

## Appendix C - DNV OS-F101 design approach

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### 1.1 Introduction

This section describes the principle design codes that will be followed for the design and construction of the proposed Nord Stream pipelines.

The principle code for the Nord Stream pipelines is DNV OS-F101 [DNV-OS-F 101 2000 with January 2003 reprints/amendments], /1/ Submarine Pipeline Systems, issued by Det Norske Veritas, Norway. DNV OS-F101 provides criteria and guidance on design, materials, fabrication, installation, testing, commissioning, operation and maintenance of pipeline systems.

The line pipe requirements of the DNV OS-F101 are based on the ISO standard 3183-3 Petroleum and natural gas industries – Steel for pipelines,/2/.

The DNV OS-F101 principle code is supported with various DNV recommended practices,/3-10/, and other international codes /2, 11, 12/.

In the following, a brief summary of the codes and standards relevant to the Nord Stream project is given.

As an alternative to DNV OS-F101, the international standard ISO/FDIS 13623, Petroleum and natural gas industries – Pipeline transportation systems, could have been adopted as the principal code for Nord Stream. However, ISO/FDIS 13623 does not cover many of the design and construction aspects encountered in the design.

The DNV OS-F101 Section 1 A403 reads: “This standard is intended to comply with the ISO standard 13623: *Petroleum and natural gas industries – Pipeline transportation systems*, specifying functional requirements for offshore pipelines and risers.” Therefore, no conflicting code requirements are anticipated.

The governing code to calculate the required wall thickness against pressure containment and all other relevant loading therefore is proposed as DNV OS-F101.

## 1.2 Design approach

The design approach within the standard is based upon a limit state and partial safety factor methodology, also called load and resistance factor design format (LRFD).

The design process involves a categorisation of fluids (category D for natural gas), a location class definition based on human activity near the pipeline sections, and a safety classification using safety classes Low, Normal and High.

The reason for having both a class location and a safety-class system is that the class location normally does not change over the lifetime of the pipelines, e.g., location class 1 away from landfalls, whereas the safety class depends on the service condition. The definitions are shown in Table 0-1.

**Table 0-1** DNV safety classification /1/.

Normal classification of safety classes				
Phase	Fluid category A, C		Fluid category B, D and E	
	Location class		Location class	
	1	2	1	2
Temporary	Low	Low	Low	Low
Operational	Low	Normal	Normal	High

## 1.3 Limit state design

The structural design in DNV operates with a number of limit states defined as a state beyond which the structure no longer satisfies the requirements. The following limit states are relevant for the pipeline system:

- SLS = serviceability limit state
- ULS = ultimate limit state
- FLS = fatigue limit state
- ALS = accidental limit state

The calculation of limit state values adopts a series of partial safety factors that have been calibrated, predominantly through probabilistic analysis.

The fundamental principle of the partial safety factor design methodology is to verify that factored design loads do not exceed factored design resistance for any of the considered failure modes. A factored design load effect is obtained by multiplying a characteristic load effect by a load effect factor. A factored resistance is obtained by dividing the characteristic resistance by a resistance factor. The level of safety is hence satisfactory if the load effect does not exceed the design resistance.

## 1.4 Recommended practices

### Recommended Practice F102 - pipeline field joint coating and field repair of linepipe coating

The recommended practice for pipeline field joint coating and field repair of linepipe coating has been prepared to facilitate the work of pipeline operators, general contractors as well as sub-contractors carrying out coating work.

The RP may either be used as a guideline for the preparation of manufacturing specifications for field joint coatings, infill systems and field repair of coatings, or it may be used as an attachment to an inquiry or purchase order specification for such systems.

#### **1.4.1 Recommended Practice F103 - cathodic protection design**

The recommended practice for cathodic protection design has been issued to assist designers, fabricators and operators of cathodic protection systems. The recommended practice contains requirements for the cathodic protection of submarine pipelines, depending on location, coating type and whether the pipelines are exposed on the seabed or buried/rock-dumped/trenched.

Recommended Practice F103, /7/, is relatively new and has been revised to provide a less conservative design approach, compared with earlier cathodic design codes.

As an alternative to Recommended Practice F103 the ISO standard 15589-2:2004, /11/ would provide similar cathodic protection of the submarine pipeline system.

#### **1.4.2 Recommended Practice F105 – free-spanning of pipelines**

When the pipeline is installed on the seabed, free spanning may occur depending on the stiffness of the pipeline and the seabed unevenness. Furthermore, free spans also can develop after installation due to, e.g., scouring and/or sand waves.

Normally, from a structural point of view limited free spanning is fully acceptable. However, free-spanning sections may be subject to current- and wave-induced vortex, shedding induced vibrations and/or unacceptable bending moments. Maximum allowable free spans therefore are calculated as part of the design work.

The free-span analysis may be based on a simple structural model or a refined finite element approach, depending on the design criticality and construction impact.

This recommended practice presents design criteria and guidance on analyses of pipeline free spans subjected to combined wave and current loading. This includes a methodology of fatigue assessment, if required.

#### **1.4.3 Recommended Practice F106 – factory applied external pipeline coatings for corrosion control**

For external coating of offshore pipeline the recommended practice has been prepared to facilitate the specification and execution of coating work.

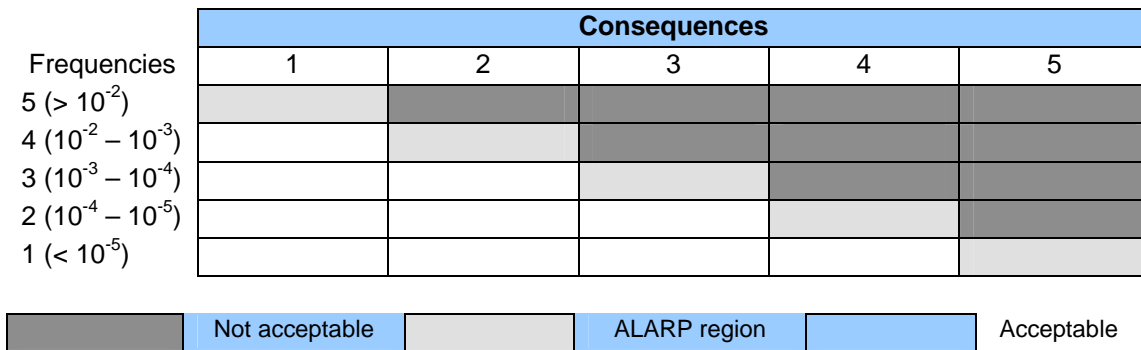
The RP may either be used as a guideline for the preparation of manufacturing specifications for external pipeline coating systems, or it may be used as an attachment to an inquiry or purchase order for such coatings.

#### **1.4.4 Recommended Practice F107 – risk assessment of pipeline protection**

The risk acceptance will follow the methodology outlined in DNV RP F107 and described in the following. RP F107 operates with the following risk types:

- Human safety
- Environment
- Financial loss

The acceptance criteria are based on the as low as reasonably practical (ALARP) principle as illustrated in Figure 0.1 below. The frequency classes are independent of the risk types.



**Figure 0.1** DNV proposal for risk acceptance criteria

In the ALARP region, the risk shall be reduced as far as technically and economically possible.

The acceptance matrix is valid for single hazards. The single hazards shall be defined on an overall level such as: anchor damage, sinking ships, internal corrosion, etc.

Table 0-2 shows the safety consequence ranking according to Recommended Practice F107.

**Table 0-2** Safety consequence ranking for human safety.

Category	Description
1 (low)	No person(s) are injured
2	(Not used)
3 (medium)	Serious injury, one fatality (working accident)
4	(Not used)
5 (high)	More than one fatality (gas cloud ignition)

**1.4.5 Recommended Practice F110 – global buckling of submarine pipelines structural design due to high temperature/high pressure**

The recommended practice F110 applies to structural design of rigid pipelines with a potential to buckle globally. This normally implies so called HP/HT pipelines, and hence not considered applicable for the North Stream pipeline.

**1.4.6 Recommended Practice F111 – interference between trawl gear and submarine pipelines**

Marine pipelines in fishing areas may be subject to interference by trawl gear, i.e., a trawl door towed across the pipeline and impacting the pipeline. The loading considered is:

- Impact, i.e., the initial phase when the fishing gear impacts the pipeline. This phase lasts some hundredths of a second, and the structural assessment is focused on the local pipe shell.
- Pull-over, i.e., the second phase when the trawl board is pulled over the pipeline. This phase can last from about one second to some 10 seconds, depending on the water depth, span height and other factors. The pipeline response is global.

- Hooking, i.e., a rare accidental situation whereby the trawl board is stuck under the pipeline.

The objective of the recommended practice is to provide rational criteria and guidance on design methods for pipelines subjected to trawl-gear interference.

The following design criteria are considered:

- Coating damage due to impact
- Pipe denting due to impact
- Stresses and strains due to pull-over or hooking

This recommended practice takes into consideration the following topics:

- Most critical trawl equipment
- Trawling frequency

#### 1.4.7 References

- /1/ Det Norske Veritas DNV, **2000**, "Code DNV OS-F101, Submarine Pipeline Systems with January 2003 reprints/amendments, Norway",
- /2/ International Standard, **2007**, "ISO 3183-3, Petroleum and Natural Gas Industries - Steel pipe for pipelines - Technical delivery conditions. Part 3: Pipes of requirement class C.",
- /3/ Det Norske Veritas DNV, **2007**, "Recommended Practice No. DNV-RP-F110, Global Buckling of Submarine Pipelines – Structural Design due to High Temperature/High Pressure",
- /4/ Det Norske Veritas, **2006**, "Recommended Practice No. DNV-RP-F105, Free Spanning Pipelines",
- /5/ Det Norske Veritas DNV, **2006**, "Recommended Practice No. DNV-RP-F111, Interference Between Trawl Gear and Pipelines",
- /6/ Det Norske Veritas, **2003**, "Recommended Practice No. DNV-RP-102, Pipeline Field Joint Coating and Field Repair of Linepipe Coating",
- /7/ Det Norske Veritas, **2003**, "Recommended Practice No. DNV-RP-F103, Cathodic Protection of Submarine Pipelines by Galvanic Anodes",
- /8/ Det Norske Veritas, **2003**, "Recommended Practice No. DNV-RP-F106, Factory Applied External Pipeline Coatings for Corrosion Control",
- /9/ Det Norske Veritas, **2001**, "Recommended Practice No. DNV-RP-F107, Risk Assessment of Pipeline Protection",
- /10/ Det Norske Veritas DNV, **1988**, "Recommended Practice No. DNV-RP-E305, On-bottom Stability Design of Submarine Pipelines",
- /11/ International Standard, **2004**, "ISO 15589-2:2004, Petroleum and Natural Gas Industries – Cathodic protection of pipeline transportation systems. Part 3: Offshore pipelines.",
- /12/ International Standard, **2000**, "ISO 13623, Petroleum and Natural Gas Industries - Pipeline transportation systems",

