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Winterization and drilling operations in cold climate areas

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ABSTRACT

Petroleum operations in remote locations offshore off northern Norway call for technical and operational solutions, sustainable and capable of withstanding extreme and harsh weather conditions. This paper discusses hazards, risks and winterization measures when working in cold climate and presents a wind chill study performed on a semi-submersible drilling rig, when operating southwest in the Barents Sea. The objective of that study was to evaluate the winterization measure of partly enclosing the drill floor, with regards to the risk of hypothermia and operational restrictions.

Five independent measurements of wind chill temperatures were performed, during a period from May to February. Information were also gathered in conversations with personnel working on the floor. It was found from the temperature measurements that the working area became less exposed for wind turbulence and the effect of wind chill after the enclosure. Feedback from personnel working in the area confirmed the findings.

The passive winterization measure of partly enclosing the drill floor showed to be an effective safeguard for personnel against heat loss and the risk of hypothermia. In addition, operational restrictions with respect to working hours at lower temperatures could be reduced.

KEY WORDS: Cold climate operations; Hypothermia; Wind chill; Winterization; Working environment.

INTRODUCTION

Low air temperatures, low seawater temperatures, wind, snow, ice, fog and polar lows prevail in the far north during the winter season. Operating in a harsh environment, such as the Barents Sea, calls for technical and operational solutions which are capable of withstanding and being sustainable in extreme weather conditions.

The drilling rig in this case study is a semi-submersible drilling rig, operating in the southwest of the Barents Sea. The rig has a harsh-environment design and was recently upgraded at a yard stay to meet winterization requirements. Implemented winterization measures involved adapting and upgrading facilities, equipment and workplaces to ensure safe and regular operations in severe winter conditions. The adaptions and implemented measures are done to ensure that all activities and tasks are performed in an ergonomically sound way, concerning low temperatures, strong winds, poor visibility and restrictions imposed by Personal Protection Equipment (PPE).

WINTERIZATION

Winterization of a drilling rig comprises all measures taken to ensure safe and efficient operations in cold climates, to control and prevent freezing, icing, wind chill and other adverse effects of harsh weather conditions, for both personnel and equipment. These winterization measures are divided into active or passive measures.

Active winterization measures

Active winterization measures are electrical, mechanical or chemical and characterized as measures in which energy is addressed to avoid the adverse effects of icing, freezing or wind chill (DNVGL-OS-A201, 2015). Active winterization measures implemented on the semi-submersible drilling rig are as follows:

- Heat-traced walkways and escape routes. Either heat tracing is molded in or heat-traced rubber mats are used.
- Heat tracing inside handrails, attached to coamings and specific ventilation heads to prevent icing.
- Heat-insulation outside pipes, e.g. mud lines and fire water lines, using heat-tracing cable systems covered with insulation.
- Heat tracing inside pipes in areas with difficult maintenance access and where forces such as waves can damage any installation outside the pipes e.g. drains under helideck and under hull.
- Circulation in lines to prevent liquid from being static, e.g. fire water mains, cooling water branch lines and glycol in lines of the Blow Out Preventer (BOP).
- Chemicals added to lower the freezing point of fluids (e.g. glycol).
- Chemical and mechanical seal on instrumentation.
- Mechanical de-icing by use of wooden hammers and bats.
- Physical removal of snow and ice from deck using shovels, salt and flushing with heated seawater.
- Improved lighting in outside areas due to 24-hour darkness in winter season.
- Drainage of systems not heat insulated, to avoid freezing, or:
- Heating of the content to a minimum of 3°C above the freezing point of the content.

To provide anti-freezing protection, the electrical heat tracing system on the rig is dimensioned for air temperatures down to -20°C and wind speed of up to 30 m/s.

Passive winterization measures

Passive winterization measures are characterized as measures in which no energy is addressed, but temporary or permanent constructions are set up to avoid the adverse effects of icing, freezing or wind chill (DNVGL-OS-A201, 2015). Passive winterization measures implemented on the semi-submersible drilling rig are as follows:

- Partly shielded walkways.
- Enclosed working areas e.g. drill floor, derrick and lifeboat station and outdoor muster area.

- Internal heating elements and heating/ventilation systems installed, e.g. in the moon pool.
- Work clothing provided to personnel working outdoors, intended for use in low temperatures.
- Elimination of pockets, dead-ended pipes and legs in piping.

Enclosing areas can be an effective winterization measure but also an expensive one when designing/upgrading a rig for polar operations. Additional hazards are introduced when enclosing areas, e.g. drill floor / derrick, concerning gas accumulation. Risk of explosion, must be risk assessed and taken into consideration.

A less costly passive winterization measure is floor grounding with rubber mats (around rotary and nearby areas), where drilling personnel have their working area (RED and YELLOW zone). Solid rubber mats reduce heat loss via radiation and provide an ergonomic solution to prevent work-related musculoskeletal disorders. The rubber mats' surfaces also have an anti-slip design and purpose.

COLD CLIMATE WEATHER FEATURES – HAZARDS AND RISKS

Icing, snow, polar lows and low temperatures combined with strong winds are common weather features in the Barents Sea during winter seasons. Icing can occur due to several weather phenomena but are in this paper divided into sea spray icing and atmospheric icing.

Sea spray icing

Sea spray icing is caused by the freezing of sea spray on rig surfaces. Freezing sea spray is the most hazardous form of icing and also the most common (ISO 19906, 2010). Freezing sea spray usually occurs when the air temperature is less than –2ºC and the water is +7ºC or colder (Dehghani-Sanij et al., 2017). The area and rate of accumulation will vary with the conditions. The danger increases with stronger winds or colder temperatures (ISO 19906, 2010). Water salinity is an additional factor, as the risk of accumulated icing due to freezing sea spray increases when the seawater salinity is lower (Dehghani-Sanij et al., 2017). Uncontrolled sea spray icing can represent a great risk regarding loss of stability, integrity and equipment failure. However, splashing is in general less intense on a semi-submersible drilling rig compared to splashing on a vessel. Due to the high air gap, and that the splash zone seldom reaches more than 5-10 m above the sea level on a semi-submersible drilling rig (Dehghani-Sanij et al., 2017), a drilling rig is less exposed to the risk of sea spray icing on deck surfaces. Most of the icing from sea spray will occur on the under-hull structures.

Atmospheric icing

Atmospheric icing can occur do to several weather conditions, such as freezing rain and fog. It is not considered a risk for the rig as regards to the accumulated weight and loss of stability, but can represent a great risk for the integrity; atmospheric icing can cover the rig's surface with clear ice (ISO 19906, 2010), covering equipment such as valves and drains, making it difficult to operate, or the occurrence of breakdown of communications systems such as radar, antennas and safety systems. In addition, the condition can pose a risk to personnel in the form of slips, trips and falls.

Cold soaking

Cold soaking is a factor to be taken into consider when operating in polar environments. When a rig has been in cold temperatures for a long period, the structure of the rig will remain cold, even if the air temperature is warmer. This can cause more severe icing than predicted (OCIMF, 2014).

Snow

Snow can affect all heights on the rig and represent a problem on horizontal surfaces such as decks; it can cause hazards with slippery surfaces and the risk of slips, trips or falls. Snow can also adhere to vertical surfaces such as bulkheads or the derrick, especially if the surfaces are wet or if the snow is wet (ISO 19906, 2010). This can introduce the risk of dropped objects in the form of ice; wet snow accumulates on beams and structures and, when the temperature drops, the snow freezes to ice. When the temperature rises, the ice blocks melt and drop down. Snow can also accumulate on equipment such as valves, drains and communication systems, introducing the same risks as those of icing. Large amounts of snow could cause concern regarding intact stability.

Polar lows

Polar lows are low-pressure systems that develop rapidly and are therefore harder to forecast and predict (ISO 19906, 2010). Polar lows are common weather phenomena in the Barents Sea in the winter season, with weather characteristics of strong winds, heavy snow showers, thunder and lightning, choppy sea surfaces and increased wave heights. The risk of icing and poor visibility increases when polar lows occur.

PERSONNEL SAFETY – HAZARDS AND RISKS

Working in cold climate always represents a risk of hypothermia. Hypothermia is caused by cooling of the whole body or of body parts; cooling of the surface (skin and subcutaneous tissue), extremities (hands, feet, nose, ears) or the respiratory system. Heat loss vs. heat production will determine a person's thermic balance. Factors contributing to thermic balance or unbalance and hypothermia are climate, clothing and work activity performed (Nordic Innovation, 2011). The combination of wind and low temperatures, expressed as wind chill, lowers the temperature actually felt by the exposed person and contributes to increased heat loss (NORSOK N-003, 2016). Wind chill temperatures are calculated (or measured), giving the wind chill temperature index.

Heat loss can occur in several ways (Brunvoll et al., 2010):

- Convection: 50-80% of heat loss occurs via convection, with body heat being lost to the surrounding air.
- Conduction: heat loss occurs via contact with cold objects, e.g. holding tools, climbing on ladders or standing on cold surfaces.
- Radiation: heat loss to surrounding objects without physically being in contact with these. With sufficient protection of clothing, heat loss via radiation can be <20% of total loss of body heat.
- Respiration: approx. 10-15% of heat loss occurs via respiration. The use of a facemask, balaclava or buff can reduce this loss significantly.
- Evaporation: heat loss via evaporation can be a challenge when working in cold climates. The inner layer of clothes can become wet (sweat) when working / being

active and the insulation effect deteriorates as the wet clothing will cool down the skin. The alignment of clothes and work tempo to control/prevent sweating is an important principle when working in cold climates.

Work at heights and work over open sea are work activities with increased risk of heat loss:

- Increased heat loss via convection, due to exposure to weather conditions (winds + low temperatures + snow/rain).
- Increased heat loss via respiration and evaporation, as work activities are demanding and strenuous to perform.
- Increased heat loss via conduction as holding/leaning/sitting against metal structures will occur during work activities.
- Increased heat loss as the wind velocity increases with height above the surface.

The risk of falling into the sea is present when working over open sea, with the adverse effects of hypothermia and possible drowning. The work activity requires the use of a safety harness (as with work at heights), to prevent personnel from dropping if they should fall. The likelihood of a safety harness failing is small, if used correctly, certified and properly controlled.

Clothing

Proper clothing is the most important means of control to avoid heat loss when working in cold climates. When working on the drilling rig, it is mandatory to wear regular PPE in all areas, except when inside the accommodation. This includes coverall, safety boots, helmet, safety glasses and gloves. In the winter season, extra clothing needs to be used in addition to the mandatory PPE. The most practical (for movement) and efficient way (control of the body's thermic balance) is to use multiple layers of clothing (Norsk olje og gass, 2013). The inner layer´s purpose is to transport moisture away and keep the skin dry (Færevik et al., 2013). Inner layers comprised of wool products are recommended, as wool materials can absorb considerable amounts of moisture without reducing the purpose of insulation. Synthetic and non-absorbing materials, e.g. polyester are also recommended as an inner layer. A cotton inner layer is not recommended, as the material absorbs and accumulates sweat and will increase heat loss, as the accumulated sweat will cool down the skin. As a mid-layer, wool products are a preferred choice, in addition to fleece products, both of which have good thermic insulating properties. As outer layers, coveralls and insulated raincoats protecting from wind, rain and snow are used (Norsk olje og gass, 2013). For the above-mentioned mandatory PPE, insulated safety boots with anti-slip soles are recommended. Using boots one size bigger than normal is often preferred, as insulated soles or extra socks then can be worn. Insulated gloves are recommended, but may not be preferred, as they limit motor skills. A balaclava, buff or insulated inner layer in the helmet is used to prevent heat loss from the head.

A common practice of rig personnel is to use disposable chemical/liquid-resistant coveralls made of polypropylene, as a final outer layer of clothing. These coveralls are wind- and water-resistant, but the coveralls do not "breathe" and prevent the evaporation of sweat, which can cause personnel to become wet and cold. The purpose of their use (protection against weather) can therefore be counter-effective. In addition, the coveralls are white, which can be a safety concern with regard to visibility, e.g. for the crane operator when performing lifts.

Work restrictions

Reduced working hours and increased intervals of rest indoors, when the temperature drops and the wind speed increases is another means of control to prevent frostbite and hypothermia. In Table 1, restrictions in working hours are given, according to set wind chill temperatures.

	Wind Chill Temperature	Consequence - Action
	Below -30°C	No outdoor work to be performed unless deemed critical from a safety or operational perspective. Must be risk assessed and compensating measures to be implemented. The work to be limited to an absolute minimum, and nobody is allowed to work alone.
	Below -21°C	Available outdoor working time is below 60% of working hour; maximum length of outdoor work periods is 40 minutes, with 20-minute breaks in heated areas. The outdoor work to be limited to total max. 5 hours per day. Not allowed to work alone, and work must be under medical surveillance.
	Below -12°C	Available outdoor working time is below 75% of working hour; maximum length of outdoor work periods should be 70 minutes with 20-minute breaks in heated areas. Limited to total max. 8 hours per day.
	Below -6°C	Available outdoor working time is below 90% of working hour; maximum length of outdoor work periods should be 90 minutes with 15-minute breaks in heated areas.
	Above -6°C	Normal work hours, but precautions and breaks in heated areas.

Table 1. Wind chill temperatures, consequences and actions. Modified from the rig`s winter operation manual.

WIND CHILL TEMPERATURE STUDY

A wind chill temperature study was performed on the drill floor. The objective of the study was to evaluate the effect of enclosing the working area, which was done in the winterization upgrade of the rig. A hydraulic door was installed in the aft opening on the drill floor. In the forward opening on the drill floor, a gate was already mounted but, during the yard stay, was modified with a heavy rubber curtain to prevent exposure to wind and snow for personnel and to hinder snow from accumulating on deck.

Method

Five measurements of wind chill temperatures were carried out, over the period from May to February. The lowest temperatures measured were logged, when the aft door and forward gate were in closed and open positions. Information was also gathered in conversations with personnel working on the drill floor, about their perception of the effect of having the area enclosed. The personnel involved in these conversations had working experience on the drill floor prior to the winterization upgrade.

Data collection

Wind chill temperatures were measured with a WeatherHawk WindMate WM-350, weather meter. Data of wind direction, wind speed, air temperatures and rig heading were collected from the drilling rig`s weather monitoring system, Fugro.

Results

The results from the wind chill temperature measurements, in combination with feedback from drill crew personnel, are utilized to evaluate the effectiveness of the passive winterization measure of enclosing the drill floor. Wind directions during the measurements no. 1 and 5 affected the aft drill floor and wind directions during the measurements no. 2, 3 and 4 affected the forward drill floor, due to the rig heading, as seen in Figure 1.

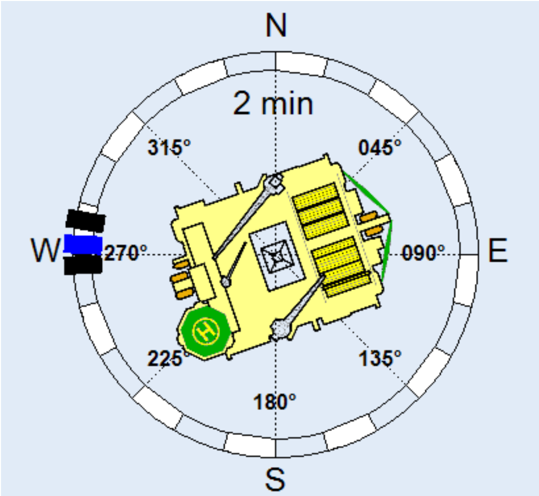

Figure 1. Rig heading showing wind from the west, affecting the forward drill floor.

Measurements of the wind chill temperatures are seen in Table 2.

Measurement no.	Wind direction	Wind speed (Knots)	Air temperature	Wind chill (doors closed)	Wind chill (doors open)
1	southeast	31.8	4.1 ºC	5.4 ºC	2.0 ºC
2	southwest	43.3	6.4 ºC	8.4 ºC	0.8 ºC
3	southwest	47.4	8.2 ºC	8.7 ºC	2.6 ºC
4	northwest	24.7	5.1 ºC	6.0 ºC	0.2 ºC
5	east	33.8	-3.8 ºC	-3.0 ºC	-10.8 ºC

Table 2. Wind chill temperatures measurements, from May to February.

An average difference in wind chill temperature, when the aft door and forward gate were in open and in closed positions, was measured to > +6 ºC. One precaution implemented on the rig to safeguard the drilling personnel from frostbite and hypothermia are reduced working hours and increased intervals of rest indoors, when the temperature drops and the wind speed increases. After enclosing the drill floor, longer working hours at lower temperatures are possible, as seen in the Table 3.

	Wind Chill Temperature	Consequence - Action		Effect of enclosing drill floor; > +6°C
	Below -36°C			Wind chill temperature < -36°C will be ≤ -30°C when aft door and forward gate are closed; no outdoor work to be performed unless deemed critical from a safety or operational perspective. Must be risk assessed and compensating measures to be implemented. The work to be limited to an absolute minimum, and nobody is allowed to work alone.
	Below -30°C	No outdoor work to be performed unless deemed critical from a safety or operational perspective. Must be risk assessed and compensating measures to be implemented. The work to be limited to an absolute minimum, and nobody is allowed to work alone.		Wind chill temperature < -30°C will be ≤ -24°C when aft door and forward gate are closed; working time <60% of working hour (40 minutes with 20-minute breaks) and total exposure of max. 5 hours per day.
	Below -21°C	Working time < 60% of working hour (40 minutes with 20-minute breaks) and total exposure of max. 5 hours per day.		Wind chill temperature < -21°C will be ≤ -15°C when aft door and forward gate are closed; working time < 75% of working hour (70 minutes with 20-minute breaks) and total exposure of max. 8 hours per day.
	Below -12°C	Working time < 75% of working hour (70 minutes with 20-minute breaks) and total exposure of max. 8 hours per day.		Wind chill temperature < -12°C will be ≤ -6°C when aft door and forward gate are closed; working time < 90% of working hours (90 minutes work periods with 15-minute breaks).
	Below -6°C	Working time < 90% of working hours (90 minutes work periods with 15-minute breaks).		Wind chill temperature < -6°C will be ≤ 0°C when aft door and forward gate are closed; 100% normal working hours.
	Above -6°C	100% normal working hours.		Wind chill temperature > -6°C will be ≥ 0°C when aft door and forward gate are closed. 100% normal working hours.

Table 3. Wind chill temperatures, consequences and actions and the effect of enclosing drill.

The feedback from personnel working on the drill floor was positive overall. No negative feedback or comments were given. When asked to range the perceived effect of having the working area enclosed, the average score was +3 on a scale from one (no effect) to five (very good effect). The aft door and forward gate are operated by panels, easily operable when wearing thick impact gloves. The panels are located near the door/gate, and the drilling personnel can swiftly open/close doors as the drilling activity and operation proceeds. It should be noted that enclosing the drill floor in this manner have not been evaluated in this study, with regards the design philosophy, area classification and on the possibility of accumulating gas in the area (DNVGL-OS-A101, 2015). However, it was noted that there still was a considerable air flow through the area after the enclosing.

CONCLUSIONS

After installing the aft door, the drill floor is less exposed to wind turbulence when the aft door and forward gate are in the closed position. Seen in comparison with the results from the wind chill temperature measurements, the passive winterization measure of enclosing the drill floor is evaluated to be effective for safeguarding the personnel against heat loss and hypothermia. Longer working hours at lower temperatures are also possible after partly enclosing the drill floor, and the passive winterization measure is considered to be reasonable from a cost-benefit perspective.

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