2. STUDY OBJECTIVES

The following study objectives were formulated at the start of the second phase of the project. Although it has not been possible to sample data as intended, the initial outline of targets for the study follows here unchanged.

The basic objective of the second phase of the study is to improve the previously proposed model for characterization of ice forces acting on vertical-sided offshore structures, notably the model that was the outcome of the Phase 1 studies. The model has been described in the project reports of Phase 1 and, more briefly, in a report to the POAC 89 conference, [1]. For the sake of continuity and completeness the most important features of the model and its background are also described in Chapter 3 of the present report.

Also, as regards the objectives of the study, it is judged to be appropriate to start out from the basic objective outlined before the start of the first phase of the study. Subsequent to such a recapitulation of the "basic objective", the particular Phase 2 objectives will be addressed.

The basic incentive for the study project was, of course, the existence of a large number of offshore tower-shaped lighthouse structures in the Gulf of Bothnia, offering a unique opportunity to study ice-structure interaction in an Arctic field, comprehensively although without unreasonable efforts. Also, the outcome of simple ice-structure interaction studies that had already been in progress in the Gulf of Bothnia during almost two decades, indicated, that extended investigations would most likely provide data for considerable improvement of the understanding of ice-structure interaction phenomena and hopefully generate well-supported generally applicable models for derivation of ice forces for the design of offshore structures. Thus, the basic incentive was twofold, an obvious need for a better understanding of ice-structure interaction and the existence of an already established experimental field with properties, both as regards the structures and the ice conditions, representative for a relatively broad range of conditions expected to be met with in various Arctic waters.

Thus, basically, the goal for the study was a model with a broad applicability for prediction of ice forces on vertical-sided offshore structures, based on field data from the northernmost part of the Gulf of Bothnia (which part is called the Bothnian Bay). Obviously, such a model must include a parametric formulation of ice forces, taking into account the following conditions primarily:

- the ice effective strength or the effective contact pressure (p_{eff}) and its time-dependent variations, particularly when drifting ice is crushed against a vertical-sided indentor.

- the gross contact area (A) between the ice and the structure.

- the time-history of the global ice force, particularly in the case of resonance vibrations of the structure.

- the relationship between the effective ice pressure p_{eff} and measurable ice strength characteristics such as the average uniaxial compression strength of standard test cores (f_{um}).

In its most simple form the global ice force was therefore expressed by the following relationship

$$F(t) = p_{eff}(t) \cdot A = k(t) \cdot f_{um} \cdot A \qquad (2:1)$$

In this formula the coefficient k(t) must then represent not only the time dependence of the contact pressure but also its well-known dependence on the size of the gross contact area, the degree of contact, the aspect ratio (i.e. width/height of the gross contact area) and the shape of the indentor (flat, circular-cylindric, etc.).

Thus, in compliance with conventions generally applied when equating static ice forces and after introducing a separate time function to account for the dynamic effects, the general ice force formula may be written

$$F(t) = k_S \cdot k_I \cdot k_C \cdot f(t) \cdot f_{um} \cdot A \qquad (2:2)$$

where the coefficients k_S, k_I and k_C are intended to account for effects of structural shape, multiaxial ice stress conditions (depending on the aspect ratio among other things) and the degree of contact (which may also include size effects), respectively. Normally the relationship between the average ice pressure and the uniaxial ice strength f_{um} is also accounted for by k_C.

However, it must be realized, that, particularly when considering the time dependence, these effects are not easily separated. They are obviously more or less interrelated and depending on the variable ice stress conditions and failure modes. Even during one single cycle of a periodic ice force sequence, these conditions and thus the above coefficients must be expected to vary considerably, which the results of the Phase 1 study clearly demonstrate. In particular, the coefficient k_C, assumed to express the degree of contact, e.g. the ratio between the net and the gross contact area, is obviously also depending on the mode of ice failure etc. The very mechanism of a fluctuating local ice pressure could thus be reflected by expressing merely k_C as a time function $k_C(t)$ and by using values averaged in time for the other coefficients, when expressing the global ice force:

$$F(t) = k_{Sm} \cdot k_{Im} \cdot k_C(t) \cdot f_{um} \cdot A \qquad (2:3)$$

However, since it is not a primary purpose of the study to evaluate shape and aspect ratio influences, a common factor k has been used in the global ice force time function

$$F(t) = p_{eff}(t) \cdot h \cdot b = k(t) \cdot f_{um} \cdot h \cdot b \qquad (2:4)$$

as well as for peak values, e.g.

$$F_{max} = k_{max} \cdot f_{um} \cdot h \cdot b \qquad (2:5)$$

where the coefficient k is relating to the global ice force acting on a cylindrical, vertical-sided indentor and to aspect ratios for which k_I is generally assumed to be unity. Other shapes and aspect ratios may be accounted for with reasonable accuracy by using empirical factors averaged for stationary ice force conditions. The function k(t) may thus be adjusted, approximately by means of time-independent proportioning, to account for other shapes, aspect ratios etc than the above.

The primary goal for the first phase of the study was thus the establishment of generic time functions F(t) for the global ice force, based on measured responses of the affected lighthouse structure and, to the largest possible extent, to relate the ice force to the uniaxial ice strength, determined from sampled ice cores. In the next chapter of this report, where the achievements during Phase 1 are summarized, such time functions are presented.

The second phase of the ice force study has several purposes which can be summarized as follows:

(1) Sampling of more data, primarily in the form of structural response data (acceleration, inclination), to be transformed into global ice forces.

(2) Improvement of the procedure for transformation of the above response data, based on an increased number of instruments and measurement points and improvement of the calculation program, separating various modes of structural vibration and thus admitting a more accurate representation of higher-frequency components of the ice force time function.

(3) Sampling of local ice pressure data by means of the ice force sensing panel system in order to evaluate the distribution of the ice pressure in space and time and to correlate the time-histories of the local ice forces with those of the global force.

    These evaluations are expected to provide a basis for a better understanding of the mechanism of ice-structure interaction, and may possibly support the more or less hypothetical explanations presented on the basis of the Phase 1 results.

In principle, the final goal is, of course, to establish ice force prediction formulae as indicated in Eq(2:4), however with improved accuracy in regard of the time-function k(t), with its "static" as well as its "dynamic" part.

In comparison with Items Nos 1 and 2 which may be regarded as direct extensions of the Phase 1 study, employing largely the same soft- and hardware facilities, Item No. 3 introduces a completely new feature into the project in the form of the ice force sensing panels and thus a novel device for ice force measurements. The panel system which was introduced and tested already during Phase 1 has been given a high priority both by the former and the present Steering Group, and even merely the testing of the performance of the system may be regarded as an important objective of the study. Consequently, a major part of the project budget has been allocated to the installation and operation of the panel system.

The introduction of the ice force sensing panel system and the limited financing means for the second phase of the ice force study, calls for a concentration of this phase on the dynamic character or the global and local ice forces. A low priority has to be given to the relationships with the laboratory-measured ice strength, as defined by standard tests.

The measured effective ice pressure functions $p_{eff}(t)$, averaged over the one, two or three panels or over the whole width of the structure, are primarily evaluated and compared. Secondly they are related or normalized to well-defined ice pressure characteristics which can in turn be related to a standard ice strength parameter. In the Phase 1 Summary Report an average of the peak global ice forces was suggested to constitute this field strength characteristic. The importance of a clear definition of the selected characteristic must be underlined, having in mind that the "effective strength" of ice when being crushed varies with time as well as the size of the gross contact area, not to speak of the net area.