5. ICE FORCE SENSING PANELS

5.1 Principle design and function

For the purpose of measuring local ice forces on the lighthouse Norströmsgrund, HSVA has developed a twodimensional ice force panel (TIP) which measures the total load acting on the panel. The normal as well as the tangential (horizontal) component of the load is measured.

The principle design of the panel is shown in Figure 5:1.

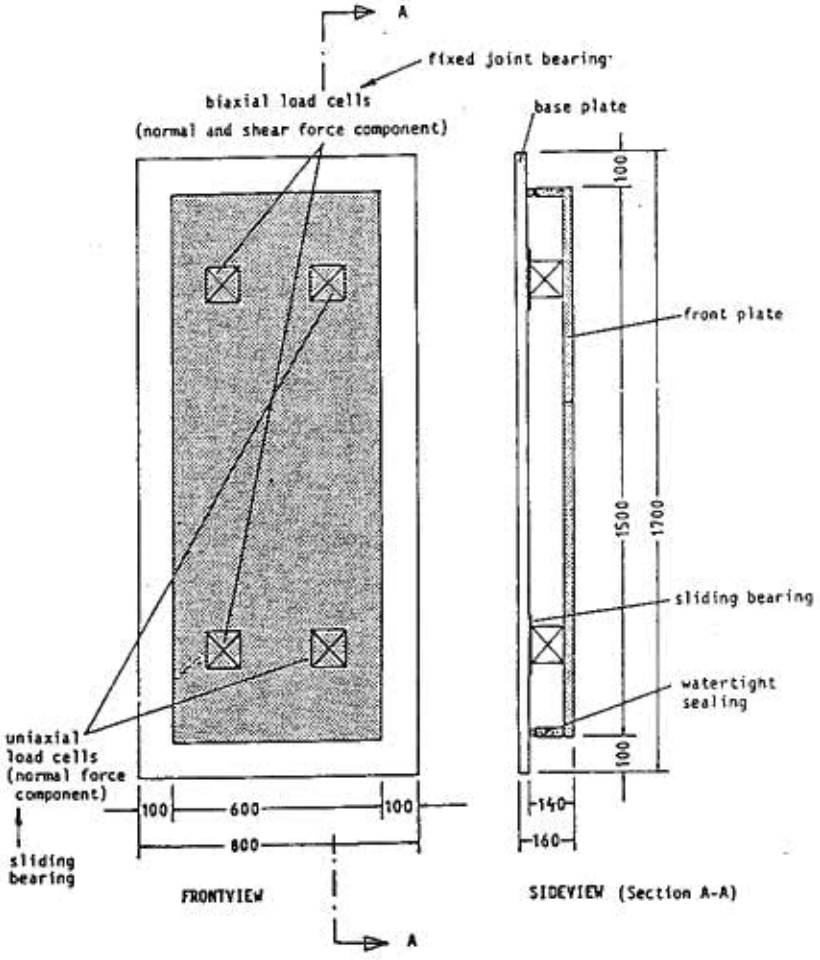

Figure 5:1
Principle design of an ice force sensing panel

The panel has a thick front plate exposed to the ice action and all the load paths towards the support base plate, i.e. the bearing points, are

instrumented with strain gauged load cells. The support reactions are superposed so that the total ice force on the panel will be measured. A unique feature of the TIP-panel is its capability of measuring two components of ice forces: the normal ice force component as well as the tangential component which acts horizontally (parallel to the waterline).

The base plate of the panel is mounted against a polygonal steel shield which is rigidly fixed to the lighthouse. The free space between the base plate and the front plate is entirely sealed, in order to avoid ice accretion and thus uncontrolled load paths. In order to upgrade the safety against water leakage and ice accretion, an internal heating system as well as passive protective means have been installed. All around the panel, the base plate extends over the dimensions of the front plate to provide the possibility of clamping the panel against the supporting steel shield.

The four load cells installed in each of the TIP ice force panels are strain gauged cylindrical load measuring bolts, supplied by Dr. Brandt GmbH, Bochum. The operational load of each load measuring bolt is 400 kN, thus providing a load capacity of 1 600 kN to the entire panel.

Two of the load cells are uniaxial to record normal load components, whereas the other two are biaxial for recording the normal as well as the tangential load components.

All functional elements of the panel have been designed to be fully operational down to a minimum temperature of -50°C.

Those structural components of the TIP-panel which are not made from stainless steel, are painted with an epoxy coating. The outer surface of the front plate is coated with a highly abrasion-resistant epoxy coating.

More details of the panel system are given in **Appendix 5.**

5.2 Static and dynamic calibration tests

Each single load measuring bolt as well as the complete TIP-ice force panels have been checked within the frame of a comprehensive testing program. Loads were applied in several steps up to the design load in normal as well as in tangential direction. The panel was loaded at various locations on the front plate, e.g. closely to the edges, in order to prove, that the response of the panel is independent of the point of load application. The test results show, that the linearity, i.e. the deviation from the straight line, is less than 5% of the design load, for normal as well as for tangential loading. The panel response on dynamic, saw-tooth like load time-histories was quite accurate.

5.3 Panel arrangement

Around the cylindrical concrete shaft of the lighthouse a 20-sided polygonal steel shield has been rigidly installed in the waterline region. The steel shield provides twenty plane steel surfaces, each outfitted with a matrix of threaded holes for optional attachment of ice force panels. Thus, any flexibility for changing the position of the existing panels is provided, as well as the possibility to increase the number of panels up to a maximum of twenty.

From assessment of previous extreme ice force events at the lighthouse Norströmsgrund, a slight tendency could be detected at mid winter conditions for prevailing ice drift directions towards the north. Therefore, the ice force panels were installed in due south of the lighthouse as illustrated in Figure 5:2.

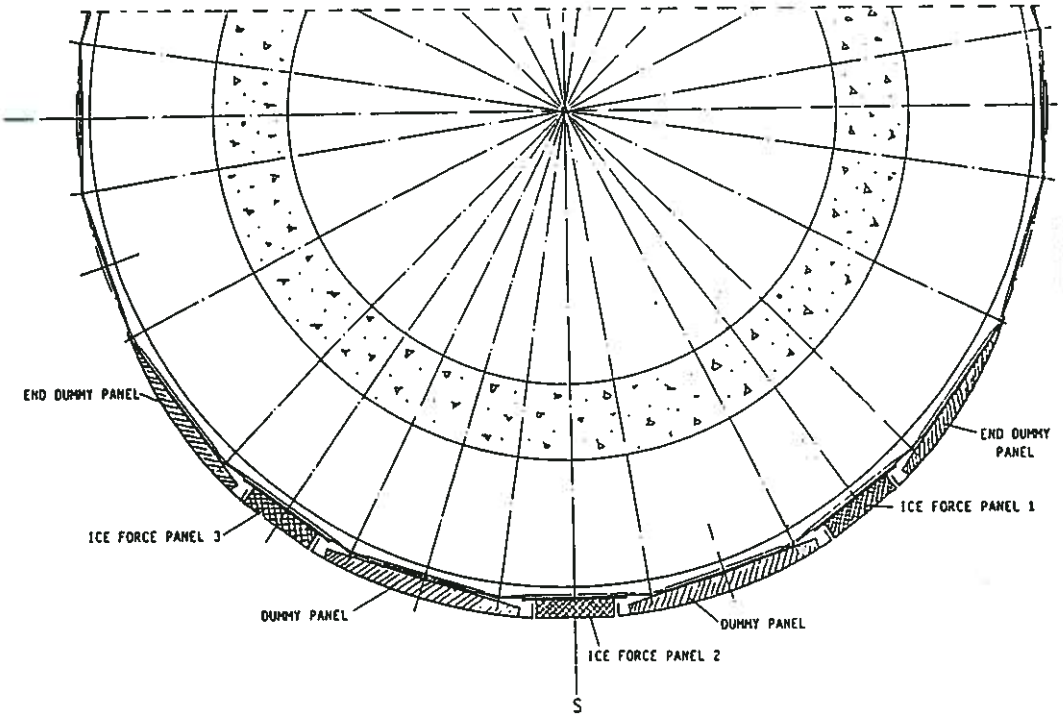

Figure 5:2
Panel arrangement

Three panels have been arranged such that they cover a 90°-sector together with two dummy panels to be installed between two sensing panels, in order to compensate for the projection of the panels. Correspondingly, two end-dummy panels have been installed in order to adjust the projection of the panels towards the actual curvature of the polygonal steel shield.

The sensing as well as the dummy panels are fixed towards the steel shield by clamping the top and the bottom part of the flanges by means of solid steel mounting bars.

5.4 Data acquisition system

Each of the three ice force panels is equipped with two biaxial and two uniaxial load cells. Therefore, there are six measuring channels per panel, and thus a total of 18 channels have to be simultaneously recorded by the data acquisition system. In order to be capable of identifying ice force peak values of short duration, the data sampling rate is about 30 Hz during dynamic ice load events.

In order to be able to automatically store as much data as possible, HSVA has developed a special "dynamic" data storage computer program; i.e. the measuring frequency will be constant at about 30 Hz, however, the measured data will only be stored for later data treatment if a certain relative change of data can be detected compared to the data measured immediately before ("dynamic threshold").

5.5 Measurements in winter 1988-89

The automatic operation of the data acquisition system for the three ice force sensing panels was started on the lighthouse Norströmsgrund in mid February 1989. Initially, due to the extreme mild winter and unfavourable ice drift directions, the ice force records were poor. The situation did not change remarkably for a period of about one month. Then, the general ice conditions in the study area altered and the major ice drift direction was towards the southern edge of the lighthouse, where the three ice force sensing panels had been installed. Thus, an almost continuous ice force recording was obtained over a period of about one month from March 24 until April 20, when the data tape was unloaded on occasion of a regular inspection trip to the lighthouse.

The analysis of the data and its results are discussed in Chapters 8 and 9.