The Pressure Area Relation in the Definition of Ice Forces

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ABSTRACT
Plots of ice pressure versus area have often been used to generalize various ice-structure interaction processes. The nature of local ice pressures on ships and structures is characterized by a relation of decreasing ice pressure with increasing contact area. In this paper two types of pressure-area relations have been defined. One pressure-area relation describes the process of ship penetration into an ice feature or ice feature impingement on a structure. The other pressure-area relation describes the spatial distribution of pressure at an instant in time. The cases examined in this paper show that even though the two types of relations demonstrate similar trends of decreasing pressure with increasing area, they are quite different in nature. Care must always be taken to distinguish what type of "pressure-area" relation is being presented.

KEYWORDS ice pressure, area effects, ice forces, offshore structures, ships.

1. INTRODUCTION
The pressure-area relation has been developed as a useful means of examining many types and sources of ice load data. From this data a trend of decreasing ice pressure with increasing contact area has emerged, sometimes referred to as an area effect. Sanderson (1988) made one of the first comprehensive compilations of pressure-area data, covering areas from $10^{-4}$ m$^2$ to $10^6$ m$^2$. This compilation encompasses many sources, ranging from small-scale laboratory tests to geophysical scale processes. More recently Masterson and Frederking (1993) prepared a compilation of data in the context of local ice loads. It covered the range $10^{-1}$ m$^2$ to $10^3$ m$^2$, and relates to local ice loading on offshore structures and ship hulls. Reviewing these papers and their data sources has revealed that there are several types of "pressure-area" definitions in use. For example, one type of pressure-area relation is developed by taking the maximum force exerted on a structure with the corresponding ice thickness and structure width to define a contact area and pressure, which then plots as one point on a pressure area graph. Results from a number of structure sizes and ice thickness are compiled onto a plot from which an envelope of maximum pressure for a given contact area is obtained. There are two other types of pressure-area relation which characterize local loading, one describing the process of a structure-ice impact during which the force and contact area varies, and another which describes the distribution of pressure within a contact area at an instant of time. This paper will focus on these latter two pressure-area relations and will explore them in the context of the nature of local ice forces on a structure during impact.

2. CLASSIFICATION OF IMPACT PROCESSES
A general examination of scale effect (Frederking, 1993) has proposed a classification system to describe impact and indentation processes. These can be related in part to Croasdale's (1984) ice loading scenarios, particularly his limit momentum and limit stress scenarios. One class of process is energy limited, that is the kinetic energy available to be consumed in the process defines a limit to the process. Examples of this are a ship ramming an ice floe or colliding with and rebounding off a floe. In the case of ramming, all the available energy is consumed as the ship comes to rest in the ice feature. In the case of a glancing collision with an ice floe, the energy consumed in crushing the ice floe corresponds to a change of the kinetic energy of the ship before and after the collision. Such processes are usually referred to as impact processes; i.e., they are of finite time duration. During the process, the contact force and contact area between the structure and the ice feature vary with time. From these values, pressure (force divided by area) can be plotted against area to describe the process. The component of velocity normal to