DYNAMIC POSITIONING CONFERENCE

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FPSOs and Shuttle Tankers

State of DP Development and Potential in Shuttle Tankers

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STATE OF DP DEVELOPMENT AND POTENTIAL IN SHUTTLE TANKERS.

1. **Brief History of DP development for shuttle tankers in the North Sea.**

Offshore loading in the Norwegian Sector of the North Sea was started at the Statfjord field back in December 1979 when two dedicated offshore loading vessels were chartered to do offtakes from an articulated loading platform (ALP) . The solution was based on taut hawser operation. The solution was initially meant to be temporary, awaiting establishment of a pipeline crossing the Norwegian Trench. The expectations were not too high , efficiency was calculated to maximum 85% ! First year of operation showed a regularity of virtually 100% , and it was decided to continue with offshore loading as the permanent export system for the Statfjord field.

The first DP trials with shuttle tankers took place at Statfjord in 1982. The thinking behind was to introduce DP as a tool that could help relieve the stress on the shuttle tanker masters, in addition to possibly prolong hawser lifetime, thus saving a considerable amount of money. The pessimists meant operating these big vessels on DP in such harsh environment would be too complicated and represent an unacceptable risk. However, the trials went extremely well and all skepticism was brushed aside. As the first oil company Statoil decided to base all their offshore loading on DP operated shuttle tankers.

2. **Progress in design and operating practices.**

The first generation DP shuttle tankers were conventional single hull tankers modified for offshore loading. Special features were:

- Controlled pitch main propeller
- 2 bow thrusters, each of 1500 hp
- Bow Control House
- Single Computer DP
- Single DP Operation Modus
- Single Position Reference System

SPM loading at Gullfaks field.

The DP computer in use onboard the first generation shuttle tankers was a Kongsberg KS503 computer offering hardwired control buttons and an unprecedented memory of 128 kB ! As positioning reference system the at the time unrivalled Microfix system was used as the sole system.

Although these tankers served the purpose they were designed for, it was soon realized a necessity of improving the equipment. Especially bow thruster capacity turned out to be a limiting factor. Operating after the ' Weather Vane ' principle, control of vessel's heading is crucial to the position keeping capability. At the same time several new types of offshore loading facilities were introduced, demanding higher performance from the DP computers.

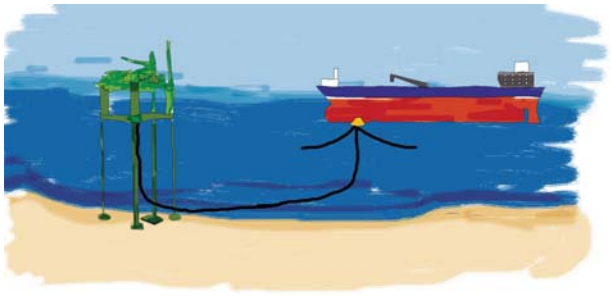
Offshore Loading Systems.

A 'revolution' with respect to offshore loading systems was introduced with the appearance of the Ugland Kongsberg Offshore Loading System; UKOLS system in 1986. In addition to be a considerably cheaper system than the traditional Single Point Mooring (SPM) buoys; it also offered more flexibility and accordingly higher safety with respect to shuttle tanker operation. However; while the SPM allowed for manual taut hawser operation as an alternative to DP operations; the UKOLS systems were totally dependant on DP.

UKOLS loading System

Following the introduction of UKOLS an environmental reference 'standard' for DP operations was introduced : 4.5 meter Significant Wave Height as a limit for hook-up; 5.5 meter Significant Wave Height for Position Keeping Capability.

A few years later was the Submerged Turret Loading (STL) introduced, offering an extended environmental operating window. A 'limiting' factor for distribution of the STL solution is the need for custom-built tankers. In the North Sea the STL solution has been chosen for the Heidrun field on Norwegian Continental Shelf and for Harding field on the UK Continental Shelf.



STL Loading System

The most challenging offloading system from a DP point of view is the Tandem Loading Operation, where shuttle tankers connect to the stern of a FPSO or FSU. Over the last ten years this has become the far most utilized solution for offshore loading in the North Sea. More than 15 fields in the North Sea are today based on this solution.

Tandem Loading.

The latest addition to the offshore loading family tree is the Single Anchor Loading (SAL) system. This is a cost effective system especially suitable for shallow waters. At the moment the SAL system is in use at the Siri and South Arne fields on the Danish Continental Shelf, together with the Banff field on UK Continental Shelf.

SAL Loading System

Evolution of DP shuttle tankers.

From the modest beginning of operating shuttle tankers on DP more than 20 years ago till today's modern DP Class II shuttle tankers there has been a continuous and extensive process of change.

Hull wise the tankers have developed along the following path:

- Single Hull
- Single Hull, with double wing tanks
- Double bottom; single sides
- Double Hull

Machinery wise there has taken place a considerable upgrade of main propulsion and thruster capacity over the years. A modern shuttle tanker of today is a very powerful lady! She would typically be equipped with twin propulsion engines of up to 15000 HP each, two high efficiency rudders, two bow thrusters of 2400 HP each out of which one is either retractable tunnel thruster or of retractable azimuth type, two tunnel thrusters aft of 1400 HP each or alternatively one retractable azimuth of similar size.

With respect to DP and Positioning Reference Systems, today's state of the art hardware and software are for miles away from the outfit starting the show.

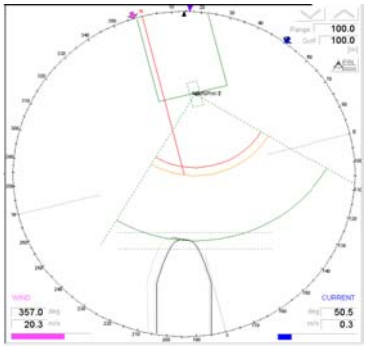
DP hardware.

Navion's requirement to DP shuttletankers today is as a rule in accordance with IMO DP Class II. That means that all shuttletankers shall be equipped with a double DP computer hooked up in an all redundant network. The installation shall meet all requirements to DP Class II installation with respect to fireprotection, switchboard splitting, Uninterruptable Power Supply (UPS) etc. All crucial sensors shall as a minimum be duplicated, the number of positioning reference sensors shall be minimum three.

DP software.

The DP software in use onboard the shuttle tankers is tailormade to match the requirements from each field operator. During loading operation the shuttle tanker will normally operate in ' Weather Vane' modus around a predefined reference point. If found necessary the vessel could also operate in 'Auto Position' modus maintaining a wanted heading. In conjunction with the field operator warning and alarm distances and sectors are defined. In order to immediately attract the attention of the DP Operator in case any of these predefined limits should be crossed, an improved Alarm Display Function containing specific visual displays have been developed. These will be in addition to the standard buzzer alarms coming with the equipment.

Tandem loading operations have turned out to be very challenging with respect to surge and fishtailing movements of the FPSO / FSU . To cope with these movements Navion together with DP vendor Kongsberg Simrad have developed a special software module named 'Tandem Loading'. In brief this programme allows the FPSO / FSU to move freely within a predefined window, without the shuttle tanlker making any attempt to follow. However; the relative distance and bearing to the stern reference point is constantly monitored by means of positioning reference systems. Introducing this programme have contributed substantially to increase the safety of tandem loading operations as well as having reduced the use of thrusters to a minimum.



Tandem Loading Operator Screen

Positioning Reference Systems (PRS).

The number and type of PRS systems will vary with the different fields and with different type of loading systems installed. However, standard requirement is to have access to minimum three PRS systems in order to allow DP operation.

Navion has always been in forefront with respect to sponsor and participate in development of new PRS systems as well as to encourage improvements of existing ones.

Together with Kongsberg Seatex (ex Kongsberg Navigation) a special version of DGPS named DARPS (Diffstar Absolute and Relative Positioning System) was developed in the mid nineties. The system, providing the shuttle tankers with absolute geographical position as well as relative distance and bearing to the corresponding FPSO / FSU or loading buoy, has become a North Sea Standard, if not to say a World Standard.

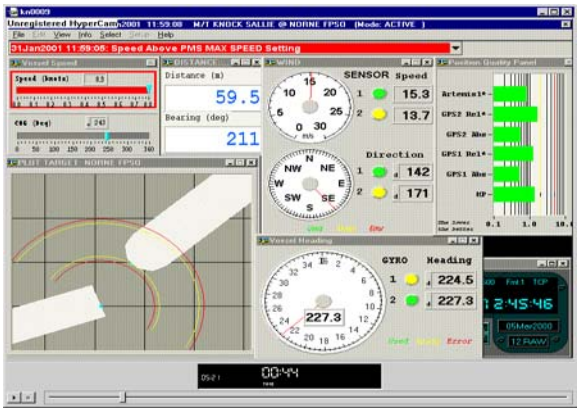
In close cooperation with vendor company Kongsberg Simrad, Statoil together with Navion also sponsored and contributed substantially to the development of the improved hydroacoustic system HiPAP (High Precision Hydroacoustic Positioning) system. The system represents superior accuracy with respect to hydro acoustic positioning in deep waters, at the same time it became possible to use long hold hydro acoustic positioning in connection with very shallow waters thanks to the spherical transducer with a steerable acoustic beam.

Positioning Monitoring System; PMS.

In order to increase the safety related to DP operations and also to ease the investigation work following an incident, Navion together with surveyor company Blom have developed a special Positioning Monitoring System (PMS). This is operating more like a black box; i.e. on an independent basis all raw data coming from all DP sensors and all positioning reference systems are registered and stored. Additionally all thruster setpoint and feedback values sent to and fro the DP are registered, so is the DP alarm list.

The system is further capable of calculating speed independent of the DP, and will trigger an alarm if the shuttle tanker should pick up speed above limits set by the DP computer.

By means of these data Navion is able to reestablish any situation and reconstruct any tanker movement when the shuttle tanker is operated in DP modus. In view of investigating incidents, this becomes an unrivalled tool.



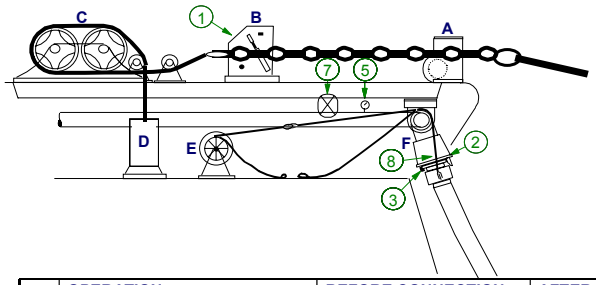
Blom PMS Operator Screen

Tanker Telemetry System.

As an extra safety device all Navion's shuttle tankers have a discharge telemetry system installed. Prior to giving permit to start crude export from the FPSO, this monitoring circuit controls that all valves and couplers onboard the tanker are in correction position, and that the mooring system and hose connections are properly secured. Upon completion of establishing the socalled 'Green Line' a ' Permit to Pump' signal is sent from the tanker to the FPSO / FSU. Before receipt of 'Permit to Pump' signal from the shuttle tanker it will not be possible for the FPSO / FSU to start their crude export pump. If any 'Green line ' status is altered for any reason during loading, the telemetry system will immediately initiate a hutdown of the crude export and close the tanker inlet valve.

BOW LOADING SYSTEM - "GREEN LINE"

NAVION



UHF

A FAIRLEAD
B CHAINSTOPPER
C TRACTION WINCH
D STOWING TANK FOR MESSENGERLINE
E HOSE HANDLING WINCH
F BOW MANIFOLD

	OPERATION	BEFORE CONNECTION	AFTER CONNECTION	ESDI	ESDII a)
11	LOADING	OFF	ON		
10	LOADING	NOT PERMITTED	PERMITTED		
9	COUPLER VALVE	CLOSED	OPEN		
8	CRUDE OIL LINE VALVE	CLOSED	OPEN		
7	ACCUMULATOR PRESSURE	NORMAL	NORMAL		
6	HAWSER TENSION	NORMAL	NORMAL		
5	CRUDE OIL PRESSURE	NORMAL	NORMAL		
4	CARGO SYSTEM	READY	READY		
3	COUPLER	OPEN	CLOSED		
2	HOSE	NOT IN POSITION	IN POSITION		
1	CHAIN STOPPER	OPEN	CLOSED		

a) THE SPRINKLER SYSTEM COVERING THE BOW AREA WILL ALSO BE ACTIVATED.

DP Test programme.

Prior to accepting any shuttletanker to start offshore operations Navion do carry out a comprehensive test programme. Initially the tanker will have to go through an inshore testprogramme. This includes check of main propulsion tunings and thruster tunings towards DP computer; checking of antenna offsets, correlation of positioning reference systems etc. Also a special 'DP Crash Stop' test is carried out. The idea behind this test is to become familiar with the shuttle tanker's acceleration and retardation rate at different drafts, which could help the master to take correct measures in case of a drive off situation . To ease the execution of all these tests Navion has established a special test site , located in Aamoyfjord outside Stavanger, where all actual positioning reference systems can be accessed.

In parallel with this a complete Failure Mode and Effect Analysis (FMEA) test is carried out, verifying that all DP related sensors and sources are properly installed and properly functioning.

Following the 'Inshore test' all shuttle tankers have to go through a specific 'DP Field Test' prior to be accepted for loading operations at each field. Here the tailor made field software will be verified, including check-out of all warning and alarm criteria.

Field Operation Procedures.

In co-operation with the field operators Navion has developed specific Field Operation Procedures for each field. This procedure will describe all safety regulations and precautions related to operation at the field; it will further describe in detail the offshore loading system installed ; positioning reference systems available and where they are located; which communication channels that are established etc. The procedure will also contain map of the seabed; traces of flowlines etc. To ease and secure the hook-up operation of the shuttle tanker a step-by-step procedure is made; telling the Master and DP Operator what to do and what to assure in each phase of the operation.

Training.

Operating a fleet of sophisticated DP shuttle tankers obviously has a demand for highly skilled personnel Prior to accept any new vessel on contract the officers onboard shall have to comply with the demands set out in document ' Navion's Competence Requirements for Shuttle Tanker DP and VOC involved Personnel. NAV/KR-508' This document describes which specific skills the different officers onboard must have in order to operate the vessel, and it has also stringent demands with respect to renewal of certificates etc.

In admission of the fact that DP Shuttle Tankers only operates on DP a small fraction of the time Diving and ROV vessels do; there is a need to ensure that the DP Operators onboard get sufficient training. As a remedial action to this problem Navion has developed an interactive training programme called 'DP Competence Assurance Practice; shortnamed DP CAP. With this 'onboard DP simulator' the DP Operators can direct real life DP operations whenever the shuttletanker may have idle time; either at the field activating the FPSO's positioning reference system, or actually anywhere establishing a fictitious buoy and utilize DGPS as positioning reference system. Nautical Institute in London has fully acknowledged this training programme and is upon completion of the programme granting 8 weeks of reduced sailing time with respect to issuing of DP Certificates .

DP CAP™ MAIN MENU

DP CAP training onboard 'Navion Scandia'.

Imposed Rules and Regulations by Authorities.

Until recently DP was seen as a pure supporting tool with respect to positioning of shuttle tankers and as such not covered by any authority regulations. However, in the new regulations from Norwegian Petroleum Directorate (NPD) coming into force 1 January 2002, shuttle tankers carrying out loading from fixed loading buoys shall demonstrate a safety level equal to the requirements of IMO DP Class I , and shuttle tankers carrying out tandem loading operations shall demonstrate a safety level equal to the requirements of IMO DP Class II.

Part of the Industry has over the last decade done a outstanding work in establishing Guidelines for shuttle tanker DP operations. In particular IMCA has played an active role in that respect. Also UKOOA has contributed considerably and has issued a separate guideline ' Tandem Loading Guideline ' which has been adopted by a number of the oil companies operating FPSO's on the UK Continental Shelf.

3. DP 2000 Joint Industry Programme JIP.

In view of an increasing number of DP shuttle tankers in operation and in view of a worrying growth in DP related incidents connected to tandem loading operations, Navion saw the need to address the problem. An initiative was taken to establish a Joint Industry Project where the major goals were:

- Mapping of areas with potensial for improvement.
- Visualisation of technical and operational improvements already being invoked.
- Focus on issues significant to safe operation.
- Focus on improvements relating to Health, Safety and Environment issues.

The project was divided into three main working groups:

- Human Factors

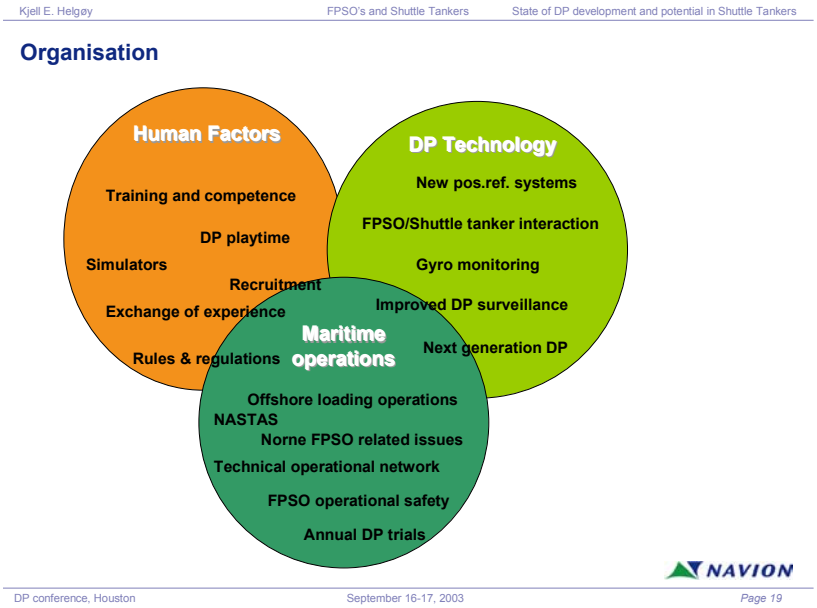
Analysing incidents from the past showed that very often the root cause of the incident was human error, or a combination of initial equipment failure and incorrect counteraction taken thereafter. The education and training of tanker personnel together with experience transfer were issues brought into focus in this group.

- DP Technology

The task of this group was to examine the technical aspects of DP operations; what could be the potential for improvements; how could the DP possibly be simplified; how to improve positioning reference systems etc.

- Maritime Operations

This group had main focus on the interaction between FPSO / FSU and the shuttle tanker. Improvements of Field procedures ; examining of FPSO Operational Safety and establishment of technical operational networks were highlighted.



DP 2000 JIP Results.

Probably the greatest result stemming from the DP 2000 Joint Industry Programme is the considerable reduction of DP related incidents , registered in Navion's Synergy system over the last two years. (It should be noted however, that in this registration the concept of incident could be anything from a near drive off situation to divagation of a positioning reference system ; either onboard the shuttle tanker or onboard the adjacent FPSO / FSU.) Navion's Synergy system showed a decrease in number from 17 incidents registered over 900 loadings in year 2000 , to 6 registered incidents over the same number of loadings in 2003 . We are convinced that much of these results can be creditted the strong focus put on all aspects of DP operations from the DP 2000 JIP.

More definite and measurable results achieved from the programme are numerous.

Among the essential ones are :

- Development of an improved system for audit of shuttle tankers, NASTAS.

The project resulted in compilation of a distinct inspection manual, tailor made to fit shuttle tankers' outfit.

- Development of improved positioning reference systems, DARPS 900, ARAP , Gyro Monitoring.

DARPS 900 is a further development of the orginal DARPS equipment where the radio transmission is moved to the 900 MHz band to avoid interference from other users, and where TDMA technique (Time Division Multiple Access) allow several users to utilize same transmission channel.

ARAP is a new application within hydro acoustic positioning; HPR. By use of this the HPR reference system can be used both for absolute geographical positioning as well as for relative positioning of a shuttle tanker.

- Improved System Surveillance

The results from this project is described under chapter Positioning Monitoring System; PMS. In addition a specific remote PMS unit was developed, especially intended for use onboard non-DP operated FPSO / FSUs. This system will allow the OIM of the FPSO / FSU to monitor the movements of the shuttle tanker connected at the stern during loading.

- Development of DP onboard training programme; DP CAP.

This training programme is described under chapter Training.

- Bridge organization during DP operations.

This project has evaluated the bridge manning onboard the shuttle tankers and gives recommendations of how to best organize the shuttle tanker bridge during DP operations. A principal recommendation is to employ an extra DP Operator in order to relieve the Master from DP duties.

- Special software release for shuttle tankers.

The project resulted in a special software release intended for shuttle tankers. In this release superfluous functions not used by shuttle tankers were removed. In addition the alarm display function has been improved; so has treatment of positioning reference systems.

4. Future Challenges ; Gulf of Mexico Shuttle Tanker Applications.

Navion's vision and pronounced goal is to be a world leader in operation of DP shuttle tankers. We state use of dynamic positioned shuttle tankers to be a safe, reliable and efficient way to handle and transport crude oil. A future goal for our company is to establish shuttle tankers operations in the Golf of Mexico. Based on the vast experience Navion has gained from more than 20 years of operation in the North Sea we are convinced this technology can be transferred and adopted to the local environmental conditions in Gulf of Mexico.

5. Conclusion.

Use of DP operated shuttle tankers for offshore loading has experienced a substantial growth over the last decade . From being a special development involving a few vessels and basically one field operator, it has now become a routine practice widely accepted by the oil industry. Today there is more than 50 DP tankers in operation serving more than 40 different oil fields in the North Sea , Canadian and Brasilian waters. On a world wide basis in the order of 1500 liftings are done yearly by use of DP operated shuttle tankers.

Over the years there has been a considerable change in operational management regarding DP shuttle tankers. From being regarded as an assisting tool to shuttle tanker operation and as such covered by little or no regulations; authorities as well as industry now have established rules and guidelines contributing to safe DP operation .

About Navion.

Navion is a shipping company located in Stavanger Norway. The company was former a subsidiary company of Statoil but is now owned by Teekay Shipping Corporation .

The company ranks as a world leader in offshore loading, and occupies a dominant position in crude oil and product transportation in the Atlantic basin. Long experience from these waters has contributed to the development of pioneering technologies.