F(P)SO Heading Control Guidelines

(First edition 2020)

Issued by the

Oil Companies International Marine Forum
29 Queen Anne's Gate
London SW1H 9BU
United Kingdom
Telephone: +44 (0)20 7654 1200
Email: enquiries@ocimf.org

www.ocimf.org

First edition 2020

The Oil Companies International Marine Forum (OCIMF)
Founded in 1970, the Oil Companies International Marine Forum (OCIMF) is a voluntary association of oil companies having an interest in the shipment and terminalling of crude oil, oil products, petrochemicals and gas, and includes companies engaged in offshore marine operations supporting oil and gas exploration, development and production.

Our vision is a global marine industry that causes no harm to people or the environment.

Our mission is to lead the global marine industry in the promotion of safe and environmentally responsible transportation of crude oil, oil products, petrochemicals and gas, and to drive the same values in the management of related offshore marine operations. We do this by developing best practices in the design, construction and safe operation of tankers, barges and offshore vessels and their interfaces with terminals and considering human factors in everything we do.

Contents

Purpose and scope

This information paper supplements the Oil Companies International Marine Forum's (OCIMF) publication *Cargo Guidelines for F(P)SOs* and should be read along with the relevant guidance for F(P)SO heading control.

These guidelines provide recommendations to safely manage heading control operations of turret moored Floating (Production) Storage and Offloading (F(P)SO) facilities. F(P)SO heading control operations are undertaken to enable surveys, installation works, maintenance works and associated F(P)SO operations, on board or within the swing circle, often while remaining in operation.

The bollard pull that is required to maintain a defined heading is often underestimated. An underestimated bollard pull may lead to an unwanted loss of position of the F(P)SO, subsequently endangering operations that require the heading control. Additionally, insufficient consideration has been given to the operational limits at which operations should be suspended or aborted.

Incidents during heading control operations have shown that personnel have an insufficient awareness of the risk associated with the operations. For example, the relationships between field water depth, subsea assets and towline catenary depth are not fully understood.

To improve management of heading control operations, these guidelines include an assurance tool and a standard methodology to calculate the bollard pull requirements for Heading Control Tugs (HCTs).

The methodology used to calculate the required bollard pull have been developed in close cooperation with the Maritime Research Institute Netherlands (MARIN).

Suitability and redundancy of F(P)SO mooring equipment becomes increasingly important when the consequences from a loss of heading control increase in severity. F(P)SO mooring equipment may not always be suitable nor redundant for the assigned tasks. Recommendations for F(P)SO deck equipment to be used during heading control operations are included in these guidelines.

Where F(P)SO facilities have thrusters, guidance for their use, whether stand-alone or in combination with one or more HCTs, is provided.

The suitability of the HCTs selected forms an important part of the operations. Redundancy guidance includes the use of two tugs with single engines versus one tug with dual engines.

With many parties involved in the operations, communication protocols should be documented and followed.

F(P)SO deck crew line handling training, competency and experience is critical to safe operations. This is especially important when connecting and disconnecting tug towlines to the F(P)SO, and specifically in adverse environmental operating conditions, when operational limits are not defined.

It is recommended that the scope of personnel competence assessment activities be undertaken in line with the OCIMF *Competence Assurance Guidelines for F(P)SOs*.

Glossary

Best practice OCIMF views this as a method of working or procedure to aspire to as part of continuous improvement.

Control of Work This refers to a process that includes Hazard Identification and Risk Assessment (HIRA), permit to work and isolation management.

Cross rigging When a chain, rope or hose crosses the boundary between the geostationary and rotating parts of the F(P)SO turret.

Duty holder Organisation or individual that has a legal duty under health and safety legislation.

Environmental conditions Are the local wind, wave, swell, current, precipitation and visibility conditions.

Failure means an occurrence in a component or system that causes one or both of the following effects:

- Loss of component or system function.
- Deterioration of functional capability to such an extent that the safety of the vessel, personnel or environment protection is significantly reduced.

F(P)SO swing circle This is the maximum radius in which a F(P)SO is expected to swing.

F(P)SO swing circle including HCTs This is the maximum overall radius in which the F(P)SO when moored on location to the seabed, with HCTs connected, are expected to swing in tandem.

Girting (girthing, girding or tripping) A towline under tension will exert a heeling moment on the HCT if the line is secured around amidships and leads towards the beam. If the force in the towline is sufficiently powerful, it may overcome the tug's righting lever causing it to capsize or girt.

Gob wire (or gog wire) A work wire used to move the effective towing point closer to the HCT stern. This prevents the towline from being taken across an HCT beam reducing the danger of girting.

Guidance Provision of advice or information by OCIMF.

Heading control assurance The systematic approach to evaluate and improve the management of heading control operations.

Heading Control Tug Vessel with towing capabilities used for controlling the heading of an F(P)SO. The HCT can be an oceangoing tug, Anchor Handling Tug and Supply vessel (AHTS) or any other tug with these towing capabilities.

Metocean conditions These are the combined wind, wave, swell and climatic conditions as found in a specific location. Metocean conditions are presented statistically, including seasonal variations, scatter tables, wind roses and probability of exceedance.

Non-redundant heading control A heading control operation where no equipment is either duplicated on a single HCT or set to a maximum operating limit to prevent loss of the controlled heading of the F(P)SO upon failure of a single component.

Recommendations OCIMF supports and endorses a particular method of working or procedure.

Redundant heading control A heading control operation where equipment is either duplicated or set to a maximum operating limit to prevent loss of the control of the F(P)SO upon failure of a single component, i.e. use of dual engines in a single tug where one engine is redundant of the other.

Subsea Term used to refer to equipment and structures that are located on or below or buried in the seafloor for the production of oil or gas from, or for the injection of fluids into, a field under an offshore production site, and includes production risers, flow lines and associated production control systems.

Subsurface Under the surface of the sea, above the seafloor.

Thruster A propulsion unit that provides thrust, in a fixed or rotational direction.

Towing strong point A strong point that is designed or can be used for tug operations.

Tugger winch An auxiliary winch designed to move loads on deck, commonly fitted on offshore vessels at the cargo deck area behind the superstructure.

Umbilicals The connections used offshore between subsea equipment and platforms or F(P)SOs enabling control from the surface.

Worst-Case Failure The identified single fault in the DP system resulting in maximum detrimental effect on DP capability as determined through the Failure Mode Effect Analysis (FMEA) (MSC.1/Circ.1580 *Guidelines for Vessels and Units with Dynamic Positioning (DP) Systems*).

Worst-Case Failure Design Intent The specified minimum DP system capabilities to be maintained following the worst-case failure. The worst-case failure design intent is used as the basis of the design. This usually relates to the number of thrusters and generators that can simultaneously fail (MSC.1/Circ.1580 *Guidelines for Vessels and Units with Dynamic Positioning (DP) Systems*).

Abbreviations

ACID tool	Assurance Category Identification tool
AHTS	Anchor Handling Tug and Supply Vessel
ALARP	As Low As Reasonably Practicable
ASOG	Activity Specific Operating Guidelines
DNV GL	Det Norske Veritas Germanisher Lloyd
DP	Dynamic Positioning
DPC	Dynamic Positioning Committee
DSV	Dive Support Vessel
FMEA	Failure Mode Effect Analysis
FME(C)A	Failure Mode Effect (and Consequence) Analysis
F(P)SO	Floating (Production) Storage and Offloading
F(P)SO MAQ	F(P)SO Marine Assessment Questionnaire
FSV	Field Support Vessel
HAZID	Hazard Identification
HCT	Heading Control Tug
HIRA	Hazard Identification and Risk Assessment
IMCA	International Marine Contractors Association
IMO	International Maritime Organization
LSA	Lifesaving Appliances
MAQ	Marine Assessment Questionnaire
MARIN	Maritime Research Institute Netherlands
MCRO	Marine Control Room Operator
MMS	Maintenance Management System
MOC	Management of Change
MSC	Marine Safety Committee
MTS	Marine Technology Society
OCIMF	Oil Companies International Marine Forum
OCV	Offshore Construction Vessel
OIM	Offshore Installation Manager
OVIQ	Offshore Vessel Inspection Questionnaire
OVMSA	Offshore Vessel Management and Self Assessment
OVPQ	Offshore Vessel Particulars Questionnaire
PMS	Planned Maintenance System
RA	Risk Assessment
ROV	Remote Operated Vehicle
SF	Ship Fixed
SIMOPS	Simultaneous Operations
SME	Subject Matter Expert

SMS	Safety Management System
STAG	Static Towing Assembly Guidelines
SWL	Safe Working Load
TEMPSC	Totally Enclosed Motor Propelled Survival Craft
WCF	Worst-Case Failure
WCFDI	Worst-Case Failure Design Intent
WLL	Working Load Limit
WSOG	Work Specific Operating Guidelines

Bibliography

Cargo Guidelines for F(P)SOs (OCIMF)

Competence Assurance Guidelines for F(P)SOs (OCIMF)

DNVGL – SE0122 Capability Plots (Det Norske Veritas Germanisher Lloyd (DNV GL))

Dynamic Positioning Assurance Framework: Risk-based Guidance (OCIMF)

Effective Mooring, Fourth Edition (OCIMF)

Guidelines for Offshore Tanker Operations (OCIMF)

IMCA M190 Guidance for Developing and Conducting DP Annual Trials Programmes (IMCA)

IMCA M220 Guidance on Operational Activity Planning (IMCA)

Mooring Equipment Guidelines (OCIMF)

MSC/Circ.645 Guidelines for Vessels with Dynamic Positioning Systems (IMO)

MSC.1 /Circ.1580 Guidelines for Vessels and Units with Dynamic Positioning Systems (IMO)

Static Towing Assembly Guidelines (OCIMF)

1 Heading control operations

F(P)SO heading control operations are carried out to control hull motions, enable surveys, installation works, maintenance works and associated F(P)SO operations, on board or within the swing circle, often while remaining in operation. The consequences of a loss of the heading control of the F(P)SO will determine the level of control required to maintain that heading.

F(P)SO heading control can be achieved by:

- Use of active heading control.
- Heading Control Tugs (HCTs).
- A combination of the above.

Active heading control is maintaining the F(P)SO heading using a heading control system on the F(P)SO. Systems include thrusters, main propulsion and active rudders, which an operator can set by using a Dynamic Positioning (DP) model.

However, HCTs control or help control the F(P)SO heading by applying a towing force to maintain a defined heading.

When carrying out heading control operations, the following, which may affect the operation and may be a hazard, should be considered:

- Rapidly changing and/or adverse environmental conditions.
- Heading control equipment failure:
  - HCT failures.
  - F(P)SO thruster failure.
  - F(P)SO propulsion failure.
  - Tow line failure.
- Interference with subsea infrastructure.
- Loss of communications.
- Human error.
- Simultaneous Operations (SIMOPS).

During F(P)SO heading control operations, if F(P)SO thrusters, HCTs or towing equipment should fail, then all dependent activities should be made safe and the heading control operation suspended until the equipment is operational (see sections 4.2.5 and 9.3).

Failure of F(P)SO thrusters, heading control equipment or HCTs should be immediately communicated to all stakeholders (see chapter 9).

1.1 Risk of loss of F(P)SO heading control

Activities that are carried out during heading control operations should be appropriate to the risk of loss of F(P)SO heading. Consideration should be given to the heading control method: F(P)SO active heading control, HCTs or a combination of the two in relation to other in-field vessels and tasks, e.g. diving in the turret area, riser pull in, etc.

Activities that may require F(P)SO heading control include:

- Diving or Remote Operated Vehicle (ROV) operations carried out from a vessel within the F(P)SO swing circle (see figure 1).
- Diving operations carried out from the F(P)SO.
- Diving operations carried out from a vessel moored alongside the F(P)SO.
- Pulling in of risers and umbilicals.
- Other subsea activities that are carried out from a vessel within the F(P)SO swing circle, e.g. pipe-laying, ROV and seismic survey activities.
- Topside activities on components that involve cross rigging an F(P)SO fixed (geostationary) turret and rotating hull interface.

- Control of F(P)SO hull motions.
- Mooring lines maintenance and replacement.

F(P)SO heading control is a key requirement in managing F(P)SO maritime risk and maximising safety. Gaps in heading control assurance may result in heading control operations that lead to damaging live subsea infrastructure, F(P)SOs, HCTs or injuring personnel.

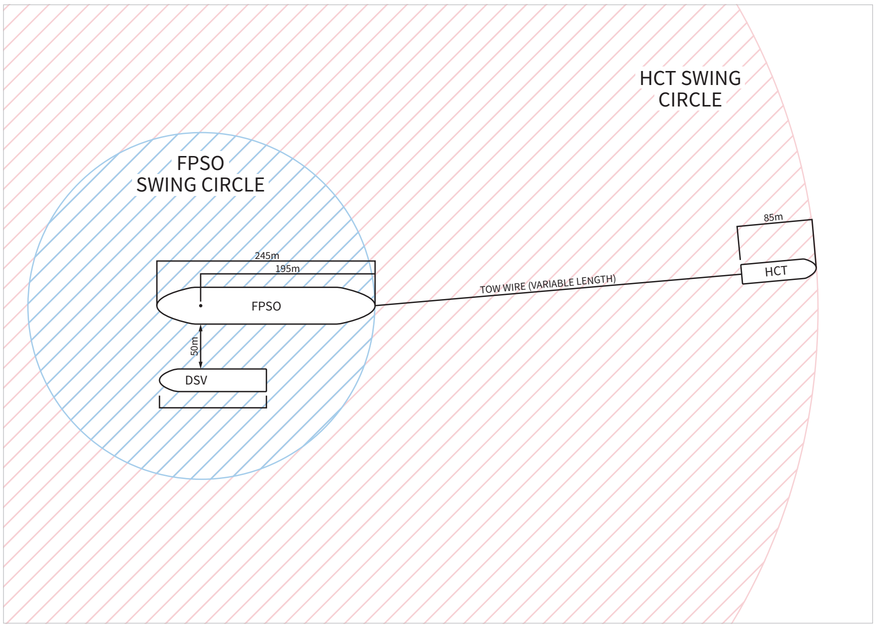


Figure 1: *F(P)SO swing circle*

Note that the radius of the HCT swing circle is depending on the length of towline paid out by the HCTs and will be variable during HCT operations.

2 Heading control assurance

Heading control assurance is the ability to validate capability and resources in a number of areas, including procedures, equipment and personnel. Heading control assurance activities should:

- Ensure that the consequences from loss of heading control for proposed operations are defined, minimised and managed to As Low As Reasonably Practicable (ALARP).
- Assess experience and competency level of personnel to verify decision-making skills, both ashore and on board the F(P)SO, HCTs and in-field vessels.
- Develop processes required for F(P)SO heading control and identify responses to potential incidents, upsets or failures, including:
  - Tow line catenary management from HCTs.
  - Water depth restrictions.
  - Weather and current restrictions.
  - Local environmental anomalies.
  - A tug's anchor handling manual that includes a static tow section, e.g. for heading control duties.
  - Primary and secondary means of F(P)SO heading control.
- Identify the configuration that achieves the highest level of F(P)SO heading control integrity:
  - HCT redundancy.
  - F(P)SO thruster redundancy.
  - A combination of the two above.
  - Assignment of primary and secondary heading control.

- Validate the F(P)SO operator's assessment that maintaining the F(P)SO heading is essential for the task and operation being carried out.
- Promote the use of established alert level identification and definition tools, e.g. Activity Specific Operating Guidelines (ASOG), that include decision-making trigger points for continuing or aborting operations.
- Identify the systems and processes in place to manage risk and changes to ensure that redundancy is not compromised. These should be in the technical operator's Safety Management System (SMS) and asset integrity programme, including Management of Change (MOC) procedures.
- Provide a bridging document between the parties involved in the F(P)SO heading control operations.

This publication is provided to:

- Be suitable for use across all types of turret moored F(P)SOs and associated in-field operations.
- Document F(P)SO heading control assurance categories based on the potential consequences of a loss of F(P)SO heading.
- Support the F(P)SO's technical operator's Marine Responsible Person to assess the F(P)SO heading control capabilities or HCTs, including the technical operator's management system to ensure that everything is working effectively before heading control operations begin.
- Ensure that all required equipment is in place, including an integrated vessel position monitoring system, on all vessels to provide an overall view of ongoing operations.
- Define the provision of experienced Tow Masters for 24-hour operations.
- Ensure Hazard Identification (HAZID)/Hazard Identification and Risk Assessment (HIRA) are being held. Participants are typically HCT key crew members, F(P)SO Tow Master, F(P)SO technical operator's responsible marine person and a Safety Adviser.
- Ensure that HCTs crew receive an appropriate safety briefing.
- Establish safe connect/disconnect zones, e.g. areas clear of subsea assets.

2.1 Consequences of loss of F(P)SO heading control

Depending upon the purpose of the heading control, the consequences of loss of heading control include:

- Excessive motions, rolling, pitching or heave.
- Personal injury.
- Compromised diving operations.
- Compromised cross rigging at turret/swivel.
- Compromised risers and/or umbilicals.
- Loss of containment.
- Collision with support vessels.

F(P)SO site-specific heading control assurance should address:

- The purpose of F(P)SO heading control.
- The consequences of a loss of F(P)SO heading control.
- Primary and secondary means of F(P)SO heading control.
- Development of effective measures to reduce the impact of a loss of F(P)SO heading control.
- Marine vessel quality assurance.
- F(P)SO thruster assurance.
- Tow Master and personnel competency.
- Tug bollard pull selection and towing assembly requirements.

Operational controls should be in place to reduce the risk of a loss of F(P)SO heading control.

A risk assessment should be conducted before operations begin to identify all hazards, consequences and remedial actions to manage the risks to ALARP.

Operational status, including reduced performance conditions, should be documented in the ASOG. Where operations are suspended because of equipment failure, they should only be resumed after completing a risk assessment. See the International Maritime Contractors Association's (IMCA) *M220 Guidance on Operational Activity Planning*.

2.2 Non-redundant F(P)SO heading control

For non-redundant F(P)SO heading control, loss of control may occur in the event of a single failure. A risk assessment focussed on the consequences of a loss of F(P)SO heading control for the proposed task should be documented.

2.3 Redundant F(P)SO heading control

For redundant F(P)SO heading control, loss of control should not occur in the event of a single failure. However, operational risk mitigation measures need to be documented to allow alignment with the task (e.g. diving or turret works) in case of loss of redundancy. Redundant heading control should be subject to verification so that cause and effect are known. This should include a verification of the Failure Mode Effect (and Consequence) Analysis FME(C)A and proving trials of F(P)SO thrusters and HCTs.

2.4 Risk-based approach

During low risk operations, non-redundant HCTs or non-redundant F(P)SO thruster heading control may be deployed where loss of heading control does not cause harm to people, the environment or damage to the facility. For higher risk operations, additional heading control assurance is recommended. A full suite of heading control assurance should be defined for the most complex F(P)SO operations and tasks with high risks, e.g. diving in the turret area or SIMOPS.

It is recommended that an Assurance Category Identification (ACID) tool is used to identify the level of heading control accuracy required. Chapter 3 details an ACID tool that defines three categories of risk: Category A (low risk), Category B (medium risk) and Category C (high risk). In the ACID tool, users assess the consequences of a loss of heading control and match it to the defined risk categories. The ACID tool may be used for any combination of F(P)SO operations, tasks to be performed and vessels in close proximity.

The F(P)SO and operation specific risk assessment should establish the consequences of a loss of heading control. The majority of heading control operations fall under Categories B and C.

Sections 3.1.1 to 3.1.3 detail heading control assurance activities for each risk category. It is recommended that users follow the defined heading control assurance activities for the F(P)SO, HCTs and other vessels. The most detailed and comprehensive heading control assurance activities are designed for Category C.

2.5 Heading Control Tugs heading control management and records

After conducting the relevant assurance as outlined in chapter 3, it is recommended that the following reviews are carried out:

- Confirm that heading control (static towing) operational observations and findings from the Offshore Vessel Inspection Questionnaire (OVIQ) and the range of pre-operation verification elements have been addressed by the technical operator, e.g. a static towing section in the HCT's operations tow manual.
- Confirm that relevant parts of the technical operator's Offshore Vessel Management and Self Assessment (OVMSA) submission and feedback have been incorporated into a continuous improvement plan.

3 Heading control: Assurance Category Identification (ACID) tool

Is the risk of F(P)SO heading control loss acceptable?

Yes → CATEGORY A

No → What is the level of incident severity following loss of F(P)SO heading control? → CATEGORY B / CATEGORY C

CATEGORY A (Low Risk)	**CATEGORY B (Medium Risk)**	**CATEGORY C (High Risk)**
Loss of F(P)SO heading control allows time to abort operations and safely clear the area, for example: • F(P)SO heading control towing catenary does not pose a risk to subsea infrastructure • F(P)SO not near any other vessels or structures • Low risk F(P)SO/in field task • F(P)SO maintains acceptable heading due to the prevailing environment conditions • F(P)SO heading control is used for non-safety critical activities such as personnel transfer, reducing hull motions Low level of heading control redundancy is acceptable.	Defined by the operator's control of work process, for example: • Activities ongoing in F(P)SO turret area that restrict F(P)SO heading change • A medium accuracy of heading control is required (< 10 degrees) Medium level of heading control redundancy is required, e.g. one DP 2 classed HCT, one HCT combined with non-redundant F(P)SO heading control thrusters.	Defined by the operator's control of work process, for example: • F(P)SO heading control towing catenary poses a risk to subsea infrastructure and live pipelines, risers and F(P)SO production installation • SIMOPS such as: – Other (DP) vessels or structures near the F(P)SO – Diving operations ongoing in the turret area – A high accuracy of heading control is required (< 5 degrees) – F(P)SO heading control is used for safety critical activities High level of heading control redundancy is required, e.g. two DP 2 classed HCTs or redundant F(P)SO heading control thruster system.

Note: where doubt exists as to the level of risk presented for a given vessel/F(P)SO task combination, select the next highest category of assurance.

3.1 Heading control assurance framework

When considering the use of a DP 2 classed HCT, the redundancy aspects of the HCT should be considered and not the operation of the HCT in DP mode.

3.1.1 Heading control assurance framework: Category A (low risk)

Assurance framework for HCTs			
Element	**Standard and/or Tools**	**Task**	**Best Practice**
HCT inspection	OVIQ Offshore Vessel Particulars Questionnaire (OVPQ)	Duty holder/F(P)SO operator reviews the inspection	Create a continuous improvement plan based on the observations and responses to the operations OVIQ questions Maintain an up-to-date OVPQ
HCT technical operator management capability	OVMSA	Duty holder/F(P)SO operator reviews the operator's OVMSA	Charterer reviews the OVMSA and uses it to create a continuous improvement plan/ contract management plan

Assurance framework for the F(P)SO with heading control capability			
Element	**Standard and/or Tools**	**Task**	**Best Practice**
F(P)SO Marine Assessment Questionnaire (F(P)SO MAQ) and F(P)SO technical operator management capability	F(P)SO MAQ	Duty holder/F(P)SO operator reviews the MAQ inspection	Create a continuous improvement plan based on the observations and responses to the operations MAQ Review and update the Asset Integrity Management of heading control systems

3.1.2 Heading control assurance framework: Category B (medium risk)

Assurance framework for HCTs in addition to Category A (low risk)			
Element	**Standard and/or Tools**	**Task**	**Best Practice**
HCT inspection	OVIQ OVPQ	Duty holder/F(P)SO operator reviews the inspection Close out all observations before beginning any heading control operations	Create a continuous improvement plan based on the observations and responses to the operations OVIQ questions Maintain an up-to-date OVPQ
HCT technical operator management capability	OVMSA	Duty holder/F(P)SO operator reviews the operator's OVMSA	Review the OVMSA and use it to create a continuous improvement plan/contract management plan
System design and Worst-Case Failure Design Intent (WCFDI)	Marine Safety Committee (MSC)/Circ.645 *Guidelines for Vessels with Dynamic Positioning Systems* MSC.1/Circ.1580 *Guidelines for Vessels and Units with Dynamic Positioning Systems* Redundancy concept (or equivalent) Assigned Class notation	Duty holder/F(P)SO operator reviews the WCFDI and verifies against the principles of the design philosophy The design philosophy should be assessed against the requirements created by the proposed task requiring F(P)SO heading control by a review of the FME(C)A (updated following any modifications)	Review should include: • Valid bollard pull test certificate • Capability plots • FME(C)A (as written) • Acceptance tests • Periodic testing requirements • Maintenance* • Inspection* *Include management and oversight
DP proving trials	MSC/Circ.645 *Guidelines for Vessels with Dynamic Positioning Systems* MSC.1/Circ.1580 *Guidelines for Vessels and Units with Dynamic Positioning Systems* DP class notation	Charterer's responsible marine person reviews evidence that DP proving trials have taken place	DP proving trials should be completed every five years
Annual DP trials	MSC/Circ.645 *Guidelines for Vessels with Dynamic Positioning Systems* MSC.1/Circ.1580 *Guidelines for Vessels and Units with Dynamic Positioning System* and Class rules, IMCA M190 *Guidance for developing and conducting DP annual trials programmes* and Marine Technology Society (MTS) MTS Dynamic Positioning Committee (DPC) guidance	Charterer's responsible marine person reviews evidence that annual DP trials have taken place	Record observations from trials, develop lessons learned and incorporate into future training programmes
Management bridging document between parties involved in the operations	Individual charterer's Contractor SMS requirements	Bridging document to be agreed between all parties involved	Outcome from HAZID, HIRA and Risk Assessment (RA) should be covered by the bridging document

Assurance framework for the F(P)SO in addition to Category A (low risk)			
Element using HCTs	**Standard and/or Tools**	**Task**	**Best Practice**
Competence assessment of F(P)SO manning	OCIMF's *Competence Assurance Guidelines for F(P)SOs*	Duty holder/F(P)SO operator reviews competency of F(P)SO manning	Two Tow Masters with Master Mariner qualification for 24-hour coverage
System design and WCFDI	OCIMF's *Mooring Equipment Guidelines*	Duty holder/F(P)SO operator reviews the WCFDI	Towing connection strong points and fairleads
ASOG/F(P)SO Specific Operating Guidelines F(P)SO heading control operations manual for critical activities	IMCA *M220 Guidance on Operational Activity Planning* and Marine Technology Society (MTS) MTS DPC guidance	Duty holder/F(P)SO operator responsible marine person to review F(P)SO operator is accountable for the establishment of appropriate alert levels (ASOG/Work Specific Operating Guidelines (WSOG))	Recommend that the F(P)SO operator Subject Matter Expert (SME) updates and verifies the operations manual to comply with the task requirements ASOG reviewed for each new activity and/or periodically for common tasks

Assurance framework for the F(P)SO with redundant heading control capabilities in addition to Category A (low risk)			
Element	**Standard and/or Tools**	**Task**	**Best Practice**
F(P)SO inspection and F(P)SO technical operator management capability	F(P)SO MAQ	Review of the F(P)SO MAQ-based inspection with emphasis on elements specific to F(P)SO heading control Risk assess and address all observations before beginning any F(P)SO heading control operations	Create a continuous improvement plan based on the observations and responses to the MAQ questions
F(P)SO manning dedicated for heading control task	OCIMF's *Competence Assurance Guidelines for F(P)SOs*	F(P)SO operator reviews competency of F(P)SO manning	Minimum requirement is one Competent Person for each shift while the F(P)SO is engaged in heading control operations by means of redundant F(P)SO thrusters/propulsion
System design and WCFDI	Redundancy concept as laid out in: MSC/Circ.645 *Guidelines for Vessels with Dynamic Positioning Systems* and MSC.1/Circ.1580 *Guidelines for Vessels and Units with Dynamic Positioning System*	Review of the WCFDI and verification against the principles of the design philosophy	Review should include: • Capability plot for heading control duties • FME(C)A (as updated) • Acceptance tests • Periodic testing requirements • Maintenance* • Inspection* *Include management and oversight

Assurance framework for the F(P)SO with redundant heading control capabilities in addition to Category A (low risk)			
Element	**Standard and/or Tools**	**Task**	**Best Practice**
ASOG/F(P)SO Specific Operating Guidelines	IMCA *M220 Guidance on Operational Activity Planning* and MTS MTS DPC guidance	Responsible marine person to review F(P)SO technical operator is accountable for the establishment of appropriate alert levels (ASOG/WSOG)	Critical activity F(P)SO heading control operations manual (reviewed for each new activity and/or periodically)
Management bridging document between parties involved in the operations	Individual charterer's Contractor SMS requirements	Bridging document to be agreed between all parties involved	Outcome from HAZID, HIRA and RA should be covered by the bridging document

3.1.3 Heading control assurance framework: Category C (high risk)

Assurance framework for HCTs in addition to Categories A and B (low and medium risk)			
Element	**Standard and/or Tools**	**Task**	**Best Practice**
System design and WCFDI	OCIMF's *Dynamic Positioning Assurance Framework: Risk-based Guidance* MSC/Circ.645 *Guidelines for Vessels with Dynamic Positioning Systems* MSC.1/Circ.1580 *Guidelines for Vessels and Units with Dynamic Positioning Systems* Redundancy concept or equivalent addressed for Category B	Duty holder/F(P)SO operator reviews the WCFDI and verifies against the principles of the design philosophy The design philosophy should be assessed against the requirements created by the proposed task by a review of the FMEA (updated following any modifications)	Review should include: • Valid bollard pull test certificate • Capability plots • FMEA (as written) • Acceptance tests • Periodic testing requirements • Maintenance* • Inspection* *Include management and oversight
Proving trials	OCIMF's *Dynamic Positioning Assurance Framework: Risk-based Guidance*	SME to review trials under direction of responsible marine person	Proving trials should be completed every five years
Annual DP trials	OCIMF's *Dynamic Positioning Assurance Framework: Risk-based Guidance*	DP SME to review trials under direction of responsible marine person	Record observations from trials, develop lessons learned and incorporate into future training programmes If changes to the DP system are required as the result of a review, the DP system designer, equipment manufacturer and the Classification Society should be engaged Implement MOC process

Assurance framework for HCTs in addition to Categories A and B (low and medium risk)			
Element	**Standard and/or Tools**	**Task**	**Best Practice**
ASOG/F(P)SO Specific Operating Guidelines Critical activity F(P)O heading control operations manual	*DNVGL-RP-E307 Dynamic positioning systems – operation guidance* IMCA *M220 Guidance on Operational Activity Planning* And MTS DPC operations guidance addressed for Category B	DP SME under direction of responsible marine person Technical operator is accountable for the establishment of appropriate alert levels (ASOG/WSOG)	Recommend that the charterer's DP SME updates and verifies the operations manual to comply with task requirements ASOG reviewed for each new activity and/or periodically for common tasks

Assurance framework for the F(P)SO with redundant heading control capabilities Category C (high risk) in addition to Categories A and B (low and medium risk)			
Element	**Standard and/or Tools**	**Task**	**Best Practice**
ASOG/F(P)SO Specific Operating Guidelines F(P)SO heading control operations manual for critical activities	*DNVGL-RP-E307 Dynamic positioning systems – operation guidance* In addition to IMCA *M220 Guidance on Operational Activity Planning* and MTS DP operations guidance addressed for Category B	Responsible marine person to review F(P)SO technical operator is accountable for the establishment of appropriate alert levels (ASOG)	Critical activity F(P)SO heading control operations manual (reviewed for each new activity and/or periodically)

4 Hazards

Several events may affect heading control operations and be a hazard that could result in a loss of F(P)SO heading control. The consequences of each identified hazard should be evaluated, with mitigating measures and operational limits set accordingly.

4.1 Metocean conditions

Metocean conditions that influence maintaining F(P)SO heading control include:

- Wind on topsides and accommodation.
- Waves on the hull.
- Current, including solitons, river plumes or local current anomalies.
- Wind, waves and swell, including non-co-linear directions.

These metocean conditions are used as the primary input to the heading control tool to determine the required HCT bollard pull and F(P)SO thruster force (see chapter 10). Environmental conditions and weather forecasts should be monitored with all available resources to ensure that operational limiting conditions are not exceeded. Environmental conditions can change rapidly. Particular attention should be given to:

- Passing fronts.
- Approaching squalls.
- Solitons.
- Excessive river flooding outflow plumes.
- Reduced visibility including darkness, fog and dust storms.
- Ice.

Site-specific weather forecasts should be received at time intervals derived from a risk assessment. Forecasts should be sent to the F(P)SO, HCTs and in-field vessels. Forecasts should include isobaric synopsis and forecast charts as well as written forecast conditions. Environmental conditions should be closely monitored by all parties to ensure that a controlled suspension of operations can be safely achieved if weather and sea conditions deteriorate.

The F(P)SO Offshore Installation Manager (OIM), Marine Responsible Person, Tow Master, Activity Responsible Person (e.g. dive supervisor) and HCT Masters should review the forecast and considering the documented operational window, decide when operations are suspended.

If a forecast will exceed any one of the operational limits the decision to remain connected on slack wire or release the tow should be made by the OIM in consultation with the HCT Masters, F(P)SO Marine Responsible Person and F(P)SO Tow Master. Consideration should be given to the safety of personnel and assets.

Operational limits and consecutive actions to be taken should be defined in the F(P)SO heading control operations manual, ASOG and should include trigger points. See section 4.7.1. for guidance on ASOG.

4.2 Heading control equipment failure

HCT equipment failure or F(P)SO thruster failure is any mechanical, electrical or control failure on the HCT or F(P)SO which prevents, or may prevent, the HCT or F(P)SO from holding position and F(P)SO heading control.

Equipment failure may result in loss of redundancy, or in the case of low risk operations the loss of F(P)SO heading control.

4.2.1 Heading Control Tug power failures

Selecting an HCT designed to or exceeding DP 2 Class redundancy will reduce the potential for a loss of F(P)SO heading control. With a DP 2 HCT, a failure will reduce position keeping capability and the available bollard pull to a maximum of 50% power output.

The use of two HCTs can give the same level of redundancy, where the smallest HCT can provide at least 100% of the required bollard pull to maintain the F(P)SO required heading. Where no redundancy is used, in low risk heading control operations, failure of the HCT will allow the F(P)SO to return to its natural weathervane heading.

4.2.2 F(P)SO thruster failures

When a F(P)SO is fitted with one or more thrusters, the setup of the drive system should be carefully analysed. Although the F(P)SO may be equipped with two thrusters, a single component failure may result in loss of both thrusters due to design.

When the F(P)SO thruster drive system is designed, tested and maintained according to the DP 2 concept, a Worst-Case Failure (WCF) will reduce the position keeping capability and the available thruster force to a maximum of 50%. A complete loss of heading control capability is considered avoidable.

When only one thruster is available, or no redundancy is used, for low risk heading control operations, failure of the single thruster will result in the F(P)SO to return to its natural weathervane heading. When a second thruster is available, this may reduce the rate of turn of the F(P)SO to return to its natural heading.

4.2.3 Combined F(P)SO thruster and Heading Control Tug operation

When required, F(P)SO heading control redundancy can be achieved by using one or more F(P)SO thrusters combined with one or more HCTs. Depending on the configuration of F(P)SO thrusters and HCTs, either the F(P)SO thrusters or the HCTs, are selected as primary and the others as secondary means of F(P)SO heading control.

If a failure affecting the propulsion or positioning happens on the F(P)SO or HCTs, all stakeholders should be informed by the F(P)SO Tow Master or F(P)SO Marine Responsible Person.

When two HCTs are used in combination with a F(P)SO thruster, it is recommended that, as a minimum, the HCT on the weather side of the F(P)SO has sufficient redundancy in its propulsion systems to safely abort operations in case of a single failure. Otherwise, a drift-on situation between HCTs or HCT and F(P)SO may happen.

4.2.4 Heading control using multiple Heading Control Tugs

Loss of propulsion or control on a non-redundant HCT introduces the risk of collision between the HCT and F(P)SO, between HCTs or between the HCT and other in-field vessels. When multiple HCTs are needed to provide the required redundancy for F(P)SO heading control, the HCT selection and specification and the positioning of each HCT requires careful consideration. Careful consideration is required in relation to the possible risks of loss of heading control of the F(P)SO and the work activities required in the field.

HCT selection considerations include:

- F(P)SO required heading in relation to metocean conditions: F(P)SO heading requires redundant HCTs to be on the weather side of the F(P)SO. Having a drift-on scenario part failure of propulsion on one redundant HCT should not impact the second HCT.
- High accuracy F(P)SO heading control: Place HCTs on port and starboard of F(P)SO. One HCT part failure of propulsion results in loss of accurate heading control accuracy.
- Availability and place on deck of towing strong points or brackets.

A redundant HCT should have a bollard pull of at least 100% required for F(P)SO heading control after a single failure in the propulsion systems occurs.

4.2.5 Towline assembly failure

Failure of a towline under tension can cause damage to equipment on the HCT and/or F(P)SO. The loss of F(P)SO heading control introduces a risk to the personnel and equipment involved in the operation.

The failure of any equipment component, from F(P)SO towing strong point to HCT towing winch, which causes the loss of the towline should be communicated to all parties concerned. Activities affected by loss of F(P)SO heading control should be suspended.

The F(P)SO and HCT positions and length of failed wire in relation to any subsea infrastructure should be evaluated. The HCT Master should be advised whether or not to remain in position to avoid fouling subsea equipment. When an HCT is required to manoeuvre clear of the F(P)SO 500m zone, care should be taken not to foul the HCT propulsion when manoeuvring away.

The failed tow line should be retrieved as much as possible at the HCT and F(P)SO ends. For a single HCT failure, the F(P)SO will naturally weathervane following a towline assembly failure. When available, the F(P)SO may use its thrusters to maintain heading control or dampen the F(P)SO's rate of turn. The risk of fouling the thrusters with the remainder of the towline should be considered, before using the thrusters.

With multiple HCTs, the redundant HCT will maintain control of the F(P)SO's heading. After assessing the situation and suspending all heading control related work activities, the F(P)SO may be allowed to weathervane to a natural heading in the prevailing conditions.

An HCT may be reconnected by using the spare tow wire, following the same procedure as for the initial connection. Operations can be resumed following normal procedures after an evaluation of the root cause for towline failure and mitigation measures are implemented to avoid recurrence.

4.3 Subsea hazard

Subsea equipment can present a hazard for ongoing operations. HCT towline length, tension and weight as related to the submerged curve assumed by the towline between the towing vessel and the F(P)SO can have a direct impact, if not managed properly.

It is important that F(P)SO and HCT operators understand the catenary depth of the towline in relation to the seabed depth and subsea hazards, natural and structural, to avoid fouling the towline and/or damaging subsea equipment.

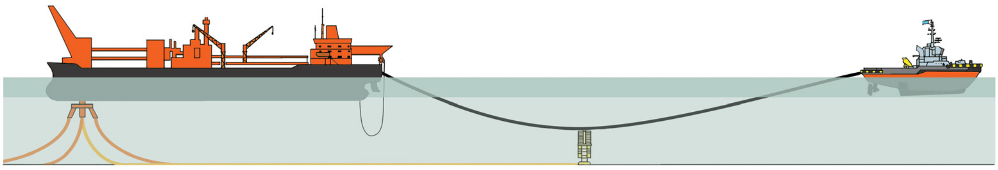


Figure 4.1: *Side view of tandem: F(P)SO + towing line with catenary + tug and subsea infrastructure*

4.3.1 Water depth

A full field evaluation of the intended HCT static towing area of operation for F(P)SO heading control should be conducted. This evaluation should identify all subsea hazards within the HCT range of operation including:

- Depth of water including applicable reduction for sea state and tidal conditions.
- Natural sea bottom obstructions.
- Sea bottom oil field fixed structures and equipment, including manifolds.
- Submerged oil field fixed structures and equipment, including mid water arch buoys.

4.3.2 Consequences of failure to manage the towline catenary

An example of the consequences of failing to manage the towline catenary was when an HCT was connected via a towline to an F(P)SO.

In this incident, the HAZID for the activity did not address the specific risk of damaging a high-pressure live gas export pipeline from the F(P)SO, should the low point of the towline catenary contact the seabed.

The HCT was being manoeuvred in DP mode and there was only one DP Officer on the HCT bridge during this operation.

When the F(P)SO weathervaned to a new heading on the turn of the tide, the distance between the HCT and the F(P)SO was allowed to decrease along with a decrease in the tension applied to the towline. This resulted in such an increase in the depth of the towline catenary that it touched the seabed.

The towline then caught on a flange on the live gas export pipeline and tore it from part of the subsea structure, which resulted in a major hydrocarbon release.

4.3.3 Calculation of catenary

To avoid dragging and/or fouling the HCT towline with subsea hazards, the towline catenary depth should be calculated for operating areas that present subsea obstructions. To estimate catenary depth, the following is required:

- Steady tension of the towline.
- Total overall length of the towline and related components.
- The weight per unit length in water of the towline and each component, which is provided by the HCT operator.

See chapter 10 for detailed calculation of bollard pull requirements and catenary depth.

4.3.4 Underwater field layout

To prevent damage from a towline or dropped objects, vulnerable subsea infrastructure should be identified. Most subsea infrastructure is mat-protected to withstand impact from dropped objects. However, in case of a tow wire catenary contacting the subsea structure, this protection may not be effective.

The F(P)SO's field specific marine operations manual should contain subsurface layout drawings that include areas marked that may be vulnerable to:

- Dropped objects (see figure 4.2).
- A dragging slack towing wire fouling subsea infrastructure (see figure 4.3).

Figure 4.2: *Subsea layout indicating areas vulnerable to dropped objects*

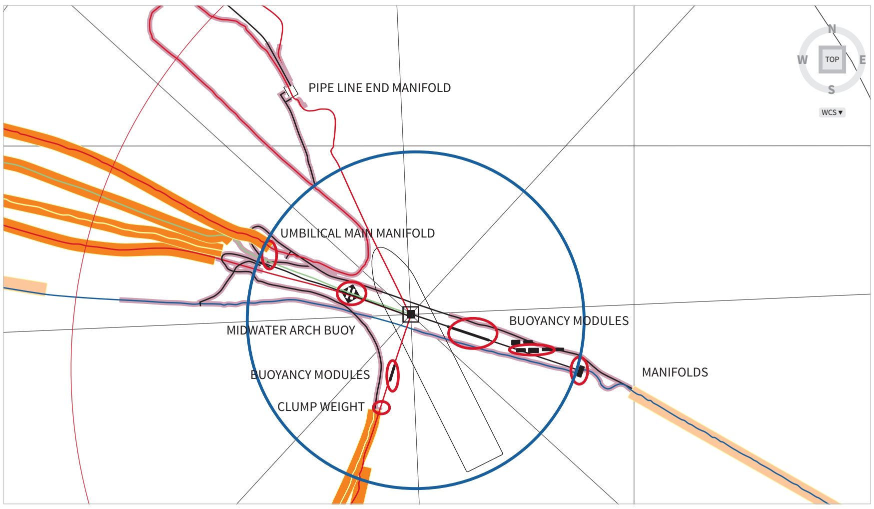


Figure 4.3: *Subsea layout indicating areas vulnerable to a dragging tow wire*

4.4 Loss of communications

Loss of, or interruption of, communications presents a risk that commands are not delivered and/or understood, which could result in required actions not properly carried out (see chapter 9).

4.5 Human factors

Human error is the failure of a planned action to achieve a desired outcome. Failures in planning and execution can result in not achieving the desired outcome.

The potential for human errors in carrying out a planned action should be evaluated when assessing safety critical steps within the heading control operation. This is done by determining the potential for human failures when carrying out activities, confirming the adequacy of control measures and, where necessary, identifying any additional controls that may need to be put in place to prevent or mitigate the risks identified.

Factors to consider:

- Competency and training.
- Communication.
- Fatigue or prolonged repetition of work.
- Initial design of equipment and human-machine interfaces.
- Alarm monitoring and management.

4.6 Simultaneous Operations and Heading Control Tugs

SIMOPS matrices are setup to compare activities against each other. When undertaking heading control operations, there may be more than two activities being carried out at the same time. In advance, each pair of planned activities should be assessed for potential hazards. If activities occur simultaneously, it is recommended that priority is given to one activity over the other. Reference should be made to SIMOPS matrices.

In the event of an emergency situation on the F(P)SO, HCTs or any of the involved field vessels or the activity itself, any ongoing work is to be suspended and workplaces made safe.

4.6.1 Diving

The need for diving operations, e.g. in the turret area, is a reason why heading control operations are undertaken to make the dive area as safe as possible. Any loss of heading control poses a risk for divers.

To manage risks in diving operations to ALARP, it is recommended that there is redundancy in heading control management.

Supply vessel operations should be avoided so as not to pose a potential hazard to any HCT or ongoing dive operation due to a loss of position of the supply vessel (see section 4.6.5).

4.6.2 Remote Operated Vehicle operations

Recommendations for diving operations also apply to ROV operations. The need for a ROV operation, e.g. in the turret area, is one reason why heading control operations are undertaken to make the ROV area as safe as possible. Any loss of heading control poses a risk for the ROV and its mother vessel, when the ROV is not launched directly from the F(P)SO.

Supply vessel operations should be avoided so as not to pose a potential hazard to any HCT, ongoing ROV operation or ROV mother vessel (see section 4.6.5).

4.6.3 Turret works

During turret works, there could be a conflict of activities, i.e. riser/umbilical hook-up, pressurisation of pipe work, rigging and lifting activities, including cross rigging and work taking place in close proximity to other work.

A loss of heading control can lead to two or more ongoing activities to occur simultaneously when they were well separated and under control while under heading control.

When activities take place in the turret area, HCT redundancy should be according to the DP Class 2 philosophy.

4.6.4 Cross rigging with chains, ropes and hoses

Typical turret works that require cross rigging and for which heading control is required is an umbilical or riser pull in.

When cross rigging takes place in the turret area, HCT redundancy should be according to the DP Class 2 philosophy.

Other maintenance work on a turret may also require cross rigging but does not necessarily require heading control, e.g. where an air hose is used to power tools.

4.6.5 Supply vessel operations

Depending on the activity, supply vessel operations should be avoided, e.g. when high risk turret works are ongoing, such as an umbilical or riser pull in.

Apart from sufficient personnel being available to handle the supply vessel, a loss pf position of the supply vessel can adversely impact the safe operation of the HCTs and the safe execution of the main activities.

When supply vessel operations are unavoidable, consideration should be given to the position of the offshore installation vessel, assisting Anchor Handling Tug and Supply (AHTS) vessel and Dive Support Vessel (DSV) so that their escape routes are not impeded.

Consideration should be given to lifting of containers and equipment during heading control operations. If a load is dropped on or near equipment under hydrocarbon pressure, this could result in loss of containment.

The method used for station keeping of the supply vessel should be reviewed, and the following considered:

- Is the supply vessel DP 2 classed and can it operate in DP 2 mode?
- Does the vessel maintain manual station keeping?
- Does the vessel maintain DP assisted station keeping?
- Will the supply vessel be moored alongside the F(P)SO?

Heading control may be used to enable supply vessel operations, e.g. when environmental conditions are such that the F(P)SO is rolling for a prolonged period of time. A change in heading may enable safe crane operations.

4.6.6 Personnel transfer

Personnel transfer during activities that require heading control should be avoided. Personnel should be transferred before beginning or after completing the activity that requires heading control.

A change in heading may enable the possibility to do basket transfers or provide a lee for a crew tender to come alongside.

When heading control is used to enable personnel transfer operations, the considerations in section 4.6.5 should be followed.

4.6.7 Helicopter operations

When helicopter operations are performed during activities that require heading control operations, it may not be possible to change the heading during ongoing activities. The F(P)SO may roll more than is safe for the helicopter to land.

Consideration should be given to the flight paths of the helicopter during approach and take off. The heliport should be advised that the F(P)SO is engaged in heading control operations.

4.6.8 Offtake tanker operations

Offtake tanker operations during activities that require heading control should not be performed simultaneously.

4.6.9 Gas venting requirements

During tank venting, hydrocarbon vapours that are released could reach a source of ignition at the work site, or drift over an HCT. Gas venting should not be performed during heading control operations for an ongoing activity.

During gas venting operations in calm weather and light winds, heading control may be a mitigating measure to force the wind across deck. The HCT should always be upwind of the F(P)SO in such operations and venting should be stopped immediately if heading control is lost.

4.6.10 Interference with Lifesaving Appliances equipment

Interference with Lifesaving Appliances (LSA) equipment should be avoided. When this may not be possible due to the positions of, for example, the Totally Enclosed Motor Propelled Survival Craft (TEMPSC) above a towing strong point, additional operational procedures should be in place. An example procedure would be the release of the HCT delaying or impeding the operation of the TEMPSC.

4.7 Emergency preparedness

Operational procedures should be in place to reduce the consequences of a loss of heading control. The HAZID should identify hazards, their associated risks and document the mitigations required to manage the risks to ALARP.

When HCTs are used, failure of one HCT may present a risk to another HCT and/or the F(P)SO.

Emergency procedures should include the mitigating actions to be taken in the event of HCT failure.

Because F(P)SOs require site specific activity heading control set-ups, emergency scenarios will depend on the specific situation. The scenarios should be documented in the ASOG.

Crew members of HCTs and the F(P)SO should understand their roles and responsibilities in an emergency situation. They should be familiar with the use and safe operation of site-specific towing and release equipment on board their vessel.

Emergency disconnection of HCTs should be possible with a towline that is under tension while ensuring the safety of personnel involved in the emergency disconnection.

4.7.1 F(P)SO Activity Specific Operating Guidelines

F(P)SOs should have their own ASOG (see OCIMF's *Dynamic Positioning Assurance Framework: Risk-based Guidance*).

Before beginning operations, the status of the F(P)SO and HCTs should be confirmed as per ASOG green level and confirmed green at agreed intervals throughout the heading control operations.

5 F(P)SO heading control system redundancy

Based on the ACID tool (see chapter 3), the following redundancy is recommended for the three risk levels (low, medium and high).

Low risk
No redundancy in heading control is required. A single F(P)SO thruster or a single HCT may be used for heading control. The F(P)SO thruster nor the HCT does not have to be redundant in design. It is recommended that an alternative heading control system could be made available when required.

Medium risk
Redundancy in heading control is required but not to the extent of 100% continuous operations.

An HCT with 100% of the required bollard pull may be backed up by a second HCT with 50% of the required bollard pull, or a limited capacity F(P)SO thruster. A loss of capacity on the main HCT can then be partially compensated by the backup system, while reducing the operational limits.

When a single F(P)SO thruster is used, it should be backed up by an HCT which may not be fully redundant but will limit the consequences of loss of the thruster to ALARP. Where no backup is used, i.e. for supply vessel or crew operations, this should be risk assessed and operational limits established.

When multiple F(P)SO thrusters are used, it is preferable that the thrusters back up each other but they may be used to their capacities. Operational limits should be established to manage the consequences of losing one thruster to ALARP.

High risk
Redundancy is required to be able to safely abort operations or to the extent of 100% continuous operations. This may be achieved with, e.g.:

- Multiple F(P)SO thrusters (2 x 100% or 3 x 50%), operated in a configuration equivalent to DP Class 2 equipment redundancy principles (control, power supply and auxiliaries) will provide full redundancy for heading control.
- Fully redundant multiple HCTs, with towing connection strong points and fairleads available on the F(P)SO and fairleads available on the F(P)SO.
- Sufficient key personnel to manage operations.

Redundancy in systems can be achieved by:

- F(P)SO design and operations.
- HCT design and operations.
- One or more HCTs combined with one or more F(P)SO thrusters.

When active heading control is categorised as safety critical, it should meet DP 2 classed standards for redundancy in systems.

Redundancy levels may be defined as:

- Non-redundant heading control:
  - A heading control operation where:
    - No equipment is duplicated on a single HCT, or
    - No equipment is set to a maximum operating limit

    for preventing loss of the controlled heading of the F(P)SO upon failure of a single component.

- Redundant heading control:
  - A heading control operation where:
    - Equipment is duplicated, or
    - Set to a maximum operating limit

  for preventing loss of the controlled heading of the F(P)SO upon failure of a single component, i.e. use of dual engines in a single tug whereby one engine is redundant of the other.

Note:

- A single HCT with a single propeller drive is considered non-redundant.
- Multiple HCTs with a single propeller drive may be considered redundant to each other when they are equal in bollard pull.
- A single HCT with dual propeller drives is considered limited redundancy. Failure of the towline will result in the loss of control of the heading of the F(P)SO.
- Multiple HCTs with dual propeller drives may be considered redundant. Failure of a towline will result in the loss of one HCT, while the second (redundant) HCT will take over the duty.

		Low		Medium		High	
		Single	Multi	Single	Multi	Single	Multi
HCT	Non-redundant	✓	✓	✗	✓	✗	!
	Limited Redundant	✓	✓	!	✓	✗	!
	Redundant	✓	✓	✓	✓	(✓)	✓
F(P)SO Thruster	Non-redundant	✓	✓	✗	✓	✗	!
	Limited Redundant	✓	✓	!	✓	✗	!
	Redundant	✓	✓	✓	✓	✗	✓
Marine Responsible Person	For HCT operations <12 hours	✓	✓	✓	(!)	✗	✗
Tow Master(s)		✓	✓	✓	✓	✓	✓

✓	No restrictions
(✓)	HCT is redundant according to DP 2 Class or DP 3 Class and fitted with dual tow drums that can be simultaneously deployed
!	Pay attention to possible limited redundancy or non-redundancy
(!)	Preference should be given to a dedicated Tow Master
✗	Not recommended

Table 5.1: *Use of single/multiple HCTs or F(P)SO thruster: not combined*

5.1 F(P)SO design and operations

5.1.1 F(P)SO design

During the design phase of the F(P)SO, the operator should decide if the F(P)SO is:

- Passive weathervaning.
- Heading assist.
- Active heading control.

Passive weather vaning F(P)SOs require HCT compatible mooring arrangements to carry out heading control with HCT assistance. This includes towing strong points, fairleads, winches and redundant equipment. It is recommended that at least two sets of HCT strong points and fairleads are available on the F(P)SO to be able to perform high risk heading control operations.

Heading assisted F(P)SOs achieve heading control via installed thrusters. The thrusters have often limited capacity to maintain every required heading. To carry out heading control with the assistance of HCTs, HCT compatible mooring arrangements should be available when required. This includes towing strong points, fairleads, winches and redundancy equipment. It is recommended that at least two sets of HCT strong points and fairleads should be available on the F(P)SO to enable high risk heading control operations.

5.1.2 F(P)SO redundancy

For continuous F(P)SO operations, the following redundancy is recommended:

- Operational thrusters ready for use.
- Qualified marine crew to support continuous operations.
- Qualified Tow Masters for continuous operation.

For short-term heading control operations (less than 12 hours), a Marine Responsible Person from the F(P)SO crew may be employed.

For long-term heading control operations, it is recommended that dedicated Tow Masters are employed. Tow Masters can be chosen from company Mooring Masters who have experience with heading control operations (see table 5.1).

5.2 Heading Control Tug design and operations

5.2.1 Heading Control Tug design

HCT redundancy can be achieved by:

- An HCT with DP 2 classed capabilities.
- An HCT with dual or triple propeller drives.
- Multiple HCTs of which at least one is redundant to the other HCTs.
- Multiple towing drums and related towing assemblies.
- Spare towing assembly.

Dependent on the heading control requirement, HCT selection should be risk-based and the following considered as a minimum:

For low risk heading control operations:

- Single HCT with no redundancy requirements.

A loss of heading control is allowed. Turning of the F(P)SO to her natural weathervaned heading does not cause harm to people and does not cause damage to equipment or the environment.

For medium risk heading control operations:

- Two limited redundant HCTs, or
- One redundant HCT with DP 2 classification, with:
  - Multiple towing drums and related towing assemblies, or
  - Spare towing assemblies.

For high risk heading control operations:

- Two redundant HCTs, or
- Two redundant HCTs with DP 2 classification, or
- One redundant HCT and one redundant HCT with DP 2 classification, with:
  - Multiple towing drums and related towing assemblies, or
  - Spare towing assemblies.

5.2.2 Heading Control Tug operations

For HCT operations, the following redundancy is required:

- Operational HCTs.
- Qualified marine crew capable of short-term operations.
- Qualified additional officers for continuous operation.

For long-term heading control operations (more than 12 hours), it is recommended that additional qualified officers are employed who have experience with heading control operations.

5.3 Redundancy for F(P)SO thrusters and Heading Control Tugs combined

In addition to the guidance in sections 5.1 and 5.2, when F(P)SO thrusters cannot maintain the required heading in metocean conditions, or when the activity risk levels are medium or high risk, HCT support is required. The following should be considered in the risk management process:

- Prevailing metocean conditions.
- Available F(P)SO thruster power.
- Availability of towing strong points on the F(P)SO for HCT connection.
- Redundancy of F(P)SO thrusters.
- Redundancy of HCTs.
- Required heading control accuracy.
- Possible F(P)SO thruster(s) and HCT(s) combinations (see table 5.2).

HCT and F(P)SO Thruster Combined[1]			F(P)SO Thruster						
				Non Redundant		Limited Redundant		Redundant	
			None	Single	Multi	Single	Multi	Single	Multi
HCT		None		L	M[2]	M	M	M	H
	Non-redundant	Single	L	M[2]	M	M	M	M	H
		Multi	M[2]	M	M	M	M	M	H
	Limited Redundant	Single	M	M	M	M	M	M[2]	H
		Multi	M	M	M	M	M[2]	H[3]	H
	Redundant	Single	M	M	M	M[2]	H[3]	H	H
		Multi	H	H	H	H	H	H	H

Table 5.2: *Use of single/multiple HCTs/F(P)SO thruster combinations for low risk (L), medium risk (M) and high risk (H)*

Notes to table 5.2:

[1] In table 5.2, each higher level of F(P)SO thruster redundancy and HCT redundancy may be used for lower levels of redundancy, e.g. multi-redundant HCTs may be used not only for high risk operations but also for medium risk operations.

[2] Medium risk combinations, indicated as M[2], should be risk assessed for the purpose of the heading control. When redundancy is required, the remaining required bollard pull or thruster force should be enough in case of the loss of one HCT or F(P)SO thruster, e.g. an HCT with a single propeller drive is limited redundant, although the use of two of those HCTs gives a redundant combination for propeller drive and towline arrangement.

[3] High risk combinations, indicated H[3], should be risk assessed for the purpose of the heading control. Because redundancy is required, the remaining required bollard pull or thruster force should be enough in case of the loss of one HCT or F(P)SO thruster.

6 Crew training and competency

Deck crews on board F(P)SOs are usually made up of personnel from a non-marine background, such as crane operators or riggers. These personnel may not be aware of or recognise the hazards and potential consequences of connecting and disconnecting HCTs. Operators should ensure that all personnel involved in HCT connection/disconnection operations are trained and are competent to carry out the task safely.

It is recommended that the scope of personnel competence assessment activities is undertaken in accordance with the guidance in OCIMF's *Competence Assurance Guidelines for F(P)SOs: Risk-based Guidance*. See OCIMF's *Effective Mooring*.

6.1 Awareness of mooring equipment

Many F(P)SOs have limited mooring equipment available, which can complicate the HCT connection/disconnection process. All personnel involved in HCT connection/disconnection should fully understand the documented limitations of the mooring equipment available and should be competent in the operation of all equipment. This knowledge should be verified via the F(P)SO competence programme.

6.2 Connection/Disconnection procedure

F(P)SO specific procedures should be developed by the F(P)SO operator. These procedures should detail the step-by-step process for HCT connection/disconnection. Copies of the procedure should be available on board the F(P)SO and the HCT(s). The procedure should detail the hazards of the operation, including, but not limited to, danger zones that should be avoided when lines are under tension. Procedures should detail the communications protocol to be followed (see chapter 9).

The procedure should be discussed between all parties involved, including the HCT Master. All parties should be aware of their individual roles and responsibilities and should be fully aware of the hazards.

6.3 Use of Tow Master

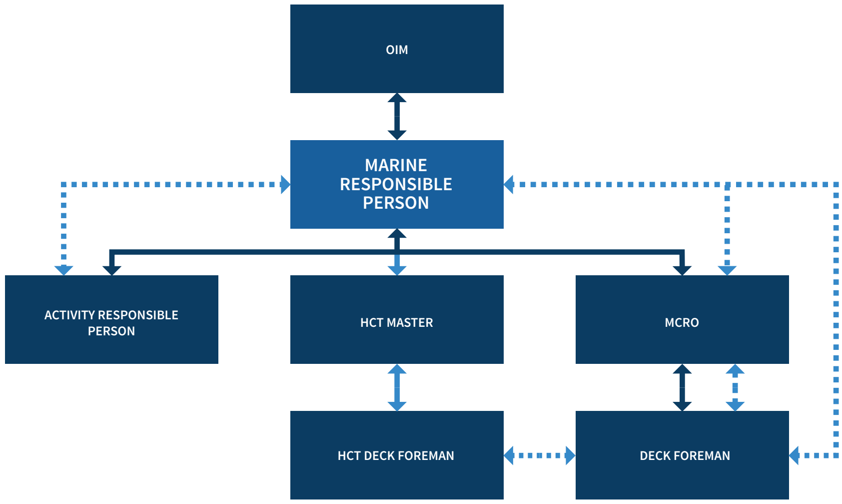
Heading control of an F(P)SO via HCTs is a complex task that requires constant monitoring of F(P)SO heading and directing of the HCTs. F(P)SO heading control can be safety critical, especially when divers are operating in the vicinity of the F(P)SO.

Because of the specialised nature and complexity of the task and to reduce the work load of the F(P)SO marine department, it is recommended that operators use a dedicated Tow Master to monitor and direct heading control operations of the F(P)SO. The Tow Master should be qualified, possess the necessary experience and be dedicated to monitoring the F(P)SO heading and directing the HCTs so as to effectively maintain heading without distraction from normal F(P)SO operations.

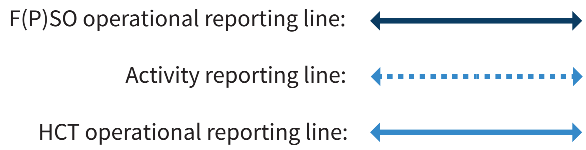
When there is no dedicated Tow Master, a single Marine Responsible Person should be appointed to make the decision on aborting operations.

6.4 Reporting line for heading control operations

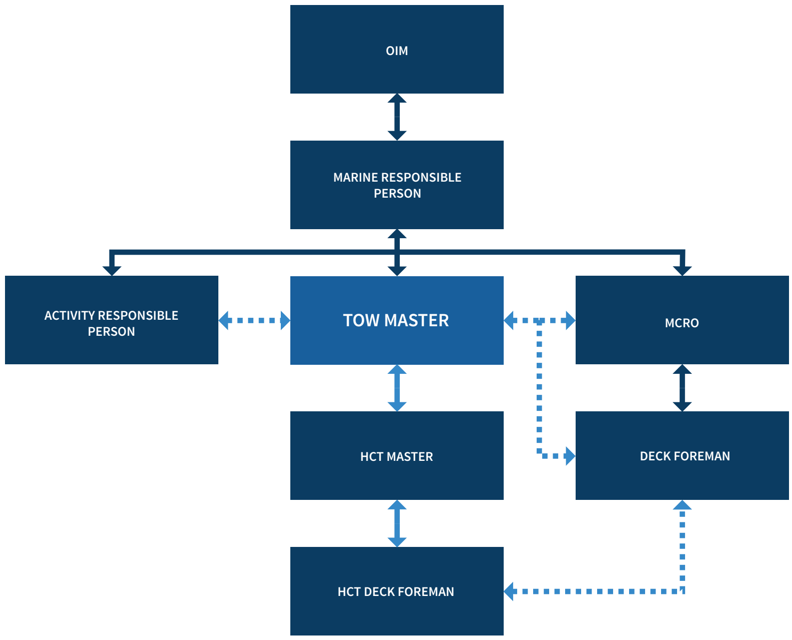
The flowcharts below visualise the recommended reporting lines when a Marine Responsible Person is in charge of directing the HCT(s) and when a dedicated Tow Master is in charge of directing the HCT(s).



Marine reporting lines without Tow Master



Reporting lines legend



Marine reporting lines with Tow Master

6.5 Roles, accountability and responsibilities

OIM: The OIM is accountable for all personnel and operations on board the F(P)SO and within the 500m zone. The decision on HCT connection/disconnection is made by the OIM, in consultation with the Marine Responsible Person and Tow Master.

Marine Responsible Person: The Marine Responsible Person acts as the OIM's delegate for marine operations, including SIMOPS. The Marine Responsible Person is responsible for the safe conduct of heading control operations. They collect data on the status of ongoing operations to feedback into the daily progress meetings of the ongoing operations.

Information collected and distributed should include as a minimum pevailing and forecasted weather conditions, HCT, DSV and Offshore Construction Vessel (OCV) technical status, as applicable. When a Tow Master is available, the Marine Responsible Person consults with the Tow Master to determine if conditions are suitable for the proposed heading control operations.

Activity Responsible Person: The Activity Responsible Person, e.g. Dive Supervisor, Project Manager or OCV Master is responsible for the safe execution of the activity which requires F(P)SO heading control.

Tow Master: The Tow Master is responsible for maintaining the required F(P)SO heading by directing the position of the HCTs, the length of the tow wire and the bollard pull applied by the HCTs. The Tow Master communicates directly with the HCTs. The Tow Master monitors ongoing operations including prevailing and forecast environmental conditions and may decide to abort work activities and suspend heading control operations based on information received.

Marine Control Room Operator (MCRO): The MCRO is responsible for vessel movements, including SIMOPS, within the F(P)SO 500m zone and ensures vessels are fully compliant before allowing them to enter. During ongoing heading control operations, this should be done in consultation with the Marine Responsible Person or Tow Master.

HCT Master: The HCT Master is responsible for the safe operation of their vessel. The HCT Master takes instruction from the Tow Master in order to maintain the F(P)SO heading.

Field Support Vessel (FSV) Master: The FSV Master is responsible for the safe operation of their vessel. The FSV Master involved with the activity that requires the heading control operation takes instruction from the Activity Responsible Person, or in case of suspension of operations from the Marine Responsible Person or Tow Master. Other FSV Masters take instruction from the MCRO responsible for vessel movements.

7 Requirements for F(P)SO deck equipment

F(P)SO deck mooring fittings and the associated machinery (winches, capstans) are not regularly used once the F(P)SO is moored on station. During the construction phase, safe mooring is the builder's responsibility, but the owner/operator should be satisfied that the mooring arrangement is suitable for future offshore operations. Consideration for the maintenance of the deck equipment should be given for service life requirements.

All mooring, towing and emergency towing equipment should be approved by a recognised Classification Society and should comply with SOLAS requirements and OCIMF's *Mooring Equipment Guidelines*.

7.1 Service life requirements

OCIMF's *Mooring Equipment Guidelines* is a useful reference for basic mooring design requirements and layout. However, the windage area on F(P)SOs is significantly larger than a tanker and therefore wind loading should be revised.

Provisions for F(P)SO heading control operations should be made available as a minimum on the port and starboard sides of the F(P)SO. Where a turret is located nearly midships, towing strong points may be located both forward and aft. On yoke moored F(P)SOs, the towing strong points may be placed forward. Consideration should be given to the design of the towing strong points, to allow for the safe release of towlines, especially in emergency scenarios.

For converted tankers, a design and condition assessment should be completed for the original mooring fittings to verify suitability. When they do not meet the service life requirements, they should be refurbished, upgraded or replaced.

Deck machinery should be included in the operator's Maintenance Management System (MMS), including inspection of hydraulic and pneumatic airlines. Small bore tubing failure on older assets has been a common source of leaks and spills. The MMS should include the inspection of all fixed deck fittings (fairleads, bits, bollards and pedestal rollers).

7.2 Deck layout and line-up of equipment

For the deck layout and line-up of equipment, the following should be considered:

- Deck fitting arrangements should be provided according to OCIMF's *Mooring Equipment Guidelines*. Winches and capstans should have line-of-sight to the fairleads, with minimum changes in direction.
- The use of pedestal rollers is not recommended within the design. However, where fitted, they should either be maintenance free with closed bearings or have grease nipples for routine maintenance of the bearings.
- Lines should not foul or be hampered by other deck equipment such as hawser reel, hose reel or quick release hooks.
- Adequate safe working areas and space for handling several lines and stowing loose tails should be available.
- Operator height should be considered as part of the ergonomic design.
- Final design to be reviewed by the marine operations department.

7.3 Winches and capstans

For winches and capstans, a critical spares strategy should be documented. With regard to the design and deck layout, the following should be considered:

- Design of winches and deck machinery should allow for easy maintenance.
- Winches should be capable of being powered from a secondary power source.
- Underdeck support structure should be designed according to the relevant Classification Society rules.
- All winches, new and refurbished, should be verified for their lifting power.
- F(P)SO crew should ensure that winch heaving capacity is rated for the intended lifts.

Capstans are not recommended unless purpose designed for the task. Where a purpose-designed capstan is fitted, it should:

- Be located with clear runs to each fairlead, bitt and towing strong point that they serve. For safe operations a minimum clear access around the capstan of at least 1m should be available.
- Include control positions clear of line routings. Capstan control points for remote operation may be considered.
- Control points should be protected against heavy weather damage.
- Redundant supply for air winches and capstans should be considered.

7.4 Chocks and fairleads

It is recommended that chocks and fairleads should be designed in line with OCIMF's *Mooring Equipment Guidelines* and be Class approved. The following are the key points to be considered:

- Fairleads designated for towing lines should be sized to accept the required size of chafing chain.

- The size and radius of fairleads should match the line diameter.
- Chocks and fairleads should be included in an inspection programme that includes non-destructive testing.

7.5 Towing strong point

The towing strong point where the HCT towline will be connected to the F(P)SO can consist of any of the following (in order of preference):

- Manually operated towing bracket capable of release of a tow wire under load (see figure 7.1).
- Quick release hook normally used for offload operations but able to release the tow wire under load (see figure 7.2).
- Mooring bitts have limited use as the Safe Working Load (SWL) is often low and a tow wire under load cannot be released without risk to personnel without additional equipment.

During the design stage of the F(P)SO, it is recommended that a study is made to identify the worst environmental conditions under which a heading control operation would be conducted. The study should determine the maximum bollard pull required to maintain the F(P)SO heading by one or more HCTs, with or without F(P)SO thrusters where available. The SWL (i.e. 200 tonnes (t), 250t or 300t) and the operating envelop as per design should be documented in the ASOG (see section 4.7.1).

This study is typically a task that involves the marine operations and engineering departments.

The towing strong point should be included in an inspection programme that includes non-destructive testing.

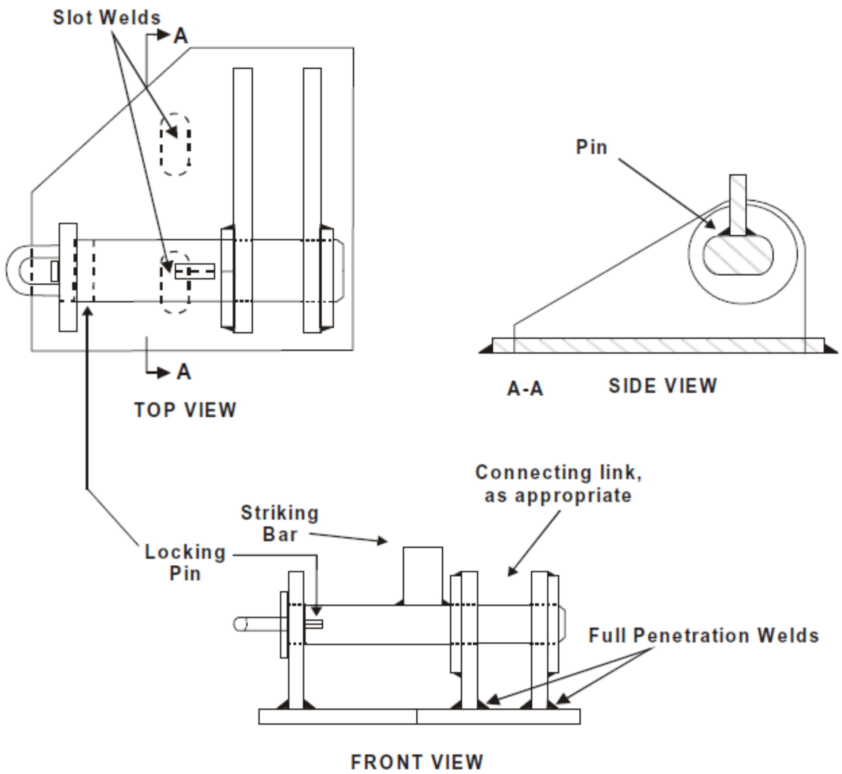


Figure 7.1: *Manual operated towing bracket*

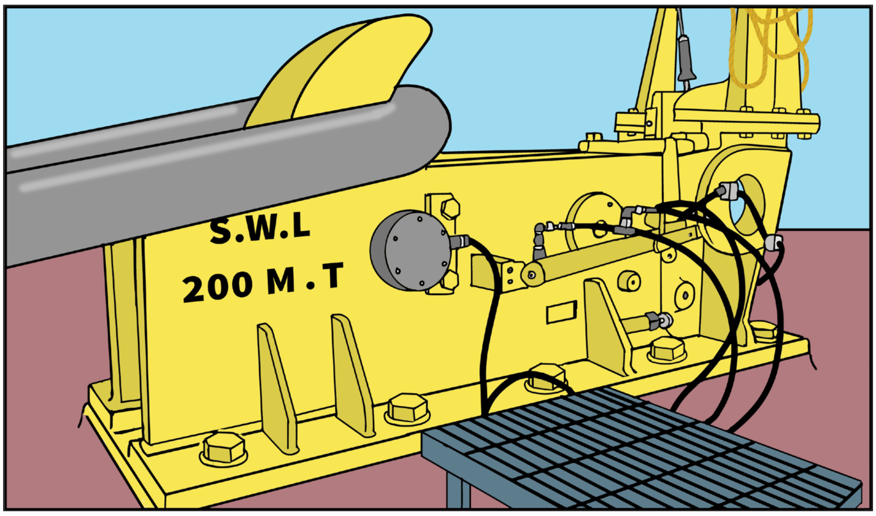


Figure 7.2: *Hydraulic operated quick release hook*

7.5.1 Heading Control Tug emergency release from F(P)SO

The F(P)SO towing strong point should be able to release the towline hydraulically or manually when under load. A release under load may be necessary when an HCT is in danger or when the weather deteriorates and a normal release is not possible. To be redundant, remotely operated hydraulic release systems should have a manual local control.

To open a towing bracket under load, a sledgehammer has to be used on the striking bar. To help open the pin, a manually operated wire rope winch, chain block or winch can be used. The design layout should be in such a way that this can be done in a direct line (see figure 7.3).

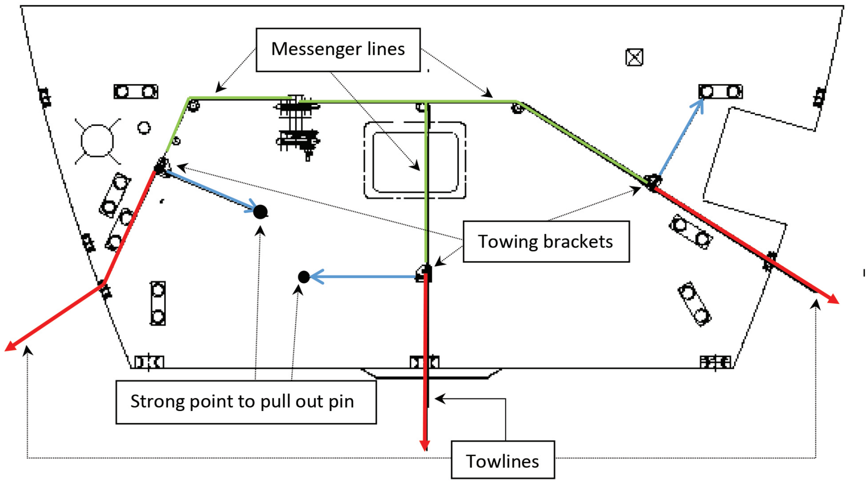


Figure 7.3: *Example aft deck lay-out with three towing brackets*

A safer method that does not require crew to stand next to the towing bracket or use a line under tension is to fit an emergency release tool in the chafe chain. When only bitts are available to connect the HCT's towline, the same release tool can be used.

The tool is fitted between the towing bracket or bitts and chafe chain or pennant. When required, the two operating parts can be hydraulic separated to release the towline (see figure 7.4).

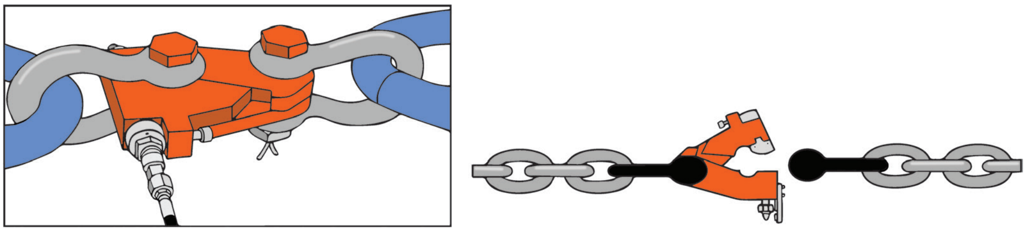


Figure 7.4: *Hydraulic operated emergency release tool*

In addition to being able to release the towline, the F(P)SO should be able to retrieve a towline which fails during HCT operations. Because of the limited capacity of the F(P)SO deck winches or capstans, it is important that the point of failing is as close as possible to the F(P)SO. This can be achieved by provision of a weak link between the F(P)SO chafe chain or F(P)SO towing pennant and HCT towline. See OCIMF's *Static Towing Assembly Guidelines (STAG)* for additional information on fitting of weak links in a towline assembly.

7.6 Messenger lines

Messenger lines should be strong enough to lift the towing assembly up to the F(P)SO. They should also be long enough to work with the HCT at a safe distance when working in higher sea states. Spare messenger lines should be held on board. All lines should be registered in an inspection and retirement criteria programme.

8 Heading Control Tug suitability

8.1 Capabilities

The functional requirement for a HCT is the ability to operate in close proximity to an F(P)SO, connect using a towline and apply a towing force to control the heading of the F(P)SO.

Because HCTs are required to work in close proximity to the F(P)SO in varying environmental conditions, they should be highly manoeuvrable and have enough reserve power to minimise the risk of collision in the event of any system failure.

It is recommended that F(P)SO operators conduct an analysis of the continuous bollard pull capability of proposed HCTs to ensure it is sufficient for the intended operation.

The HCT bollard pull should be certified by a valid bollard pull test certificate to ensure that the required bollard pull for operations can be met.

8.2 Heading Control Tug selection for suitability

The F(P)SO operator should verify that any proposed HCT is suitable for the intended use by performing a suitability survey, or alternatively by reviewing an existing suitability survey report.

The HCT suitability for the intended operation should be checked by comparing the vessel's capabilities against the specific operational requirements. The F(P)SO operator should ensure that the HCT complies with the following:

- The HCT towing equipment design should allow easy connection of the towline to be easily connected with minimum human intervention on the deck. Disconnection of towing equipment in adverse weather can be very hazardous and the design should minimise risk to personnel.
- The loads on towing equipment should be capable of being monitored from the HCT bridge.
- The HCT should be equipped with a galvanised, lubricated and certified tow wire that is mounted on the towing winch. A second winch with suitable tow wire is recommended for redundancy purposes.

- When an HCT is not fitted with a constant tension winch, or when the length of the towline is restricted, a nylon stretcher should be used outboard of the towline to help absorb shock loading. The Work Load Limit (WLL) of the stretcher should be as per OCIMF's *STAG.* Spare stretchers should be available to guarantee redundancy for the operations.

8.2.1 Alignment with *Static Towing Assembly Guidelines*

The purpose of OCIMF's *STAG* is 'to provide technical guidance on selecting fit for purpose towing assemblies that minimise risk of injury to crew members or damage to equipment, and to optimise the effectiveness of static towing operations.'

The majority of the technical advice and recommendations provided in *STAG* is applicable to heading control operations of F(P)SOs and it is recommended that operators of F(P)SOs should refer to *STAG* for towing technical assembly guidance.

Static towing operations differ from heading control operations in the following ways:

- The orientation of the HCT compared to the orientation of a hold-back tug. When an HCT pulls a F(P)SO into the weather, it will be orientated with the bow into the weather and so the tow wire will be over the stern. A pull-back tug will align with the weather and will usually deploy the towline leading from the bow to orientate itself also into the weather.
- Bollard pull requirements. Pulling into the weather requires more power and consequently a higher bollard pull.

The HCT should carry a fully certified spare set of connecting hardware required to connect to the F(P)SO. The connecting hardware, also known as jewelry, consists of shackles, chain links, special fittings, splices and end terminations for wire and synthetic line.

A remotely operated towing winch is an essential requirement for the safety of the crew and for effective recovery of towlines in adverse weather conditions.

The tow winch should include at least two drums: a working drum and a tow drum. The winch should be remotely operated from an aft bridge control console, preferably by single joystick operation. The tow winch's status (hydraulic pressure, brake position, speed, tow tension, line out) should be displayed at the winch operation console. Local winch controls should be positioned where they can be safely operated given that they may have to be operated while the winch and tow wire are under heavy load.

The winch should be designed with an emergency quick release mechanism that can release the winch brake and reduce the towline tension to maintain control of the vessel, including in circumstances that may cause girting or capsizing. Crew members should be familiar with these ship-specific arrangements, including any limitations. Emergency quick release arrangements may not always release immediately due to various factors such as the direction of pull and the heeling angle. Allowance should be made when considering an emergency quick release.

An HCT should be able to control the lead of the tow wire, using towing pins, a towing pod or a gob wire which can be mechanically operated from a remote location (e.g. a powered tugger winch or capstan) to prevent girting.

Information should be made available to the vessel's crew and displayed on the bridge, showing the maximum vertical and horizontal forces that can be exerted on the vessel while remaining within the International Maritime Organization's (IMO) stability criteria. This information should be displayed in an easy to understand format so that operators can check against the actual towline tension and ensure that they do not exceed the limiting criteria.

The aft deck should be fitted with remote operated hydraulic stoppers for securing the towline and pennants:

The stoppers should be equipped with suitable inserts for various wire sizes. The operating panel for the pins and forks should be at the aft bridge console. The panel should have status lights, with an audible warning to sound if hydraulic oil pressure is low.

The deck should also be equipped with remotely operated capped (or winged) towing pins close to the stern. These pins are designed to prevent the towline passing over the quarter.

8.2.2 Emergency response and contingency procedures

HCT selection should include specific emergency response procedures and duties in case an emergency develops on board the HCT. The crew should understand the effects of an emergency on board the HCT and the risk and consequences for the heading control operation.

As part of the preparedness for an emergency, the HCT crew should understand HCT emergency winch stop and release tests procedures.

HCTs should have an emergency stop and release system. These release systems should be capable of being remotely activated from the bridge and with a local manual override arrangement.

Maintenance and testing of winch gear and associated emergency stops and releases should be recorded in the vessels Planned Maintenance System (PMS) and be verified.

8.3 Heading control operations

When developing heading control procedures, the F(P)SO operator should determine the number of HCTs required for the operation and the optimal locations for connecting HCTs. The location and number of available towing strong points, their related deck fittings and the location of the F(P)SO turret affect these considerations.

Criticality of planned work also affects the number of HCTs required, for example:

- Any work involving divers and/or ROV operations within the F(P)SO swing circle requires a high degree of heading control and multiple HCTs should be considered.
- On an F(P)SO with forward accommodation and the turret situated astern of the accommodation, it may be necessary to connect the HCT on the bow, as this would provide the best lever for maintaining heading control.
- An F(P)SO may be fitted with only one towing strong point or bracket, located on the centre line aft, meaning only one HCT can be connected.

When only one towing strong point or bracket is fitted, the SWL of the deck equipment on the F(P)SO becomes the limiting factor regarding the operating envelope in which heading control operations can be undertaken.

8.4 Heading control trials

Heading control trials should be carried out to validate a planned operation. Trials should be carried out before the work scope and verified that the HCTs can be safely connected to the F(P)SO and maintain heading control through all tidal cycles of a day. Trials should include validation of redundancy systems.

9 Communication procedures

To ensure the safe control of operations, it is the responsibility of all parties to follow the documented communications procedures.

Information must be exchanged in English and/or the common working language.

The following should be agreed and documented by all parties involved with F(P)SO heading control:

- Primary communications.
- Secondary communications.
- Bridging document detailing communication requirements for SIMOPS.
- Dedicated external communications for tug operations.
- Communications checks and frequency of checks.
- Actions to take if primary and/or secondary communications are lost.
- Emergency signals.

Difficulties in verbal communications should be managed by a person with adequate technical and operational knowledge and a good command of the languages understood by all parties involved.

9.1 Internal communications

A clear line of internal communications should be defined during the job planning phase. Communications should remain available, open and reciprocal before, during and after completing the task.

The following are the primary points of contact for internal communication:

- OIM.
- Mooring Master/Tow Master.
- Marine Responsible Person.
- Activity Responsible Person.
- MCRO.
- Deck Foreman.

9.2 External communications

Designated F(P)SO contacts should be assigned to external marine support activities and associated external contacts that will be directed.

F(P)SOs communicate with the following external primary contacts:

- HCT Captains.
- HCT Mates.
- HCT Deck Foremen.
- Support Vessel Captains.
- Support Vessel Mates.
- Support Vessel Deck Foremen.

Additional external communications are required to manage the F(P)SO's 500m security zone.

9.3 Redundant/Emergency communications

When primary and secondary communications between the F(P)SO and the HCT(s) fail and cannot be restored, all heading control dependent activities should cease. HCT(s) should maintain the F(P)SO heading. Heading control dependent activities may resume when primary and secondary communications are restored.

9.4 Pre-operations meetings

A pre-operations meeting should take place before beginning the F(P)SO heading control operations. Appointed contacts responsible for carrying out the task (or their substitutes involved in the task) should meet face to face. Those attending the meeting should transfer all meeting information to their respective work force. The meeting should preferably take place onboard the F(P)SO but may easier be organised in an onshore location.

The following internal and external points of contact should attend:

- Onshore managers.
- OIM.
- Marine Responsible Person.
- Activity Responsible Person.
- Mooring Master/Tow Master.

- MCRO.
- HCT Masters.
- FSV Masters.

9.5 Communication protocol

To safely execute F(P)SO heading control operations, correct communications protocols should be established and followed.

Effective communications should be via a clear and agreed channel and may be face to face, or remote and be verbal or written.

The following protocol is recommended:

- Sender: The sender responsible for ensuring that information is clearly and completely communicated. The sender should request confirmation from the receiver that information is understood.
- Receiver: The receiver is responsible for ensuring that information received from the sender is complete. They should repeat the communication to ensure that there is no misunderstanding.

This protocol is commonly referred to as closed loop communication.

9.6 Information reporting requirements

The following information should be communicated at agreed intervals between the F(P)SO and the HCT(s):

- Tug power percentage applied.
- Tug line pull force applied.
- Tug heading as applied.
- Tug movement from applied position.
- Length of towline applied and change in catenary depth.
- Deficiencies with equipment or personnel.
- Operational status.

It is recommended that all vessels involved in the operations be fitted with a remote vessel position monitoring system based on satellite positioning to provide an overview of FSV locations.

10 Standard methodology to calculate tug bollard pull requirements

To support calculation of tug bollard pull requirements, an excel tool has been developed to evaluate the minimum bollard pull required to maintain heading control of a weathervaning F(P)SO.

The tool calculates the required HCT bollard pull needed for maintaining heading control of a turret moored F(P)SO in an environmental weather condition with current, wind and two wave systems. After each component is specified in magnitude and direction, the main parameters of the F(P)SO are used to estimate the resulting moment around the turret for various vessel headings. For the required heading, a transverse tug pull is calculated to balance the moment. The tool provides quasi-static snapshots for transient events and does not consider dynamic vessel motions.

With a specified length and weight of towline, the tool calculates the catenary depth of the towing line and visualises this to ensure it stays above the mooring lines and obstacles defined in the interface.

The applied sign convention and coordinate system are in accordance with the OCIMF standard. An overview of this standard is given in figure 10.1. The origin of the Local Coordinate System (LCS) is located at the intersection of the keel, centreline and halfway L_{pp}. A right-handed coordinate system is applicable.

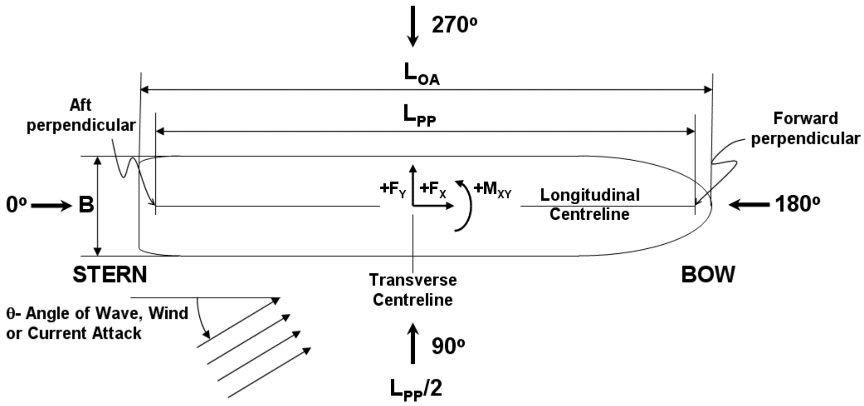


Figure 10.1: *General OCIMF convention*

The forces and moments are positive in the following directions:

positive longitudinal force	(F_x)	: towards the bow
positive lateral force	(F_y)	: towards port side
positive yaw moment	(M_z)	: bow towards port side

The relative environmental headings are defined as follows:

0 degree heading	: stern on
90 degrees heading	: starboard side on
180 degrees heading	: bow on
270 degrees heading	: port side on

10.1 Parameters used

Selection of HCTs depends on the F(P)SO dimensions and the weather conditions in which the F(P)SO heading needs to be controlled.

The relevant input parameters for the F(P)SO dimensions are:

Length	m	Length between perpendiculars.
Beam	m	Width of the F(P)SO.
Draft	m	If the vessel operates with a trim angle, specify the draft amidships.
Wind area	m^2	Only the lateral (side) area is required and should include both the hull area above the water line and all projected topside areas.
Turret location	m	The tool assumes the turret to be on the vessel centreline, the position of the centre of the turret forward of amidships needs to be specified. If this dimension exceeds half the vessel length, the turret is assumed to be an external turret above the waterline.

Environmental conditions are specified with the following parameters:

Wave height	m	Significant wave height of the sea or swell component.
Wave period	s	Wave peak period.
Gamma	[-]	Spectral shape parameter between 1 and 7. A larger value makes the results more sensitive to the wave periods. If this parameter is not available, it is recommended that a gamma of 1 for both sea and swell is used.
Wind speed	knots	One hour mean wind speed.

Current speed	knots	Equivalent current speed over draft of F(P)SO.
Directions	deg	Wind and wave directions are specified coming from compass directions and current direction going towards compass directions.

Up to two additional loads can be applied to the F(P)SO before the size of the HCTs and their pull direction are calculated. These external forces may represent:

- Mooring or riser load.
- F(P)SO thrusters.
- Second HCT working in the opposite direction of the main HCT.
- Any other known force acting on the equilibrium heading of the F(P)SO, i.e. a second HCT with a limited bollard pull different from the bollard pull of the main HCT.

The external (tug) forces are specified with the following parameters:

Force	tonne	Magnitude of the load or towing force.
Direction	deg	Compass direction towards.
Position	m	Position on the vessel in longitudinal direction is positive when forward of ½L_{pp} and negative when aft of ½L_{pp}. Position on the vessel in lateral direction is positive to portside of the centreline and negative to starboard of the centre line. For a tow pulling from a bracket on the starboard quarter, this position should be specified as -½B.

With the forces resulting from weather and external forces entered, the tool calculates the resulting equilibrium heading of the F(P)SO. If a different heading needs to be maintained, a towing force will be calculated based on the strong point location on the F(P)SO. This requires the following input:

Heading	deg	Required compass heading of the F(P)SO.
Position	m	Position of the strong point on the F(P)SO in longitudinal direction forward of amidships and in lateral direction portside of centreline. For an HCT pulling from a bracket on the portside stern, this position should be specified as –½L_{pp} and +½B.

It is possible to add a second HCT by increasing the number of tugs to two, but this requires specification of the required angle between the two HCTs. Both of these connect to the same strong point for the calculation in the tool, which is representative for the more practical situation of two tugs pulling from nearby brackets on the F(P)SO. The tool assumes that the bollard pull from both HCTs is equal. If the bollard pulls are not equal, one HCT should be represented by a vector. If more or different HCTs are involved in the operation, the user can specify some HCTs as external forces, such that the tool resolves the remaining required bollard pull to the tug(s) specified in this section.

To limit the allowable towing directions, the user can specify a green sector relative to the F(P)SO. These limits are specified as a minimum and maximum Ship Fixed (SF) towing angle. These angles are specified counterclockwise from the bow and are visualised with the green shaded area in the plot.

Reducing the allowable deviation of the heading control may further align the HCT towlines with the heading of the F(P)SO. This increases the stability of the heading, but requires larger bollard pull from the HCTs.

When the limits of the minimum and maximum SF towing angles are set further forward towards the bow of the F(PSO), a single HCT will pull at a maximum angle of 90 degrees with the centre line of the F(P)SO. This is because a transverse HCT pull is calculated to balance the moment for the required heading.

When the limits of the minimum and maximum SF towing angles are set further forward towards the bow of the F(PSO) and two HCTs are selected, the forward HCT is moved ½ the angle between the two HCTs further forward. This is because the tool divides the required transverse bollard pull equally between both HCTs.

The tool also uses input on the HCT parameters for visualisation and warnings. The length and width of the HCT is used for visualisation in the tool. If the required bollard pull calculate by the tool, exceeds the rated bollard pull multiplied by the bollard pull efficiency, the tool warns the user to increase the HCT size or number of HCTs.

The remaining input is used to calculate the catenary shape of the towline and mooring lines to identify possible interactions. The catenary shape of the towline follows from the deployed towline length and the towline weight in water. The weight in water can either be specified by the user or can be derived from input of the towline material and towline diameter.

The F(P)SO mooring line catenary also follows from the specified length, submerged weight and pretension of the lines. To visualise the complete F(P)SO mooring system, the number of mooring bundles, number of lines per bundle and the relative angle between lines is a mandatory entry.

Up to three obstacles can be defined to be added to the visual. Each obstacle is specified with its height above the seabed, the radius of the obstruction to specify its characteristic size, the heading sector from the turret and the distance from the turret. Elevations are plotted for three different depth limits with three different colours.

When an HCT reduces the applied bollard pull, the catenary depth will increase. To check what tension needs to be maintained in the line, a maximum catenary depth can be specified. The tool will display a warning message: 'Maintain at least xx tonne bollard pull to limit catenary depth to yy m'.

10.2 Formulae and coefficients

There are three different environmental forces: current, wind and mean wave drift forces that determine the heading of a free-weathervaning F(P)SO.

The mean current moment around a turret on the F(P)SO centreline is found from:

$$C = \tfrac{1}{2} \rho\, v^2\, T\, L_{pp} \left(CC_{mz}\, L_{pp} - CC_y\, X_{TUR} \right) \quad \text{(Formula 10-1)}$$

Similarly, the wind moment around the turret is calculated with the following formula:

$$W = \tfrac{1}{2} \rho\, v^2\, A_s \left(CW_{mz}\, L_{pp} - CW_y\, X_{TUR} \right) \quad \text{(Formula 10-2)}$$

Finally, the mean wave drift moment around the turret is calculated with

$$H = -\, L_{pp}\, H_s^2\, CH_y\, X_{TUR} \quad \text{(Formula 10-3)}$$

In which:

X_{TUR}	Turret location forward of amidships	[m]
ρ	Water or air density (specified as 1.025 and 0.00125)	[tonne/m^3]
v	Current or wind velocity	[m/s]
T	Draft	[m]
L_{pp}	Length between perpendiculars	[m]
A_s	Lateral (side) wind area	[m^2]
CC_y	Dimensionless sway current force coefficient	[-]
CC_{mz}	Dimensionless yaw current moment coefficient	[-]
CW_y	Dimensionless sway wind force coefficient	[-]
CW_{mz}	Dimensionless yaw wind moment coefficient	[-]
CH_y	Sway mean wave drift force coefficient	[kN/m^3]

The generic coefficients shown in figure 10.2 are used for the sway force and yaw moment around amidships. Two things should be noted:

- Figure 10.2 shows current force for two water depth over draft (WD/T) ratios. For other WD/T ratios, the tool linearly interpolates.
- Figure 10.2 shows the wave drift force for short waves. In long waves compared to the draft and beam of the F(P)SO this forces reduces to zero.

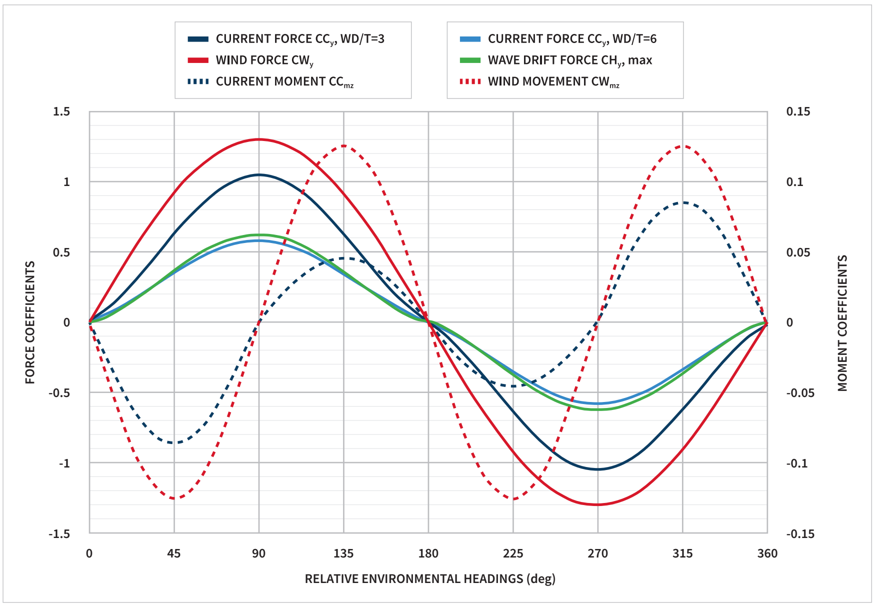


Figure 10.2: *Environmental force coefficients*

10.3 Example calculation

Calculate required bollard pull

To calculate the required bollard pull to maintain a required heading towards East (90 degrees) for a turret moored F(P)SO, the weather moments around the turret are calculated. This requires input for the weather and main dimensions of the F(P)SO. An example calculation is shown below for an F(P)SO in 100m water depth:

Water depth	100m
Length	300m
Draft	15m
Side wind area	2000m^2
Turret distance forward of amidships	120m

From figure 10.2 the load coefficients can be derived for a specific weather condition:

	Speed	Direction	Heading	CFy	CMz
Current	1 knot	to 170 deg	280 deg	-0.5667	0.02907
Wind	20 knots	from 0 deg	270 deg	-1.3	0
Wave	1.5m	from 45 deg	225 deg	-0.37163	

When these dimensions and coefficients are entered into the equations of the previous paragraph, the results are:

$C = ½ * 1.025 * (1 * 0.5144)^2 * 15 * 300 * (0.02907 * 300 + 0.5667 * 120) = 46,821\text{kNm}$

$W = ½ * 0.00125 * (20 * 0.5144)^2 * 2000 * (0 * 300 + 1.3 * 120) = 20,639\text{kNm}$

$H = –300 * 1.5^2 * (–0.37163 * 120) = 30,102\text{kNm}$

The transverse required force follows from the sum of these moments divided by the moment arm of the HCT around the turret. Assuming the HCT connects at aft perpendicular the output resulting is:

Current	46,821
Wind	20,639
Waves	30,102
Sum	97,562kNm
Arm	120 + 150m
Transverse force	361kN

For a towing sector up to 45 degrees from the centreline of the F(P)SO, this results in a similar longitudinal force astern of the F(P)SO, such that the total required force equals

$\sqrt{361^2 + 361^2}$ = 511kN (52 tonnes) bollard pull.

If the tow line is still on the seabed at this bollard pull, the tool increases the tow tension as shown in the towline catenary calculation.

Calculate towline catenary

To ensure the tow line remains off the seabed, the catenary depth is calculated and if this value exceeds the water depth the tow line tension is increased to keep the line off the seabed.

The catenary depth (C) of the tow line follows from its weight in water (TM), deployed towline length (TL) and the tow line tension (T) as follows:

$$C = \frac{T}{TM} * \left(1 - \sqrt{1 - \left(\frac{TM * TL}{2 * T}\right)^2}\right)$$

This towline tension (T) consists of a vertical component (TM * TL / 2) and a horizontal component calculated from the required bollard pull in the previous section:

With:

Tow line weight	0.2kN/m
Tow line length	600m
Required force	511kN

The output:

Vertical tension	0.2 * 600 / 2 = 60kN
Tow line tension	$\sqrt{(511^2 + 60^2)}$ = 514.5kN
Catenary depth	514.5 / 0.2 * (1 - $\sqrt{(1-(0.2 * 600 / 2 * 514.5)^2)}$ = 17.6m

The tool visualises the depth of towlines, mooring lines and obstructions with up to three colours. The orange colour is reserved for elements located between the still water line and the F(P)SO draft. The second blue colour indicates elements located from the draft of the F(P)SO to half of the water depth. Elements with depth beyond half the water depth are indicated as grey. An exception to this occurs when the towline catenary depth exceeds the draft and the grey colours start at this catenary depth level instead. The exact threshold is identified in the legend of the figure and ensures that it is always clear if the tow line is above the mooring lines (see example in figure 10.3).

Calculate equilibrium heading

Figure 10.3 also shows the equilibrium heading with a dashed orange outline of the F(P)SO. At this heading the total moment around the turret equals zero. This follows from the same equations as shown in section 10.2:

At a heading of 21 degrees:

Wind	4,068kNm
Current	9,094kNm
Waves	-13,162kNm
Sum	0kNm

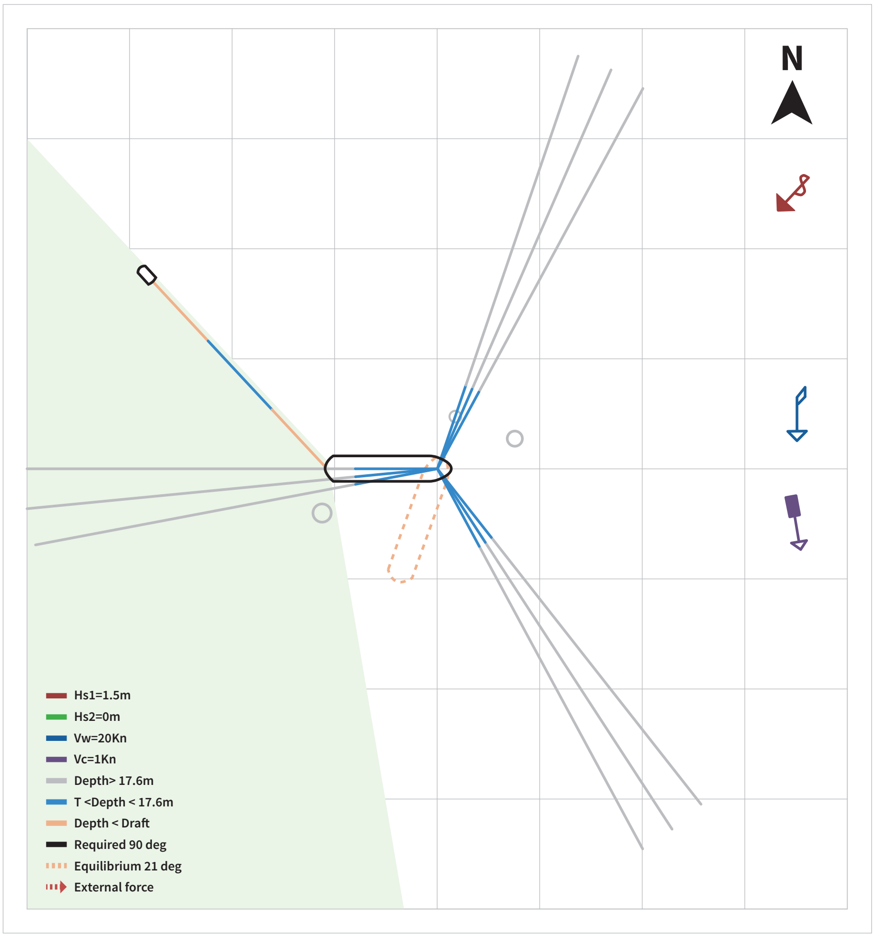
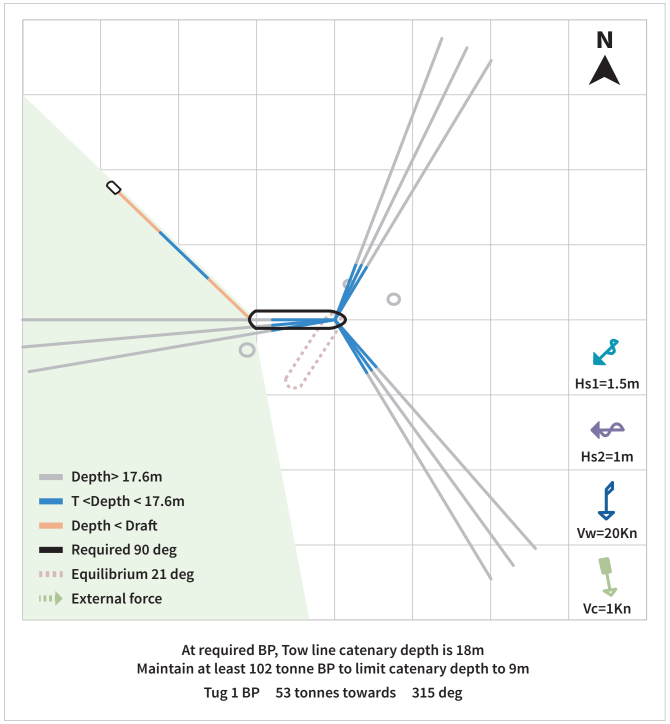


Figure 10.3: *Calculation example tug tool output*

The excel tool to make the calculations to evaluate the minimum bollard pull required to maintain heading control of a weathervaning F(P)SO can be downloaded from the OCIMF website.

An example of the tool input and output is shown in figure 10.4.

	Quantity	Symbol	Input	Units	Range	Used
Weather input	Significant sea wave height	Hs1	1.5	m	[0:5]	1.5
	Sea wave peak period	Tp1	4	s	[1:25]	4
	Sea Jonswap gamma value	$\gamma 1$	1		[1:7]	1
	Mean sea direction from	Dir1	45	deg	[0:360]	45
	Significant swell wave height	Hs2	1	m	[0:5]	1
	Swell wave peak period	Tp2	6	s	[1:25]	6
	Swell Jonswap gamma value	$\gamma 2$	1		[1:7]	1
	Mean swell direction from	Dir2	90	deg	[0:360]	90
	Mean wind speed	Vw	20	knots	[0:50]	20
	Wind direction coming from	Dir3	0	deg	[0:360]	0
	Mean current speed	Vc	1	knots	[0:10]	1
	Current direction towards	Dir4	170	deg	[0:360]	170
Force 1	External (thrust) force	Fext 1	0	tonne		0
	Direction of Load	Fdir1	90	deg	[0:360]	90
	Position lon fwd of midships	Xef1	-150	m	[$-L_{pp}$:L_{pp}]	-150
	Position lat PS of centerline	Yef1	10	m	[-B:B]	10
Force 2	External (thrust) force	Fext2	0	tonne		0
	Direction of Load	Fdir2	0	deg	[0:360]	0
	Position lon fwd of midships	Xef2	-100	m	[$-L_{pp}$:L_{pp}]	-100
	Position lat PS of centerline	Yef2	0	m	[-B:B]	0
Heading control	Required heading	Heading	90	deg	[0:360]	90
	Allowable deviation	Hdev	5	deg	[0:180]	5
	Strong point lon fwd of midships	Xsp	-150	m	[-300:300]	-150
	Strong point lat ps of centerline	Ysp	0	m	[-50:50]	0
	Number of tugs	No	1	-	[1 or 2]	1
	Angle between tugs	Tdir	60	deg	[0:180]	0
	Minimum SF towing angle	Pdirm	135	deg	<165	135
	Maximum SF towing angle	Pdirp	280	deg	>195	280
Towline	Deployed towline length	TL	600	m	[0:600]	600
	Towline material	TT	user def			200
	Main towline weight in water	TM	200	N/m	[0.1:1000]	200



	Quantity	Symbol	Input	Units	Range	Used
Tug input	Length between perpendiculars	$L_{pp}2$	50	m	[0:150]	50
	Width	B2	20	m	[0:50]	20
	Rated bollard pull	BP	100	tonne	[0:300]	100
	Bollard Pull Efficiency	Eff	75	%	[0:100]	75
FPSO input	Length between perpendiculars	L_{pp}	300	m	[100:500]	300
	Width	B	50	m	[30:80]	50
	Draft	T	15	m	[5:25]	15
	Wind side area	A_s	2000	m^2	[5L:60L]	2000
	Turret location fwd of midship	X_{TUR}	120	m	[0:L_{pp}]	120
Mooring Lines	Water depth	WD	100	m	[30:10000]	100
	Number of bundles	NB	3	-	[1:40]	3
	Number of lines per bundle	NL	3	-	[0:13]	3
	Angle between lines	aML	5	deg	[0:40]	5
	Heading line 1	Ldir	20	deg	[0:360]	20
	Mooring Line Length	LL	1000	m	[>WD]	1000
	Mooring Line Pretension	LT	200	tonne	[2:200]	200
	Mooring line material	MT	steel wire			100
	Mooring line diameter	MD	54	mm	[20:200]	54
obstacle 1	Height above seabed	h1	10	m	[0:100]	10
	Radius of obstruction 1	r1	10	m	[0:500]	10
	Sector from turret	s1	20	deg	[0:360]	20
	Distance from turret	d1	125	m	[0:1000]	125
obstacle 2	Height above seabed	h2	20	m	[0:100]	20
	Radius of obstruction 2	r2	15	m	[0:500]	15
	Sector from turret	s2	70	deg	[0:360]	70
	Distance from turret	d2	200	m	[0:1000]	200
obstacle 3	Height above seabed	h3	30	m	[0:100]	30
	Radius of obstruction 3	r3	20	m	[0:500]	20
	Sector from turret	s3	250	deg	[0:360]	250
	Distance from turret	d3	300	m	[0:1000]	300
	Maximum Catenary Depth		9	m	[1:100]	9

Figure 10.4: *Example tool input and output*

Our vision

A global marine industry that causes no harm to people or the environment

Oil Companies
International Marine Forum
29 Queen Anne's Gate
London SW1H 9BU
United Kingdom

T +44 (0)20 7654 1200
E enquiries@ocimf.org

ocimf.org