FORECASTING OF SUPERSTRUCTURE ICING FOR ALASKAN WATERS*

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ABSTRACT

Methods available for determining the potential for forming ice on ship superstructures are summarized. The National Meteorological Center (NMC) ice accretion forecast system is described and two ice accretion forecast techniques, Overland et al and Wise and Comisky, are evaluated using observations taken in the Alaskan waters. The results of the evaluation indicate that the Overland et al technique is superior.

1. INTRODUCTION

Marine weather at high latitudes is associated with a number of problems unique to the cold regions of the globe. Among these is the hazard created by the conditions of sub-freezing air temperatures combined with strong winds and sea temperatures near freezing. This hazard is called superstructure ice accretion and is defined as the accumulation of ice formed on exposed structural components of ships or structures above the water surface either on the coast or at sea. Advising marine interests of the existence and expected location and intensity of ice accretion is important for both the safety of the vessel and its efficiency of operation.

The accumulation of ice on small vessels has the potential of causing serious handling problems leading to instability and, ultimately, capsizing. This is particularly true of fishing trawlers which may have tons of fish and water shifting about in their holds. There are numerous instances of loss of life at sea directly or indirectly attributable to icing problems. To cite a couple of examples, Shekhtman (2) notes the loss, in the Bering Sea on 19 January 1965, of 10 Soviet vessels due to instability brought on by the accumulation of ice. On 14 January 1980, two of five hands were lost aboard a crabber, the Gemini, when it capsized off the Alaskan coast due to icing induced instability.

The extra weight of ice on masts and rigging not only makes the vessel top heavy but also increases its "sail area," thereby creating difficulties in handling due to the effect of winds. Although the result of such increased windage is not likely to be as disastrous as instability, it is a situation to be avoided.

While larger ships have less of a problem with ice induced instability, they are not immune. The accumulation of ice on antennae makes radio communication difficult if not impossible (3). On all sizes of vessels ice accumulation results in hazardous working conditions on deck. During fishing operations the ability to work with deck equipment in an unhampered manner is of prime importance. Ice accretion, of course, impedes the efficient use of deck equipment and slows the work. Cargo vessels, particularly container ships, may find that upon reaching the destination port, the deck cargo is ice encrusted to the point where unloading is impossible, even though the vessel is safely berthed, resulting in costly delays.

A major obstacle to the development of improved forecast techniques is the lack of accurate and consistent observations from vessels at sea. This is not surprising since ice accretion rates and amounts are greatly affected by such factors as the size and shape of the ship's hull and superstructure, the heading of the vessel relative to the wind and the sea keeping ability of the ship. An example of the type of data needed to permit a full description of the problem may be found in Minsk (4). He reports on objectively measuring ice accretion by exposing an array of cylinders mounted on a drilling rig in the North Aleutian shelf to freezing spray and weighing and profiling the ice at regular intervals. Clearly, this is not appropriate for obtaining observations from commercial vessels.

A number of authors have reviewed the various aspects involved in the icing of the ocean structures. Among them Makkonen (5), Lozowski and Gates (6) and Jessup (7). The reader is encouraged to refer to these papers for a more general view of the subject. The purpose of this paper is to describe the method adopted by the National Meteorological Center (NMC) to produce automated ice accretion guidance forecasts from information available through operational numerical weather prediction models.

2. SOURCES OF ICE ACCRETION

Among the various causes of ice accretion on ships, the most common are fog, freezing rain, snowfall and freezing spray. The relative importance of these factors is discussed below.

In the marine environment two types of fog occur most frequently. The first, advection fog, is not an expected source of icing since it is formed when warm air flows over cold water and the air temperature can be expected to be above freezing in virtually all cases. The second, sea smoke, although not a common cause of icing, cannot be disregarded as a source. Sea smoke ranges in thickness from a few meters to several hundred. It occurs when very cold air flows over substantially warmer water. The process for forming ice may be summarized as follows: Relatively warm water evaporates at the surface but condenses into droplets again as it is convectively transported into the colder air. If this overlying air is very much below freezing the droplets will be supercooled and freeze upon impact with the ship. An example of an extreme case is described by Lee (8) in which a vessel traveling through sea smoke (visibility 200 yds) picked up approximately 26 tons of ice in 10 hours.

Another atmospheric source of ice accretion is freezing precipitation. This occurs in the form of rain or drizzle. Its effect is to glaze the ships surface with a clear hard coating of ice. This type of icing is not considered serious because the accumulated weight tends to remain relatively low and the handling properties of the ship due to increased sail area are not significantly affected. On the other hand the glaze may affect communications and impede the work of deck hands. Precipitation in the form of snow plays a minimal role as a source of ice accretion since most of it generally tends to blow off the ship. The remaining snow is usually not very dense and adds little to the accumulated weight and sail area.

Finally, the most important of the causative factors is freezing spray. Freezing spray is a result of either the action of the wind on the water or the impact of the ship against the waves. In both cases the spray is carried by the wind and exchanges heat with the cooler air. The temperature ultimately reached by the spray is dependent upon the ambient temperature, the amount of time it is being transported, the initial temperature of the spray and the initial size of the spray droplets.

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Borisenkov and Panov (9) statistically analyzed more than 2000 instances of icing on Soviet fishing vessels. The results are summarized in Table 1.

Table 1. Percentage frequency of occurrence of ice accretion (after Borisenkov and Panov, 9).

	Spray	Spray with Fog, rain or drizzle	Snow	Fog, rain or drizzle
Northern Hemisphere	89.9	6.4	1.1	2.7
Arctic	50.0	41.0		9.0

As can be seen their study indicates that the most frequent cause of icing is freezing spray. This supports similar conclusions reached in other studies, e.g. Shekhtman (10). The remainder of this paper will be concerned with forecasting ice accretion due to freezing spray.

3. FORECAST APPROACHES

Over the years a number of efforts have been made to model and establish relationships between ice accretion on ships and meteorological and oceanographic parameters. Two basic approaches, numerical and empirical/statistical, have been used by researchers to attack the problem of specifying the potential for superstructure icing on ships.

Employing numerical methods, researchers, notably Stallabrass (11, 12), have attempted to model the complex and multiple processes related to the accumulation of ice on ships. These processes can be grouped in three categories as follows:

1. Liquid water must be generated in the air stream passing over the ship. This liquid water may be droplets generated mechanically by the action of the ship against the waves, the action of wind on the water or by atmospheric processes such as rain or fog.
2. The kinematics and associated process of the droplets striking the ship must be accounted for. This includes droplet trajectory and collection efficiency.
3. The thermodynamic processes related to the growth of ice on structures must be formulated. These processes include latent heat release, convective evaporative heat transfer and the exchange of thermal energy between the droplets and accretion surface.

Little use has been made of numerical models in an operational setting due to the complexity of the models and the simplified assumptions that must be made about the structure upon which the ice forms.

The empirical/statistical approach has enjoyed more success operationally. Sawada (13) developed an ice accretion nomogram for use in the Sea of Japan. The graph is based on data obtained by Japanese vessels. It provides icing estimates by category i.e., light, moderate or heavy. The graph does not consider sea temperature and is based on wind speed and surface air temperature as shown in fig. 1. Mertins (14) studied nearly 400 observations taken by trawlers in the Northeast Atlantic. The study resulted in a series of nomograms which provided guidance for forecasting the severity of ice accretion. The charts required sea surface temperature as well as wind speed and air temperature. (Fig. 2). Wise and Comisky (15) combined the Mertin charts into a single nomogram. The new nomogram was then modified based on climatological differences between the Northeast Atlantic and the Northeast Pacific. In addition they integrated some 50 quantified icing reports from the northeast Pacific region. The end result was a diagram constructed purely on an empirical basis without recourse to a derived functional relationship between variables (see Fig. 3).

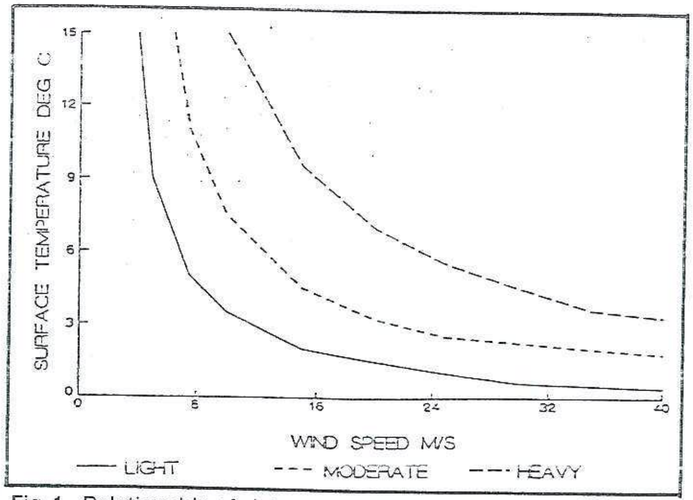

Fig. 1. Relationship of air temperature and wind speed to icing rates (Sawada, 13).

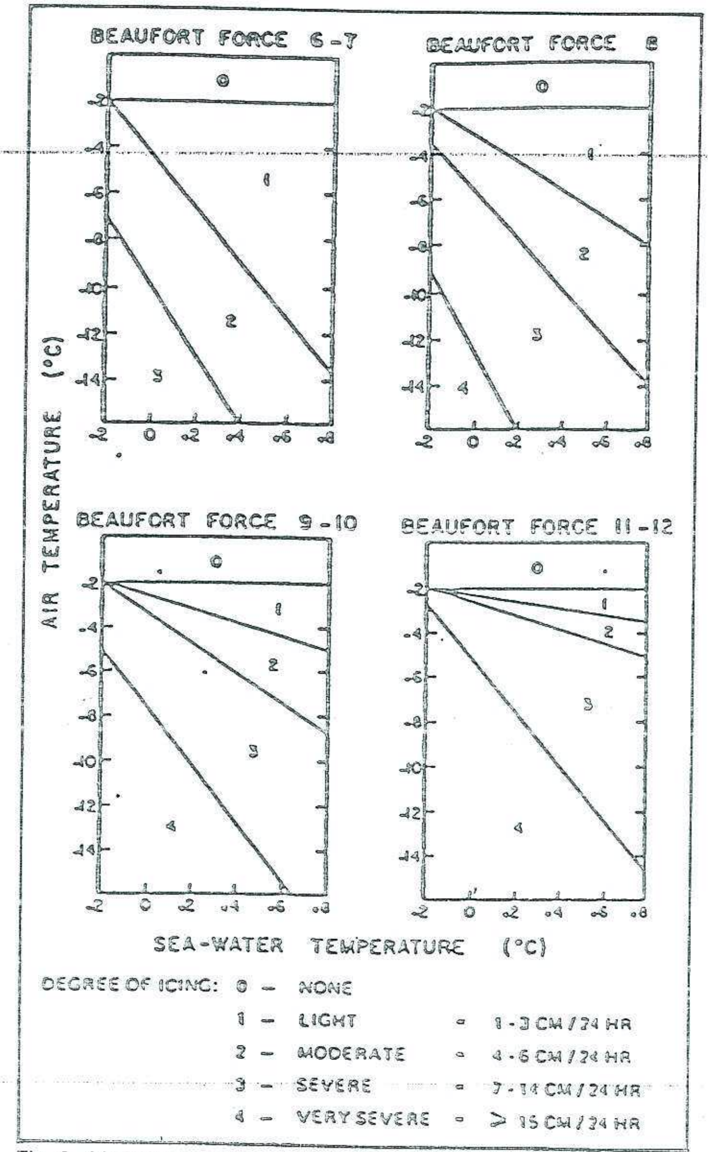

Fig. 2. Mertin's (14) Charts of Icing Rates.