Arctic Mooring Guidance

Summary Guidance Document

For Arctic Mooring JIP

GMH-8500-3122

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1. INTRODUCTION

1.1 Background

1.1.1 Mooring designs for Arctic operations have been developed since the 1970s for Arctic drilling operations with Mobile Offshore Drilling Units (MODU), such as the Kulluk and the Canmar drillships. In the more recent contractor concepts, e.g., Transocean ADS (Arctic Drillship), the mooring systems are intended for seasonal operations with limited number and size of mooring lines to allow mobility. Thruster assist and ice management could be used to widen the operational window. New conceptual designs for year round drilling published recently consist of large number and size of mooring lines that are typically used for permanent moorings. They are not considered suitable for MODUs since the requirement for mobility cannot be met.

1.1.2 The industry experience in Arctic floating production systems is limited. The most significant operations are the Terra Nova project and the White Rose project. The Shtokman project has gone through some conceptual and front end engineering studies (FEED), and the mooring design from the FEED provides valuable information on mooring design for a very challenging set of ice conditions.

1.1.3 The design of Arctic mooring systems can be very challenging due to the following:

- Arctic ice conditions may impose loads that are much higher and more uncertain than those for open water (ice free) requiring higher holding capacity and stiffness to meet mooring strength and offset requirements.
- Arctic temperatures in open air (above water) could reach -50^{o}C with implications for material requirements.
- A disconnection procedure may be considered for severe ice conditions and guidance is needed for the design of mooring systems with and without disconnection systems. Also disconnect devices operating in the Arctic may require special features.

1.2 Objective and General Approach

1.2.1 A number of standards can be applied for the design of mooring systems in open water conditions such as API RP 2SK, ISO 19901-7 and DNV-OS-E301 but their safety factors (or load and resistance factors) and material requirements were not developed for Arctic conditions.

1.2.2 ISO 19906 gives calibrated processes to evaluate ice loads and design steel platforms (fixed and floating) for Arctic conditions but its load and resistance factors were not specifically developed for mooring systems.

1.2.3 The objective of the JIP is to address the lack of standards specifically developed to address the challenges of mooring in the Arctic. The Arctic Mooring JIP addressed such challenges through the following tasks:

- Methods for ice load prediction for use in mooring design considering vertical, column stabilized, conical and ship-shaped structures with and without ice management (Task 4).

- Guidance on ice management strategies (Task 5).
- Mooring strength design practice (Task 1) covering a review of past and current practice and recommended mooring analysis procedures with safety factors for mooring line tension and anchor holding, illustrated with a design example.
- Extensive material testing of different components (Task 3) to assess material requirements for Arctic conditions.
- Assessment of disconnect devices with recommended testing requirements followed by a trade-off study considering mooring systems with and without disconnection capabilities (Task 2).

1.2.4 It has been agreed with the Project Steering Committee (PSC) that all the detailed task reports are confidential to Participants. It has also been agreed that this brief Summary Guidance Document would be developed to be freely distributed to industry to initiate discussions towards a future Arctic Annex to API RP 2SK (initially) and ISO 19901-7 (at a later stage).

1.2.5 This JIP decided to recommend the mooring strength design approach used by API RP 2SK, which is a practical mooring design code widely used by the industry for more than 30 years in open water locations. It provides an effective design procedure that is well established and can be readily adopted by mooring design contractors allowing efficient analysis of a large number of load cases. The necessary adjustments in environmental criteria, analysis method, and treatment of ice load uncertainty are summarized herein.

1.2.6 In addition API is also working in resolving differences with ISO 19901-7 so the proposed approach can be transitioned in the future to application with such ISO standard. The future extension of the proposed approach to other standards is also discussed.

1.2.7 The JIP reviewed the application of probabilistic methods (such as Monte Carlo Simulation) based on processes used by one of the participants but this will not covered in detail here due to confidentiality.

2. MOORING STRENGTH DESIGN REQUIREMENTS

2.1 JIP Recommended Approach

2.1.1 The recommended design environments are as follows:

- For floating units operating in ice free environments (open water), the mooring system, permanent or mobile needs to meet the API RP 2SK requirements.
- Floating units operating in ice environments without disconnect capability need to have a mooring system designed for the Extreme Level (EL) events: a minimum of 100-year return period ice environment for permanent installations and a minimum of 10-year return period ice environment for MODUs.
- Floating units operating in ice environments with disconnect capability need to have a mooring system designed for the maximum ice environment in which the floating unit, permanent or mobile, is intended to remain moored before disconnection takes place.

2.1.2 The Task 4 report of this JIP provides a detailed discussion on ice load prediction and software for ice load prediction based on ISO 19906. In summary the following needs to be established:

- Ice features to be designed for such as level ice, ice ridge, ice floe, iceberg, etc. For each feature define limiting mechanism for ice load calculation (Limit Stress / Limit Energy / Limit Force) based on the structure type (conical caisson, spar with a conical top, ship shaped vessel with vertical or sloped bow, single or multiple vertical cylinders, etc.) and ice feature.
- Ice feature parameters such as level ice thickness, ice density, ice sheet flexural strength, ice ridge keel draught and cohesion, ice-structure friction, etc. based on target return periods (without disconnect capability) or operation limits from operability and downtime analysis (with disconnect capability).
- Ice feature directions: The critical directions need be identified and included in the mooring analysis. Special attention needs to be given to turret moored ship shaped vessel in level ice where change of the ice drift direction causing weathervane of the vessel may yield higher ice loads.

2.1.3 The ice load on the vessel is calculated as follows:

- Establish load case matrix based on environmental criteria, floating vessel configuration and mooring pattern, etc.
- Conduct initial ice load evaluation using available tools such as ISO 19906, numerical simulation, or model test / monitoring data.
- Determine the final design loads for the load case matrix. The design loads can be reduced by taking into account ice management if an effective ice management system will be in place.
- Identify the most critical load cases for mooring analysis

2.1.4 Currently there are four methods for ice load prediction:

- Design codes (such as ISO 19906) provide analytical methods which have undergone a larger degree of calibration and validation for fixed and floating steel structures.
- Full scale measurements, which are more costly and limited to a few cases in the public domain (Kulluk, Molikpaq, etc.).
- Model testing, which are increasingly used by industry for major Arctic projects. Challenges are cost and scale effects as many ice, mooring, and vessel parameters are difficult to model.
- Numerical simulation, which is under rapid development but needs more work in validation with model test or full scale data.

2.1.5 Each method has its advantages and limitations and to reduce uncertainty more than one method needs to be used to check against each other. ISO 19906 formulations can be used as a convenient starting point for ice load calculation. Then the calculated ice load is compared with the ice loads predicted by the other methods to arrive at an ice load for mooring design. Specialists may be engaged in the process to gain more confidence on the ice load prediction. Model testing or numerical simulation can be used as a starting point if available and in this case ISO 19906 is used for checking.

2.1.6 Ice management can be accounted for in mooring strength design if the ice management system can provide the specific capabilities for:

- Ice detection, including tracking and forecasting;
- Threat evaluation with procedures to identify potentially hazardous ice features and situations;
- Methods to physically intervene (e.g. icebreaking, ice clearing, iceberg towing) on hazardous ice features or ice situations;
- Ice alert procedure designed to initiate appropriate operational reactions to ice hazards or adverse ice situations in a timely manner.
- Provision for disconnection and move off, where appropriate.

2.1.7 In addition all of the system components associated with ice management should be demonstrated to operate in the context of offshore operations and expected environmental conditions (e.g. all weather, day/night, storm waves, etc.).

2.1.8 All responsible personnel involved in ice management activities need to be trained with respect to the metocean and ice environment, the performance capabilities and limitations of the installation (or system) being supported, the production operations of the installation, the performance capabilities and limitations of the ice management support vessel(s), and the interrelationships within the overall ice management system.

2.1.9 Task 4 of this JIP detailed a calculation procedure for ice loading considering ice management utilizing Appendix A of the report 'Full Scale Experience with Kulluk Stationkeeping Operations in Pack Ice', PERD/CHC Report 25-44, B. Wright Associates Ltd., July 2000. This procedure is applicable to managed level ice only.

2.1.10 Floating structures interacting with ice features may be subjected to dynamic loads (in terms of the dynamic interaction of the floater with ice features and in some cases also dynamic response of the mooring system) and therefore time domain dynamic mooring analysis is recommended for calculating line tensions, anchor loads, vessel offsets, etc. If available, numerical simulation software calibrated by model test data, can be the best approach to properly account for the dynamic interaction between the ice feature and the floater / mooring system.

2.1.11 Some ice load prediction procedures such as ISO 19906 providing maximum static load can be used as a simpler alternative with some approximations as discussed below:

- Static analysis can be used where dynamic effect is known to be small and negligible.
- Dynamic analysis can be performed for a simulated time history with the peak equal to the calculated maximum static load.
- Dynamic analyses or model testing can be used to derive a dynamic amplification factor (DAF) for use in further design static analysis.

2.1.12 The mooring analysis procedure is as follows:

- Establish preliminary mooring design parameters such as number of lines, mooring pattern, size and strength of mooring components, etc.
- Prepare the hull-mooring model for the mooring analysis software to be used. It is now common practice to consider the hull-mooring-riser system in a coupled analysis under waves, wind and current as the risers provide a substantial contribution to the overall system stiffness and damping. This may not be relevant for Arctic floating structure as the mooring systems are typically designed for larger ice loads and therefore much stiffer than the risers. Also damping may not be important since there is little wave induced vessel motions. However, such assumptions need to be examined on a case-by-case basis. If the risers are found to have high impact on the mooring design, a fully coupled hull-mooring-riser model may be considered.
- Prepare simulated ice load time history or evaluate dynamic amplification factor DAF from model tests or dynamic analysis.
- Conduct static or dynamic mooring analysis to determine responses such as line tension, anchor load, and vessel offset, etc., which are checked against the design criteria. An alternative is the use of simulation software that models the dynamic interaction between the ice feature and the vessel / mooring system in time domain, if available.
- Modify the mooring design if the design criteria are not met, and repeat previous steps until the mooring design is finalized.

2.1.13 The following safety factors are recommended:

- Factor of Safety for Line Tension (Intact and Damaged Line Cases)

	Factor of Safety
Intact	1.67
Damaged	1.25

- Factor of Safety for Anchor

Permanent Mooring	
Intact condition	1.5
Damaged condition	1.0
Mobile Mooring	
Intact condition	0.8
Damaged condition	Not required

- Factor of Safety for Pile, Plate, and Gravity Anchors

Condition	**Suction/Driven Pile and Gravity Anchor**				**Plate Anchor**	
	Permanent		**Mobile**		**Permanent**	**Mobile**
	Lateral	**Axial**	**Lateral**	**Axial**		
Intact	1.6	2.0	1.2	1.5	2.0	1.5
Damaged	1.2	1.5	1.0	1.2	1.5	1.2

2.1.14 Other design criteria such as vessel offset, line length, mooring test load, fatigue life, corrosion and wear, clearance, and supporting structures are the same as API RP 2SK.

2.2 Other Considerations

2.2.1 Abnormal Level (AL) event design requirements can be considered to ensure that the mooring system and foundation have sufficient reserve strength, displacement or energy dissipation capacity to sustain large actions and other action effects in a partially damaged condition without complete loss of integrity.

2.2.2 The following AL events were identified in this JIP to be considered in a case-by-case basis:

- Failure of ice management systems
- Failure of disconnect devices
- Abnormally high ice loads

2.2.3 The actions on the floating structure due to such events can be considered on a case-by-case basis such as: a) abnormal ice level events of sufficiently low probability are investigated; b) adverse environmental events combined with a failure to safely disconnect are investigated. These investigations may not be needed if it is verified that the joint probability of occurrence of the adverse environmental events combined with the failure to disconnect is sufficiently low.

2.2.4 A further situation arises for the combined environment where wind, wave, and current are present with ice features. The joint probability distribution of the ice and ice-free environmental parameters (considered as companion environmental actions applied simultaneously with the principal ice actions) can be used to determine the appropriate combined environments. Tables 7.2 and 7.3 in ISO 19906 can be used as a starting point

2.2.5 Other limit states that need be considered are: Serviceability limit states (SLS) that correspond to criteria governing normal operations; Fatigue limit states (FLS) for the accumulated effect of repetitive actions. These were not covered in detail in this JIP and may need future investigation to provide appropriate guidance.

2.3 Future Development

2.3.1 The processes proposed in this JIP for use with API RP 2SK should be reviewed for inclusion as a regional Annex to API RP 2SK or other industry standards.

2.3.2 There is an on-going effort by API to eventually harmonize API RP 2SK with ISO 19901-7, but important differences still exist. It is noted that both standards can be considered as working from a limit state approach, defining a limit state as the load on a mooring line exceeding the line's breaking load. If the mooring line load is factored up and the mooring breaking load is factored down one is essentially brought back to a safety factor. There can be a discussion on whether the load factor can be applied to the rig / platform loading (wave, ice, etc.) prior to calculating the mooring line load or it can be applied to the mooring line load due to the un-factored rig / platform load. The answers will be different due to the non-linear nature of mooring response but neither API RP 2SK nor ISO 19901-7 have gone in this direction yet.

2.3.3 ISO 19906 (Arctic Steel Structures), DNVGL-OS-C101 (Steel Structures) and DNVGL-OS-E301 (Mooring in Open Waters) offer a limit state design methodology (ULS, SLS, FLS and ALS limit states) and load and resistance factors (LRFD) calibrated for a range of structures and geographical areas. This JIP evaluation indicates that although such standards provide a framework for a more advanced design methodology, there are significant gaps to bridge before it can be used for practical mooring design. The identified gaps include MODU design methodology, calibration of load factors for mooring system, guidance on redundancy check, evaluation of reliability for design strategy incorporating operational measures such as physical ice management and disconnection, and the state of technology to cover all limit states.

2.3.4 A framework that will help to address such gaps is under development within API and ISO where the required performance objectives (operability, safety, prevention of failure, economic and environmental consequences, etc.) are covered by categorizing the partial safety factors in distinct levels according to performance requirements. For offshore structures ISO 19900 specifies general principles for the design and assessment of structures subjected to known or foreseeable types of actions. API 2GEN is currently under development to harmonize API standards with the ISO tiered approach. In terms of mooring design the same concepts are under development. Mooring design is different from steel structure design as it generally utilizes safety factors that are in the high end when compared with many other offshore structures and has incorporated an intact mooring check with a higher safety factor and a check with one line damaged and a smaller safety factor.

3. MOORING HARDWARE RELATED ASPECTS

3.1 Key Aspects

3.1.1 The key material related aspects identified by this JIP were investigated based on in-kind participation from various manufacturers:

- The air temperature in the Arctic environment can be very low and the risk of mooring hardware above the water level being susceptible to brittle fracture failure due to low impact strength needs to be mitigated.
- The existence of moving ice present the risk of local contact loading on the mooring hardware causing damage and therefore needs to be mitigated.
- Other aspects are performance of drag anchor in Arctic soil, performance of fiber rope, wire rope, buoy, and winching equipment in Arctic environment.

3.1.2 Fatigue under long term ice loading was not part of the scope of this investigation but some of the results obtained suggest it to be an important consideration for future study.

3.2 Guidance for Chain and Accessories Operating in the Arctic

3.2.1 Mooring chain and accessories are typically manufactured, tested, and inspected according to the requirements of Recognized Classification Societies (RCS). The RCS specifications include tensile testing (yield strength, tensile strength, elongation, and reduction of area) and impact strength testing (Charpy energy), which is typically conducted at -20ºC. The Task 3 studies indicated that tensile strength is not affected by low temperature, but impact strength decreases with decreasing temperature. Therefore the testing temperature for impact strength may need special consideration for the Arctic environment.

3.2.2 Mooring chain and accessories operating in the Arctic experience: a) Under water environment where temperature is typically slightly below 0ºC, and standard mooring chain and accessories that meet current RCS requirements should be satisfactory; b) Open air environment where the temperature can be much lower than 0ºC. Temperature varies significantly for different regions and seasons, but the lowest temperature in the Arctic is expected to be about -50ºC. Therefore it is recommended that the impact strength testing be conducted at -50ºC, and the Charpy values obtained at this lower temperature meet the minimum requirements specified by RCS at the higher temperature of -20ºC.

3.2.3 The above provides guidance for the type of testing to be utilized in qualifying specific parts and manufacturers for Arctic mooring applications. It is however recognized that industry experience is not as extensive at this point in time. It is recommended that project specific material testing and monitoring be conducted to a scope in agreement with the relevant RCS and regulatory authorities.

3.3 Guidance for Fiber Rope

3.3.1 DSM Dyneema, Lankhorst, and Bexco joined the Arctic Mooring JIP through service in kind and investigated the following issues.

- Fiber properties such as the modulus of a polymer can be affected by low temperature. This issue was investigated by DSM Dyneema.
- Low temperature and ice in rope structure can reduce the Minimum Breaking Load (MBL) and affect the stiffness of a fiber rope. This issue was investigated by Lankhorst.
- Subrope load sharing and rope strength can be affected after rope frozen on bobbin, then unspooling and deploying in arctic low temperature condition. This issue was investigated by Bexco.

The fibers and ropes investigated are polyester, HMPE, and nylon, which can be used in the Arctic region for mooring line, hawser, towing and installation line, etc. Although the investigations are of limited scope, the JIP finds no significant hurdle in using these fiber ropes in the Arctic.

3.3.2 Conclusions from the DSM Dyneema Study

1. Within the framework and temperature range (-80°C and +20°C) of the study, all three fibers (HMPE, polyester and nylon) are suitable to be used in an Arctic environment. Also these fibers did not show any large change in modulus that are typically associated with phase transition.

2. HMPE appears to have some advantage over nylon and polyester when used as mooring lines since its modulus is higher and less affected by temperature. Moisture does not affect modulus nor strength of HMPE.

3. Within the temperature range investigated the mechanical properties of HMPE and Polyester are not influenced by moisture whereas these properties change with nylon because of water absorption.

3.3.3 Conclusions from the Lankhorst Study

1. Polyester, Polyamide (nylon) and Dyneema® DM20 ropes show an increase of stiffness for a decrease of temperature from 20°C to -20°C. The higher variations on stiffness were found on the polyamide and Dyneema® DM20 ropes. Polyester is less sensitive to stiffness variation with temperature.

2. It appears that the failure mechanism at break was not influenced by the range of tested temperature (-20°C to +20°).

3.3.4 Conclusions from the Bexco Study

1. There is no significant drop in breaking strength for all tested ropes (polyester, nylon and Dyneema® DM20) frozen and then unspooled in arctic temperatures under dry or wet conditions.

2. Testing of nylon ropes shows the typical loss in strength for wet Nylon ropes due to water intake in both room and Arctic temperature.

3. For ropes with Dyneema® DM20, a significant strength increase of 15% is seen for soaked ropes under Arctic temperature.

3.4 Guidance for Drag Embedment Anchors – Vryhof

3.4.1 The suitability and technology readiness level of Drag Embedment Anchors (DEA) for Arctic and sub-Arctic conditions was evaluated by Vryhof through its in-kind participation. The investigation was limited to Vryhof DEAs such as Stevshark, Stevpris, Stevmanta, and Stevin.

3.4.2 The results of study show that the investigated anchor types can readily and effectively address the mooring and anchoring requirements in most Arctic regions. The studied anchor models have vast experience base both in Arctic and sub-Arctic conditions as well as under soil/rock conditions that are comparable to that of Arctic regions.

3.4.3 The studied anchors are welded constructions from offshore grade steel. The steel grades and welding materials and techniques for Arctic are readily available. Thus the structural strength and durability of subject anchors under Arctic conditions are satisfied.

3.4.4 The study mapped the typical DEA types from the Vryhof range of anchors against the upper and lower bound soil condition strength as shown in the table below.

Suitable DEA types for the known upper bound subseabed conditions of Arctic	Suitable DEA types for the lower bound subseabed conditions of Arctic
• Vryhof Stevshark® (depending on soil/rock mass strength special designs may be required)	• Vryhof Stevshark® • Vryhof Stevpris® • Vryhof Stevmanta VLA® • Vryhof Stevin®

3.4.5 The study also identified those characteristics that will require further research and testing to populate the experience base. These soil characteristic are associated with the subsea permafrost, gas hydrates, and the potential seasonal variations in sub-seabed soil conditions.

3.4.6 A series of model anchor tests were performed in the Vryhof R&D center. The test results in sand and very soft clay are in agreement with the previous laboratory tests which are further supported by field scale tests. Thus the established Vryhof anchor performance curves can be used for preliminary estimates of anchor capacity in Arctic soils of comparable character. The tests in gravel and firm to stiff clay like material, however, will require further field scale tests to calibrate the results for a range of anchor sizes. Furthermore, it is recommended the same set of tests should be performed in the future in frozen soil to better analyze the behavior and performance of anchors in ice bearing soils or permafrost.

3.5 Guidance for Other Mooring Hardware

3.5.1 Information about the performance of other mooring hardware such as wire rope, winch, windlass, fairlead, and buoy in the Arctic environment is rare. Drilling operations with Kulluk platform and Canmar drillships were carried out from 1970's to late 80's in the Beaufort Sea using wire ropes and winches, which were shielded for Kulluk but not for the Canmar Drillships. There is no report of wire rope or winch problems for these drilling operations. For the Canmar Drillships, however, the mooring lines came off the deck going through the waterline, and large ice features often tended to get stuck at the mooring lines, making ice clearance more difficult and increasing line tensions.

3.6 Direct contact of Ice with Mooring System

3.6.1 Based on industry experience, the following general guidance is provided which is useful during both installation and operation.

- Direct contact of ice with fiber rope mooring line should be avoided as much as possible. This may not be a problem for fiber rope moorings since the upper part of the mooring line in contact with the winching equipment is generally a steel component.
- Direct contact of ice with fiber rope in other applications such as hawsers, tow lines, and installation lines may be acceptable and can be determined based on careful evaluation of the rope and ice type and potential contact load, etc.
- Direct contact of small ice features such as broken and level ice with chain or wire rope mooring line may be acceptable. However, direct contact of large ice features such as ice ridge, ice floe, and iceberg with chain or wire rope mooring line may need special consideration on the potential impact of the ice features getting stuck at the mooring lines. The need for ice clearing and the potential of increased mooring line load needs to be carefully evaluated.

4. REQUIREMENTS FOR DISCONNECT AND RECONNECT DEVICES

4.1 Introduction

4.1.1 Disconnect is usually the last resort after all other ice management options have been tried. In general there are two categories: planned and emergency disconnect.

4.1.2 A planned disconnect involves shut down of production or drilling operations and riser systems, and clearing process facilities before actual disconnect of the moorings / risers.

4.1.3 Emergency disconnect will take place very rapidly without fully executing the disconnect procedures required by the planned disconnect. Such a condition might occur in the case of an unexpected impact with a large multi-year ridge or in the case a ship shaped vessels which is unable to turn its heading up against the ice drift rapidly enough to avoid significant heeling of the vessel. Reconnect is expected to take longer for the emergency disconnect scenario.

4.1.4 The in-line connector types can be classified by the main mechanism of action for holding and releasing the mooring loads. In general, there are 4 categories:

- Interference connectors (I)
- Ball and Taper connectors (BT)
- Locking Shoe and Plunger connectors (LSP)
- Chain Severing device (CS)

4.1.5 Currently, there are 8 in-line devices that are commercially available or under development:

Emergency Disconnect?	Hardware Type*	Product Name	Manufacturer
N	BT	MoorLOK	BallTec
Y	CS	Control Cutter	Control Cutter AS
N	I	Subsea Connector	Delmar Systems Inc.
N	I	Quick Release	Delmar Systems Inc.
N	BT	Subsea Mooring Connector	First Subsea
Y	BT	Quick Disconnect Reconnect	First Subsea
Y	LSP	Rig Anchor Release	InterOcean Systems
N	LSP	Rocksteady	Subsea Riser Products

4.1.6 Existing disconnectable turret mooring systems use a mooring / riser buoy (MRB) that is located in a receptacle in the FPSO hull. There are a few designers of these systems, and each has a slightly different implementation of the concept. Our survey found seventeen (17) of such systems which may or may not be directly applicable in the Arctic environment, and modifications have been proposed by some turret mooring designers such as Bluewater and SBM.

4.1.7 Of the many options available for disconnecting and reconnecting a mooring system, only 4 are identified to adequately meet the very short response times required for the emergency disconnect scenario, as listed below:

- Disconnectable turret mooring
- InterOcean RAR (Rig Anchor Release)
- First Subsea QDR (Quick Disconnect Reconnect)
- Control Cutter CC

4.1.8 These devices and systems were investigated in detail in Task 2 of the JIP (proprietary information). A summary of general conclusions in terms of requirements is given below.

4.2 Functional Requirements

4.2.1 Functional requirements for disconnect devices may include:

- Ultimate, proof, and release load
- Time for disconnect and reconnect
- Operating temperature
- Control and monitoring
- Inspection and maintenance

4.2.2 Functional requirements are project specific and the operator must determine if the functional specifications provided by the hardware manufacturer meet the unique requirements of the project. Functional testing in a comparable environment should be conducted by the manufacturer prior to product delivery. This testing is to demonstrate that the device can be released and reconnected in the anticipated environmental service conditions.

4.3 Testing Requirements - Factory Testing

4.3.1 Materials used in the manufacture of disconnect devices should meet the requirements for chain accessories specified by a RCS. Proof load, break load, and mechanical (i.e. Charpy impact tests, tensile tests, etc.) testing should be conducted according to specifications by RCS for chain accessories. For disconnect devices operating at or above sea level the Charpy impact testing should meet the special material requirements discussed in Section 3.2.

4.4 Testing Requirements – On-site Testing

4.4.1 On-site testing needs to be considered to ensure that the device will function properly in the field. An on-site testing program can be developed based on project specifics and the following general principles:

- If the disconnect capability is critical to the project, a more rigorous on-site testing program needs to be in place.
- Mooring system design needs to consider options to allow periodic testing of the disconnect device.
- New devices that have little or no service experience require more rigorous testing. On the other hand, mature devices that have extensive service experience require less or no testing.
- On-site testing need to be conducted in conditions as close to the real operating conditions as possible. However, for the options that are destructive in nature to the mooring system (i.e. control cutter), a comparable demonstration such as testing on the back deck of a workboat (in Arctic conditions) can be considered.
- On-site testing and training can be conducted simultaneously.
- Maintenance and monitoring need to be conducted according to manufacturer's specifications.

4.5 Training Requirements

4.5.1 Operators need to coordinate and plan for a training cycle with the manufacturer's representatives. Manufacturers need to provide training manuals for the operations personnel and familiarize them with the materials and procedures for safe disconnect and reconnect. Training time and frequency need to be adequate so that the critical release scenarios are simulated with the crew who will be making the decision to release. Documentation of the training performed needs to include the full name and affiliation of each individual trained, the date and location of the training, the full name and affiliation of the trainer, and the performance of the trainees in the practical examination.

4.6 Trade-off Study

4.6.1 A trade-off study showed that a permanent (non-disconnectable) option can have advantages over the disconnectable option for a spar or caisson considering ice features where there is limited difference between the 10-year and 100-year loads (ridges were considered in the study).

4.6.2 However it is likely that a permanent option is feasible for the areas having first year ice only. Also all MODUs are expected to be equipped with disconnectable moorings so they can operate in areas of different environments.

4.6.3 In addition, the turret moored FPUs are expected to be disconnectable because they can be exposed to high ice loads from broadside. From this point of view the majority of Arctic floating units are expected to have disconnectable moorings.