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Winterization Techniques for Offshore and Marine Environments - New Standards and Design Approaches

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CONTENTS

WINTERIZATION TECHNIQUES FOR OFFSHORE AND MARINE ENVIRONMENTS – NEW STANDARDS AND DESIGN APPROACHES (REV 0/2017)

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ABSTRACT

Arctic oil development dates back to August 24, 1920 when oil deposits were discovered on the Mackenzie River at Norman Wells, Northwest Territories. In the late 1950s and early 1960s, the UK, Russia and US began wide scale exploration and development of Arctic oil followed by Norway and Greenland (Denmark). According to the U.S. Geological Survey (USGS), the existing fields beyond the Arctic Circle contained about 240 billion proven barrels of oil and oil-equivalent natural gas comprising about 10% of the world's existing conventional resources. Roughly 84% of the undiscovered Arctic resources are expected to be found offshore.[1] Although Arctic development may be necessary for future energy needs, the technical, economic and environmental challenges are staggering. Over the past five decades, much technological advancement has been made to arctic and cold weather vessels and equipment. Such equipment was specifically designed to withstand snow, wind, and ice extremes and to ensure the safety of personnel and equipment. Likewise, many international standards were developed to provide guidance to manufacturers and operators of such equipment.

nVent has been a leading supplier of RAYCHEM winterization products for more than 40 years. In the early 1980s, nVent pioneered the engineering design, supply and installation practices for equipment and surface anti-icing, de-icing and frost prevention on cold climate offshore rigs, platforms and vessels. Many of the test methods and models developed by nVent to measure and predict surface temperatures during severe environmental conditions became industry best practices[2]. More recently, nVent has developed thermal modeling methods to better qualify and design heating systems for a wide range of surface anti-icing and de-icing applications. Since early 2017 nVent also collaborates with Tranberg AS, aimed at providing customers in the marine market with integrated winterization solutions for operation in arctic climates. The new collaboration unites best in class products from leading product brands RAYCHEM and Tranberg with proven and superior design capabilities.

Index Terms – Winterization, Anti-icing, De-icing, Electric Trace Heating, Heat Management System, Offshore and Marine Vessels, Arctic Oil Development, Icing, Freezing, Extreme Temperatures

I. INTRODUCTION

This paper presents a new and unique approach for design of winterization equipment for offshore applications. Recent standards such as DNVGL-OS-A201 provide general world-wide principles for mobile units and offshore installations intended for cold-climate conditions. Together with the required product and equipment safety approvals and certifications required by the local reviewing authorities, manufacturers can now provide written confirmation that equipment has been tested for suitability for cold-climate conditions consistent with DNVGL-OS-A201.

nVent has recently created sophisticated predictive modelling techniques and compared the results of the models with test data for a wide range of conditions consistent with DNVGL-OS-A201. They further qualified the models with data accumulated over their 40 years of application experience. Since winterization designs cover a wide range of equipment, surfaces and conditions, the use of qualified predictive modelling techniques can greatly facilitate engineering design for anti-icing and de-icing applications.

In addition, the availability of new and improved heating technologies,
state-of-the-art monitoring and control electronics, and customized software can further improve and optimize winterization designs as well as reduce CO_2 emissions for specific applications and energy efficiency.

A. MARKET INDICATORS

Governments continue to be attracted to oil exploration and development in the arctic primarily due to the large estimated quantities of undiscovered oil and gas and the potential independence of a given country on oil imports. With continuing global warming, the ice coverage of the Arctic Ocean has been shrinking thereby removing many engineering and logistic obstacles present in the past. [4]

There are six countries with regions beyond the Arctic Circle with direct access to the Arctic Ocean - Russia, USA, Canada, Norway, Denmark (via Greenland) and Iceland. Only the first four countries listed above are actively drilling for oil and natural gas in these areas.

The Arctic is estimated to contain about 90 billion barrels of undiscovered oil, 500 billion cubic meters of undiscovered gas and 44 billion barrels of natural gas liquids, making up, respectively, 16%, 30% and 26% of the world's individual undiscovered hydrocarbon resources.[1] Roughly 84% of the undiscovered Arctic resources are expected to be found offshore. Figure 1 illustrates the probability of the presence of undiscovered oil/gas fields with significant amount of recoverable resources (> 50 million barrels of oil equivalent).across various regions in the Arctic. A darker blue means a higher probability.

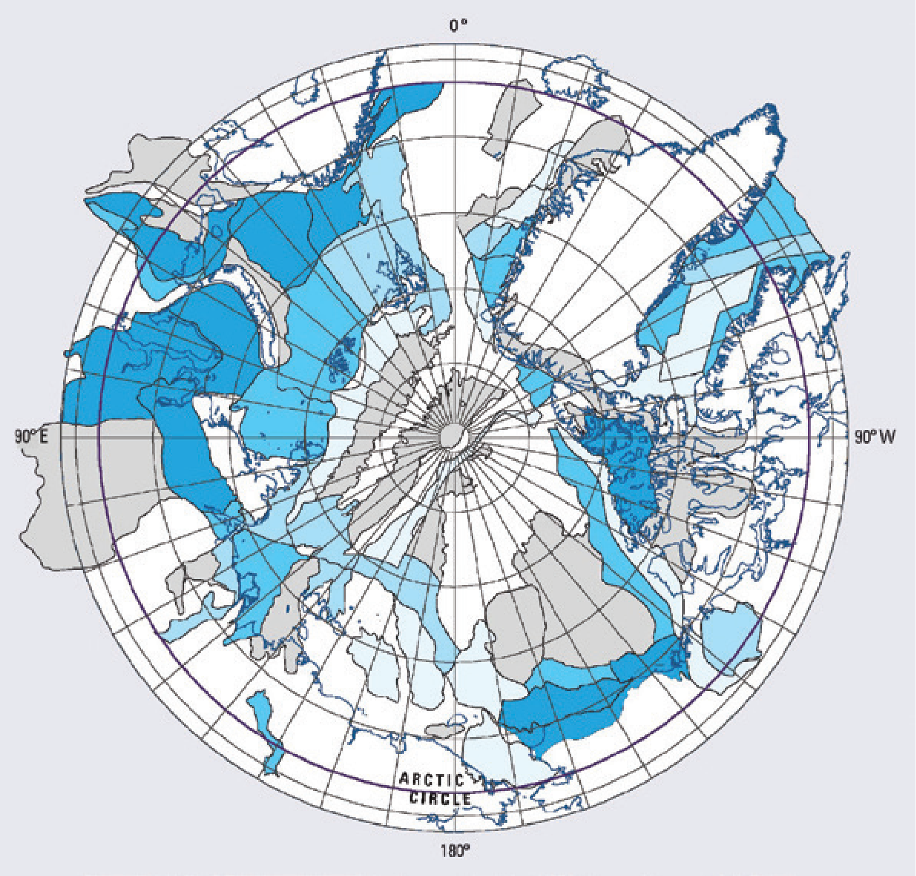

Figure 1. Arctic undiscovered oil/gas probability. Darker blue indicates higher probability. [1]

In addition to the demand for Arctic oil, the potential for minerals, fisheries, marine transport, scientific exploration and research and even tourism are also increasing in the region.

B. CHALLENGES WITH COLD CLIMATES

Sub-zero temperatures and ice may have a severe impact on the operations, vessels, equipment and personnel in many geographical areas. In addition, many of these operations are often remote with limited navigational and support infrastructure. Sea ice might be encountered seasonally or even year-round. Even though global warming has opened up portions of the Arctic Ocean, the naval routes can at times be easy or treacherous as the frequency and number of icebergs changes. Land transportation gets complicated in the summer, when the top layer of the permafrost melts into mud and may be unable to support heavy machinery and equipment. Weather conditions are also becoming unstable and less predictable as the weather patterns change. Additionally, ocean wave motion and forces are increasing as the polar ice cover reduces.

Harsh Arctic environments require specially designed equipment, vessels and disaster-prevention measures to be in place. Disaster prevention measures became especially clear after the 2010 Deepwater Horizon spill in the Mexican gulf. Such a disaster in the Arctic would be even more devastating where the oil would not be able to evaporate from the water and firefighting and prevention equipment as well as the firefighting personnel might have to battle extreme cold and icy conditions. Figures 2 and 3 are examples of the typical environments encountered in the Arctic.

Figure 2. Typical Arctic oil production.

Figure 3. Typical Arctic rough seas.

Given these issues, the engineering challenges with the design of equipment, operating procedures, and safety equipment are massive. For example, sea spray icing on offshore vessels and rigs operating in sub-arctic waters can threaten operations by blocking or hindering essential components such as instruments, valves, doors, hatches, walkways, helicopter decks or lifeboat loading areas. Figure 4 is a photo of ice buildup on critical vessel components.

Figure 4. Example ice buildup on Essential Equipment.

Ice buildup on key structures can inhibit stability or even increase the possibility of capsizing. For example, just a 50mm ice buildup on the bottom deck of a typical rig can add 200-300 tons of extra weight. If the ice load is unbalanced or if the ice causes unwanted mechanical resonance, the rig or vessel could tilt, have severe vibrations or capsize. In 2011, the Russian jack-up rig Kolskaya capsized and sank off of the Sakhalin Islands while being towed through a winter storm leaving 53 dead or missing in the icy Sea of Okhotsk. Figure 5 is a photo of the Kolskaya one year prior to the disaster.

Figure 5. The "Kolskaya" oil rig near Murmansk.

Personnel safety risks are greatly increased due to icy walkways and stairs possibly causing lost work hours. Figure 6 shows a graph indicating frostbite dangers as a function of temperature and wind speed. Figure 7 is a photo of worker with cold weather protection.

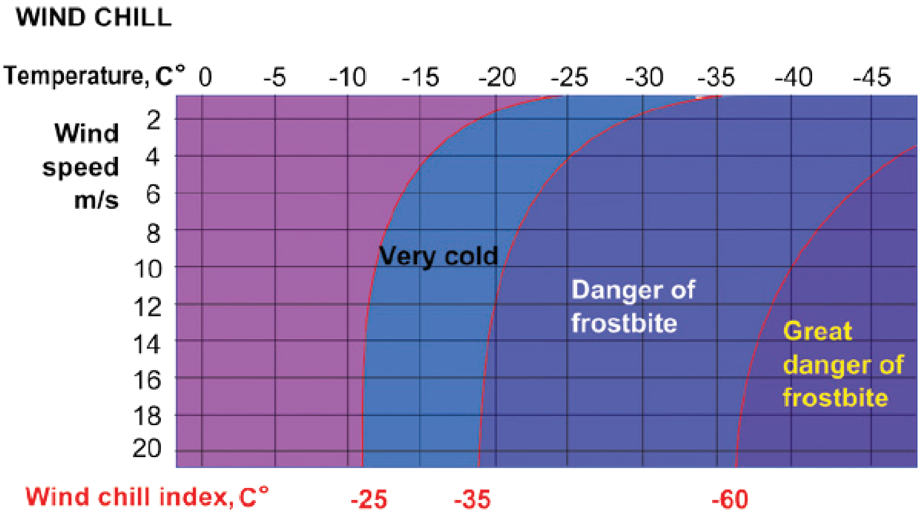

Figure 6. Frostbite potential as a function of temperature and wind.

Figure 7. Personnel protection in cold conditions.

C. TRAGEDIES DUE TO EXTREME CONDITIONS

Unfortunately there have been many accidents caused either directly or indirectly due to extreme weather conditions. The most notable are:

- 1969: Bohai No.2 oil rig capsized due to icing
- 1978: Dutch tanker M/S Anna Broere abandoned in Baltics, due to heavy icing
- 1980: Alexander L Kielland rig collapsed in North Sea; structural failure heavy wave conditions; 122 died
- 1982: Ocean Ranger rig sank in Canadian waters, during heavy storms; 84 died
- 2011: Kolskaya rig sank in Sea of Okhotsk, when being towed back in a fierce winter storm; 53 died
- 2013: Kulluk platform drifted aground while being towed in arctic waters. Shell scrapped the rig.

Even though all of the listed vessels had some degree of winterization protection, their demise point out the constant threat of danger encountered in Arctic and sub-zero environments. Figure 8 includes three photos of rigs and vessels in weather related distress.

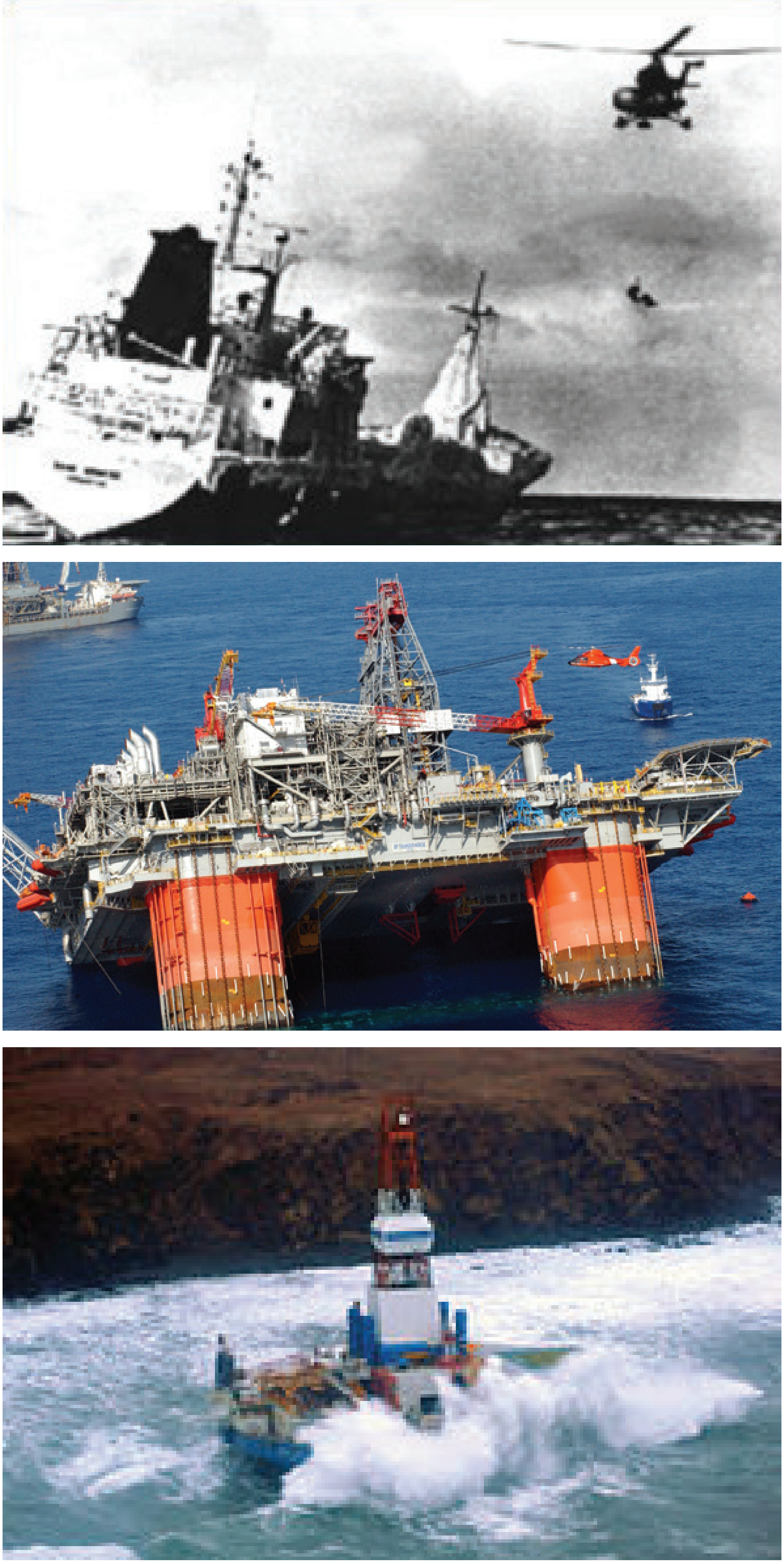

Figure 8. Photos of rigs and vessels in weather distress.

II. WINTERIZATION RULES, REGULATIONS AND GUIDELINES

For more than 20 years, many international and country sponsored agencies developed a raft of requirements, guidelines and recommendations regarding marine vessels, oil equipment and personnel safety that operate in cold and/or polar ice-covered waters. Most notable are:

- The International Maritime Organization (IMO)
- DNV GL (Formerly Det Norske Veritas)
- American Bureau of Shipping (ABS)
- UK Maritime and Coastguard Agency (MCA)
- Russian Maritime Register of Shipping
- Canadian Coast Guard
- Lloyd’s Register
- International Association of Drilling Contractors (IADC)
- PEW Charitable Trusts

In addition most multinational oil companies such as Statoil, BP, Shell and Chevron have their own standards for operation of vessels and equipment in cold and Arctic environments.

Although there is no single international standard the DNV GL standard DNVGL-OS-A201 includes one of the most comprehensive set of principles for winterization of systems, equipment and vessels. The standard uses a three tiered approach. First, winterization requirements are based upon fulfilling the stated functional requirements, which provide the fundamental rationale and intent behind a particular winterization issue. Second, some functional requirements are further supported by one or more performance requirements. These explain in greater detail the type of performance a winterization measure should achieve in order to fulfill the intent of the functional requirement. Third, functional and performance requirements are supported by prescriptive rules and guidance notes. These provide a set of generally acceptable solutions to meet the functional and performance requirements.

III. WINTERIZATION METHODS

A. WINTERIZATION REQUIREMENTS AND METHODS

Winterization requirements can be broken into two classes:

- Anti-icing is the prevention of ice formation. An example of anti-icing is keeping an emergency passageway ice free.
- De-icing is the removal of ice from an area. An example of this is the removal of ice from the underside of a rig to prevent dangerous ice loadings.

Anti-icing requirements are generally related to personnel safety. They include emergency passageways, helidecks, and emergency doorways. These areas must be kept free of ice for a possible evacuation during the worst expected conditions.

De-icing requirements are for prevention of excessive ice loading such as the bottom deck or for personnel safety such as stairs, handrails or walkways.

Since anti-icing and de-icing measures can vary greatly with environment conditions, it is important to define specific winterization temperature conditions. DNVGL-OS-A201 defines three such conditions (Basic, Cold and Polar) as indicated in Table 1.

Qualifier	"Indicative" Winterization Temperature (tw)	Sea Water Temperature
Basic	-15°C	+4°C without ice class -2°C with ice class
Cold	-30°C	+2°C without ice class -2°C with ice class
Polar	-45°C	-2°C

Table 1. Design Environmental Conditions.

Many active and passive methods and techniques exist for anti-icing and de-icing including:

- Steam
- Electric Heat Tracing
- Hot Water
- Infrared Radiation
- Chemical Freezing Point Depressants
- Ice Phobic Coatings
- Mechanical Methods

Steam hoses have proven to be very effective for the removal of ice. This is particularly true for irregularly shaped objects such as lifeboats and mooring winches. Steam's high temperature and energy content allow it to remove ice quickly. However, there are issues with using steam. For example, many of the surfaces that require anti-icing or de-icing are surfaces where personnel are exposed or are in hard-to-reach areas.

Hot water has most of the drawbacks of steam and is less effective since it has lower energy content. Figure 9 is a picture of ice being removed by a steam wand.

Figure 9. Ice removal using steam wands.

Infrared radiation, chemical freezing point depressants and ice phobic coatings have all been used with some degree of success, but in very limited specific applications.

Mechanical methods to remove ice using shovels, hammers, and crowbars can be effective, but are not practical for large areas on most vessels. Furthermore, such manual methods increase the personnel risk of hypothermia. Figure 10 includes three photos of ice being removed by mechanical methods.

Figure 10. Ice removal using mechanical methods.

B. ELECTRIC WINTERIZATION

nVent RAYCHEM Electrical heat tracing has been used for both anti-icing and de-icing for many years. It has proven to be effective and reliable for a wide range of applications including walkways (Figures 11 & 12), handrails (Figures 13 & 14), stairs (Figure 15), helidecks (Figure 16), and many others.

Figure 11. Heated Walkway

Figure 12. Heated Walkway

Figure 13. Heated Handrails

Figure 14. Heated Handrails

Figure 15. Heated Stairs

Figure 16. Heated Helideck

C. RAYCHEM WINTERIZATION SOLUTIONS

nVent has been supplying nVent RAYCHEM anti-icing and de-icing solutions to the offshore industry for nearly 40 years. Early applications were primarily for pipe and drain freeze protection with some limited snow and ice prevention. In 1985, the first semi-submersible rig purposely built for Arctic conditions, the Polar Pioneer, utilized RAYCHEM winterization products for a wide range of applications such as walkways, stairs, handrails, and helideck. De-icing was provided for under deck ice removal. Figure 17 is a photo of Polar Pioneer.

Figure 17. Polar Pioneer 1985.

To engineer the various winterization designs needed for the Polar Pioneer, nVent developed and tested models to establish heat loss of various surfaces under varying temperature and wind conditions. These models proved to be effective and served as the engineering design basis for nVent long list of successful applications on nearly 100 rigs, platforms and vessels.

Other notable nVent projects include:

- CNOOC QK17-2 platform (1999) used for oil and gas production in the north China Sea
- The Scarabeo 8 (2009) an ultra deepwater semi-submersible rig designed for cold water applications
- FPSO Sevar Goliat (2014) which was the first FPSO for the Barents Sea.

A. NEW STANDARDS

DNV GL has been a leader in supplying guidelines and standards for ships and vessels for over 100 years. Its leadership reputation is widely accepted by global manufacturers and clients. In 2013, DNV GL launched DNV TS-501 for ships and DNVGL-OS-A201 for offshore installations. These standards provide winterization principles for marine installations intended for cold-climate conditions. DNV GL are also leading The Barents2020 project to better understand and harmonize international standards for safe exploration, production and transportation of oil and gas in the Barents Sea including winterization standards.

Besides defining the winterization levels Basic, Cold, and Polar mentioned earlier and depicted in Table 1, DNVGL-OS-A201 spells out the requirements for materials, stability, hull equipment, electrical, safety, navigation, machinery and telecommunications. Two key equipment categories along with the recommended winterization principles are defined in Table 2.

Category	Winterization principle
Cat I - navigation, steering, propulsion, anchoring, lifesaving/escape routes	anti-icing required with sufficient capacity to keep equipment or areas free from ice at all times.
Cat II - decks and superstructures, helicopter decks, railings, cargo deck area	de-icing required with sufficient capacity for removal of accreted ice within 4 to 6 hours under the icing conditions specified.

Table 2. Equipment Categories

B. NEW STANDARDS USED TO CREATE NEW HEAT LOSS MODELS

Based on the new standards, nVent developed and tested new heat loss models using state-of the art simulation and finite element analysis tools that conform to the winterization levels and principles called out in the DNV GL standards. The predicted temperatures of the models were compared to empirical data generated by tests to verify the model's accuracy. Figure 18 is a graph of measured and predicted surface temperature results as a function of ambient temperature and wind speed. The repeatability and linearity of the data demonstrate the ability of the model to accurately predict surface temperatures under varying conditions.

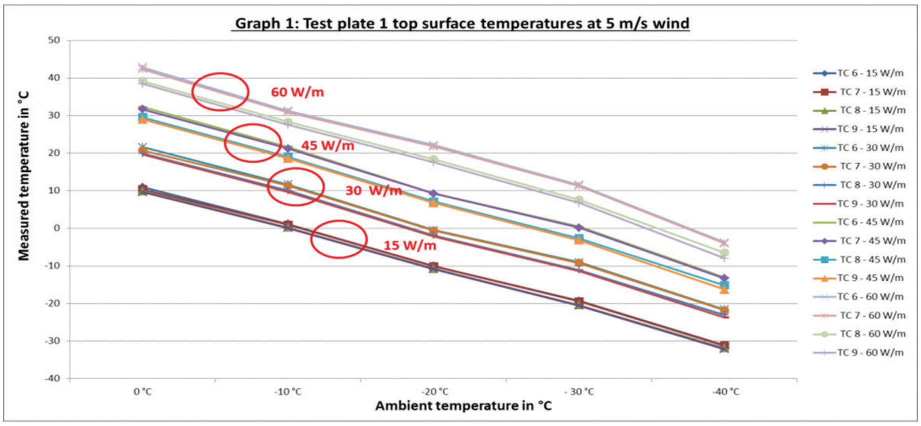

Figure 18. Measured and predicted surface temperatures as a function of ambient temperature and wind.

To further refine the model, the heat transfer coefficients of the model were adjusted to allow for surface roughness. Figure 19 is a test sample of a plate with a diamond texture. This was used to compare the heat transfer of the model against flat plate predictions and to make the necessary adjustments to the model.

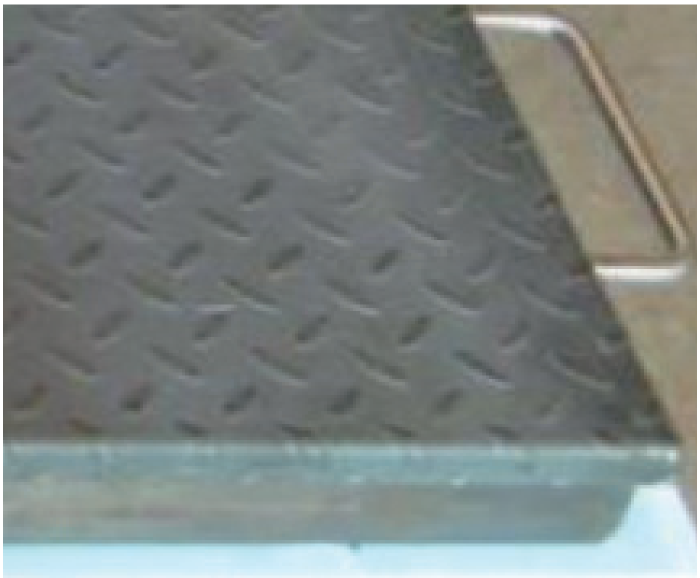

Figure 19. Test plate with diamond texture.

Similarly, the testing was initially done using a duct to simulate wind (Figure 20). Heat transfer due to the simulated localized wind will be higher than that of bulk wind in real applications. The model was thereby adjusted for this factor.

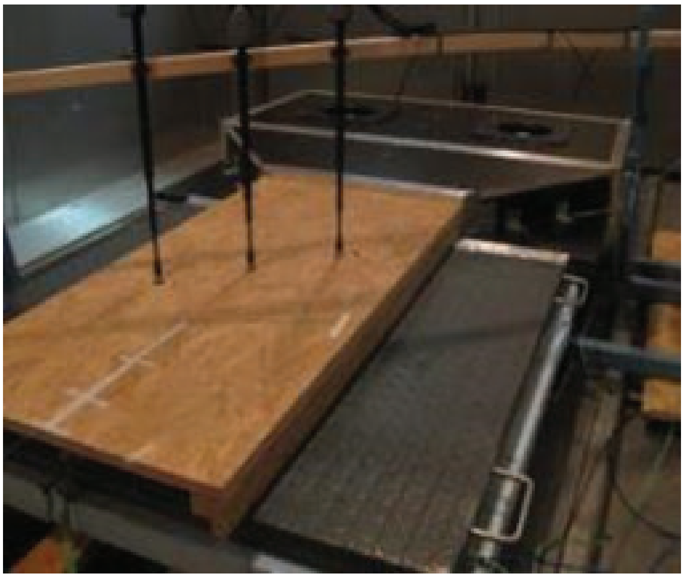

Figure 20. Test set up using duct for wind simulation.

Another design parameter simulated and tested was the impact of surface edge effects. In general, heat transfer at the leading edge of a flat surface is higher than in the center. This is because the thickness of the boundary layer at the edge is thinner and the conductive impedance to heat flow is less. Figure 21 illustrates the different types of flow and heat transfer as a function of distance from the leading edge of a surface. Figure 22 illustrates the dramatic difference in heat loss as a function of distance from the leading edge. This is an explanation of why ice tends to build more quickly at the edge of a surface such as a walkway or helideck.

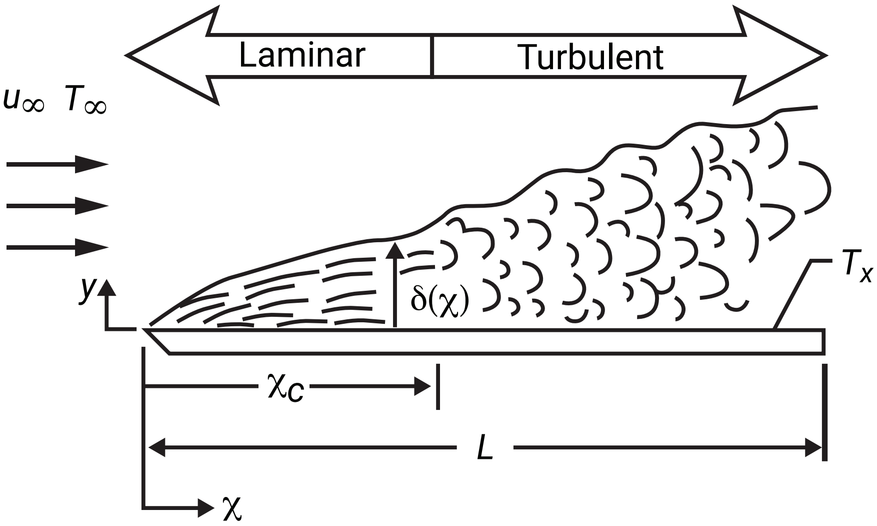

Figure 21. Flow types at a surface leading edge.

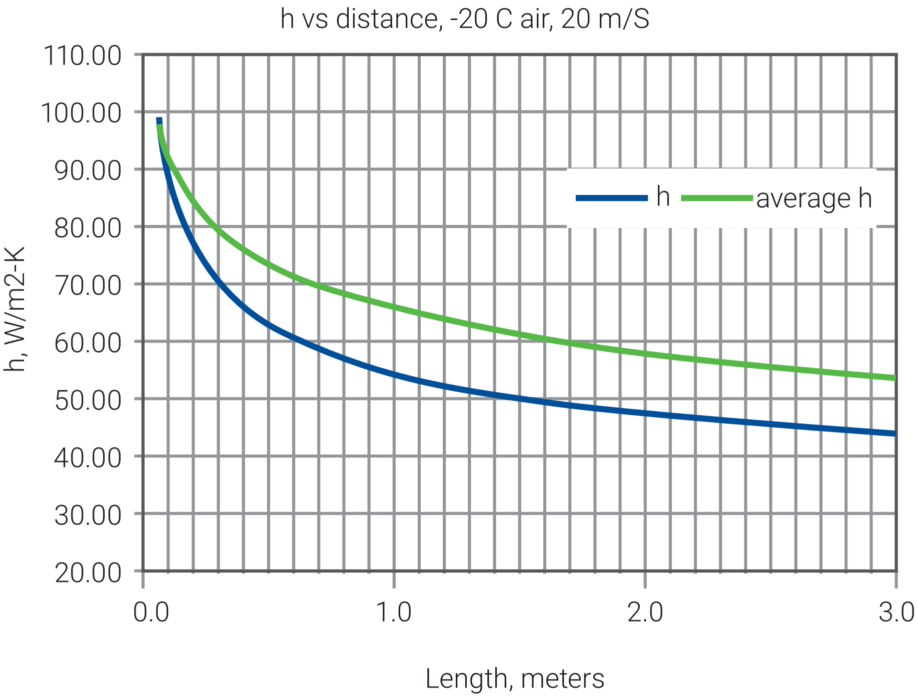

Figure 22. Heat loss as a function of distance from a surface leading edge.

The net result of the created model is that it can be used to create design tools for a wide variety of winterization applications and conditions. Further, new and improved heating systems can be better designed and optimized for specific applications and conditions.

C. NEW HEATER DESIGNS

One example of how the model can be used to design a custom purpose product is the anti-icing cassette. In many offshore applications there is a need for prefabricated modular walkways. In the past, design of heated walkways was based on the worst case conditions anywhere along the path of the walkway. By creating standard sized modules, or cassettes, with different heat profiles, they can be put together to form walkways of varying length and configurations that better optimize the heat profile needs as illustrated in Figure 23.

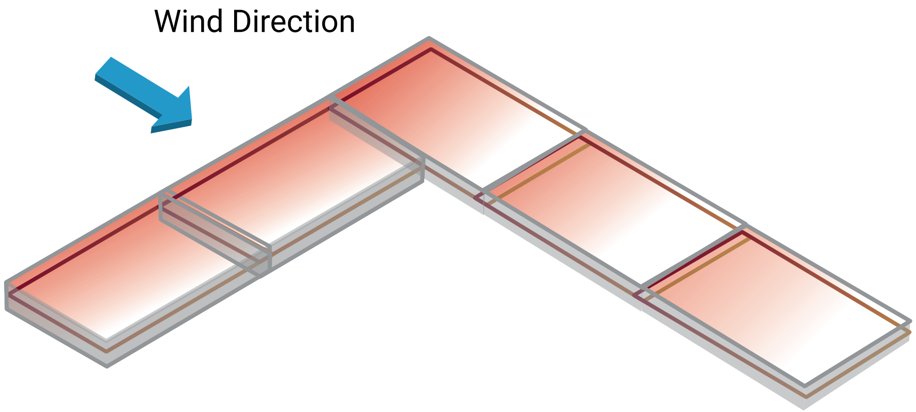

Figure 23. Example walkway designed using modular heated cassettes. Red indicates heat required.

For example, walkways fully exposed to wind and elements would require more heat than those better protected or isolated. If the modular approach was used for a helicopter deck, modules close to the edge would necessarily provide more heat than modules closer to the middle. Using the model, it is now possible to design such systems. Additionally, todays nVent RAYCHEM control and monitoring capabilities coupled with the latest controller software can make it possible to turn individual modules on and off based on the localized measured need at each module location. The result is a winterization system that uses less energy and is better suited to the specific basic, cold or polar application need.

V. CONCLUSIONS

The Arctic holds 10% of the world's existing conventional resources most of which is offshore. The technical, economic and environmental challenges to develop those resources are staggering. However, much advancement has been made over the past five decades to arctic and cold weather offshore and marine vessels, exploration and production equipment. Likewise, many international standards exist to provide guidance to manufacturers and operators of such equipment. Recent standards such as DNVGL-OS-A201 provide better defined world-wide principles for vessels and offshore installations intended for cold-climate conditions.

nVent has been a leading supplier of RAYCHEM winterization products for more than 40 years. Many of the test methods and models developed by nVent to measure and predict surface temperatures during severe environmental conditions are industry best practices. More recently, nVent has developed better thermal modeling methods to better qualify and design heating systems for a wide range of surface anti-icing and de-icing applications.

Since winterization designs cover a wide range of equipment, surfaces and conditions, the use of qualified predictive modelling techniques can greatly facilitate engineering design for anti-icing and de-icing applications.

In addition, the availability of new and improved heating technologies, state-of-the-art monitoring and control electronics and customized software can further improve and optimize winterization designs for specific applications and energy efficiency.

VI. ACKNOWLEDGMENTS

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