 2 show a summary of the results from these tests (Børve, 1999). Although there is a large scatter in the results from each configuration, the mean values indicates a clear trend in positive effect of modifications as both slam pressure and height of green water decreases with the different modifications.

Description of green water mitigation
Restrictions with respect to draft, trim (one degree) and personnel exposure was made for the spring and summer of 1999.

During the spring of 1999, local protection was fitted for critical equipment, windows and helideck support. In addition some operational measures have been taken related to draft, trim and personnel access to green water zones for the future (Børve, 1999).

JOTUN A

The production ship Jotun A has been on location in the North Sea (59°N 2°E) since the summer of 1999. A list of relevant data for the ship with regards to green water is given in table 1.

Green water incidents
No green water incidents have occurred on the Jotun A ship so far.

Description of analysis and model tests
In the design phase of the Jotun FPSO MARIN performed model tests and hydrodynamic analysis using the program DIFFRAC. These tests were primarily carried out because of the requirements for the mooring system design. The testing for green water was not extensive. Measurements were taken at the bow for green water and relative motion, and a video was produced recording some information regarding green water on the FPSO. Due to the limited number of data points from the model testing, Caran has made calculations using linear diffraction theory (WAMIT) to predict the wave elevation above the deck. In this analysis, non-linearities are included in the calculations by scaling the wavecrest by an empirical factor. Dam breaking theory has been used to transform the wave elevation into water on deck. The best fit between calculations and model test was at the bow.
Esso have defined and identified green water zones as areas onboard the vessel, which may be affected by green water. Equipment in these zones is identified, and modifications are specified for safety equipment not capable of withstanding the green water load.

Description of green water mitigation
According to the model test results and the calculations the waves will reach above the bow and onto the tank deck at midship. Structures and equipment have been evaluated for potential damage from green water. This includes fire deluge skids, hydrants, emergency generator container, cable trays, pipe support and HVAC. Preventive actions have been taken by fabricating protection screens in front of critical equipment such as fire deluge skids, hydrants and emergency generator container. Cable trays around the turret have been strengthened. Equipment regarded as standard tanker equipment is not protected as it is "proven by history to be ok" on tankers.

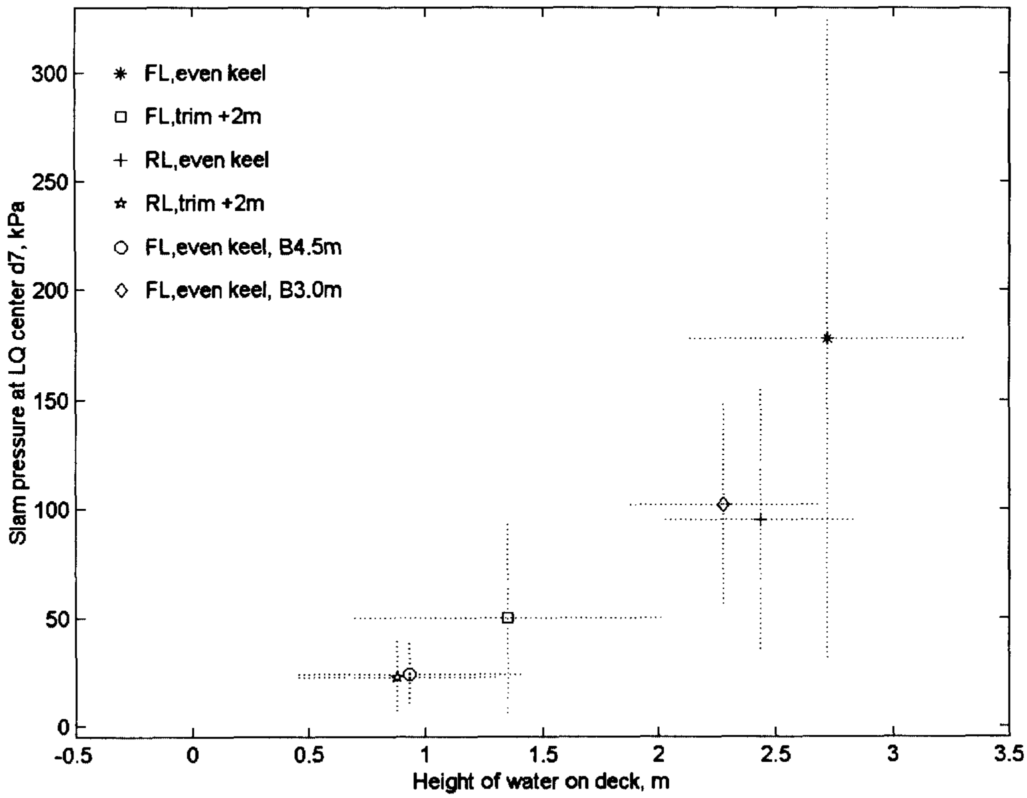

Figure 2, Pressure on living quarter versus height of water on deck for various configurations of modifications to the Varg ship. FL: fully loaded, RL: reduced loading (1.5m decrease in draft), B: increased bow. Mean values are marked, variations are indicated (Børve 1999).

Information about Jotun A is according to information given by Esso Norge (Skandsen, 1.6.99, Skandsen, 28.6.99 and Skandsen, 21.9.99).

BALDER FSU

The production ship Balder has been on location in the North Sea (59°N 2°E) since the summer of 1999. A list of relevant data for the ship with regards to green water is given in table 1.

Green water incidents
One green sea event leading to moderate damages have occurred on the Balder FSU during the winter season 1999-2000 (personal information from Severin Høye). The Norwegian Petroleum Directorate has not at present received a damage report from this event.

Description of analysis and model tests
DNV have performed seakeeping calculations, giving transferfunctions and motions for the FSU. Exxon have performed calculations on Greenwater and slamming using the programs WAMIT and SPOT. Both calculations are performed using linear diffraction theory to predict the freeboard exceedance. As for Jotun, the nonlinearities are included in the calculations by scaling the wave crest by an empirical factor. To transform the wave elevation into water on deck a factor of 1.5 was used.

Description of green water mitigation
According to model testing and calculations the waves will reach above the bow and onto the tank deck at midship. Structures and equipment have been evaluated for potential damage from green water. Identified critical equipment:

- Forecastle deck: Helideck columns and living quarter front wall
- Tank deck: Fire deluge skids, hydrants, emergency generator container, HVAC, piping, pipe support and cable trays.

Preventive actions have been taken by:

- adding support knee brace to each of the eight helideck support columns.
- Adding a 4.25 m high protection wall along side edge of the vessel to prevent green water impacting facilities. The wall extends along the full length of the exposed main deck. The wall consists of stainless steel panels supported by a steel frame.
- Restriction for personnel access to some areas will be made.

Information about Balder FSU is according to information given by Esso Norge (Skandsen, 1.6.99 and Skandsen, 28.6.99).

DISCUSSION

Introduction
Green water should be regarded as a safety hazard for the following reasons:

- it may be a threat to people staying in the green water zones,
- living quarters can be damaged in such a manner that people inside may be hurt,
- damage to equipment which is critical with respect to safety, may occur.

Statements from the operators of the production ships also indicate that green water may lead to shut down of production as often as on a yearly basis.

Identified critical events
Based on the events, the analysis performed and the model tests for the five ships discussed in this paper, critical events with respect to green water may be:
- Slamming on living quarters,
- Increased load on helideck support,
- Water in air inlet,
- Increased loads on equipment,
- Water damage to equipment.

Unsolved problems in general
The physics behind a green water event is not deterministic, and to our knowledge it is not fully understood. It is not necessarily the greatest wave that causes maximum green water. Instead it seems as if one or more waves inducing large pitch motions, followed by a relatively large wave is the most critical condition for the green water events. The maximum slamming on i.e. living quarter or other equipment in the bow area, however, does not necessarily occur at the same wave as the one causing maximum green water in the bow area.

Furthermore, there is no agreement as how to calculate the wave causing green water to enter the deck of the ship, nor as to how well the green water wave height and the freeboard exceedance are correlated. The model tests show diverging results in the matter of correlation between green water height and freeboard exceedance. Statoil (Eidissen, 12.5.99) indicates a non-linear relationship varying from no green water at low freeboard excedances to a one-to-one relationship at larger freeboard excedances. Saga has shown results indicating a one-to-one relationship between freeboard exceedance and green water wave height at the bow for Varg B. Also different kinematics seems to be applicable in the bow area and at midship. At
midship the dam breaking theory seems to be in common use. In the bow area 3-D effects of the dam breaking seems to be important. Wave slamming is also a possible loading mechanism in the bow area.

Unsolved problems regarding metocean
An unsolved question with respect to green water is the existence of wave groups. One very severe situation was observed during the model testing of Norne were a group of waves gave a very extreme response. Wave group research was performed in Norway at the end of the 1970-ies and in the beginning of the 1980-ies, based on the loss of several fishing boats. Kjeldsen and Myrhaug (1979, page 197) concluded that wave group formation among waves with heights exceeding 5 m was very pronounced in the field data. Kjeldsen (1984, page 7) states that most wave groups containing the highest waves in a sea state is composed by 6, 8 or 10 individual waves.

Unsolved problems regarding hydrodynamic loading
Linear diffraction analysis with empirical corrections gives reasonable results, but no calculation method or program is capable of analysing the phenomenon in an optimal way. Model tests are at present necessary in the prediction of green water and impact of green water.

The effect of bow shape on the occurrence of green water has been a point of discussion over a large number of years (Buchner 1995, 1996 and 1997). IMO (1999) concludes that deck wetness and green water loads were very sensitive to bow height and forward speed for bulk carriers. Bow shapes however marginally change deck wetness. Standing (1997) concludes that bow shape is important, but no clear trends have emerged from model testing. It is generally beneficial to maximise freeboard.

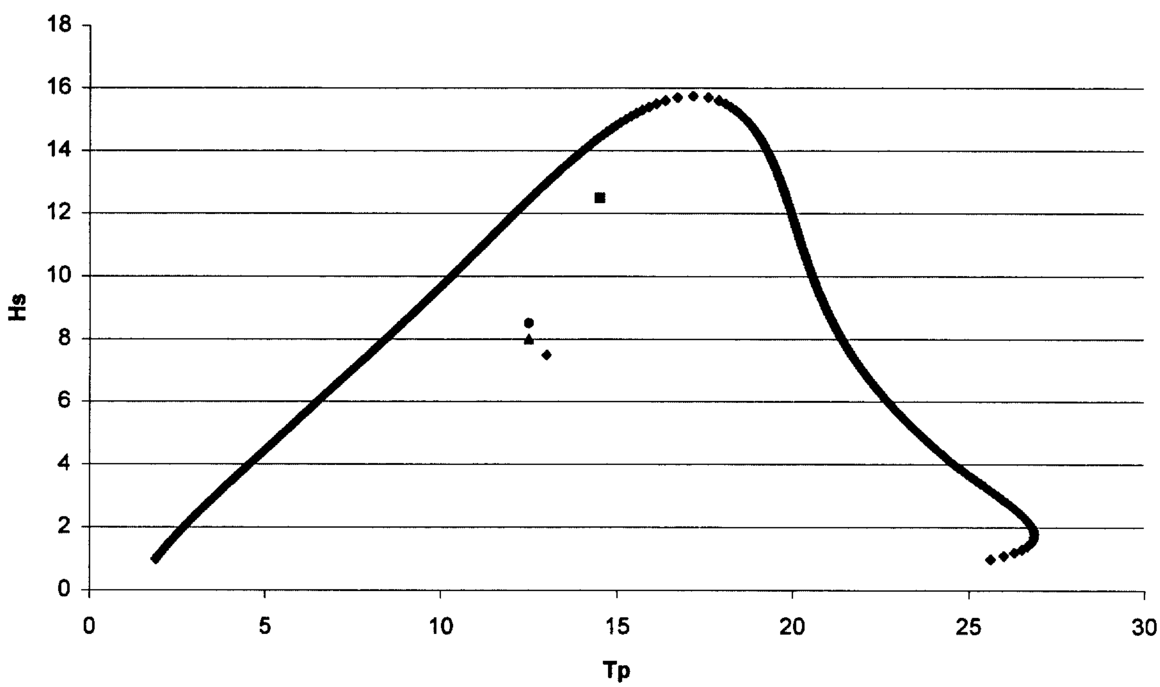

Figure 3, The green water events on Norwegian production ships and a $H_s - T_p$ design curves with the annual probability of exceedance of 10^{-2} for the Haltenbanken area. The incidents occurred at sea states significantly lower than the design sea states

The green water incidents recorded are plotted in figure 3 together with a 100-year contour line for the Haltenbanken area. The figure shows very clearly that the green water has occurred at significant wave heights much smaller than the 100-year values. The figure also indicates that the incidents have all occurred at peak periods lower than the peak period of the maximum significant wave height in the H_s-T_p design curves. The peak period where green water has occurred is closer to the pitch forcing period (the wave period when the wave length is equal to the ship's length assuming deep water).

The conclusions drawn from the analysis and model testing that has been performed are:

- large scatter in results from the same simulation when repeated
- positive effects of static trim, reduced draft and increased freeboardgreen water is more likely to occur when peak period is close to pitch forcing period

Possible points to consider during design of FPSO's:

- the range of periods considered should include the natural periods of the ship in pitch, roll, heave and the pitch forcing period as well as the period of the maximum significant wave height in the H_s – T_p design curves,
- the length of the ship determines the pitch forcing period and the wave statistics shows the period of maximum sea state. These two periods should, if possible, be as far apart as possible,
- the natural periods should be as far as possible from the pitch forcing period,
- the FPSO's are often fully loaded in a storm, due to the difficulties in offloading in such conditions.

	Water depth (m)	Length Lpp (m	Heave natural period (s)	Roll natural period (s	Pitch natural period (s	Pitch forcing period (s)	Freeboard bow (m)	Freeboard midships (m)	Freeboard poop deck (m)	Freeboard excedance bow (m)	Freeboard excedance midships (m)	Freeboard excedance aft deck (m)	Analysis (Company)	Model testing (Company)
Norne	380	242	10.1	25.0	8.6	12.4	14.3	6.3	9.8	8.5	7	3	MARIN Statoil	Marintek
Åsgard A	300	278	10.8	12-17	9.7	13.3	20.5	6.6	11.1	2.5	4.9	1.5	MARIN	No test
Jotun A	126	216	10.0	17.0	9.0	11.8	15.2	7.8	11.7	9.5	5.5	0	MARIN Caran	MARIN
Varg B	84	200	9.0	25.0	9.0	11.3	14	6	9.6	6.6	4.5	NA	MARIN Marintek Saga	Marintek
Balder	127	200	10.0	18.0	8.0	11.3	14.5	6.8	10	6	5.5	NA	DNV Exxon	MARIN

Table 1, Key data for Norwegian production ships. The pitch forcing period is the wave period when the wave length is equal to the ship's length assuming deep water. Note that for Balder a 4.3 m protection wall are built along midships.

REFERENCES

Bowitz Carsten: Grønn sjø – Åsgard A – referat fra møte i Oljedirektoratet, letter from Statoil, Stavanger 22.9.1999. (in Norwegian).

Buchner B: The impact of green water on FPSO design, OTC 7698, Houston, 1995

Buchner Bas: The influence of the bow shape of FPSOs on the drift forces and green water, OTC 8073, Houston, 1996

Buchner Bas: A new method for the prediction of non-linear relative wave motions, OMAE98-0592, 1998

Buchner B and J L Cozjin: An investigation into the numerical simulation of green water, BOSS, Delft, 1997

Buchner B and J J de Wilde: Green water assessment of Norne FPSO and Åsgard FPSO, Volume A: Norne FPSO, MARIN Research Institute, Report No. 14709-1-OE , Netherlands, 1998.

Buchner B and J J de Wilde: Green water assessment of Norne FPSO and Asgard FPSO, Volume B: Åsgard FPSO, MARIN Research Institute, Report No. 14709-1-OE , Netherlands, 1998.

Børve Bente Kleiveland: Risikovurderinger av grønn sjø på norske produksjonsskip, letter from Saga Petroleum, Oslo 27.9.1999. (in Norwegian).

Eidissen Hans: Norne – referat fra møte 30.10.98 vedrørende grønn sjø, Letter from Statoil, Stavanger 20.11.1998 (in Norwegian).

Eidissen Hans: Norne – Grønn sjø på dekk – Beregningsmetoder og programvare, Letter from Statoil, Stavanger 17.2.1999 (in Norwegian).

Eidissen Hans: Norne Green sea Model Tests, Letter from Statoil, Stavanger 16.3.1999.

Eidissen Hans: Norne – Referat fra møtet 29.04.99 vedrørende grønn sjø, Letter from Statoil, Stavanger 12.05.99 (in Norwegian).

Høye Severin: Esso Norge AS, conversation between Severin Høye and Gerhard Ersdal 17th February 2000.

Iden Knut: Norwegian Meteorological Institute, conversation between Knut Iden and Gerhard Ersdal 7th May 1999.

Iden Knut: Norwegian Meteorological Institutte, conversation between Knut Iden and Gerhard Ersdal 3rd February 2000.

IMO: Bulk carrier safety, Sensitivity of wetness and deck loads to bow height and forward buoyancy reserves in extreme weather conditions, MSC 71/4/4, 19 March 1999.

Kjeldsen Søren Peter og Dag Myrhaug: Wave-wave and wave-current interactions in deep water, POAC, Trondheim, 1979.

Kjeldsen Søren Peter: Dangerous wave groups, Norwegian Maritime Research, no 2, 1984.

Kverneland Kari Anne: Informasjon om bølgeskader, om status på thrustere og om status på nødgenerator på Varg B, Facsimile from Saga Petroleum, Stavanger 9.2.1999 (in Norwegian).

Ljosland Eva: Hendelse "Petrojarl Varg" 29.01.00, Letter from Norsk Hydro, Oslo 07.02.2000 (in Norwegian).

Mosbergvik Odd: Risikovurdering av "grønn sjø" på Statoils produksjonskip, Letter from Statoil, Stavanger 27.09.1999 (in Norwegian).

Mundheim Øystein: Green sea, letter from Esso Norge, Stavanger 23.9.1999. (in Norwegian).

Nygaard Ivar: Varg model tests, Green sea and slamming, Marintek report 512287.00.01, Trondheim, 1999-08-20.

Sandberg Sverre: Varg utbyggingsprosjekt, utredning vedrørende sannsynlighet for overskridelse av fribord, Letter from Saga Petroleum, Oslo, 4.3.1999 (in Norwegian).

Skandsen Hugo: Balder/Jotun A – Greenwater – Minutes of meeting 11.05.99, Letter from Esso Norge AS, Stavanger 1.6.1999.

Skandsen Hugo: Jotun A - Documentation – Green water & slamming, Letter from Esso Norge, Forus, Stavanger 28.06.99

Skandsen Hugo: Jotun A – Document transmittal on Green water, Letter from Esso Norge, Forus, Stavanger 21 September 1999.

Standing R G: Green Seas damage on FPSOs and FSUs, HSE report OTH 486, London 1997

Statoil: Åsgard A – "Green Sea on Deck", status per February 25th 1999, Letter from Statoil, Stavanger.

Torsethhaugen K: "Model for a Double Peaked Wave Spectrum", Sintef Civil and Environmental Engineering, Rep. no. STF22A96204, Trondheim 1996

Ude T.C., Kumar Satyendra, K., Winterstein S.R., "Stochastic response analysis of floating structures under wind, current and second-order wave loads", Civil Engineering Dept., Stanford University, June 1996.

Vestbøstad T.M, "Relative Wave Motions Along the Side of an FPSO Hull", OMAE'99, St. Johns, July 1999.