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Ice protection of offshore platforms

Charles C. Ryerson *

U.S. Army Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory, Hanover, NH, United States

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ABSTRACT

Climate change-induced reduction in the extent and duration of sea ice cover, as well as an increase in energy demands, has caused renewed interest in exploring and drilling for oil in Arctic waters. Superstructure icing from sea spray and atmospheric icing in the Arctic may impact offshore platform operations. Though icing has not caused the loss of an offshore platform, it can reduce safety, operational tempo, and productivity. Historically, many ice protection technologies were tested on offshore platforms with little success. However, new technologies and modern versions of old technologies used successfully in aviation, the electric power industry, and ground transportation systems, may be adapted to an offshore environment. This paper provides a framework for assessing the relative threat of ice accumulation types, such as superstructure ice, glaze, rime, frost, and snow, to the safety of platform functions. A review of ice protection strategies for functional platform areas is also provided.

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1. Introduction

Arctic oil exploration and production have increased because of a reduction in sea ice cover. The increased global demand for oil will result in a larger number of offshore structures built, used, and exposed to icing from atmospheric sources. Atmospheric icing is defined by the International Standards Organization (ISO) and the International Council on Large Electric Systems (CIGRE) as any process of ice or snow accumulation on objects exposed to the atmosphere (Farzaneh, 2008; Fikke et al., 2006). Atmospheric icing is further classified as types of ice, based upon methods of deposition and characteristics of deposits. These include glaze from precipitating freezing rain or freezing drizzle, snow, rime ice resulting from supercooled cloud or fog droplets, and hoar frost resulting from the deposition of water vapor directly as ice crystals. Sleet, a form of freezing precipitation, and superstructure ice resulting from sea spray, are traditionally not classified as atmospheric icing, but they are similar in formation processes. More complete descriptions of these ice types may be found in Farzaneh (2008); Fikke et al. (2006), Ryerson (2008), and SAE (2002). These types of icing can reduce offshore operations safety and operational tempo and are discussed in this paper. Though floating sea ice also degrades offshore platform operations and safety, floating sea ice types are not discussed in this paper and should not be confused with atmospheric ice types (AES, 1994).

Offshore platforms are complex with regard to the types of operations conducted onboard, and the type of and variability of icing problems. Selection of safety-enhancing ice protection technologies requires consideration of platform design, operations compromised, type, amount and frequency of ice formation, and applicability of ice protection technologies.

The creation of a comprehensive offshore platform icing safety plan is also benefitted by knowledge of the physics of ice accretion processes and methods for prediction of icing events. Because platforms are difficult to move on short notice, weather prediction is rarely useful for avoidance of icing events. Forecasting, however, can aid in tactical preparation of a platform prior to an icing event. Superstructure and atmospheric icing physics and modeling are not discussed in this article, but comprehensive reviews are available from Makkonen (1989) and Lozowski et al. (1986, 2000) for superstructure icing, and from Farzaneh (2008), Poots (1996), and Makkonen (1984) for glaze, rime, snow, and frost.

This paper presents an assessment of the threat of icing to structural and operational areas of platforms through the use of a cross-tabulation matrix. The matrix combines relative safety threats of six ice types and the relative importance of seventeen areas and operations of offshore platforms. Cross tabulations provide an indication of the importance of ice type versus location. Although not currently available, the addition of explicit ice frequency and magnitude information would add value. A table is also included to present the most successful technologies for protection of differing platform areas and operations.

* Tel.: +1 603 646 4487; fax: +1 603 646 4561.
E-mail address: charles.c.ryerson@usace.army.mil.

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More quantitative approaches for assessing platform ice safety threats and appropriate location-specific ice protection technologies are not currently available. However, the approach presented here provides structure to the complexities of icing-related, platform area safety and choice of appropriate ice protection technologies.

2. Background

The icing environment and unique structures and operations of offshore oil exploration and production platforms make superstructure and atmospheric icing a threat to safety and operational tempo. In addition to observations about the effects of icing on platforms (Ryerson, 2008, 2009), icing as a safety threat is consistent with conceptual theories of accident causation. Using material from a wide variety of industrial accidents compiled by the insurance industry, Heinrich (1950) suggested that frequent minor unreported events caused by phenomena such as icing may lead to more serious accidents. This premise was known as the accident pyramid or triangle where many minor unreported incidents lead to fewer but more serious reportable accidents. If allowed to continue, fewer reportable accidents or injuries could lead to one or more fatal or catastrophic events. Following this logic, the apparently benign impact of small icing events that are of little threat may ultimately lead to major serious icing accidents. Though Heinrich's theory is controversial and often challenged, it has been widely accepted for over 70 years (Conklin, 2007). Many other theories, such as the confluence of multiple factors commonly used in assessment of aviation accidents, attempt to explain accident causation. Gunter (2008) reviewed theories of accident causation and concluded that the importance of ergonomics and stress is influenced, in part, by the physical environment. These theories of accident causation suggest the potential safety impact of icing in the marine industrial environment.

Superstructure icing from sea spray, and atmospheric icing from snow, glaze, rime, and frost were recognized hazards to offshore platforms in the 1980s (Jorgensen, 1982). Icing hazards identified 25 years ago still, in large part, exist today. Overall, little systematically-collected information about the impact of superstructure or atmospheric ice on offshore operations is available.

Neither atmospheric nor superstructure icing have caused the loss of any oil rigs (Oilrigdisasters, 2008). Although some major rig losses have occurred during winter storms, there is no indication that icing has contributed to these losses. The North Sea, with its reputation for severe, cold weather, has not created significant icing problems for platforms (Jorgensen, 1982), although ice loadings in the range of 225–450 MT have occurred on these rigs (Liljestrom and Lindgren, 1983; Liljestrom, 1985).

Icing is typically a nuisance rather than a significant threat, as suggested in a study (Brown and Mitten, 1988) of icing on rigs located off of the Canadian East Coast. This study found that icing events on drilling platforms are “quite frequent,” but most accrete less than 18 MT of ice and have minimal impact on offshore operations. However, despite the infrequency of truly dangerous conditions in Canada, there are documented cases of significant icing impacts upon rig safety in locations such as Alaska (Nauman and Tyagi, 1985).

The specific hazards caused by offshore icing are a function of the type of icing, and how each icing type affects specific areas and functions of platforms. Icing is not a general problem; the types of ice that can be experienced offshore, where it forms, and its physical characteristics impact various activities and areas of platforms differently (Ryerson, 2009). Fig. 1 shows where different ice types may be expected to accumulate on an Arctic semisubmersible platform.

3. Icing safety assessment

A cross-tabular methodology was developed to assess the impact of ice by type on platform function (Table 1). Ice type was ranked by the expected hazard that ice types might inflict on platform safety. Platform function was ranked by the relative importance of each function to overall platform safety. For example, when compared to snow, frost as an icing type has little impact on a helicopter landing pad. However, the helicopter pad has a greater impact on platform safety than railings, for example, if each is iced. Justifications for each ice and platform function safety ranking are described below.

Fig. 1. Potential ice accretion areas, by ice type, on the Ocean Rig semisubmersible *Erik Raude* (from Paulin, 2008).

3.1. Ice type

The following superstructure and atmospheric ice hazards are rated for overall threat to platform safety and operations. A rating of 10 is the highest threat. Ratings are indicated in Table 1 and in parentheses next to the description of the icing type.

3.1.1. Sea spray (superstructure) ice (10)

Most investigators, except for a few (Makkonen, 1984; Minsk, 1984), agree that sea-spray-created superstructure icing is typically the

Table 1
Joint safety impacts by ice type and platform component or function, with large numbers denoting a more serious safety hazard.

	Safety rating	Spray ice	Snow	Glaze	Rime	Frost	Sleet
Hazard rating		10	8	7	6	4	1
Stability	10	100	80	70	60	40	10
Integrity	10	100	80	70	60	40	10
Fire and rescue	9	90	72	63	54	36	9
Communications	8	80	64	56	48	32	8
Helicopter pad	8	80	64	56	48	32	8
Air vents	8	80	64	56	48	32	8
Flare boom	7	70	56	49	42	28	7
Handles, valves	6	60	48	42	36	24	6
Windows	5	50	40	35	30	20	5
Cranes	4	40	32	28	24	16	4
Winches	4	40	32	28	24	16	4
Stairs	4	40	32	28	24	16	4
Decks	3	30	24	21	18	12	3
Railings	3	30	24	21	18	12	3
Hatches	2	20	16	14	12	8	1
Cellar deck	1	10	8	7	6	4	1
Moon pool	1	10	8	7	6	4	1

Classification: 70–100 dark grey, 30–69 medium grey, 0–29 light grey.