DRAFT
Proceedings of the 32th International Conference on Ocean, Offshore and Arctic Engineering
OMAE2013
June 9-14, 2013, Nantes, France

OMAE2013-10045

WINTERIZATION NEEDS FOR PLATFORMS OPERATING IN LOW TEMPERATURE ENVIRONMENT

Ove Tobias Gudmestad
University of Stavanger
Stavanger, Norway

Yaroslav Efimov
Gubkin Russian State University of Oil and Gas,
University of Stavanger
Moscow, Russia

Konstantin Kornishin
Rosneft
Moscow, Russia

ABSTRACT

According to a common belief which is shared by a lot of specialists from different areas petroleum business goes far into the offshore. One of the most promising regions of hydrocarbon production in the nearest future is stated to be Arctic region. But this surprisingly rich region is also happens to be one of the toughest and challenging areas to operate. Due to extremely cold air temperatures, strong winds, presence of ice and other harsh physical and climatic conditions safety requirements and technological demands call for new conceptual solutions for constructions that are panned to be used in Arctic. For exploration and production facilities in the cold climate the following aspects are essential: personnel and environment safety, as well as uninterrupted fail-safe technological process. In cold climates the main concern goes to low ambient air temperatures and presence/accretion of ice. Cold temperatures affect both personnel and equipment on the platform. To protect platform from influence of cold temperatures special heated covers can be used. This solution has certain concerns with heating, ventilation and air conditioning (HVAC) and energy supply systems. Yet another way here might be partial cover of equipment with special shelters and climatic modifications. Ice is considered to be the second limiting factor: sea ice that requires ICE CLASS vessels or specially designed platforms (not to mention ice bergs) and icing that endangers all unprotected systems on the platform. To deal with these threats different strategies might be used but there is still no one answer. Every case is some kind of unique when speaking about Arctic constructions. Ice-induced vibrations observed on platforms in the Bohay bay that haven't been studied or even considered is a good example. Winterization for platforms is not fully developed yet and requires deeper research. The paper anticipates different codes and standards for offshore oil and gas facilities designed to operate in low temperature environments (American Bureau of Shipping ABS, Russian Maritime Register of Shipping, Det Norske Veritas DNV, International Organization for Standardization ISO, Canadian Standards Association CSA). These rules are compared against the experience of several major oil and gas operators and service companies gained during studies of conceptual design for Arctic exploration and production constructions at pre-FEED and FEED stages. New approaches to platforms winterization for HVAC and equipment vibration protection are proposed and compared with stated above standards and codes. The most important winterization concerns are highlighted and scrutinized.

INTRODUCTION

The Arctic region is extremely rich in hydro-carbon resources. On the basis of a geology-based probabilistic methodology the Arctic region is estimated to hold almost 25% of the world non-proven HC resources of the planet [8]. Approximately 84% is expected to be present in the offshore areas. However, this region can be characterized as a territory with extremely harsh weather conditions. A lot has been published on sea ice challenges (ice bergs, pack ice, stamukhas) in the Arctic, but much less on low air temperatures. Besides we strongly believe that the problems related to low ambient temperatures and ice should be treated more as general “cold weather” issues rather than “Arctic issues”. Yes, there is no doubt that the Arctic is one on of the most prospective regions of future HC developments but there are also a lot of areas all over the world that should be studied, having pretty much the same problems. The cold climate evaluations should, therefore, be extended to areas of so called “Sub-Arctic” with cold climate.

Ongoing activities in such regions are mainly represented by oil and gas companies and environment-protection organizations. It is suggested that only effective, responsible and experienced majors of the oil and gas business should be given access to the Arctic – due to very high risks and uncertainties of the projects. More importantly some of the projects can’t be realized by only one big company – there is a constant need for technologies and knowledge exchange. This situation calls for a business and governmental cooperation that isn’t such an easy thing to organize: each project in these areas is some kind of unique. The development of an offshore field in a low temperature environment requires design and use of special constructions (fixed, floating or subsea). But as it comes out, there is no single code or standard that covers all issues of concern. Nevertheless there are different codes, international standards and guidelines on winterization of platforms and vessels for drilling, production and transportation operations in cold climate [12]. Unfortunately none of these documents give a comprehensive and full-scale view to the problem. Design and construction companies might have gained great experience in this field but this experience is stored somewhere in the company or some limited information is given in certain guidelines. We admit that a lot of work now is steered in the direction of development of such documents but still a lot of work should be done [10]

Historically the problem of winterization of ships was faced by expedition vessels and then by military vessels. Quite a lot has been done in this direction. But there is always one big feature: when we are talking about drilling or structures for production we should understand that the time of operation is supposed to be months, years and even decades. This problem of station keeping puts huge requirements on any systems and equipment and reduces the analogy with military vessels. Besides we should consider technological equipment that is ought to work within cold temperatures and in presence of freezing water (splashes, mist, fog).

NOMENCLATURE

ELB – Electric Load Balance
USGS – the U.S. Geological Survey
HC – Hydrocarbons
RMRS – Russian Maritime Register of Shipping
HVAC – Heating, Ventilation, and Air Conditioning
ISO – International Organization for Standardization

Winterization philosophy

Winterization affects several most important aspects of the structure (both floating and fixed): the design (load capacity, control systems, materials), the safety (personnel safety in cold temperatures, equipment reliability, technological process) that eventually influence the cost-effectiveness (cost of construction, operational costs, energy consumption, design life duration). So what is behind the “winterization” term? Generally winterization can be defined as structured preparation actions for safe and reliable operations under extreme conditions of cold ambient temperatures. Such measures are taken to ensure functionality of the structure at low temperatures and the comfort and safety of the personnel aboard. This calls for special design features, equipment and operation procedures. A lot work has been done in the field of design modifications and operational aspects for traditional merchant ships in cold climate, there are particularities specific to drilling and production constructions:

- Materials and coatings;
- Design and hull constructions;
- Equipment and machinery;
- Heat and energy consumption plan;
- Crew considerations and training.

Basically the facilities should be designed to be adequate for all the possible cases of operation with extremely low air temperatures.

The main basic principles of winterization are developed for the safe, reliable, and effective operations in a low temperature and harsh environment, and include the following:

- Safe design, which includes construction integrity and personnel safety
- Technological process (survey, drilling, production) performance
- Non-stop and reliable on-board equipment performance:
    - Maintaining integrity and functionality
    - Preservation
- Personnel concerns:
    - Comfort conditions for work and accommodation;
    - Minimizing personnel exposure to harsh environment;
    - Protection from the aggressive environment.

To illustrate a typical standard for winterization we introduce some info from the RMRS [11]. RMRS is one of the leaders in classification of vessels for navigation in ice and related technical supervision. There are the following directions for the further development:

- Regulatory and Engineering Provisions for structural reliability of the vessels and structures to operate safely in cold climate regions;

• Development of additional safety requirements.

RMRS requires the following specific conditions and equipment to be documented for the WINTERIZATION class notation to be issued:

- the conceptual design scheme;
- technical documentation;
- specified temperature values;
- materials;
- mooring, tie down constructions, tow and other gears and machinery;
- life rafts and rescue systems;
- standby emergency power sources;
- vessel systems and on-deck pipes;
- fuel and lubricants, hydraulic and other liquids that have to keep their properties under low temperatures;
- Enclosure of the derrick;
- Closed drains from all deck areas;
- Water treatment system;
- Fluids;
- Heated walkways.

One of the possible ways to achieve the stated above requirements is to make technological and equipment modules fully enclosed with special heat regime and humidity conditioned air. This method is well-known and has quite a long record history on the North Slope of Alaska and in Northern Norway. The modules are usually heated to 5° C or above. This temperature is considered to be sufficient to protect machinery and instrumentation and to permit personnel to perform according to standard procedures and practices. Other advantages of fully enclosed areas include protection of the interior from atmospheric precipitation and sea splash as well as the material handling corridor. Accumulations of snow and ice in or near work areas enhance the possibility of personnel injuries due to falls and slips. Snow, ice and rain also endangers equipment, machinery and other tools. It also puts strong limitations on their reliable performance.

There are six operation modes that can be defined in order to describe the construction and the environment conditions.

The first two of them can be classified as «Normal Mode Operation» and «Stand-by Mode» (caused by weather or technological). Both of the scenarios represent conditions of full or partial capacity operation (even the Stand-by Mode) because there is the presence of produced HC in the systems. This standard situation requires:

• Full (standard) personnel capacity to control the operation;

• Full (according to the procedures) personnel capacity for situation control and evacuation in case of needs.

There are two possible “Emergency” situations when the produced HC are not completely removed from the facilities:

• “Manual Emergency Mode”: when personnel is on board the facility with potentially limited means for evacuation

• “Automatic Emergency Mode”: when where no personnel onboard and no facility systems are in use.

The last two modes are extreme cases of operation mode:

• “Emergency Shutdown”: Rapid but safe shutdown of the technological processes and utilities in the case of an emergency situation (fire, explosion, collapse, etc.) that may result in catastrophic consequences for the construction and personnel onboard.

“Black Start”: Start-up of the facilities when no main or essential power sources are available. The need for ventilation is discussed below under “Topsides”.

Design of the hull

Structures must be designed in compliance with Classification Society Requirements for ships intended for long-term operations at low temperatures in cold climatic conditions. Within these requirements designers should consider different variants of structures for staying in Arctic or other cold climate environment including the following combinations:

• Low temperatures,
• Atmospheric precipitations,
• Icing loads (sea spray and atmospheric icing),
• Sea ice loads,
• Hydrodynamic loads.

Topsides

Generally the following types of working areas of the offshore facilities can be distinguished:

Buildings that are enclosed rooms with conditioning of ambient atmospheric air (air temperature and humidity level are controlled from the HVAC system) and external heat insulation. These are represented by Living Quarters/Temporary Refuge, Control Rooms, Electrical and Instrumentation Rooms, Stores and workshops, Emergency Generator room, etc.

Enclosed Working Areas

All topsides modules should be fully enclosed, heated and have forced ventilation. The temperature should be maintained at approximately about 5° C during operations. The stated temperature is proven to be sufficient to protect equipment and machinery. This system protects the module interiors from accumulations of atmospheric precipitations. Heat tracing or other anti-icing technologies must be provided to ensure permanent de-icing of all door mechanisms.

Electrical heating from emergency sources shall be provided for the accommodations module. It means that Temporary Refuge for the personnel in case of black-out at low ambient temperature must be provided for heating during an appropriate time (generally up to 4 hours). Power demand and heating appliances must be taken into account in ELB calculations of the facilities.

The main problem for the fully enclosed modules is the explosion strength design analysis which might result in difficulty to use enclosed ventilated and heated modules at all.

Open Working Areas

These are areas that aren't enclosed and therefore may be directly exposed to external weather conditions. Nevertheless the possibility of local shielding should be taken into account during the design stage of the project. In this respect special wind walls for personnel areas or access ways can help a lot as well as special covers for pieces of equipment.

HVAC systems

The systems are extremely important to create safe environment. HVAC must be designed to operate safely and satisfactorily at all expected combinations of process, utilities, climates and environmental conditions and to meet the meet the following objectives:

- Provide controlled environment in which personnel, equipment and systems can operate effectively;
- Provide satisfactory environmental conditions for the safe operation of temperature sensitive equipment;
- Pressurize enclosed areas to maintain a non-hazardous area classification by preventing the entry of flammable gases and smoke;
- Prevent the formation of potentially hazardous concentrations of flammable gaseous mixtures in hazardous areas;
- All enclosed areas must be equipped with means of mechanical ventilation;
- Should be an emergency response in case of fire and gas leakage.

Here comes a question of fresh air flow and ventilation rate. Ventilation rates depend on the operational mode: normal and emergency. It should be also defined for different locations: non-hazardous and hazardous. Usually ventilation rate is set as six or twelve air changes in hour.

Equipment

All equipment and machinery on the offshore facilities should be specified for work within cold air temperatures (special climatic class of equipment) and the presence of water (need for special isolation). Design ambient temperature value is established by the construction operator company according to the purpose and service conditions.

Local electrical heaters must be installed in technical rooms to maintain minimum temperature in case of break-down of the HVAC system and a dark start of the whole energy system.

To provide reliable use, the redundancy of equipment in areas with limited access to the maintenance personnel should be evaluated.

Open deck stationary equipment (pipes, heat exchangers, control units, pressure tanks, etc.) should be heat-insulated.

Any equipment located in half-open and external areas should be protected from weather influences and low temperatures by an appropriate casing with local ventilation and heating, or demountable protection cover with heating.

Control valves, safety valves, shutoff valves, flow meters, level gauges and all other devices requiring accessibility should be protected from weather influences and low temperatures by heated casings or a demountable cover if casing installation is unpractical.

When designing the thermal insulation and heating of equipment and piping directly exposed to wind influence the increased heat losses due to the so called "chill effect" should be taken into account, Figure 1.

Wind-Chill Equivalent Temperature (°F). A 20-mi/hr Wind Combined with an Air Temperature of 20°F Produces a Wind-Chill Equivalent Temperature of 4°F.*

WIND SPEED (MI/HR)	AIR TEMPERATURE (°F)																
Calm	40	35	30	25	20	15	10	5	0	−5	−10	−15	−20	−25	−30	−35	−40
5	36	31	25	19	13	7	1	−5	−11	−16	−22	−28	−34	−40	−46	−52	−57
10	34	27	21	15	9	3	−4	−10	−16	−22	−28	−35	−41	−47	−53	−59	−66
15	32	25	19	13	6	0	−7	−13	−19	−26	−32	−39	−45	−51	−58	−64	−71
20	30	24	17	11	4	−2	−9	−15	−22	−29	−35	−42	−48	−55	−61	−68	−74
25	29	23	16	9	3	−4	−11	−17	−24	−31	−37	−44	−51	−58	−64	−71	−78
30	28	22	15	8	1	−5	−12	−19	−26	−33	−39	−46	−53	−60	−67	−73	−80
35	28	21	14	7	0	−7	−14	−21	−27	−34	−41	−48	−55	−62	−69	−76	−82
40	27	20	13	6	−1	−8	−15	−22	−29	−36	−43	−50	−57	−64	−71	−78	−84
45	26	19	12	5	−2	−9	−16	−23	−30	−37	−44	−51	−58	−65	−72	−79	−86
50	26	19	12	4	−3	−10	−17	−24	−31	−38	−45	−52	−60	−67	−74	−81	−88
55	25	18	11	4	−3	−11	−18	−25	−32	−39	−46	−54	−61	−68	−75	−82	−89
60	25	17	10	3	−4	−11	−19	−26	−33	−40	−48	−55	−62	−69	−76	−84	−91

*Dark blue shaded areas represent conditions where frostbite occurs in 30 minutes or less.

Fig. 1 Chill effect table [2]

All generators for electric energy should be provided with anti-moisture heaters. Also, electric motors should be equipped with starting heaters (internal or external), designed for cold start.

Systems should be located in places convenient for easy installation and removal of temporary shelters and heating for working in critical conditions in severe climatic conditions. The main problem that comes here is to decide which kind of shelter to design. There are two types of shelters to use: fully enclosed heated covers for the whole deck as discussed above and unheated covers. In the second case the cover protects only from atmospheric precipitations (rain, snow) but not from the low temperatures. Nevertheless heating is implemented only in special shelters for certain equipment (generators, flow meters, control modules) that are not designed for ambient temperatures. This approach is considered to be less expensive than fully enclosed heated cover mainly due to the lower level of energy consumption [5].

Here we should say that energy consumption of the facilities operating in low temperatures is the driving parameter that puts very strong limitations on the design. And one of the main goals for the designers in this respect is to create a cost and energy – effective design solution.

Personnel

The total number of manual operations carried out by the personnel on the open deck and in unheated areas should be minimized through using remote control systems and highly reliable technological equipment. Material handling operations should be automated as much as possible for eliminating manual labor in these areas.

For providing comfortable working conditions for the personnel performing maintenance and repair operations, the possibility of installing permanent or temporary partitions in open working areas should be studied. When determining the location for installation of such partitions it is necessary to consider possible reduction in the natural ventilation rate.

Icing effects

Superstructure sea spray icing and atmospheric icing may combine to reduce the safety of offshore platform operations. For floating structures and vessels, the effects can be quite serious, in that ice accretion can increase the draught, reduce the freeboard, and raise the center of gravity of the structure, thereby compromising stability.

Marine icing is caused by several phenomena, all a result of liquid drops or frozen precipitation intercepting and adhering to surfaces. These fall under the general categories of atmospheric and superstructure icing and both compromise safety in operations [9].

Atmospheric and superstructure (or sea spray icing) icing are usually considered as distinctly different phenomena because the source of the ice accretion affects where it forms on the vessel. Water salinity also change the physical properties of ice. The physical properties affect the adhesive strength of the ice and thus affect the effectiveness of methods used to either prevent its formation (anti-icing) or to remove it (de-icing).

Icing mitigation methods discussed can be categorized as follows:

- Thermal Methods
- Coatings and Chemicals
- Other De-icing Methods

Ice-induced vibrations

Ice-induced vibrations have not been considered as a potential threat until recently. But operational problems caused to jacket platforms in the Bohai Bay have changed this attitude. Vibrations caused by passing ice have created undesirable conditions and all works were stopped. Fatigue damage has been of concern. Later, platforms were re-designed to mitigate vibrations with use of special breaking cones [2,3].

Ice vibrations represent a very dangerous phenomenon due to the negative effect on reliability and performance of construction systems, machinery and personnel.

In this regard the following measures should be implemented:

- Calculation of accepted vibration level;
- Calculation of maximum possible vibration level of equipment during different exploitation scenarios;
- Reduction of vibration level.

Full-scale and in-time execution of these measures will allow achieving:

- Reduction of operational costs for equipment maintenance and repair;
- Less maintenance work;
- Reduction of equipment and machinery failures;
- Creation of comfortable conditions for personnel.

Introduction of norms in standards is very important for this. In particular, ISO 19906 [12] for design of technological systems of topsides, support structures, pipes and equipment considers the following factors:

- Ice loads on the support structures that cause abnormal vibrations similar to earth quake vibrations;
- Ice loads on the support structures with medium duration that cause short-period vibrations;
- Resonance caused by ice loads when the natural frequency of the construction equals the rotation frequency (vibration) of rotating parts of technological equipment (e.g. compressors, pumps, gas turbine generators, etc.).

Special attention should be paid to the problem of associated fatigue damages under low ambient temperatures.

For design of technological complex and vibro protection of equipment, the dynamic character of ice loads and corresponding ice induced vibrations should be taken into account. Calculations of possible amplification of vibrations due to synchronization with the eigen frequency of the structure and the frequency of the icebreaking are important, Figure 2,3,4.

Fig. 2 Crushing failure [1]

Fig. 3 Buckling failure [1]

Fig. 4 Bending failure on a sloping structure [1]

Dynamic ice loads appear in the following processes: periodical ice crushing, resonance vibrations and random vibrations during continuous ice cracking. The main purpose of the dynamic analysis is to ensure that there will be no resonance and auto-vibrations of the structure.

According to the ISO 19906 standard resonance dynamic loads on the construction can appear in the case of continuous ice moving with a relative speed from 0.04 m/s to 0.1 m/s. Constant vibration in this case can easily cause fatigue damages.

Conclusions

As it has been shown above, winterization is essential for facilities operating in the cold climate regions. Unfortunately, there is no guideline for the designers in this respect. A huge call from the industry urges specialists and institutions to develop standards and rules that could cover all of these challenges. At the moment each project is some kind of unique and project solutions are not generally opened to the engineering society, they stay in secret chambers of the companies. Nevertheless more and more info is coming out after realizations of edge projects, such as Russian research vessel “Academic Tereshnikov” which has recently been launched.

The first step in the progress is to combine the knowledge gained during design and operations in cold climate regions with academic research. This might give good results for further formalization of this experience in special codes and standards.

REFERENCES

[1] J.P. Ou, Z.D. Duan, G. Wang, Y.Q. Xiao. Ice Dynamic Excitation Models and ice-induced Vibration Analysis of Jacket Platform Structures. Harbin institute of technology. Dalian, Sep. 2002;

[2] Atmospheric Sciences. Real weather. Real experience. http://www.atmos.illinois.edu/index.html

[3] Yanlin Wang, Qianjin Yue ,Fengwei Guo, Xiangjun Bi, Zhongmin Shi, Yan Qu. Performance evaluation of a new ice-resistant jacket platform based on field monitoring. Cold Regions Science and Technology 71, pp. 44–53, 2012;

[4] J.R. Neason. OTC 19359 Specialized AC Drilling Rig for Arctic Offshore Drilling Applications. Texas, U.S.A., 5–8 May 2008;

[5] Rajiv Aggarwal, Richard D’Souza. OTC 22155 Deepwater Arctic – Technical Challenges and Solutions. Texas, U.S.A., 7–9 February 2011;

[6] Charles C. Ryerson. Assessment of Superstructure Ice Protection as Applied to Offshore Oil Operations Safety. September 2008;

[7] NORSOK Standard N-003, Actions and Action Effects, Edition 2. September 2007;

[8] U.S. Geological Survey Open-File Report, 2008;

[9] Charles C. Ryerson. Ice protection of offshore platforms. Cold Regions Science and Technology 65, pp. 97–110, 2011;

[10] Barents 2020 Final Report. 2012;

[11] Russian Maritime Register of Shipping. Construction and Equipment of Floating Offshore Oil-and-Gas Production Units, 2011;

[12] ISO 19906:2010. Petroleum and natural gas industries -- Arctic offshore structures. 2010.

