1. INTRODUCTION

1.1 Background

For about 30 years ice action on offshore lighthouse structures in the Gulf of Bothnia has been increasingly studied. Largely, each decade represents a specific stage of development.

During the 1960's the studies were quite unsophisticated: simply a follow-up of the performance of the structures when affected by drifting ice, ice-piling, icing etc. On the basis of the rather poor knowledge of ice action at that stage and, apparently, a portion of good intuition, ice forces were predicted rather closely to the optimum risk level. A few cases of damage gave fairly clear indications as regards particular ice conditions, requiring adjustments of the design loads.

During the 70's the problem of ice-induced vibrations was realized and the most strongly affected structure was instrumented. Vibration records sampled during that decade, together with the continued follow-up and analysis of a few cases of static and dynamic overloading of Finnish and Swedish lighthouses, improved the understanding of ice-structure interaction considerably.

During the 80's the studies were expanded appreciably, quantitatively as well as qualitatively. Taking advantage of the Gulf of Bothnia as a convenient facility for Arctic research, several independent ice study projects with international participation have been conducted and some are still in progress. The product is a continuous inflow of parametrically well-defined data and subsequent improvements of the bases for ice-force predictions for Arctic areas, wherever the fundamental ice parameters can be quantified and where ice conditions are not essentially different from those prevailing in the Gulf of Bothnia.

1.2 The first phase of the Joint Industry Ice Force Study

In 1985 the studies of ice-structure interaction were intensified in that a joint study project was agreed between Arco, Exxon and Mobil (USA), Norwegian Contractors, Canadian Coast Guard, Mitsubishi, the Swedish National Industrial Board, Hamburgische Schiffbau-Versuchanstalt and VBB. The latter two companies, cooperating with the Swedish National Maritime Administration and with the University of Luleå obtained financial and advisory support for a comprehensively extended field study of ice-structure interaction, by employing two large lighthouses in the Bothnian Bay as objects for data sampling and other observations.

The lighthouses were provided with instrumentation for measuring and recording ice-induced structural responses and the character of ice

action. During a three years' period the database was greatly enlarged, and new analysis methods were developed for transformation of measured structural response to ice forces. Since the instrumented lighthouse structures serve, in principle, as full-scale elastic obstacles and measurement devices with calibrated constitutive properties, static as well as dynamic relations between the structural response and the ice forces were determined within uncertainty ranges that are judged to be quite acceptable for most engineering purposes.

A summary of the outcome of this first phase of the study as well as the applied methodology is presented in Chapter 3 of the present report. Very briefly the outcome may be characterized as model for prediction of ice-forces exerted by drifting ice on a vertical-sided (even slender and vibrating) offshore structure with ice strength and thickness as input parameters and with a particular attention paid to the time-history of the ice force in the case of resonance vibrations.

During the course of the first phase of the study, HSVA proposed an extension of the investigations, employing a set of ice force sensing panels mounted on the lighthouse. Costs beyond the project budget were covered by HSVA and the German government and to some extent by the Swedish Maritime Administration.

The Steering Group accepted the proposal and the panel system was fabricated, installed and tentatively operated in winter 1987/88. However, the sealing of the panels appeared not to be completely watertight and the panels had to be removed and the sealing improved.

1.3 Phase 2 activities

At the end of the first phase of the project, the Steering Group decided on a second phase, including reinstallation of the ice force sensing panels which was implemented before the winter 1988/89. The ice drift events causing strong vibrations were few during that winter, but a collection of more or less "dynamic" ice force records were still obtained, at least sufficiently for confirmation of the efficiency of the panel system. Since the formal start of the second project phase was delayed for several reasons, the costs had still to be covered mainly by the German sponsors and partly by the Swedish Maritime Administration. After the winter season the panels were removed for service and repair. An attempt to reinstall the panels in late 1989 was interrupted by rapidly increasing winds and waves, and for similar reasons several attempts during 1990 and 1991 were unsuccessful until July 15, 1991, when the reinstallation was successfully completed. Supplementary installation work and testing was carried out in the autumn 1991.

The instrumentation for structural response measurements and the video cameras were removed from the two lighthouses after the termi-

nation of the first phase. The reinstallation was conducted in early 1992. All the equipment and efforts were now concentrated to one lighthouse for reasons explained in Chapter 4.

Thus, after a long period of preparatory work (and expenses beyond the budget, carried mainly by the Maritime Administration, VBB and HSVA) the lighthouse Norströmsgrund was fully equipped with its test devices in early January, 1992. Until then, the winter had been extraordinarily warm (actually the 5th in a series of warm winters, see Appendix 6, page 45) and there was merely very thin ice in the Bothnian Bay.

However, no significant drifting ice appeared during the whole winter and, still worse, even the following winter was essentially free from drifting ice of such persistence that ice force measurements could be expected to be successful. Until mid 1993 the maintenance and repair work had proceeded in accordance with the work plans from -91 and -92 (Appendix 5). The cost of this work and the operation of the power system, etc. of the lighthouse consumed so much of the budget, that in mid 1993 it was clear, that the budget would not permit any more comprehensive repair of the panels. During the autumn personnel from HSVA and NMA made a number of expeditions to the lighthouse in order to examine the panels and necessary service systems as regards operability. It was reported that a large number of the sensors of the panels were out of operation so that one panel was definitely useless and it was questionable, whether any reliable data could be expected to be obtained from the others. The power system of the lighthouse was also out of operation due to leaks in the fuel system, etc. It was obvious that neither the budget nor the available time and resources would be sufficient for removal, repair and reinstallation of the panels before the winter.

These circumstances were explained in letters of January 11, 1994, to MOBIL and CANMAR, where it was recommended, among other things, that no more means be spent on trying to operate an incomplete measurement system but rather to postpone the activities until after the present winter or to break off the project, temporarily or definitely. At the present stage, final decisions have not been made as regards the future of the project, but, whatever happens in the future we have decided to finalize the previously drafted report covering the work which has been carried out until the present date and the outcome of that work. Thus, although it has not been possible to sample any ice force measurement data during Phase 2 of the project, it has been possible to improve the model outlined during Phase 1 for characterization of ice forces on offshore structures, as accounted for in Chapter 9.