NWRI CONTRIBUTION 88-62

SHOALING WAVES PROGRAMME IN LAKE ONTARIO

by

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MANAGEMENT PERSPECTIVE

In order to effectively and efficiently design offshore structures that are environmentally compatible in the zone where the bottom affects waves, it is necessary to know the joint probability distribution of wave heights and periods. The field programme described in this report, partially funded by the Panel on Energy Research and Development, provides data to address this issue. The study is in the first year of a four-year investigation.

Dr. J. Lawrence
Director
Research and Applications Branch

PERSPECTIVE GESTION

Pour pouvoir concevoir des ouvrages marins non nuisibles à l'environnement dans les zones où le fond influe sur la configuration des vagues, il faut connaître la distribution de probabilité combinée de la hauteur et de la période des vagues. Les travaux sur le terrain décrits dans le présent rapport ont fourni des données à ce sujet; ils ont été financés en partie par le Programme de R et D énergétiques. Figurent ici les résultats obtenus pendant la première des quatre années que dureront les recherches.

J. Lawrence
Directeur
Recherche et applications

RÉSUMÉ

Trois tours temporaires et deux houlographes ancrés ont été installés à l'extrémité ouest du lac Ontario, respectivement à des endroits où la profondeur de l'eau est de 2, 4, 8, 20 et 59 mètres de profondeur, pour l'étude des caractéristiques des vagues sur les hauts-fonds. Ils ont été alignés avec la plate-forme de recherche du Centre canadien des eaux intérieures (CCEI) sur la normale à la plage Van Wagner (240 degrés vrais). Les instruments, les dispositifs de calcul, le principe de fonctionnement et l'objet des différents capteurs ainsi que les systèmes d'acquisition et de saisie des donées font l'objet d'une brève description.

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ABSTRACT

Three temporary towers and two moored waverider buoys were placed in 2, 4, 8 m and 20, 59 m of water, respectively, in the west end of Lake Ontario off Van Wagner's Beach and aligned with the permanent CCIW research platform along the normal to the shore (240° T) in order to study the characteristics of the waves in shoaling water. The instrumentation and computational facilities, including the principle and purpose of the various sensors, the data acquisition system and the data gathering system are briefly described.

INTRODUCTION

Knowledge of wave characteristics in shoaling water provides information for the calculation of wave forces which are critical for the design of offshore structures. In particular, knowledge of the joint probability distribution between wave heights and periods in shoaling water is essential in determining the wave forces on these structures.

Little is known about the joint probability distribution of wave heights and periods in shoaling water. The purpose of this field study was to obtain a data base from which this information can be extracted. During the next two years, further laboratory studies will be conducted at NWRI. Results from these field and laboratory studies will be used to devise a theoretical procedure to obtain the joint distribution of wave heights and periods in shoaling water. This procedure will eventually help to improve the engineering prediction of wave

forces on structures.

The field study was carried out in the fall of 1987, in parallel with the WAVES field study (Tsanis and Donelan, 1986). The correlation of the data set from this study with the larger WAVES data set provided an excellent opportunity for a more detailed study of the environmental parameters at one site.

The measurement system was developed from equipment used in Lake St. Clair in 1985. Three towers (T1, T2 and T3, see Figures 1 and 2) were placed inshore of the WAVES research platform at the west end of Lake Ontario near Van Wagner's Beach. These towers were at nominal depths of 2, 4, and 8 m and at distances of 84 m, 230 m and 523 m, respectively, from the beach. The three towers were aligned along the normal to the shore (240° T), offset by 60 m to the north of the WAVES research platform (P) to avoid interference with and possible damage to the platform's power and signal cables during the installation process. Additionally, two Datawell Waverider buoys (B1 & B2) were mooored at depths of 20 m and 59 m, 4.4 km and 12.2 km from shore respectively, and also aligned with the CCIW tower along the normal to the shore.

DESIGN OF THE 3-TOWERS

The main criteria for the design of the three towers were that they remain upright without damage under the design wave and wind loads, that they be portable from dockside to the installation site by an available crane barge with a lift capacity of 65 tonnes, and that no site preparation or diver support be required for their installation. The tower base had to be sufficiently large to counter overturning force moments from environmental loads. It also had to distribute the load on the sand bottom to avoid erosion and long term instability of the foundation.

A modular design approach was taken, using four modules. This included a welded steel base, base legs of hollow rectangular steel section, ballast weights consisting of railroad wheels, and standard Millard Type 18-S-75 tower sections. Following fabrication in the CCIW Machine Shop, the modules were transported to dockside by a forklift truck. The towers were then assembled on the dock, guy wires were attached, and underwater instrumentation and wiring was installed. The fully assembled towers were then loaded onto the crane barge ("Cargo Master") for transport to the field site and installation (see Figures 3 to 6).

Environmental Loads : Wind loads were calculated using a wind pressure of 364 Pa (55 mph standard air) applied to blockage areas of the structure above still water level.

Wave loads were calculated using the Morison equation (McCormick, 1973) with effective drag area and drag coefficients for Millard Tower Section taken from Engel (1975). Waves were assumed to be spilling waves and drag coefficients were doubled for this reason. Design wave heights were taken as the maximum breaking wave height at each tower depth, using data from the U.S Army Corps of Engineers Shore Protection Manual. These were 6.1, 3.4 and 1.8 m at tower depths of 8, 4, and 2 m respectively. Wave period was taken as 6.8 s from previous observations at the site (Donelan and Kahma, 1986, Run 85145).

Loadings due to ice accumulation were not calculated, but were considered in assessing the margin of righting moment against overturning moment in the final specification of the design of the tower bases.

Tower Design : Following the calculation of overturning moments due to the environmental loads, the tower base, leg, and ballast modules were arranged to provide sufficient mass and base dimension to ensure that the righting moment was at least 1.5 times the overturning moment. The module assembly was then analyzed for stresses on detail parts, joints and cable guys to ensure that internal stress safety factors exceeded 2.0 under both environmental loads and handling loads.

INSTALLATION AND DESCRIPTION OF THE 3 TEMPORARY TOWERS

Figures 1 and 2 show the location of the three towers (T), the WAVES platform (P) and the waverider buoys (B). Figure 3 shows the commercial barge used for the transportation and placement of the three towers and the three towers on the dock. Another view of the three towers, two of which are loaded on the barge is shown in Figure 4. Figure 5 shows the barge and the three towers on it and Figure 6 shows the barge at the assigned location (shown with the floating red plastic ball) ready to place one of the towers. Figure 7 shows the placement of the tower closest to shore. In the background the WAVES platform and the other two towers are visible. Finally in Figure 8 the three towers were placed and aligned along the normal to the shore (240° T).

The principal sensors on each tower were arrays of three wave staffs, arranged in a right isosceles triangle for measuring directional spectra of waves, see Figure 9. In addition, in Figure 9 the other instruments are visible and in the background the formation of whitecaps is evident. The sides of the triangle of the array were 50 cm,

50 cm and 70.7 cm. The wave staffs were 2.8 m long at the 2 m tower (T1), 6.0 m at the 4 m tower (T2) and 6.0 m long at the 8 m tower (T3). The wave staffs were capacitance gauges and were held taut with rubber shock cords.

Each tower had a Neil Brown current meter, see Figure 10, which measured current velocity by means of an acoustic phase-shift technique. The velocity vector is sensed by four piezo-electric disc transducers arranged in diametrically opposed pairs with axes at right angles to each other. The transducers transmit high-frequency sound, which is reflected off an acoustic mirror at the base of the instrument and received by the other transducer in each pair. By measuring the phase shift between transmitted and received signals the instrument can accurately determine the effect of fluid movement in the area of the sensor head, and thus the local current velocity vector. Water temperature data, required for the correction of current velocity for the local speed of sound, is provided by a thermistor mounted close to the velocity sensor.

The Neil Brown sensors used in the present study were of the "cranked sensor head" type (the sensing head is tilted 90 degrees from the electronics body, see Figure 10). The sensors were mounted such that the sensing volume was 1.1 m from the tower at a distance of 1.6 m from the lake bottom. Each sensor was on the southern face of the tower and was oriented to measure the horizontal velocity components parallel and normal to the shore.

The outer two towers T2 and T3 had 25 cm path-length Sea Tech transmittance sensors, which were mounted on the opposite side to the water velocity sensors at the same depth (see Figure 10). These sensors provided information on the turbidity in the nearshore regions but not on the size distribution of the sediments. Sediment traps at the two outer tower locations were installed as part of another study to provide the additional information on the size distribution of the suspended sediments.

The middle tower T2 had an anemometer-bivane and the others had K-Gill anemometer-vanes. Both the anemometer-bivane and the K-vane provide information on the three components of wind velocity and hence the wind speed, direction and stress. Both bivane and K-vane sensors have an effective frequency response of about 5 Hz in moderate winds. Figure 11 shows the upper part of the tower, with the signs indicating high voltage, the electronic box with the data acquisition system and the atmospheric sensors on the top. Figure 12 is a close-up view of the K-Gill anemometer-vane and of the air temperature sensor (thermistor). The temperature

sensor is attached to the K-Gill's support and is protected by a double radiation shield in order to reduce solar radiation errors. The lightning rod is also evident in this photograph.

DATA ACQUISITION

The tower data acquisition system was built around an 80535 based microcontroller. The microcontroller card had eight channels of analog to digital conversion providing an effective 10 bit resolution over a 0 to 5 V range, two independent serial ports (one on the 80535 itself and another using a multifunction microprocessor support controller 8256), and multiple digital I/O ports and timer/counters. Such a device was needed since the analog data and serial (actually Serial ASCII Instrumentation Loop (SAIL)) data from the Neil Brown current meter are converted to serial data. The carriage return at the end of the first data bundle was used to synchronize the data acquisition on each tower. An interrupt timer controlled the analog data acquisition on an interrupt basis. The analog data acquisition rate was 10 samples per sec per channel. Analog and digital data were merged and buffered in RAM and check sum bits were added. This data was sent to shore via a baseband serial link. At the end of the data stream a "break" was sent to enable the shore-end serial link to recognize end of transmission.

The eight analog inputs were identical, having transient voltage protection, buffering and filtration at the Nyquist frequency. The filtration was by means of switched capacitor type 4-pole Bessel filters. Power for the tower electronics was provided via 120VAC (approx 10mA) from shore which was converted to +/-12VDC and +5VDC at each tower. Ground-Fault-Interrupt (GFI) protection was also provided at each tower.

The tower electronics consisted of three wave staff electronics boards, one interface board, one digital board and a power supply, all encased in a Hammond NEMA 4 type box. The AC power from shore was sent via armoured cables.

In each tower, data was buffered and then digitized by an 80535 based microcontroller board from Allen Systems. This board buffered the data, computed a check sum and transmitted the data to shore via a 9600 baud link. Data were received from the three towers using a multiple input serial card. The received data were merged together with real time clock data using an IBM PC-AT and then streamed to the AT's hard disk. Once the hard disk was full (about 9 hours) the data were transferred to 1.2 Mb floppy disks. The data rates were

such that 33 1/3 minutes of data could reside on one high density floppy. The program "SPLIT" splits up to 9 hours of continuous data to 1.2 Mb floppies and the program "GENERATE" copies the content of these floppies back to the hard disk in one file. The data could be then transferred to 9-track tapes using the WAVES AT & Telebyte tape drive. In the event of problems, data could be downloaded to the CDC Cyber 830 by using an AT with "PC Connect" at 9600 baud.

CALIBRATION

The calibration of the sensors was carried out both before and after field exposure. The NWRI towing tank was used for the calibration of the air and water velocity sensors, i.e., bivane, K-vane anemometer and Neil Brown current meter, respectively. Voltage calibrations between 0 to 5 V were performed on the ADC cards at various temperatures between 0° to 30° C. Phase shifts between channels were measured at several frequencies.

OPERATION AND DISMANTLING

Figure 13 shows a technologist working on the tower (T2). Wave breaking occured repeatedly inshore of the outermost tower (T3) in this particular storm as shown in Figure 14. The wind was blowing from the east with a fetch of 300 km causing 6-8 sec waves.

Figure 15 shows the commercial barge heading towards the tower (T1) having dismantled the towers (T2) and (T3). The retrieval of tower (T1) is shown in Figure 16. The dismantling operation of the three towers has been accomplished and the barge is heading towards the CCIW (see Figure 17).

Finally Figure 18 shows the waves breaking on shore on a cold December morning. As a part of our contribution this year we hope to improve our understanding of wave characteristics in shoaling water. This will help engineers to calculate wave forces more accurately and eventually help to improve the design of offshore structures.

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(5) M.A. Donelan and K.K. Kahma, "Observations of Velocities Beneath Wind-Driven Waves", Proceedings of the International Workshop on Wave Hindcasting and Forecasting, Halifax, Nova Scotia, Sept. 23-26, 1986, pp. 243-252.

ACKNOWLEDGEMENTS

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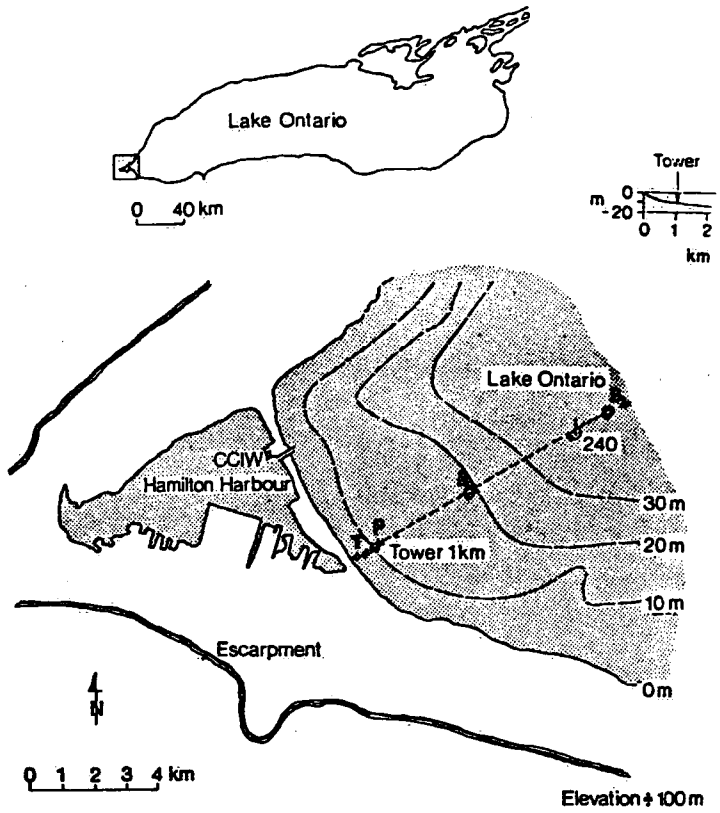
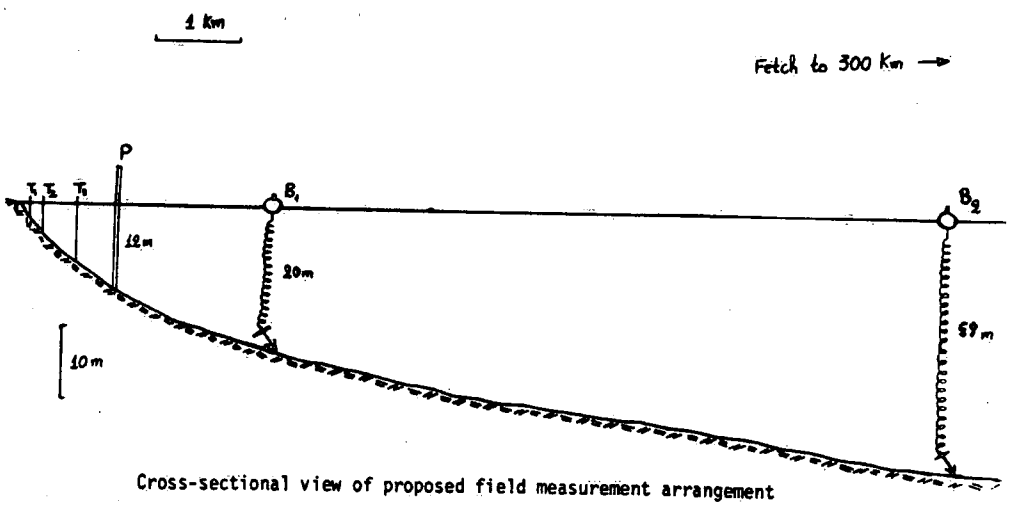
LIST OF FIGURES



Map showing the location of the research tower in Lake Ontario and the shore-normal profile in the vicinity of the tower. (The proposed additional research towers (T) and waverider buoys are shown in FIGURE 2).

Figure 1

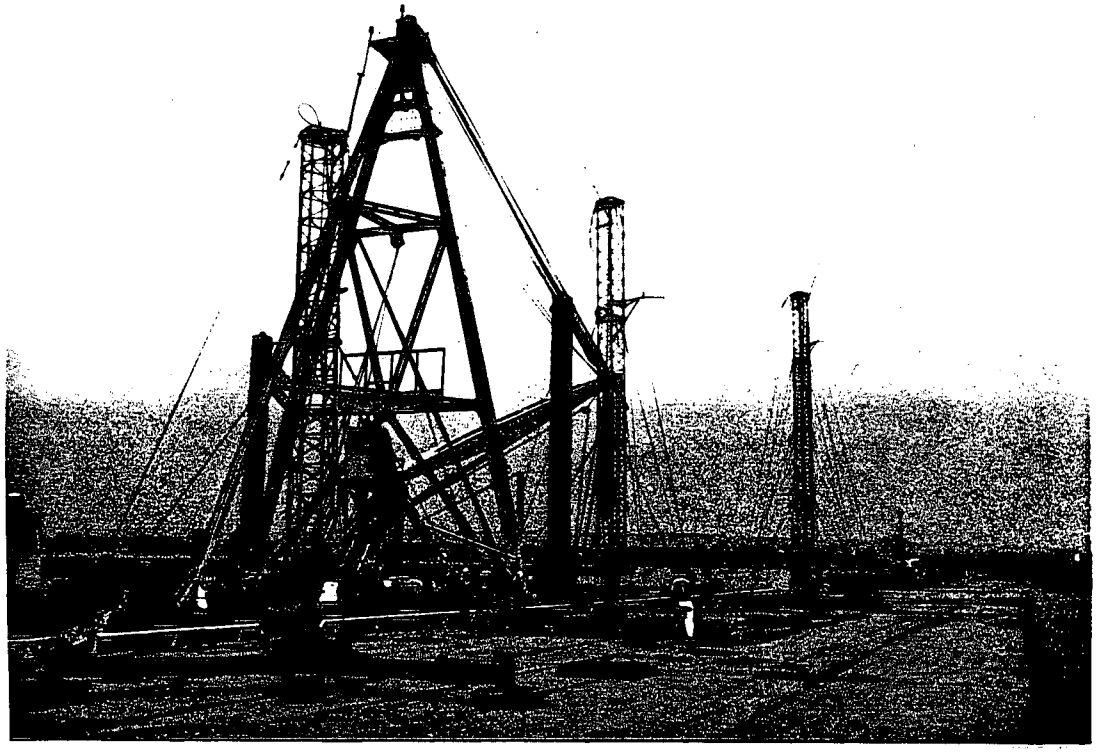


Cross-sectional view of proposed field measurement arrangement

T_1, T_2, T_3	Temporary towers in 2, 4 and 8 metres depth. Each tower also measures wind stress and temperature
P	Permanent tower at 12 m depth includes wind measurements
B_1, B_2	Moored waverider buoys at 20 m and 59 m depth.

NOTE: All towers are equipped with directional arrays of capacitance staffs.

Figure 2



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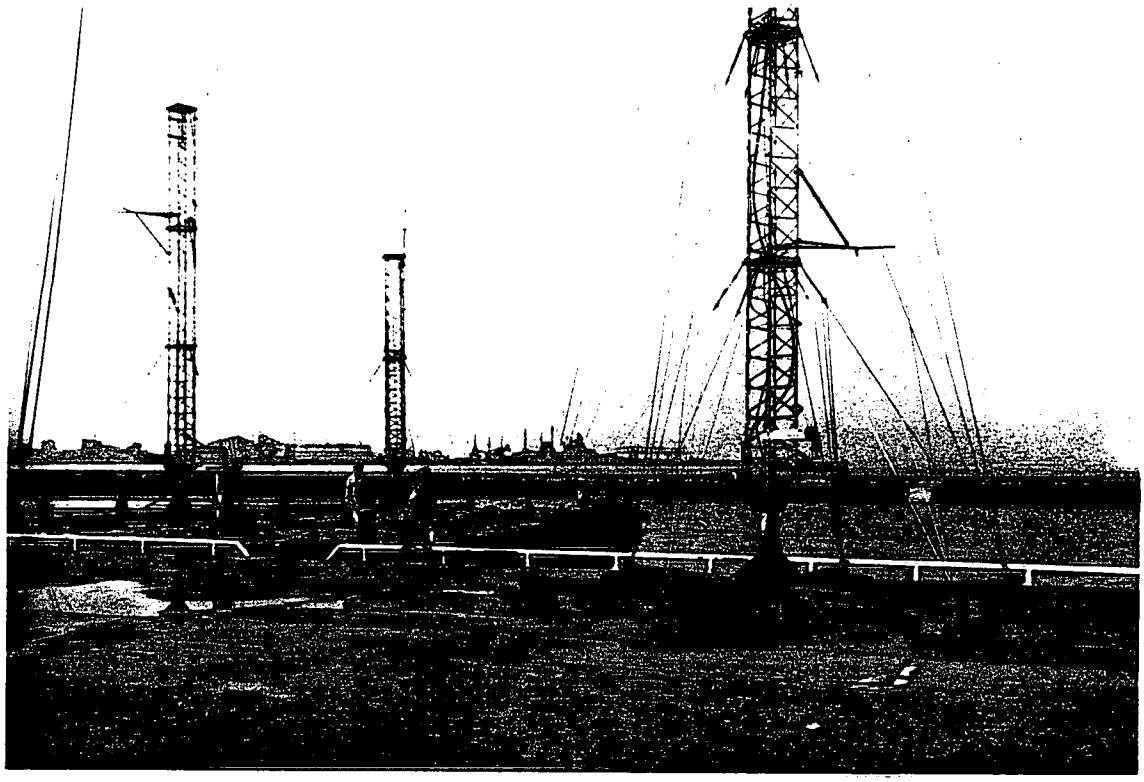

Figure 4

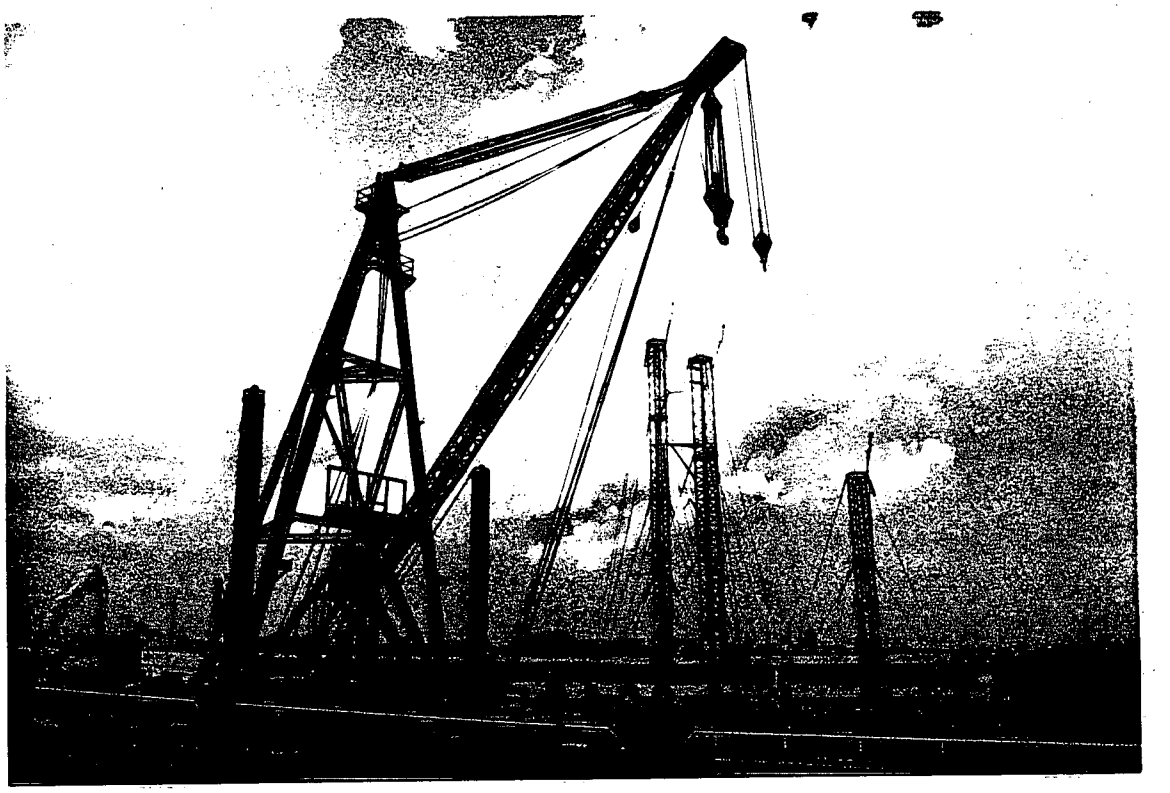

Figure 5

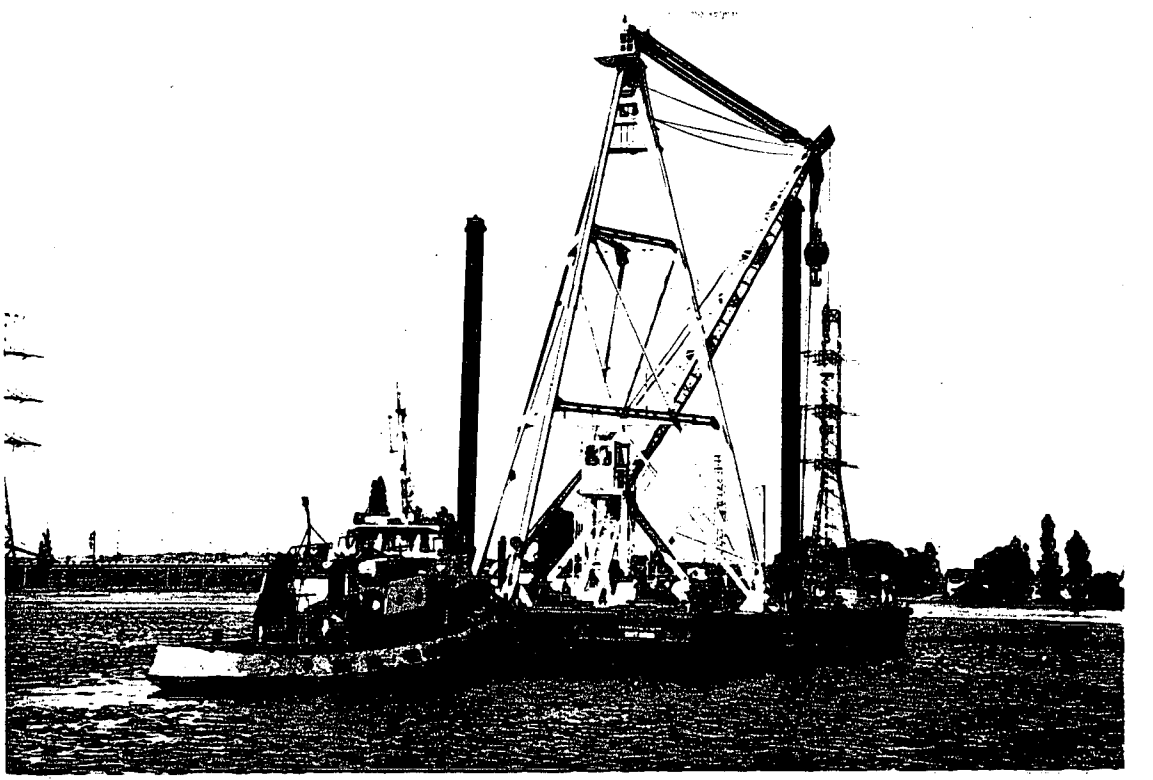

Figure 6

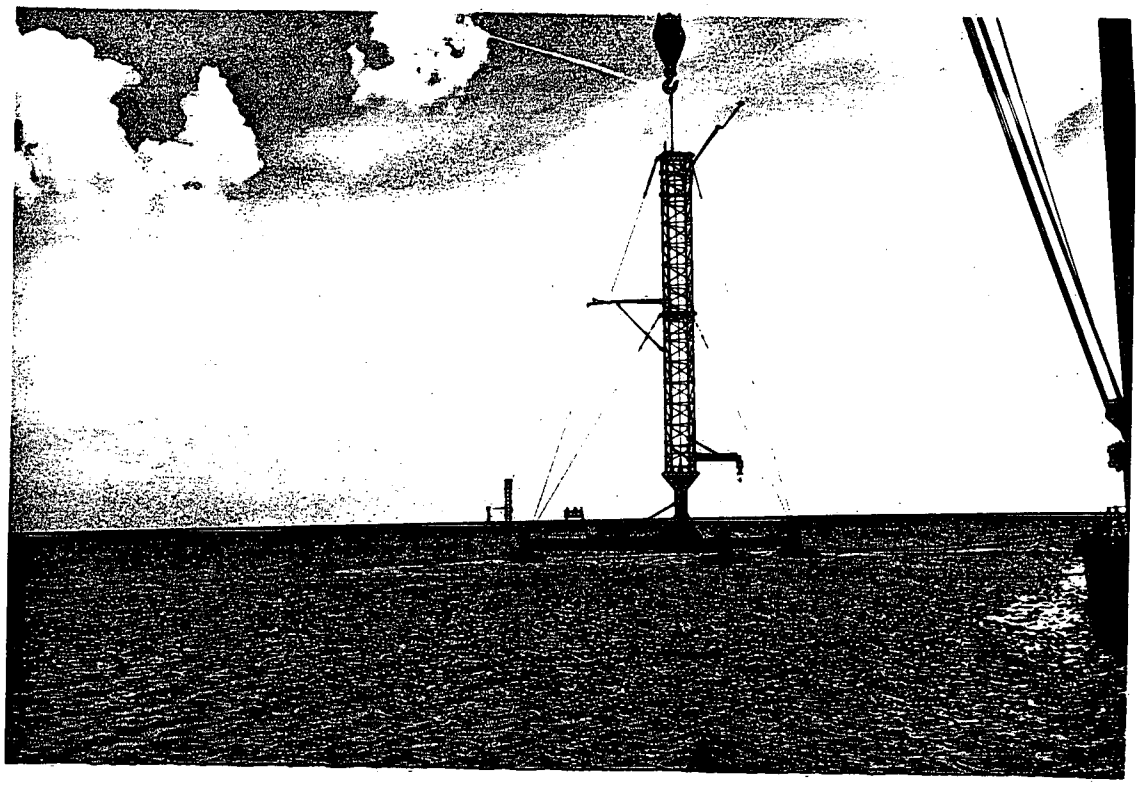

Figure 7

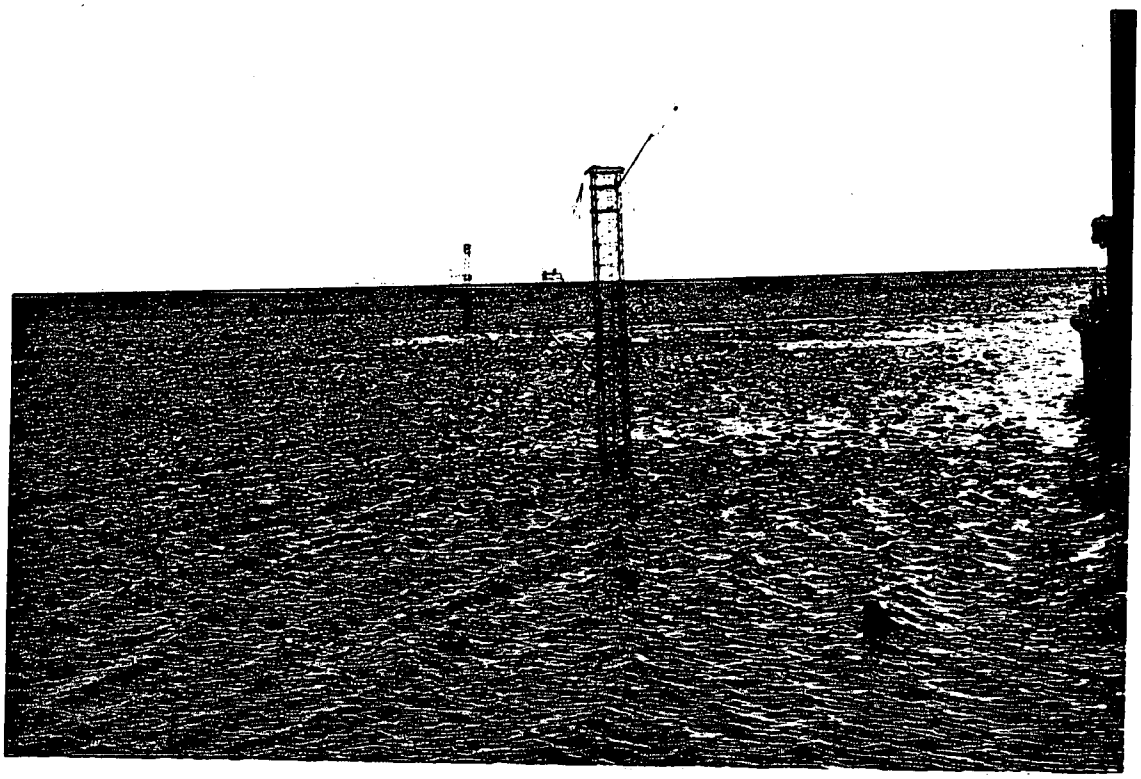

Figure 8

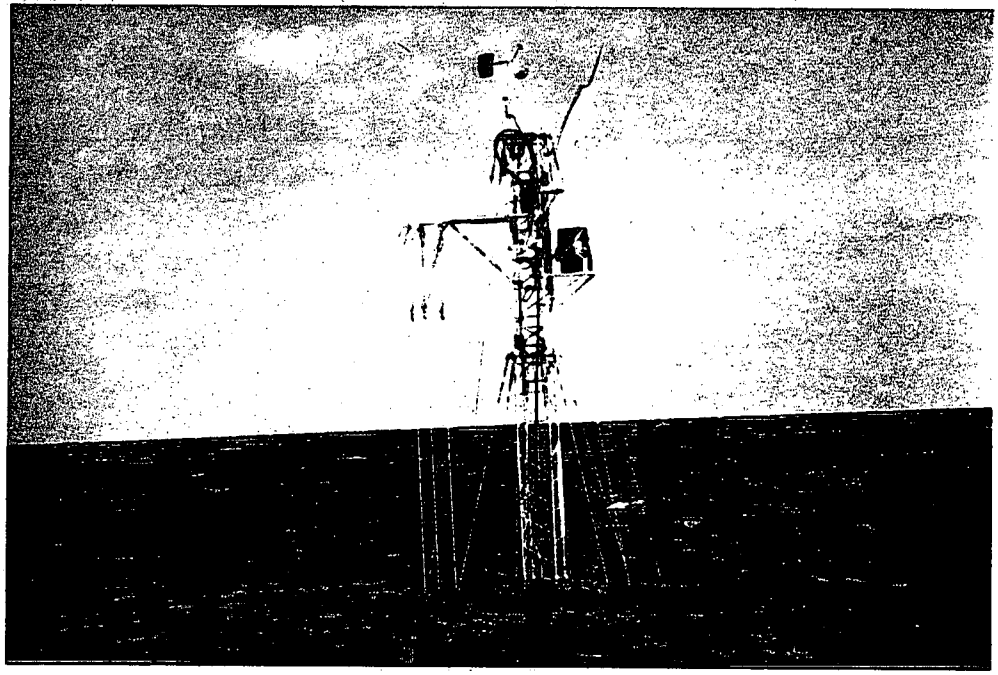

Figure 9

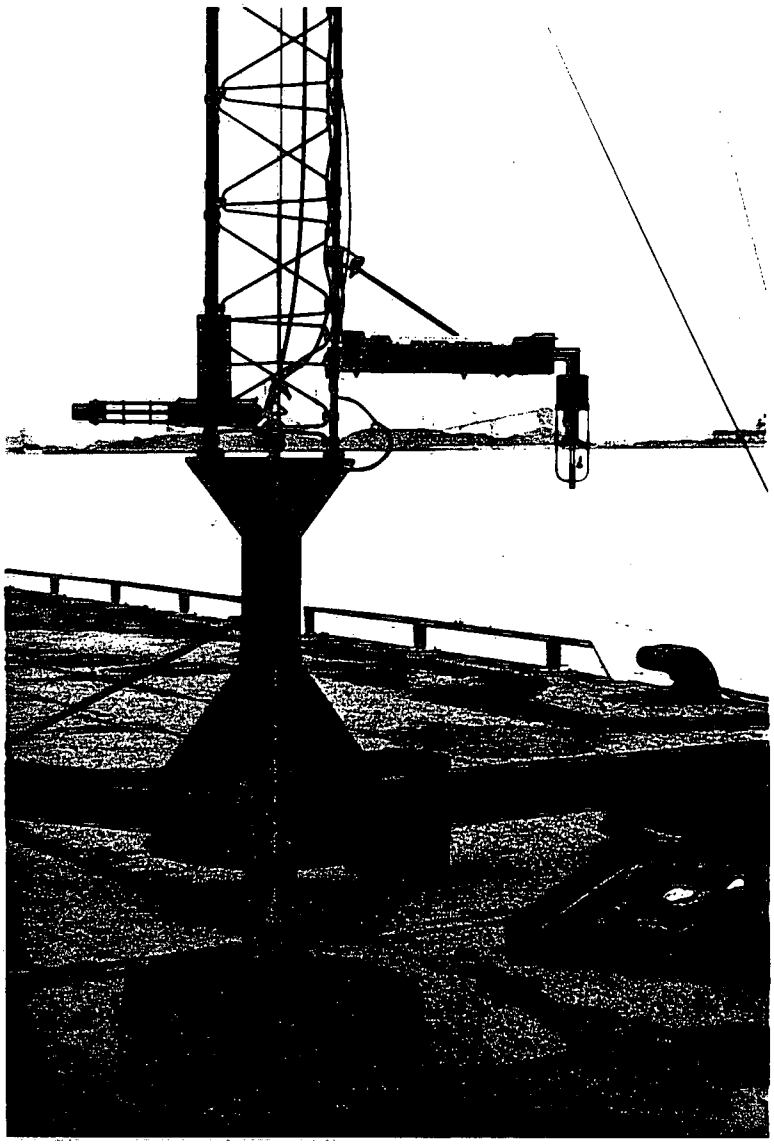

Figure 10

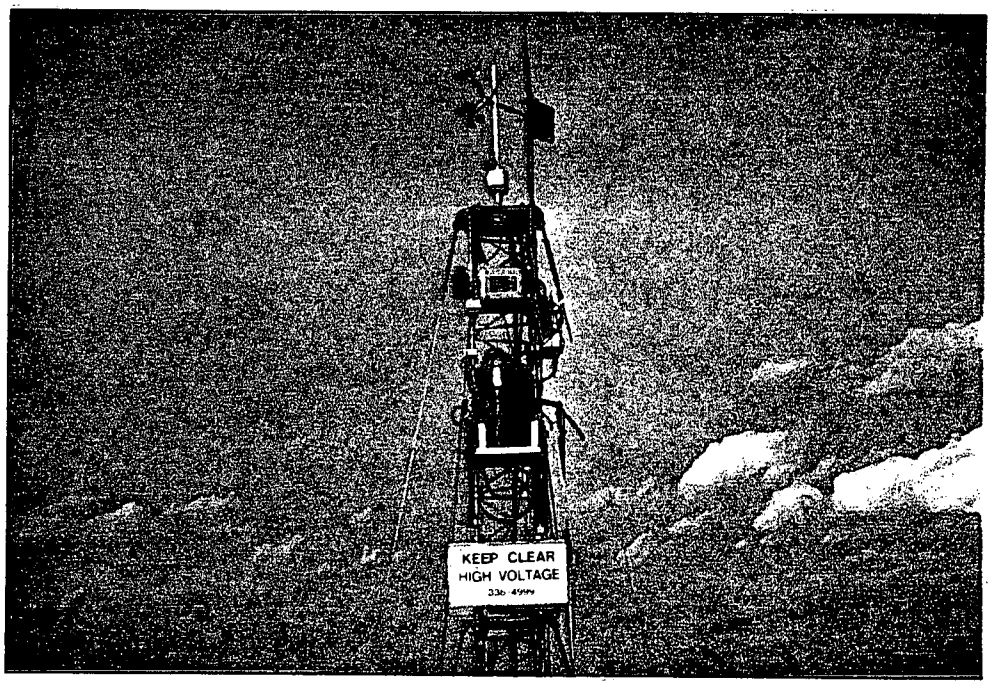

Figure 11

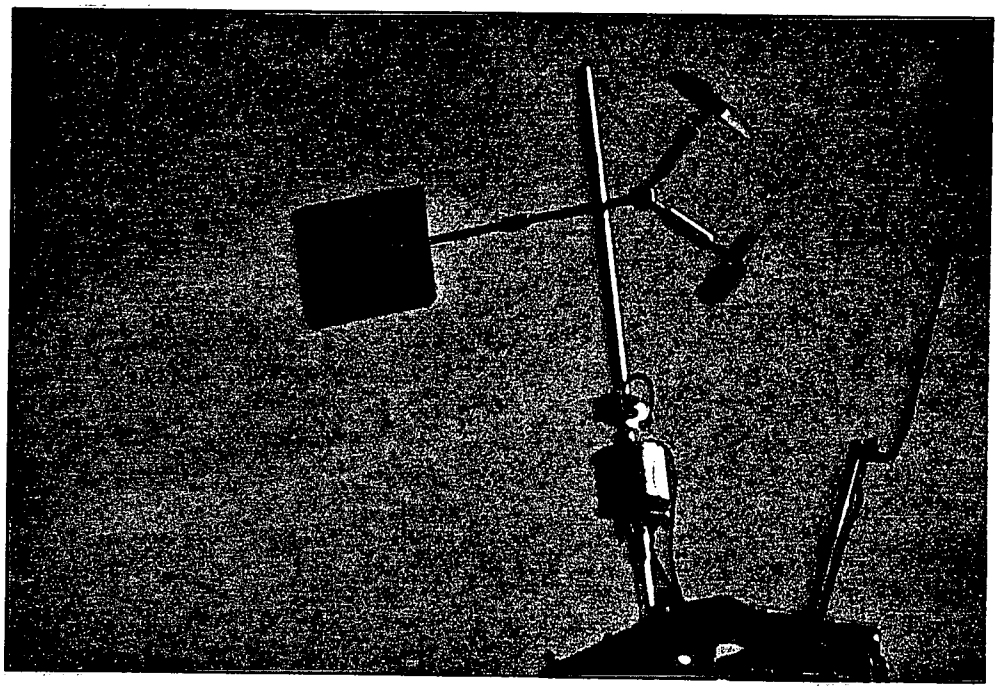

Figure 12

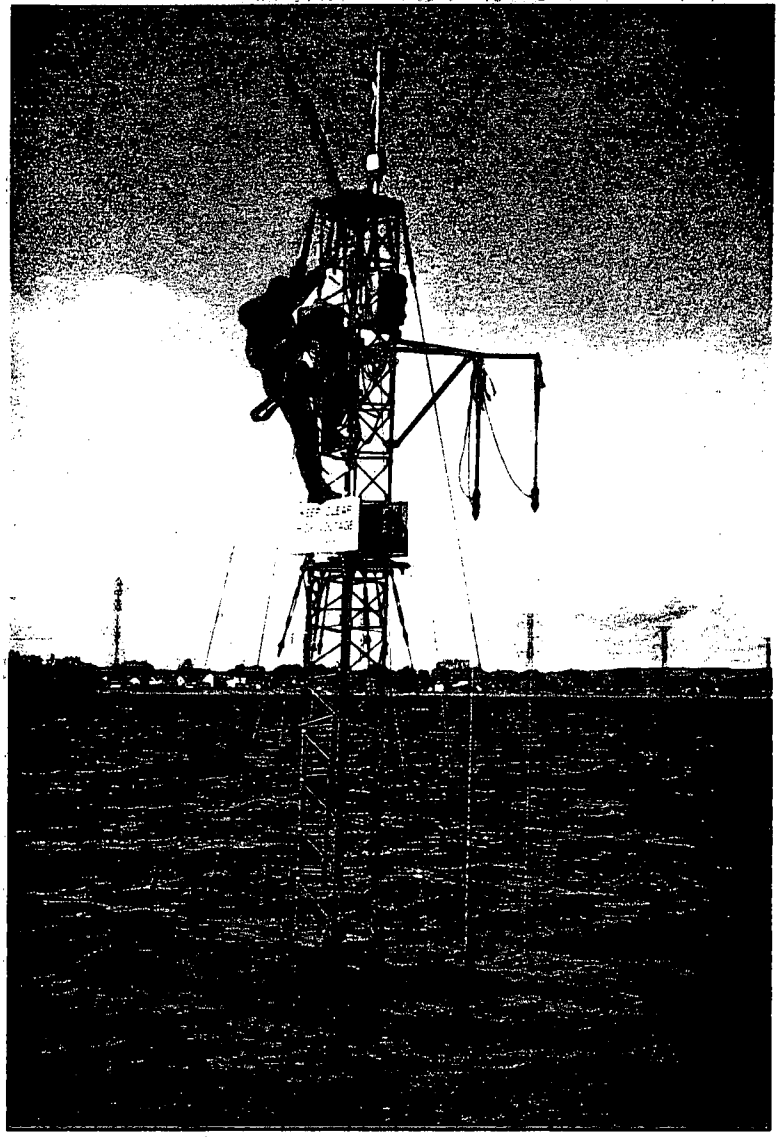

Figure 13

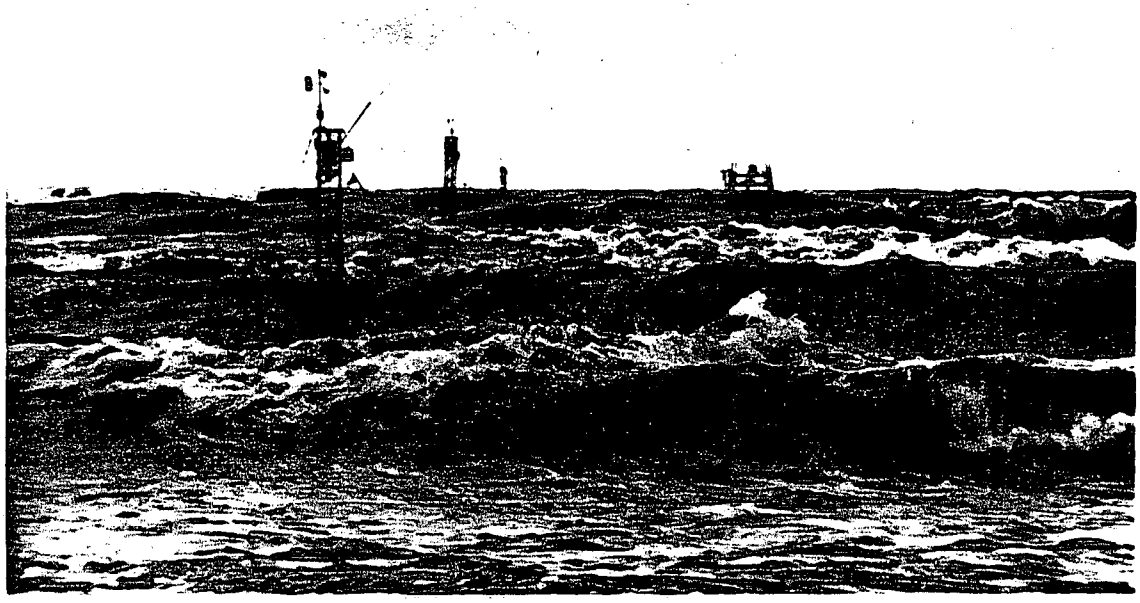

Figure 14

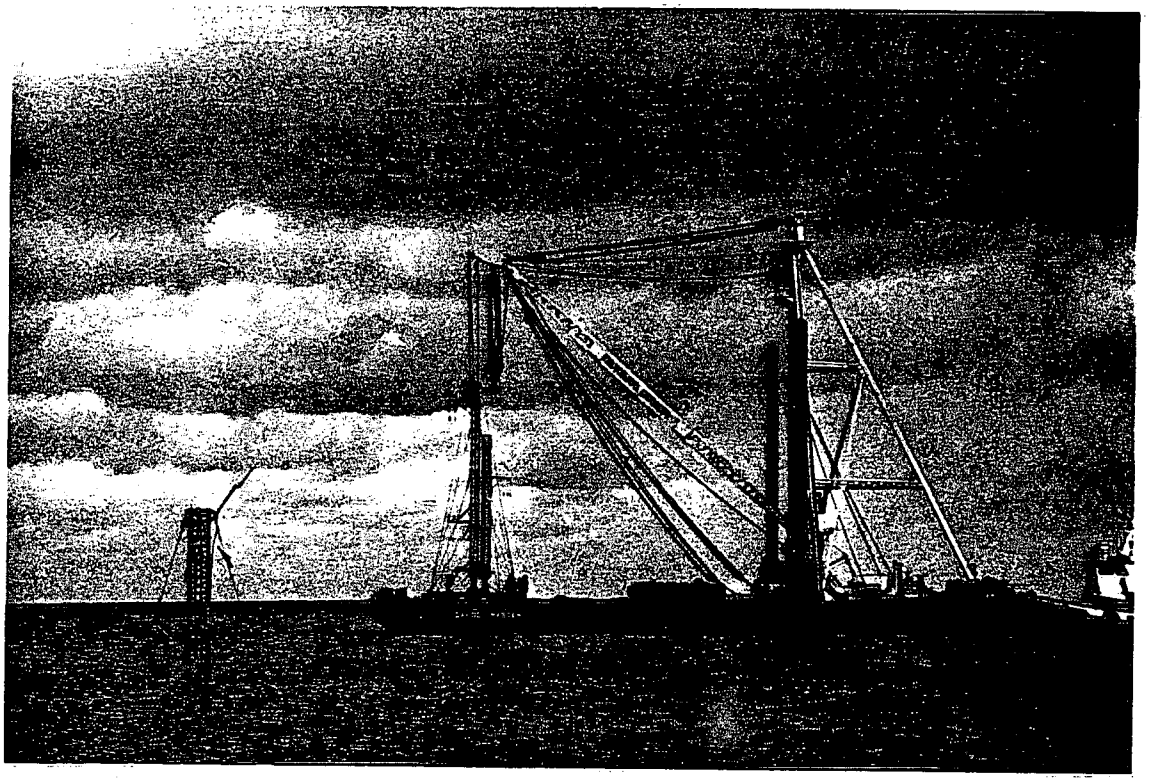

Figure 15

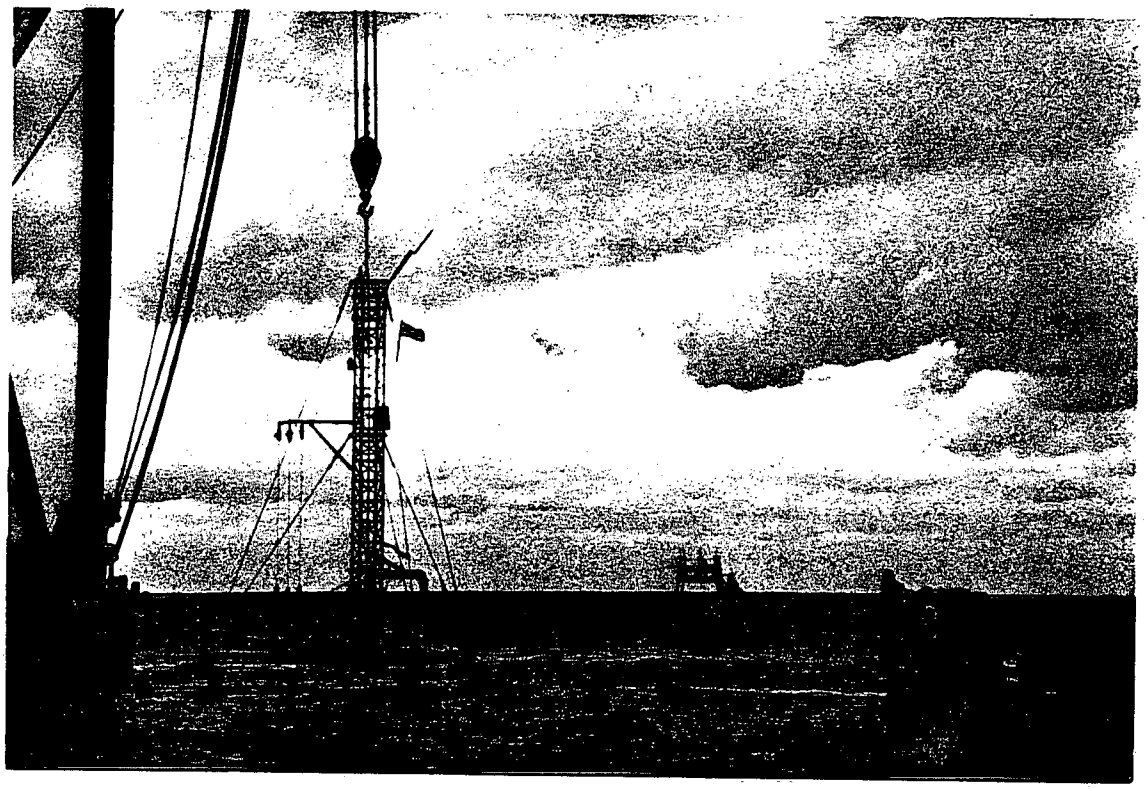

Figure 16

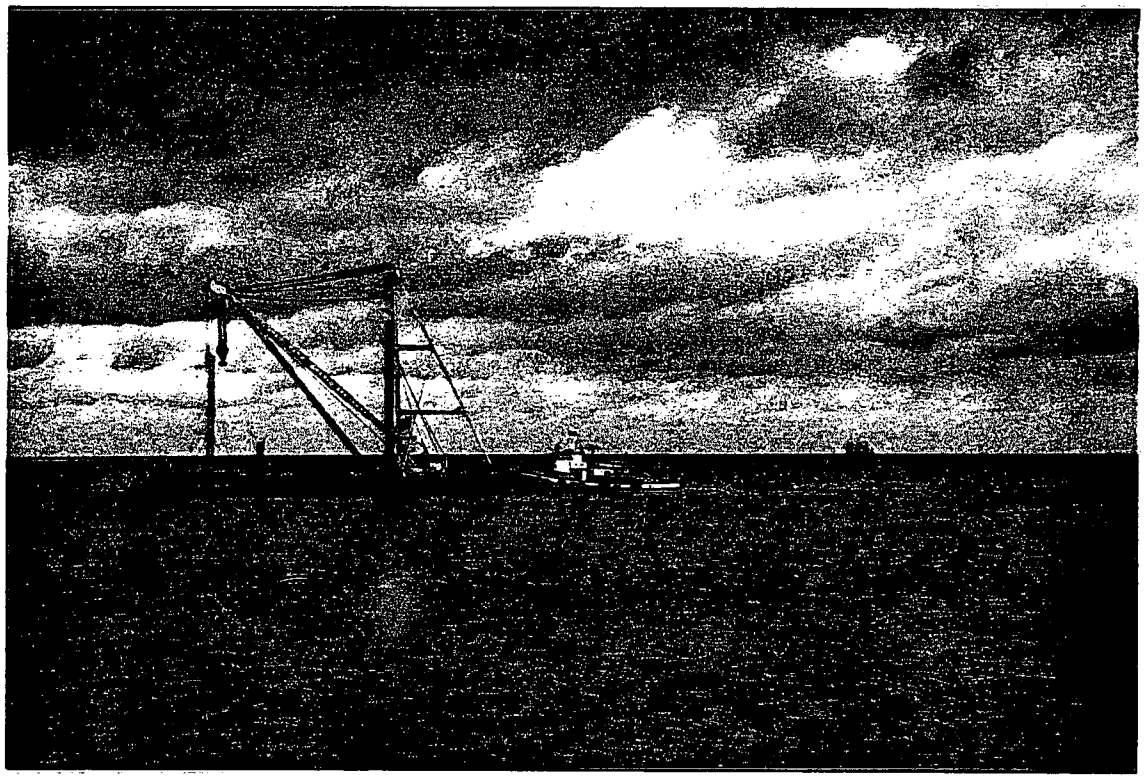

Figure 17

Figure 18