International Journal of Offshore and Polar Engineering
Vol. 9, No. 1, March 1999 (ISSN 1053-5381)

Measurement of Ice Growth and Melt in the Labrador Pack Ice

Donald J. Belliveau and Charles L. Tang

Department of Fisheries and Oceans, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada

Andrew M. Mahon
Axiom Engineering Ltd., Mt. Pearl, Newfoundland, Canada

ABSTRACT

Ice growth and melt play a major role in the length of time the yearly offshore pack ice impacts on shipping, fishing and offshore petroleum development. This paper describes an automated acoustic system that will monitor the growth and melt of ice and transmit its data via satellite. System design, calibration and results from three deployments are presented.

INTRODUCTION

The presence of sea ice in the coastal waters is a major concern to marine transportation, off-shore oil development and fishing industries in high-latitude regions. Information on the time of freeze-up and ice thickness in harbors, lakes, continental shelves and shipping routes is needed for the day-to-day operation of marine industries. Long-term ice thickness data are required for climate change research, as changes in ice thickness and ice area in the Arctic and sub-Arctic oceans are major indicators of global warming.

The simplest method used to measure ice thickness is to drill holes. Manual sampling is labor intensive, and the amount of data that can be collected is severely limited by weather and ice conditions. Airborne instruments using electromagnetic induction methods have been developed to measure ice thickness over a large area (Kovacs et al., 1987). Ice growth has been reliably determined by measuring the temperature profile through air/ice/water boundaries (Wettlaufer, 1991; Peterson et al., 1991). Ice melt is more difficult to measure as the ice and water temperature gradients become indistinguishable during melting.

This paper describes an automated acoustic system designed to collect long-term data for both ice growth and ice melt in drifting and land-fast ice, the Ice Thickness Measuring System (ITMS). The system was developed under contract by Axiom Engineering of St. John's, Newfoundland, for the Department of Fisheries and Oceans, Ocean Science Division at Bedford Institute of Oceanography (BIO). The system provides a thickness estimate by: 1) measuring the distance between an acoustic transducer fixed in air and the top of the ice; 2) measuring the distance between a transducer fixed underwater and the bottom of the ice; 3) subtracting these two distances from the total distance between the acoustic transducers. Since ice growth and melt are primarily dependent upon air and water temperatures, two temperature sensors have been included in the system. The system attitude is also monitored as measurement accuracy is degraded if the structure tilts.

Received March 2, 1998: revised manuscript received by the editors November 2, 1998. The original version (pior to the final revised manuscript) was presented at the Eighth International Offshore and Polar Engineering Conference (ISOPE-98), Montréal, Canada, May 24-29, 1998.
KEY WORDS: Ice thickness, ice instrumentation.

SYSTEM DESIGN

Design Goals

The original specification stipulated a system that would be transportable by helicopter and assembled on the ice by two operators wearing gloves. The system would be installed in an 8-inch augured hole. The system would measure air and water temperatures with a resolution and accuracy of 0.1°C. The air and water distance measurements were to have a resolution/accuracy of 1.0/5.0 cm. The datalogger would collect hourly measurements, buffer a history of previous hour's data, and transmit the data via the ARGOS satellite system. The system life would be 4 months in air temperatures as low as –40°C. To maximize battery life it was recommended that the batteries be located in a case under the ice where the temperature would not drop below –1.8°C. The system had to be inexpensive as units deployed on the pack ice would not be recovered.

Sensor Support Frame

Fig. 1 is an outline drawing of the ITMS showing the location of the major components. The frame is constructed of aluminum tubing with a maximum section length of 1.5 m. This length allows up to three uncrated units to fit in the passenger compartment of a Bell 206L Jet Ranger helicopter for deployment. The sections are held together by Kee Clamp slip on fittings which lock in place using a single hex key. The upper sensor support arm is attached with a right-angle Kee Clamp. The lower arm is attached using a pivoting connection, allowing the arm to be raised into position by a cable after the ITMS is deployed through the ice. The system is supported on the ice by 4 horizontal legs, which are isolated from the ice surface by insulated pads at their ends. Three plastic disks located in the ice add extra stability as the ice melts. The system is painted white to reduce solar heating effects, which will lead to the ice melting around the structure. One system weighs 65 kg.

Moored System

A moored system was constructed with both temperature sensors but only an in-water distance sensor. The system was supported at the surface by five 14-in plastic floats and anchored to the bottom using a Danforth anchor and chain attached to the bottom of the vertical member. The unit was assembled on shore and