ENVIRONMENTAL LOADS ON STRUCTURES NPD – GUIDELINES FOR LOADS AND LOAD EFFECTS

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ABSTRACT

The NPD issued in 1987 "Guidelines for determination of loads and load effects".

For the first time the NPD has given specific recommendation for the Barents Sea. This paper describes some of the data collection programs for the Barents Sea. In broad terms the content of the document describes the recommendations given, the considerations and analyses which form the basis of the recommendations.

1. INTRODUCTION

The Norwegian Petroleum Directorate (NPD) is the governmental body who is responsible and for regulatory supervision of petroleum activities on the Norwegian continental shelf and for issuing regulations.

NPD have issued "Guidelines for the determination of loads and load effects" (NPD,1987). The guidelines are made as an appendix to the "Regulation for the structural design of loadbearing structures intended for exploitation of petroleum resourses" (NPD,1984). Based on the internal control philosophy the operators may deviate from the guidelines whithout having obtained formal consent from NPD. NPD expects that the operator do undertake a thorough evaluation and dokumentation of any deviation. The operator then informs the NPD of deviations from the guidelines.

The regulation stipulates that envivonmental conditions shall be evaluated at two different probability levels. The two levels are the annual probabilities of 10^{-2} and 10^{-4}. The loads should be based on the present conditions and near past. The

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Environmental Data Center at the Meteorological Institute in Oslo. The main databases of interest are :

STATION	YEARS	LOCATION	
TROMSØFLAKET	1976-87	71°30'N	19°00'E
NORDKAPBANKEN	1988-	72°00'N	31°01'E
BJØRNØYA	1985-	73°30'N	19°52'E
SENTRALBANKEN	1985-	74°30'N	30°55'E

Table 1 : Wave measurement stations and measuring periode. The measurements at Sentralbanken and Bjørnøya will be finished in 1989.

The general trend from different measurement stations at the Norwegian coast is that the wave height increases from the North Sea (56°N) up a maxima at the central parts of the Norwegian Sea (63° - 64°N) and decreases again further north. This is the same as found for average conditions using the so called WINCH hincast model (Eide,1986). The WINCH hindcast model is the model used by the Norwegian Meteorological Institute (DNMI). For more information see Barstow et al (1988). The recommendations in the NPD guidelines (figure 1) are based on the measurements and on a subjective use of the hindcast data to evaluate the conditions between the measuring stations. Because of the changing extension of sea ice, the hindcast results for the Barents sea are not as good as for the Norwegian Sea and the North Sea. Figure 1 should only be used for early phases of a field development project. For detailed engineering a site specific evaluation should be done.

In general there has not been found any evidence that the wave conditions in the Barents Sea deviate significantly from what has been experienced on other parts of the shelf. The general description of waves in the guidelines is expected to be valid also in the Barents Sea.

3. CURRENTS

The NPD and the operators have carried out several current measurement projects in the Barents Sea area. At this time most of the current measurement projects are performed by the Norwegian oil companies. Table 3 gives a summary of the measuring stations in the Barents Sea area:

STATION	PERIODE	LOCATION
Tromsøflaket	1976-84	71°30'N 19°00'E
Tromsøflaket	1985	71°45'N 20°37'E
Nordkapbanken	1988-	72°00'N 31°00'E
Bjørnøya	1987-88	72°20'N 24°20'E
Nordkapbanken	1985	73°02'N 26°33'E
Bjørnøya	1987-88	73°30'N 21°30'E
Bjørnøya	1985	73°45'N 19°50'E
Bjørnøya	1987	73°50'N 20°00'E
Sentralbanken	1985-87	74°31'N 30°55'E
S5	1987-88	74°51'N 28°43'E
S1II	1988	75°00'N 21°15'E
S4	1987-88	75°02'N 27°07'E
S3	1987-88	75°20'N 24°59'E
S2	1987-88	75°34'N 23°26'E
S1I	1987-88	75°44'N 21°57'E

Table 2 : Current measurement stations

The NPD has not found that there are sufficient measurements in the area to produce a map of extreme currents. The guidelines give recommentations for the maximum tide current which can occur at vernal equinox (figure 2). In general the highest tidal currents occur near Bjørnoy. The tidal currents will not exceed 0,5 m/s. Current measurements performed so far have not registrated any situation with extremly high currents such as those experienced at the Troll-field in the North Sea (61°N). Maximum measured current in the Barents Sea is less than 1 m/s. For a semisubmercible or an other gravity structure a current of 1m/s will only contribute with 1,5% of the total environmental loads.

4. WIND

NPD has recommended use of 41 m/s on the entire Continental shelf. This applies at 10m height averaged over 10 min. The values are based on measurements from the North Sea and Haltenbank area. Weibull and Gumbel extatrapolations of data from Tromsøflaket give values in the order of 35-40 m/s at 10m height and averaged over 10 min. The mean wind velocities on the shelf decreases when moving from Haltenbanken (65°N) to the Barents Sea (Børresen, 1987). Based on this, the NPD recommendation of 41 m/s is belived to be conservative also for the Barents Sea.

A major research project has been performed by different Norwegian research institutions studying polar lows (Lystad, 1986). The highest measured wind velocity in any polar low was 35 m/s at 10m height averaged over 10 min. One of the conclusions from the the project was that it was unlikely that a polar low could give higher wind velocities than ordinary storm conditions. Extreme value statistics give 38m/s for the Tromsøflaket area at an annual probability of occurance of 10^{-2}. (Houmb et al, 1986). For a specific location the extreme value will be lower. For design purpose polar lows is not a large problem and the polar lows do not increase extreme estimates of wind speed, wave height, air temperature nor ice loads (Houmb et al,1986). They may, however, cause operational problems.

5. SNOW AND ICE

SNOW

NPD is recommending a snow load of 0,5 kPa which is based on measurements from Utsira (59°N). It is based on an assumption that it should be possible to remove snow from the platform within two days. If an unmanned platform is used this value should be increased. A meteorological evaluation concludes that 0,5kPa should be concervative also for the Barents Sea. A deck structure of say 100 * 100 will give a snow load of 500 tonn. This is not expected to cause problems for the structural design.

ICING

The largest observation of icing was on the drilling rig Treasure Seeker 20-21.04.1981 on the Haltenbanken (65°N). The total amount of ice was then estimated at 300 tonn (Loset,1985).

NPD recommends to use the following ice thichnesses north of 68°N:

Height	Loadcase 1	Loadcase 2
Under 5 m	0	10 mm
5-10 m	150 mm	10 mm
10-25 m	Linear reduction from 150 mm to 0	10 mm
Above 25 m	0	10 mm

Table 3: Ice thicknesses at an annual probability of 10^{-2}

The recommended icing thicknesses have been checked on the semi-submersibles Borgny Dolphin and Zapata Ugland against calculations done with numerical models based on Tromsøflaket conditions. A theoretical desciption of the model used by NHL on Borgny Dolphin is given by Horje and Vefsnmo (1985). These examples gave a total load from NPD guidelines which was 0-40 % higher than the model results.

Situations in the Barent Sea were heavy icing were expected have not caused significant icing. One reason for this is the heat from the platforms itself which is not taken into account in numerical calculations. The NPD recommendations is expected to be very conservative.

The weight of ice on a rig using the NPD guidelines is typically 1500 tons. This amount of ice does not cause serious structural nor stability problems neither on mobile drilling riggs nor fixed production platforms.

SEA ICE

Vinje (1980) gives the extension of sea ice in the periode 1966-80 when the ice coverage was higher than 40%. An update for the periode 1971-80 was made in 1985 (Vinje,1985). The guidelines give recommentation of where to evaluate sea ice (solid line on figure 3). It is mainly a subjective use of the results from Vinje. A more rare event is sea ice covering the sea to the coast of Finnmark which occured in 1870-71. The ice thickness at the coast was approximately 0.15m (Hoel,1961-62).

Sea ice is not expected to cause serious structural problems for fixed production platform. For platforms expected to be subject to sea ice, local redesign is expected. Sea ice might though cause station keeping problems for a semi-submersible (Mobil,1988).

ICEBERGS

In the Barents Sea, several icebergs reached the coast of Kola and East-Finnmark in 1929 . The icebergs had an extension from 24°E to 44°E. The same year icebergs were also observed in the open sea (Hønsi,1988). According to the local newspapers in 1929 the icebergs at the coast was up to 30m above the sea level. This is the most extreme extension of icebergs known on the Norwegian Continental Shelf.

The known icebergs are based on random observations. Figure 3 shows the known iceberg observations in an area south of 74°N and west of 32°E (Hønsi,1988). On the figure a line is drawn indicating where the NPD guidelines recommend evaluation of ice and icebergs for the design. A line for a Russian indication of a " 1% probability of encountering icebergs" is also drawn on the figure (Atlas of the Murmansk Oblast,1971). How this line was found is not explained in the text.

No systematic countings of icebergs have been done before 1987 (Vinje,1988). In 1988 icebergs was instrumented and followed by satellite (Carstens et al 1988). Systematic countings of icebergs are expected to give significantly higher number of iceberg observations than previously have been reported.

Up to now NPD have not demanded any exploration rigs to be designed against icebergs nor sea ice. In 1988 the drilling has been performed in an area where sea ice and icebergs has been seen earlier. For the the 1988 exploration drilling south of Bjornøya at approximate 73°20'N the NPD has instructed the operators (Mobil and Norsk Hydro) to have a warning system for icebergs which might be in the area. During the drilling in august 1988 Mobil observed four icebergs 90-130 km north of the drilling location.

6. EARTHQUAKE

The NPD recommended earthquake criteria are mainly based on a study performed by the norwegian company NORSAR (Ringdal et al,1982). These criteria are at present under revision and a new map as given in figure 4 will be used in the updated revision of the guidelines (Bungum and Selnes,1988). In general the earthquake activity east of 15°E is low. Figure 4 should only be used for early phases of a field development project. For detailed engineering a site specific investigation has to be performed based on the local geological and geotechnical conditions.

7. TEMPERATURE

The guidelines give maps of temperatures at an annual probability of 10^{-2} for seawater (max,min) and air (max,min). In figure 5, the minimum and maximum air temperatures are given. The figure is made by Lars Ingolf Eide at Norsk Hydro for the NPD and is mainly based on unpublished papers from Lars Håland at the Norwegian Meteorological Institute.

As expected the figure indicate that the air temperature decreases by going further north. The decrease is moderate and are not expected to cause significant structural problems neither for exploration nor production activities in the north. The test temperatures of the materials have to be based on the actual conditions.

For the structural design and selection of materials the changes in sea water temperatures from the North Sea to the Barents Sea are almost of no significance.

8. SHIP COLLISIONS

Examinations of damages of offshore structures in the North Sea indicate that ship collisions is the most frequent reason for damage.

In the northern parts of Norway the ship trafic is less frequent than in the southern parts (Technica, 1987). The picture is dominated by merchant ships to and from Russian ports, fishing and naval vessels. Calculations of collision probabilities are expected to give a lower contribution to the probability of damage than in the North Sea.

9. ORGANIZATION OF RESEARCH

In 1976 the NPD started the environmental data collection at Tromsøflaket. In 1985 the measurements were moved to the Barents Sea. In 1980-83 Statoil gave financial contribution to the project. In 1983-88 the Oceanographic Data Acquisition Project (ODAP) contributed. From 1989 the project will again be financed only by NPD.

Through OKN (Operatør Komitè Nord) all the operators (OKN) north of 62°N contributes to several research projects in the Barents Sea. The main projects conserning loads on the structures are : ODAP, MOMOP and IDAP.

The purpose of the ODAP (Oceanographic Data Aquisition Project) is to provide environmental data on the Norwegian Continental Shelf north of 62°N.

MOMOP (Meteorological and Oceanographical Modeling Project) has the purpose to develop models to be used in the description of environmental conditions.

The purpose of IDAP (Ice Data Aquisition Project) is to provide data conserning the ice conditions on the Norwegian Continental Shelf.

Research on earthquake and ship collisions hazards has been organized as joint industry projects with different participants from project to project.

Most of the load desciptions in the guidelines are based on measurements in the sea and onshore in these projects. In the future further use of satellite data and improved numerical models might be good suplement, but still there is a long way to go.

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REFERENCES

Atlas of the Murmansk Oblast, Moscow 1971.

Barstow S, Vardal L, Guddal J, Reistad M: Evaluation of the WINCH hindcast for the Barent Sea. Oceanor report OCN 88015, Trondheim 1988,

Bungum, H and Selnes, P B : Earthquake loading on the norwegian continental shelf, summary report, Oslo 1988.

Børresen, J A: Vindatlas for Nordsjøen og Norskehavet, Oslo 1987.

Carstens, T, Løset, S and Løvås, S M : Ice drift modelling for the Barents Sea, NHL, Trondheim 1988.

Eide, L I : Plans for future wave measurements and analysis, ANODA-ODAP seminar, Sintef, Trondheim 1986.

Hoel, A : Isfjell på kysten av Øst-Finnmark, Norsk Geografisk Tidsskrift, Volume XVIII, no. 5-6, Oslo 1961-62.

Horjen, I and Vefsnmo, S : Computer modelling of sea spray iceing on marine structures, IFIP/IFAC Symposium, Automation for safety in shipping and offshore petroleum operations - ASSOPO 85, Trondheim, June 1985.

Houmb, O G, Lønseth, L, Schjølberg P, Vollan B : Environmental conditions under polar lows. Oceanor report OCN86022, Trondheim 1986

Hønsi, I : Isfjell i Barenthavet, Norwegian Petroleum Directorate, Stavanger 1988

Løset, S : Icing on marine units - experiences and research Norske Sivilingeniørers forening seminar : Vinterboring på norsk kontinentalsokkel, Fagernes, Norway november 1985.

Lystad, M : Polar lows in the Norwegian, Greenland and Barents Sea, DNMI, Oslo 1986.

Mobil Oil Canada and Mobil Exploration Norway : A synopsis of Canadian cold water environmental research, Stavanger 1988.

Norwegian Petroleum Directorate : Regulation for the structural design of loadbearing structures intended for exploitation of petroleum resourses, Stavanger 1984.

Norwegian Petroleum Directorate : Guidelines for the determination of loads and load effects, Stavanger 1987.

Ringdal, F, Huseby, E S, Bungum, H, Mykkeltveit, S and Sandvin, O A : Earthquake Hazard Offshore Norway, NORSAR Contribution No 302, Oslo 1982.

Technica: Risk assessment of buoyancy loss, project PP4-assessment of MUDU, Collision frequencies, London 1987.

Vinje, T: Frequency distribution and sea ice in Greenland and Barents Seas 1971-1980. Norsk Polarinstitutt, Årbok 1980, page 60. Oslo 1980.

Vinje, T: The physical environment, Western Barents Sea, Drift, composition, morphology and distribution of the sea ice fields in the Barents Sea, Norsk Polarinstitutt skrifter no 179c, Oslo 1985.

Vinje, T: Sources of Barents Sea ice data, NHL seminar, Trondheim 1988.

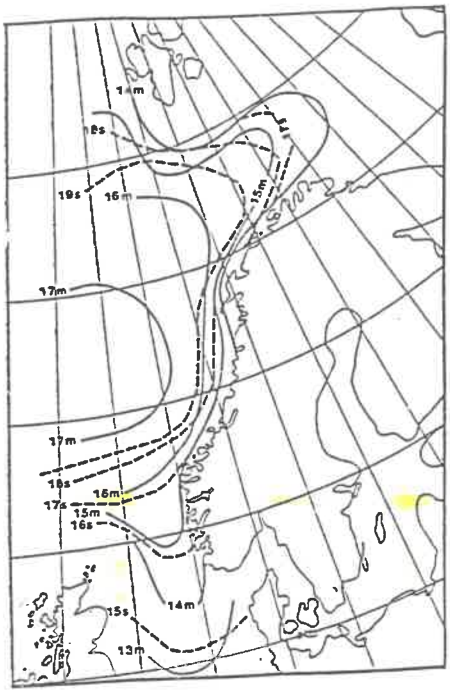

Figure 1 : Significant wave height HMO and peak periode TP with annual probability of exceedence of 10^{-2}. Isocurves for the wave heights are given with solid lines. Regarding the periods the lines are dotted.

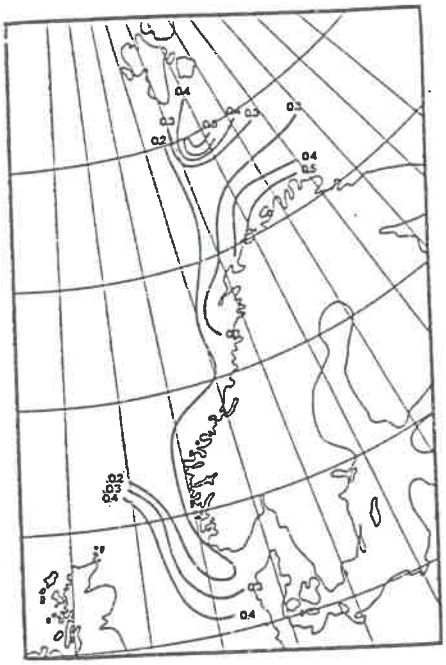

Figure 2 : Maximum tide current in m/s at vernal equinox spring tide.

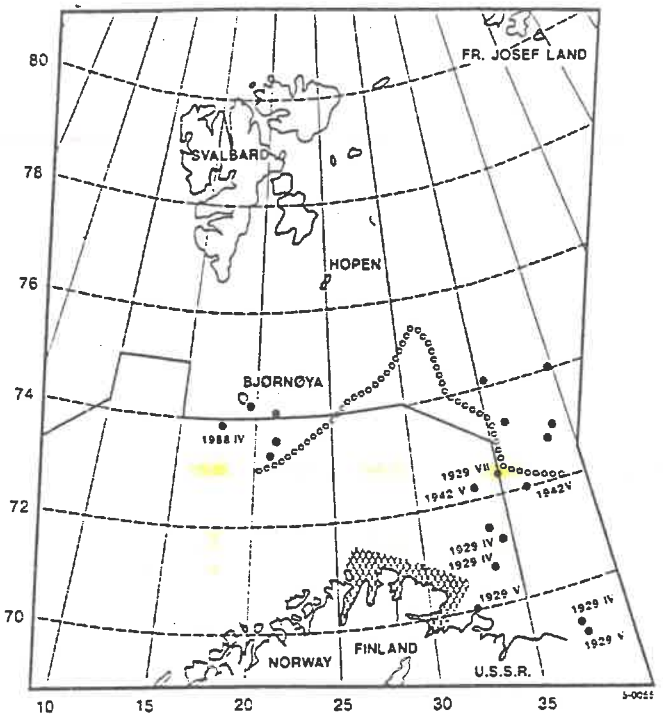

Figure 3 : Icebergs in the Barents Sea south of 74° N (Hønsi 1988)

- • : Observation of iceberg.
- 1929 VII : Month and year for observations.
- : In the shaddowed area 20 icebergs were observed in May-June 1929.
- ooo : 1% probability of encountering icebergs (Atlas of the Murmansk Oblast, 1971).
- —— : NPD guidelines (1987).

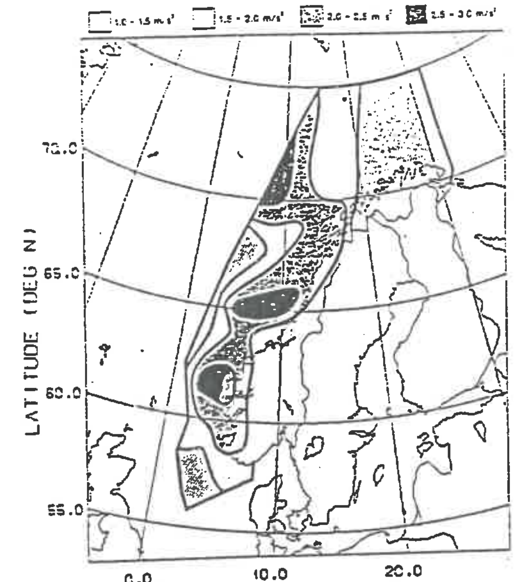

Figure 4 : Seismic zoning map with annual probability of exceedence of 10^{-4}.

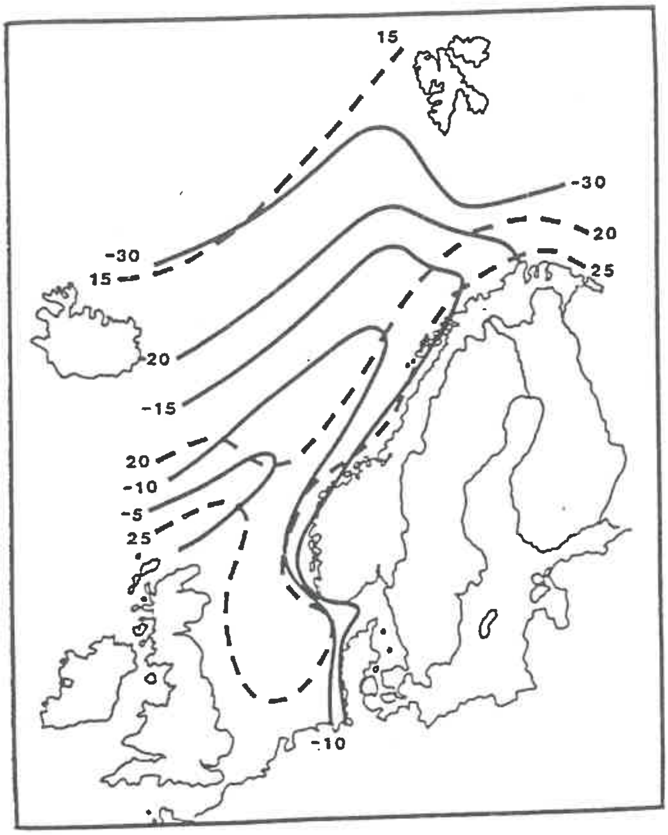

Figure 5 : Maximum and minimum air temperatures with annual probability of occurrence of 10^{-2}. The numbers are given in degrees Celcius.
—— : minimum air temperature
---- : maximum air temperature