Model tests of pressured broken ice on a segmented inclined plane = Étude sur modèle de la glace de pression fracturée sur un ouvrage plan incliné et segmenté

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MODEL TESTS OF PRESSURED BROKEN ICE ON A SEGMENTED INCLINED PLANE

ÉTUDE SUR MODÈLE DE LA GLACE DE PRESSION FRACTURÉE SUR UN OUVRAGE PLAN INCLINÉ ET SEGMENTÉ

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ABSTRACT

A test program has been performed to study, in a laboratory environment, the behaviour of ice loading through pressured broken ice. This problem is of interest in several loading situations on both structures and ships in Arctic regions. The work was performed by measuring the loads on a segmented planar structure for various loading conditions. Several parameters were varied including the ice strength, the ice thickness, the ice density, the ice/structure friction and the angle of inclination of the structure. The data are presented in various formats for the reader's ease of use. Vertical distributions of loads, point of resultant load application and overturning moments have been examined. The data are meant to serve as input for verifying theoretical models of this type of loading situation. Preliminary interpretation of the results indicates that the action of pressured ice against a listing vessel would tend to right it.

RÉSUMÉ

Un programme d'essais a été entrepris dans le laboratoire, afin d'étudier les caractéristiques d'efforts engendrés par les glaces de pression en morceaux (glace fracturée). Cette étude est importante car elle représente plusieurs situations d'efforts sur des ouvrages et des navires, dans la région arctique. Le travail consistait à mesurer les efforts sur un ouvrage plan segmenté dans diverses conditions de charge. La répartition verticale d'efforts, le point d'application d'effort résultant et le moment de renversement ont été examinés. Les différents paramètres qui ont été modifiés lors de cette étude sont: la résistance, l'épaisseur et la densité de la glace, le frottement entre la glace et l'ouvrage et l'angle d'inclinaison de l'ouvrage. Les résultats sont présentés sous différentes formes par souci d'utilisation facile pour les lecteurs. Ces données sont destinées à valider les modèles numériques, qui tentent de reproduire ces situations d'efforts. L'interprétation préliminaire des résultats indiquent que, dans le cas d'un navire en bande, les glaces de pression entraîneront le redressement du navire.

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LIST OF SYMBOLS

a	moment arm	m
b	width of one plate (= 15 cm)	cm
F	force	N
F_i	force on plate;	N
F_n	normal force	N
F_{N_tot}	total normal load on the structure	N
F_t	tangential force	N
h_i	ice thickness	cm
L	beam length	cm
M	mass	gm
M_w	moment relative to the waterline	N-m
P	load	N
w	beam width	cm
α	angle of model from vertical position	°
λ	scale factor	-
μ	friction	-
ρ	density	$gm\text{-}cm^{-3}$
σ_F	flexural strength	kPa
θ	resultant loading direction	°

MODEL TESTS OF PRESSURED BROKEN ICE ON A SEGMENTED INCLINED PLANE

1.0 INTRODUCTION

In the Arctic, broken ice plays an important role in several situations. For example, it is known that broken ice can accumulate beside offshore drilling structures. Also, in certain situations, broken ice can accumulate along the side of a ship. If this ice is pressured by an advancing ice sheet driven by environmental forces, the broken ice will transmit this load to the structure or ship. For a structure, this has important implications in terms of the load distribution on its face. For a ship, this could lead to a high overturning moment. To date, very little is known about this problem.

The National Research Council of Canada and the Canadian Coast Guard have collaborated to conduct research in this area. There are several research tasks in this area, and the work reported here forms only one part of the full research program. The tasks identified for study include: a review of the potential for, and the consequences of, ice rubble pile-up against the sides of structures and ships (Sayed and Frederking, 1988; Canatec, 1990); a review of the data from the Gulf caisson Molikpaq to provide quantitative full-scale information on ice behaviour against a near-vertical sided structure (Neth, 1989); a series of model tests to investigate the basic physics of the interaction process of broken ice with a rigid structure, reported herein; a model study to investigate the behaviour of pressured broken ice against the side of a floating vessel, to be carried out at the NRC Institute of Marine Dynamics; and the development of an analytical model of ice rubble against ships (Savage, 1990).

The work in this report centres on a description of a model test series to investigate the behaviour of broken ice pressured against a rigid structure. To perform these tests, an idealized two-dimensional model was designed and constructed. The model was designed to represent a plane-surface that could be rotated through an angular range of ± 30° from the vertical. In addition, since the loads and load distribution were of interest, the plane was segmented in six sections so that a vertical pressure distribution on the model could be obtained.

Details of this test program are described and the full test results given here.

2.0 EXPERIMENTAL

The tests were performed in the ice tank at the Institute of Mechanical Engineering in Ottawa (Pratte and Timco, 1981). This tank, which is 21 m long, 7 m wide and 1 m deep, is spanned by a carriage that can travel the full length of the tank. For this test study, a model structure was mounted to this carriage, and the ice loads were measured as the carriage was driven along the tank.

In designing the structure, several aspects had to be considered. First, it was necessary to have the model as rigid as possible. Second, the model, which was idealized as a simple two-dimensional plane, had to be rotatable over an angular range of ± 30° from the vertical. Third, since both the total load and the load distribution on the plane were important to measure, a scheme had to be devised to do this. Fourth, the overturning moment on the plane had to be measured.

The scheme and basic design of the model was developed by Ed Funke of IME/NRC while the detailed design work was contracted out to Davis Engineering Limited and Ed Arambarri. The general concept is depicted in Figure 1, which shows a side view of the carriage in the ice tank and the various components of the design. A large bracket containing a circular track was mounted to the front face of the carriage. This track supported the basic frame for the model and allowed it to be rotated to angles of ± 30° from the vertical. Note that the chosen sign convention is a positive value for the case when the model is inclined back from the advancing ice sheet (see Figure 2). Six 5-component dynamometers were mounted in the frame such that two were above the water line and four were below it. A separate plate was attached to each 5-component dynamometer. Each plate is 15 cm high by 95 cm wide. The dynamometers measured the total normal and vertical tangential load acting on each plate. Thus, the model was segmented vertically into six sections. With this design and appropriate instrumentation, the total loads and moments on the plane could be measured, as well as the vertical distribution of normal and tangential loads. In addition, by re-coating the plates, the ice structure friction coefficient could be set at any desired value. Photographs of the test assembly are shown in Figure 3.

For the present tests, two different friction coatings were used. First, each plate was painted with a very high-gloss paint. That gave a very low friction factor. Second, the plates were re-coated with a paint in which fine grains of sand were imbedded. This rough surface gave a very high ice structure friction. A separate set of experiments was performed to determine the friction of the plates. In these tests, each plate was placed on a horizontal surface and levelled. Then, the force (F) required to start moving the ice (static friction) and keep it moving at a constant speed (dynamic friction) was determined. The friction (μ) was calculated from

$$\mu = F / M \tag{1}$$

where M is the mass of the ice. The measured values of friction were 0.06 and 0.04 for the static and dynamic friction coefficient of the low friction plates, and 0.83 and 0.40 for the static and dynamic friction coefficient of the high friction plates.

The tests were arranged such that ice behaviour was essentially two-dimensional i.e., in the direction of motion of the carriage and vertically perpendicular to that direction (x and z directions - see Figure 1). This was accomplished by positioning vertical side plates to either side of the structure to restrict horizontal transverse motions of the ice. Since it was desirable to observe the ice during the test, two plexiglass sides were used for this purpose (see Figure 3), forming a "chute" arrangement. Slots were cut in the ice in front of each plexiglass side, leaving a tongue of ice slightly narrower than the "chute" to come in contact with the structure. With this arrangement and a video camera photographing the tests, it was possible to identify the various processes occurring throughout the interaction events.

The individual 5-component dynamometers were designed at NRC using waterproofed sealed superbeam load cells manufactured by Interface Inc., of Scotsdale, Arizona, U.S.A. Three 1.1 kN capacity load cells measured the loads in the normal direction, and two 0.5 kN capacity cells measured the vertical tangential loads to the face of the plate. No measurement was made of the sideways loading in the horizontal direction on the plates.

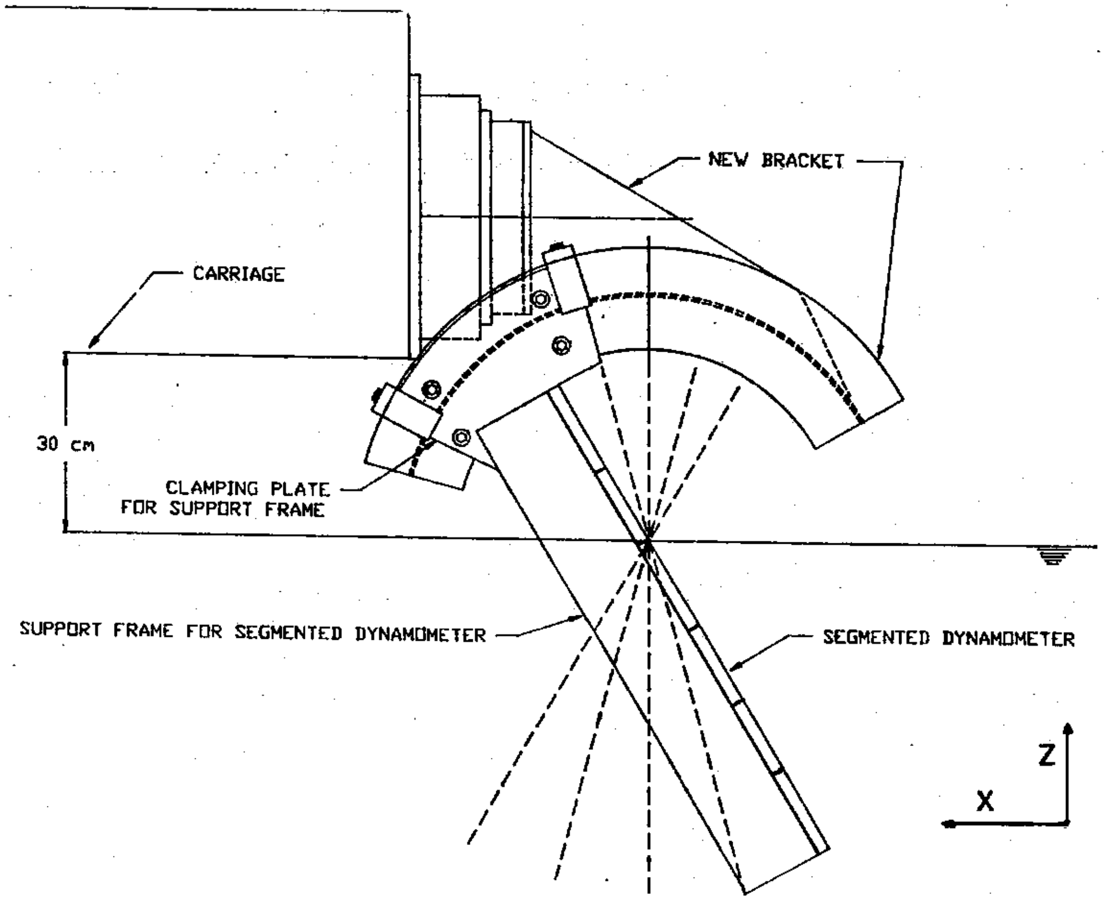

Figure 1. Schematic showing a side-view of the experimental arrangement. The structure in this figure has a positive angle of inclination.

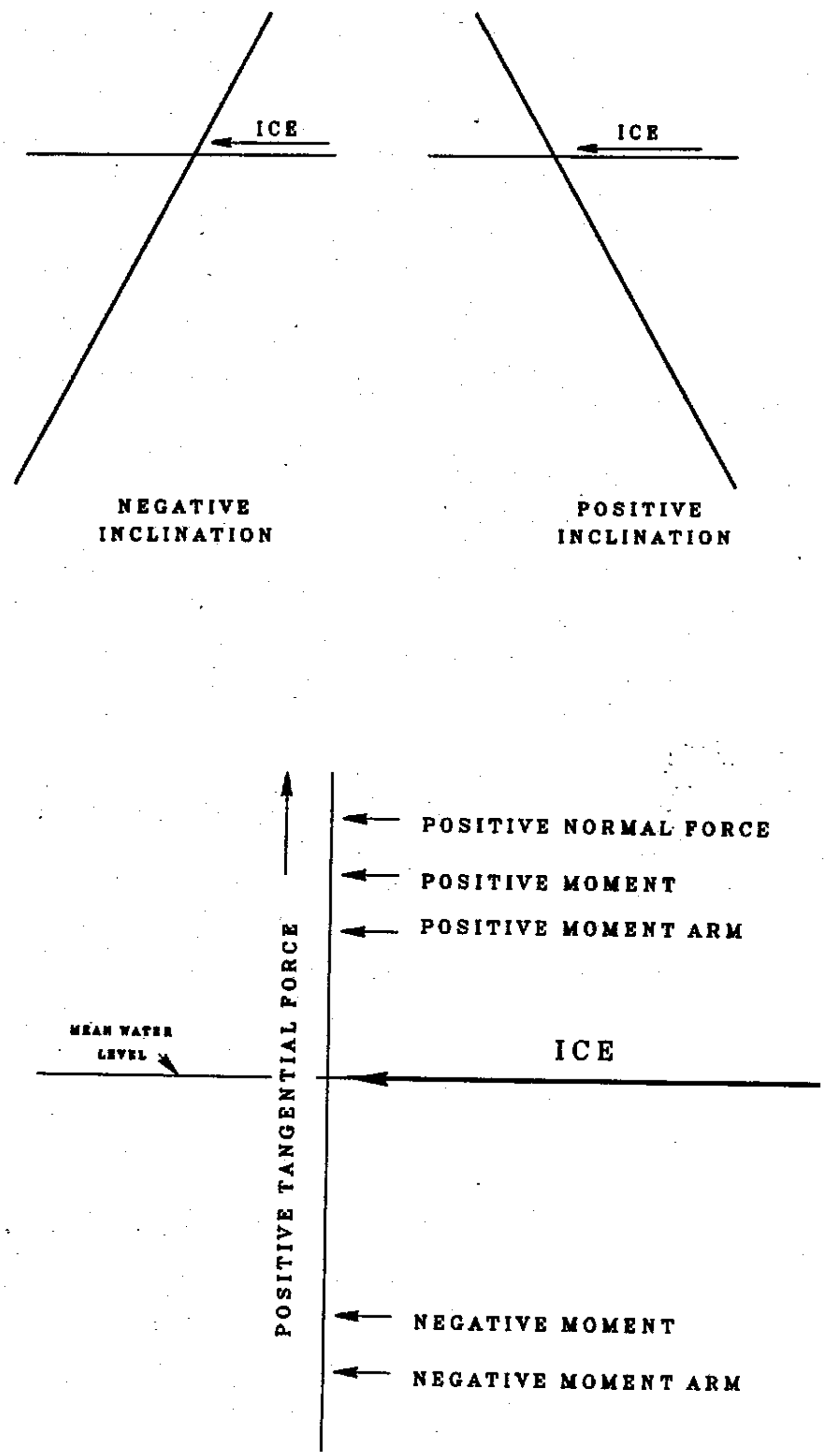

Figure 2. Schematic showing the sign-convention used in the test program.

For the test, the model was mounted on the front of the carriage, and it was slowly driven along the full length of the tank at a rate of 2 cm/s. At this rate, it took approximately 510 s (8.5 minutes) to travel a length of 10.2 m. As the test progressed, a large pile of broken ice would accumulate in front of the structure. Thus, for the latter part of the time series, the structure was loaded through pressured broken ice. During the test, the output from all of the instrumentation was measured using a NEFF 620 buffered data acquisition system. This consists of Series 100 amplifier/multiplexer units, Series 300 signal conditioners and Series 500 measurement and control systems. The data were sampled at a rate of 20 Hz, and a 10 Hz filter was used to prevent aliasing from signals with frequencies above this value. The data were stored on disk and magnetic tape for subsequent data analysis.

For the tests, EG/AD model ice was used (Timco, 1986). This ice well represents, at model scale, many of the full-scale properties of sea ice. With this ice, the strength reduction is achieved through a process of chemical entrapment in the ice sheet. The chemicals trapped in the ice internally melt it, thereby giving the desired lower strength ice. Although many of the ice properties are very well scaled using this technique, this mechanism of strength reduction has the disadvantage of improper scaling of ice density. Typically, the density of EG/AD ice is 0.93 gm-cm^{-3}, slightly higher than the target density of 0.89 gm-cm^{-3}. Although this difference is relatively small in actual value, the difference is significant when viewed in terms of the buoyancy force on the ice. In this case, the conventional EG/AD ice can lead to inaccuracies in buoyancy scaling of up to 50%. Since the density of the ice plays an important role in the processes investigated in this test program, use was made of a new technique to produce correct density (CD) ice. This technique involves the use of a submarine carriage which travels under the growing ice sheet, releasing small air bubbles. These air bubbles are trapped in the growing ice sheet and result in a lower density ice (Spencer and Timco, 1990). This ice was used for part of the test program, giving ice densities of 0.87-0.89 gm-cm^{-3}. For one test, the density was lowered to 0.79 gm-cm^{-3}.

Before each test, the flexural strength of the ice was measured. This was done by cutting cantilever beams in the ice and measuring the load (P) necessary to cause failure. The flexural strength of the ice (σ_F) was determined from

$$\sigma_F = 6\,P\,L\,/\,w\,h_i^{\,2} \tag{2}$$

where L, w and h_i are the beam length, width and thickness, respectively. The calculated flexural strength is not a true material property; instead, it is a strength index. Knowing the value of the flexural strength gives information on other mechanical properties through calibration curves published by Timco (1986). From the value of the flexural strength, information is obtained on the uniaxial and confined compressive strength, strain modulus and fracture toughness.

In addition to the strength, the density of the ice was measured by cutting rectangular beams from the ice and measuring the dimensions and mass. The density (ρ) was determined from

$$\rho = M\,/\,L\,w\,h_i \tag{3}$$

where M is the mass of the beam.

Immediately after each test, a number of the ice pieces in the rubble pile were removed, and the thickness of the ice sheet was measured using calipers.

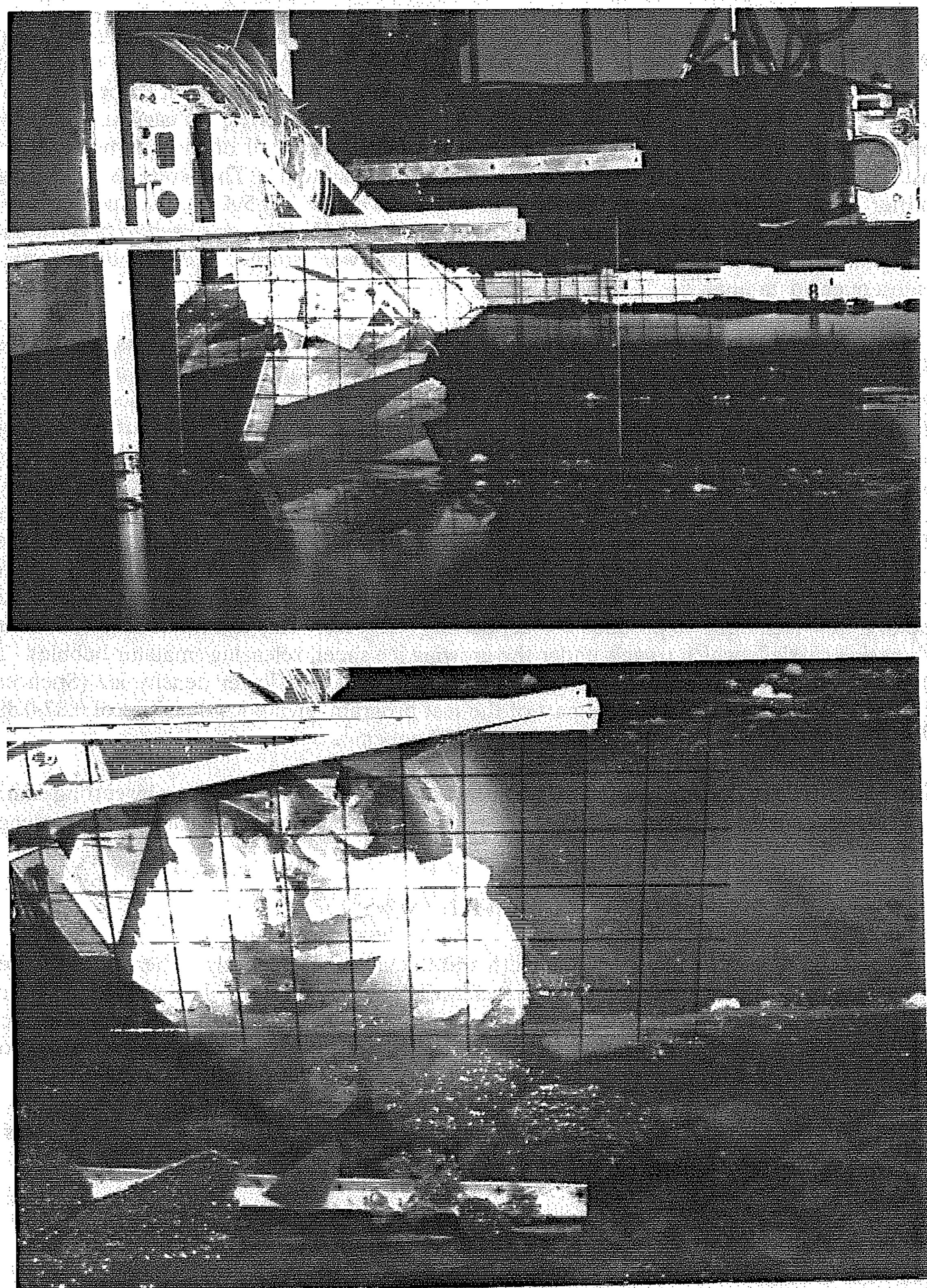

Figure 3. Photographs of the test assembly.

3.0 RESULTS AND ANALYSIS

3.1 General Analysis

At the start of each test, no ice was touching the model. However, as the carriage was driven along the length of the tank, the ice would contact the structure, and fail, usually by buckling. With further advance of the structure, more ice would contact it and a natural rubble pile would start to form in front. By the end of the test, a very large pile of broken ice would be in front of the structure. The size of the rubble pile was a function of the angle of inclination of the structure. For tests where the structure was inclined towards the advancing ice sheet with angles greater than 15° a lot of the ice would slide down the face of the model and exit from underneath it. However, for other loading configurations, virtually all of the broken ice would stay in front of the structure, and quite large rubble piles would form.

With this test arrangement, the situation of loading on the structure is different at different times during the test. At the start, there is no ice rubble; at the end of the test, a considerable pile of broken ice is in front of it. Thus, there is a natural evolution in the loading conditions on the structure, reflected in the time series of the loads on the structure. The time series are quite complex and vary in both form and magnitude on each plate.

The tests produced a considerable amount of experimental data. All thirty-six data channels were monitored throughout the test run. To make the results meaningful, it was necessary to perform suitable signal processing. For this, the output from each of the load cells supporting the separate plates were summed up to give the total normal and tangential load on each plate. Then, as an output for each test, the following information is presented, representing the full length of each test:

First, a series of time series show the normal, tangential and resultant loads for each of the six plates, as well as the total loads on the model. The resultant load (F_r) and loading direction (θ) were determined from

$$F_r = (F_n^2 + F_t^2)^{1/2} \tag{4}$$

and

$$\theta = \tan^{-1}(F_t/F_n) \tag{5}$$

where F_n and F_t are the normal and tangential loads, respectively. The sign convention is shown in Figure 2. Also, the total loads were resolved to give the total loads in the horizontal and vertical directions. For each of the time series, the maximum, mean and minimum loads are also listed on the plots.

Second, the point of load application relative to the water line (i.e., the moment arm "a") was determined from the output of the segmented plane. This was determined from

$$a = \sum_{i=1}^{6} (5-2i)\ F_{Ni}\ b/2\ F_{N\_tot} \tag{6}$$

where b is the plate width (b = 15 cm), F_{N_tot} is the total normal load and F_{Ni} is the normal load on plate i.

Using the calculated value of the moment arm (a) along with the total normal load on the structure (F_{N_tot}), it is possible to determine the overturning moment on the structure. The total overturning moment relative to the water line (M_w) is given as a time series determined from

$$M_w = F_{N\_tot} * a \tag{7}$$

In Appendix A, both a and M_w are presented in time series form, as well as the probability density for all of the tests.

Third, a schematic illustration is presented showing the evolution of the ice rubble in front of the structure as a function of time. From these plots, an estimate of the volume of broken ice is presented as a function of time during the whole loading event.

Fourth, a depth histogram was plotted for each test based on the measured maximum, mean and minimum value for each test. On these plots, the distribution of the extreme values of the loads on each plate are shown as a function of depth. These graphs are given for the normal, tangential and resultant force on each plate. Note that these graphs represent the total time series during the test.

Fifth, the time series were analyzed to give both the probability density and cumulative distribution of the loads on each plate. These are also presented for normal, tangential and resultant loads.

Although the representation of the data in the above-mentioned formats are instructive, it is also desirable to isolate individual loading events and examine the behaviour of the loads during the course of the loading event. To do this, it is necessary to identify a loading event of interest, then "time select" the data to isolate the loading event. From this data, it is possible to look at the same type of plots as discussed above for the full time series. The results of this analysis are presented in Appendix B for 13 events.

During this test program, 22 tests were performed. The file names of the data are numbered TN_001 to TN_022 corresponding to each ice sheet. The details of each test are shown in Table 1. The parameters that were varied include the angle of the model from the vertical position (α), the friction (μ) of the plate, the flexural strength (σ_F) of the ice, the thickness (h_i) of the ice and the density (ρ) of the ice. The tests were divided into two phases depending on the friction of the model. For the first phase, a very low-friction model was used. For the second phase, a much higher-friction model was used. Additionally, for the first nine ice sheets, regular EG/AD ice was used without modifying the ice density. In each phase, tests were performed with the model at various angles of inclination for various ice strengths, ice thicknesses and ice densities. The details of each phase are presented below.

3.2 Phase 1: Low-Friction Structure

Ice Sheet #1 - TN_001 - For the first test, the model was rotated so that the top part of the plane was inclined towards the advancing ice sheet at an angle of -23° from the vertical. The strength of the ice was quite high for this test, with σ_F = 106 kPa. The thickness of the ice was 3.1 cm. During

Table 1 Details of the set-up for each test.

FILE NAME	σ_F	ρ	h_i	ANGLE OF PLANE	FRICTION	BUBBLED ICE
	(kPa)	(g/cm^3)	(cm)	(o)		
TN_001	106	0.93	3.1	-23	LOW	NO
TN_002	44	0.93	3.6	-23	LOW	NO
TN_003	83	0.93	2.8	-23	LOW	NO
TN_004	70	0.93	3.5	-15	LOW	NO
TN_005	86	0.93	3.3	-5	LOW	NO
TN_006	64	0.93	3.2	0	LOW	NO
TN_007	101	0.93	3.5	8	LOW	NO
TN_008	85	0.93	3.5	15	LOW	NO
TN_009	62	0.93	3.6	24	LOW	NO
TN_010	60	0.87	3.1	24	LOW	YES
TN_011	94	0.89	3.3	13	LOW	YES
TN_012	58	0.88	3.2	0	LOW	YES
TN_013	53	0.85	3.2	-10	LOW	YES
TN_014	39	0.89	3.4	-30	HIGH	YES
TN_015	35	0.89	3.4	-12	HIGH	YES
TN_016	64	0.88	3.3	0	HIGH	YES
TN_017	50	0.90	3.4	24	HIGH	YES
TN_018	61	0.85	3.0	7	HIGH	YES
TN_019	24	0.93	2.3	7	HIGH	YES
TN_020	15	0.93	3.6	7	HIGH	YES
TN_021	24	0.93	2.6	7	HIGH	YES
TN_022	21	0.79	3.8	7	HIGH	YES

this test, a number of large ice pieces slid down the full length of the model and exited underneath the model. Thus, after the test a number of large ice pieces were floating in the wake of the model. In fact, the ice volume in the chute was approximately only half the input volume (see page 38). This only occurred for tests with a large angle of inclination towards the ice loading direction. With the low-friction plate and high angle of inclination, there was little resistance for the ice pieces sliding along the model. As evidenced from the figures in Appendix A for this test, the time series are clearly quite complex. For this test, there is no loading on the upper plate (Plate #1), whereas there are a number of loading events on the other plates. This reflects the fact that the ice did not ride up or touch the upper plate during this test. Note that the tangential loads on plate #2 are both positive and negative in value. This shows that the ice would sometimes move up the plate (positive value), whereas at other times it would slide down the plate (negative value). Note also that the magnitude of the normal loads are always significantly higher than the tangential loads on the plate. Also, the majority of the loading occurs on the second and third plates, at the water line region.

Ice Sheet #2 - TN_002 - For the next test, the same angle was used, but the strength of the ice was reduced to a value of 44 kPa, and the ice thickness was increased to 3.6 cm. Once again, a number of large ice pieces slid along the model and exited to the wake of the model.

Ice Sheet #3 - TN_003 - The model angle again was kept at -23° and an intermediate ice strength was used, with a thin ice sheet of 2.8 cm. With these first three ice sheets, information is available on both the influence of ice strength and ice thickness for a constant angle of the structure.

Ice Sheet #4 - TN_004 - The model was rotated to an angle of -15° and a strength of 70 kPa and ice thickness of 3.5 cm were used for this test. In this case, with a steeper angle, little of the ice exited from below the model.

Ice Sheet #5 - TN_005 - The model was rotated to a steep angle of -5° for the next test. The ice strength and thickness were 86 kPa and 3.3 cm, respectively, for this test.

Ice Sheet #6 - TN_006 - The model was positioned so that it was vertical for this test. An ice strength and thickness of 64 kPa and 3.2 cm were used. In this test, the ice sheet broke away from the edge of the tank, with approximately 1.5 minutes of sampling time remaining. After this, the model simply pushed the ice sheet along with it. Thus, the test data are only useable for the first seven minutes of the test.

Ice Sheet #7 - TN_007 - For the next test, the model was rotated so that it was inclined away from the advancing ice sheet at an angle of 8°. A high strength of 101 kPa and an ice thickness of 3.5 cm were used for this test. Note that with the model angling away from the advancing ice sheet, there is considerably more ice loading on the upper plate (Plate #1) of the model.

Ice Sheet #8 - TN_008 - The model was rotated further to an angle of 15° for this test. A strength of 85 kPa and a thickness of 3.5 cm were used for the test.

Ice Sheet #9 - TN_009 - For the next two tests, the model was rotated to an angle of 24°. For this test, the ice strength was 62 kPa and the ice thickness was 3.6 cm.

Ice Sheet #10 - TN_010 - The model was left at an angle of 24° and the ice strength was similar to the previous test at 60 kPa, but the ice thickness was reduced to 3.1 cm. For this test, the CD model ice was used, giving a lower density ice.

Ice Sheet #11 - TN_011 - The model was rotated to an angle of 13° such that it was sloping further away from the advancing ice sheet. The air carriage was again used to give lower density ice. For this test, an ice strength of 93 kPa and a thickness of 3.3 cm were used. The underwater camera was set up and used in this test for the first time. For this test, the ice sheet broke away from the side walls with approximately one minute remaining in the test. Therefore, the data in the last minute of the time series do not represent pressured ice loading through ice rubble.

Ice Sheet #12 - TN_012 - The model was rotated to the vertical position for the next test, and the air carriage was again used to give a lower ice density. The ice strength was 58 kPa, and the thickness was 3.2 cm. The underwater camera was again used for this test. As in the last test, the ice sheet broke away from the side walls. In this test, however, the breakage occurred with approximately three minutes remaining in the test. Therefore, the data are useable only in the first five and a half minutes in the time series.

Ice Sheet #13 - TN_013 - The model was rotated to a position of -10° such that it was inclined towards the advancing ice sheet. The air carriage was again used in this test. The ice strength and thickness were 53 kPa and 3.2 cm, respectively. For this test, a few ice pieces slid along the model and exited from below it. The underwater camera was used for this test. It revealed good details of the rubble formation and the general large movement of the ice rubble pile when disturbed by the failure of the ice sheet.

3.3 Phase 2: High-Friction Structure

Ice Sheet #14 - TN_014 - For all of the remaining tests, new plates were put on the model. These plates were produced to have a high-friction coating. Friction tests yielded friction values of 0.83 and 0.40 for the static and dynamic friction coefficients respectively. For the first test in this series, the model was set to an angle of -30°. The air carriage was used to produce ice with a density of 0.89 gm-cm^{-3}. The strength of the ice was 39 kPa, and the average ice thickness was 3.4 cm.

Ice Sheet #15 - TN_015 - For this ice sheet, the model was rotated to an angle of -12°, and the test conditions were set to be the same as for ice sheet #14. The strength of the ice during the test was 35 kPa, and the ice thickness was 3.4 cm. The density of the ice was 0.89 gm-cm^{-3}.

Ice Sheet #16 - TN_016 - The model was rotated to the vertical position for this test. The strength of the ice was 64 kPa, and the thickness was 3.3 cm. The density of the ice was 0.88 gm-cm^{-3}.

Ice Sheet #17 - TN_017 - For this test, the model was rotated to an angle of 24°. The strength of the ice was 50 kPa, and the thickness was 3.4 cm. The ice density was 0.90 gm-cm^{-3}. During this test, at a time of approximately 410 s, the ice sheet buckled and broke outside of the plexiglass side walls. This relieved the load on the broken ice in front of the structure from that point until the end of the test.

Ice Sheet #18 - TN_018 - For the remaining tests, the model was rotated to an angle of 7°. This angle is the same as the angle of the Gulf Resources Canada mobile arctic caisson Molikpaq. For this test, the ice strength was 61 kPa, and the ice thickness was 3 cm. The density of the ice was

0.85 gm-cm^{-3}. This test was particularly interesting since there was a lot of ice crushing at the interface between the ice sheet and the structure. Some ice rode up over the top of the structure during the test.

Ice Sheet #19 - TN_019 - With the angle of the structure still at 7°, this test was performed with an ice strength of 24 kPa and an ice thickness of 2.3 cm. The density of the ice was high at 0.93 gm-cm^{-3}. During this test, the ice again broke outside the chute at a time of approximately 220 s. From then on, the advancing ice slid underneath the ice edge and started to push against the lower ice rubble.

Ice Sheet #20 - TN_020 - With the model set at an angle of 7°, this test was performed with very weak ice. The strength for this test was 15 kPa, and the thickness was 3.6 cm. The density of the ice was again high, 0.93 gm-cm^{-3}. Again in this test the ice broke along the ice tongue at a time of 320 s. For the remainder of the test, the ice pushed against the lower ice rubble.

Ice Sheet #21 - TN_021 - With an angle of 7°, the ice strength was 24 kPa, and the thickness was 2.6 cm. The density of the ice was 0.93 gm-cm^{-3}.

Ice Sheet #22 - TN_022 - To have a large difference in the ice density, the ice for this test was grown to have a very low density. During the test, the density of the ice was 0.79 gm-cm^{-3}. Ice of this type would represent ice conditions during spring break-up. For the test, the strength of the ice was 21 kPa, and the thickness was 3.8 cm. The test was interesting, with a lot of ice piling up in front of the structure. The difference in density was quite noticeable and significantly influenced the relative proportion between the sail and keel of the rubble pile in front of the structure.

4.0 DISCUSSION

4.1 General Discussion

This test program gives a great deal of experimental information on the behaviour of broken ice and the loading of structures through pressured ice. As mentioned in the Introduction, the present test program forms only one part of the total investigation into this topic. Future work includes similar types of tests with floating structures and a detailed analysis of loading through pressured ice by Professor Savage of McGill University. Because of this, the work reported here will not be analyzed in detail. Instead, effort was spent in trying to present the test information in as many forms as possible, so that the reader can easily make use of the data.

As evidenced in Table 1, there were many varied parameters in this test program, including ice strength, ice thickness, ice density, the ice structure friction and the angle of inclination of the planar structure. All of these factors affected the loads and the load distribution on the structure. Thus, it is necessary to consider each of these in any analysis of this situation. During a single test, there were several individual loading events. Moreover, the loading process is dynamic, with "slow" turbulence in the broken ice pile. This leads to a complex time series variation of the loads on the structure. Because of this complexity, it is not easy to separate the influence of each of the varied parameters during this test program. However, the parameters were varied over a wide range so that the test data should provide a good basis for evaluating any theory to describe this phenomenon.

In observing the tests, it was evident the ice could fail in many different ways. On several occasions, the ice would fail in a bending or flexural-type failure. The advancing ice sheet would usually ride up over the ice rubble and fail as it pushed against the sail of the rubble close to the structure. Depending on the angle of the model, the bending failures could be either up or down. Large-scale buckling was a frequent mode, especially in the early part of the test when there was little rubble in front of the structure. Ice crushing was also observed to occur, especially in small local crushing events. Large-scale ice splitting occurred on a few occasions, especially when the underwater camera was used. The details of the ice structure interaction were a function of the angle of the structure. For those tests where the structure was inclined towards the advancing ice sheet (negative slope), the ice tended to ride over the rubble pile and load the structure directly. Then, the ice usually failed in a bending mode, and the newly broken ice pieces would rotate and slide down the face of the model. In some instances, some local crushing would occur. When the model was inclined away from the advancing ice sheet (positive slope), the broken ice tended to ride up the model. Broken ice pieces would form a small sail in the region in front of the structure. Then, subsequent loading events occurred by loading the structure through a layer of ice rubble. Thus, the advancing ice sheet loaded the structure through only a few pieces of ice rubble, and the ice sheet was buoyantly supported from below by a large mass of broken ice. In this case there was much more ice crushing, and, in some cases, large scale ice splitting. In the cases where a relatively large sail developed through ice ride-up, the ice would accumulate on top of the rubble until a critical level was reached. At that time, a large-scale bending failure of the ice would occur, and the sail of the rubble would slide down the face of the structure.

The underwater camera provided useful information on the behaviour of the rubble below the water line. In many tests, the ice rubble would exhibit behaviour whereby the whole rubble pile would "roll" in a circular fashion in the direction of the advancing ice sheet. Because of this, a considerable amount of the broken ice would be turned upside down from its original orientation. If there were a wide range of ice piece sizes in the rubble, the rolling events would reorganize the rubble and give the rubble a more random orientation of ice pieces.

4.2 Trends in the Overturning Moment

One of the most important properties which was measured in this test program was the overturning moment on the structure. It is of interest, therefore, to examine the measured values in more detail. A straightforward approach would be to compare the mean moment, the maximum moment and the minimum (i.e., the maximum negative) moment on the structure for all tests. These are plotted in Figure 4 as a function of the structure angle for all tests except TN_022, which had the very low density. Although there is scatter due to the differences in the tests conditions of ice strength and ice thickness, a few trends are evident. First, the mean moment for all tests is always negative. Also, there appears to be a general decrease in the mean moment as the angle of the model changes from negative to positive. The behaviour of the maximum negative moment also behaves in this fashion. On the other hand, there appears to be a peak value in the maximum positive moment when the model is near the vertical position.

The apparent variation in average overturning moment implies a basic stability i.e., the net average overturning moment acts in a direction so as to right a listing vessel. This is shown schematically in Figure 5, for the scenario of a listing ship, which is trapped in pressured ice, which creates rubble. In this case, the *average* overturning moment would be negative on both sides of the ship. However,

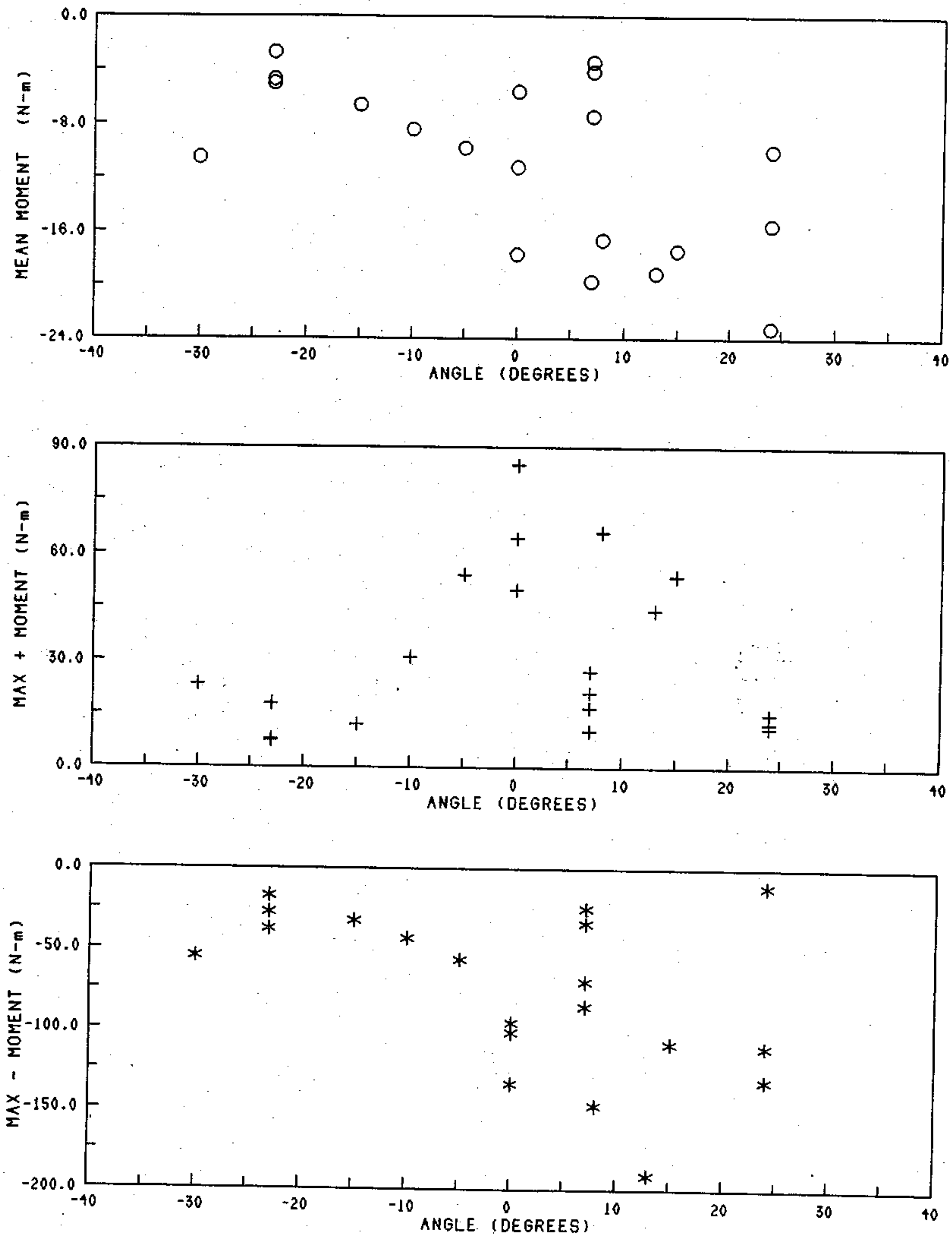

Figure 4. Mean moment, maximum positive (+) moment, maximum negative (-) moment for the tests.

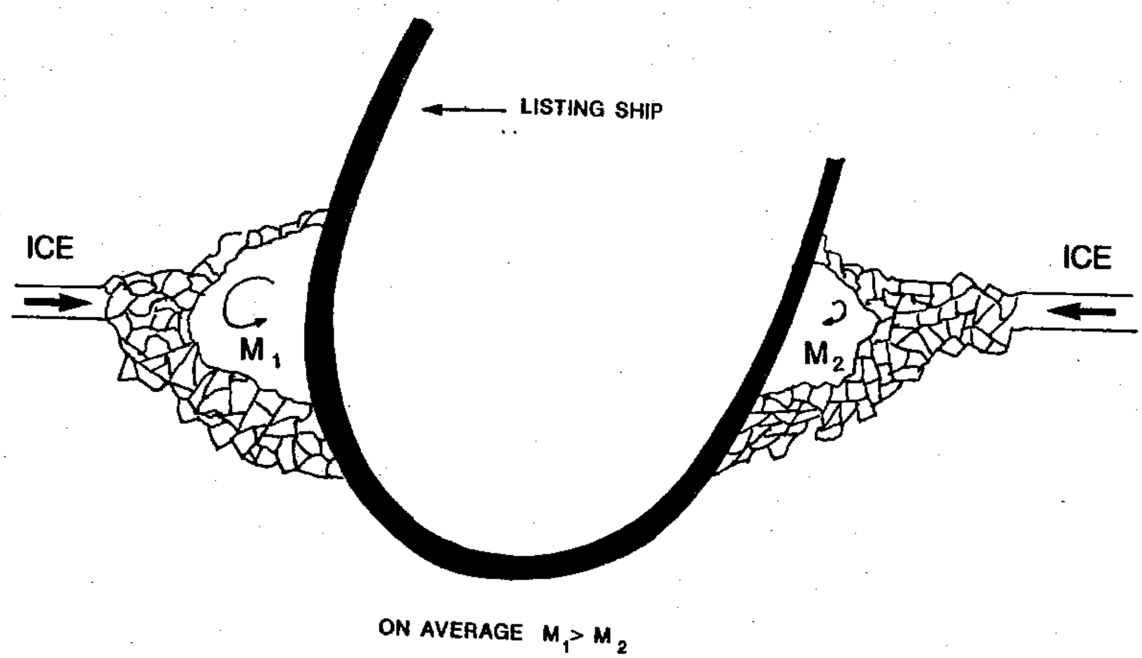

Figure 5. Schematic illustration of a listing ship trapped in pressured ice. The tests indicate that there will be a net restoring moment in this case.

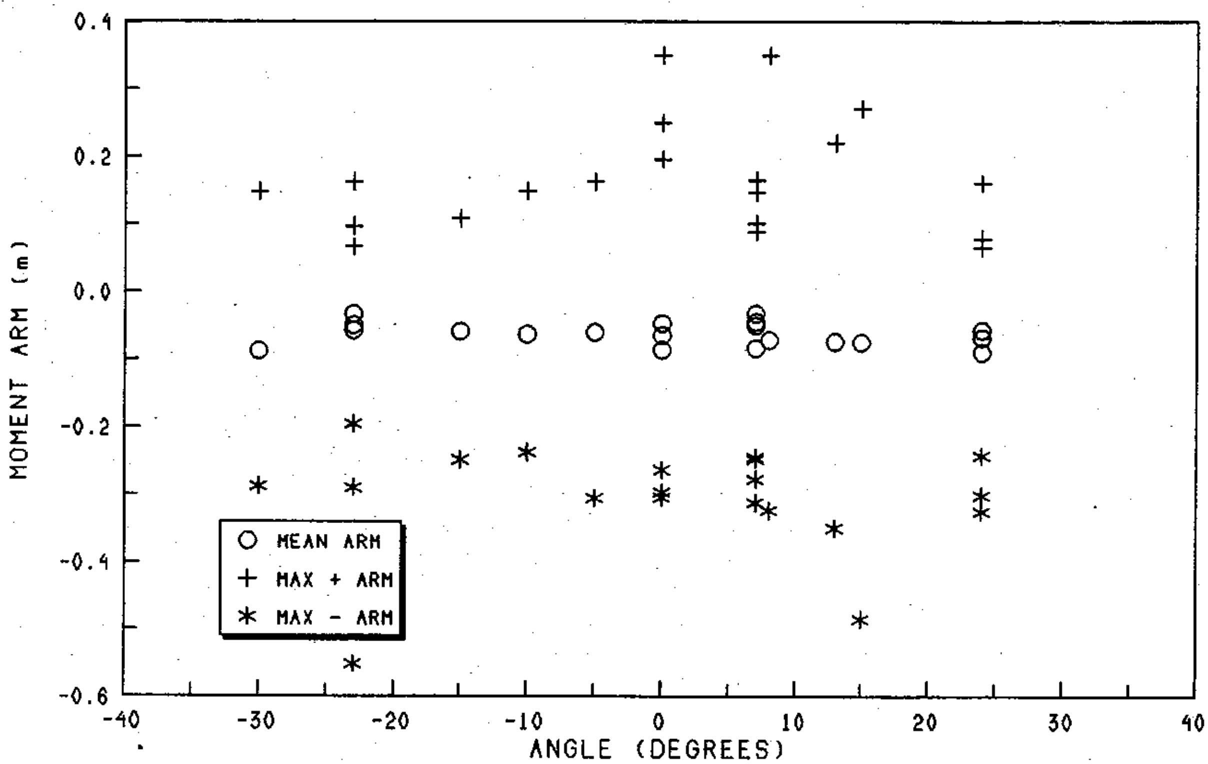

Figure 6. Moment arm versus the angle of the structure for the tests.

the average moment, although negative, is larger for the side inclined away from the advancing ice sheet (see Figure 5). Thus, on average there is a net moment which will tend to right a listing ship in this situation. Moreover, as the model tilts, the average moment difference becomes larger. It should be noted that the test conditions reported here are for a fixed structure. Thus, this should be verified with a floating model structure.

It is also possible to compare the moment arm determined from each of these tests. The moment arm is a measure of the point at which the load is applied. This comparison is made as a function of the structure angle for all of the tests except TN_022 in Figure 6. Contrary to Figure 4 which showed the behaviour of the moment, there does not appear to be a strong trend in the moment arm in terms of the angle of the model. For the present tests, the maximum positive moment arm is typically 0.15 m, the mean moment arm is -0.08 m, and the maximum negative moment arm is -0.3 m.

This behaviour of both the moment and the moment arm provides information that can be used to assess the stability of a structure. In the present case, the model was fixed, so the point of load application and overturning moments did not affect the stability. However, for a floating structure, this effect becomes extremely important. It is essential to have these values correctly predicted in any analytical or numerical model of this type of interaction process.

4.3 Comparison to the Molikpaq 1984/85 Data

As part of the entire investigation into this problem, an analysis was made of the loading events on the Gulf Arctic structure "Molikpaq" and, in particular, of the vertical and horizontal load distribution on it during loading events. For the year 1984/85, the results of the rubble-building events are in the public domain (Neth, 1989). In this year, Neth identified three rubble-building events. The details of the events are too voluminous to present here. A qualitative comparison of the ice loading events in the full-scale situation were in very good agreement with the test results reported here. Several of the failure modes observed in the field situation were observed in the model tests including bending failures, ice ride up, ice crushing and large-scale bending due to ice accumulation in the sail of the rubble ice.

Although there are some uncertainties, it is possible to make a quantitative comparison between the pressure data from the Molikpaq and the present test results. From Neth's analysis, the three events had the following characteristics:

EVENT NUMBER	ICE THICKNESS	PEAK PRESSURE	TIME OF EVENT
	(m)	(MPa)	
33R	0.7	1.2, 0.9	Feb 15/16
44R	0.6	0.5	April 10
45R	0.6	0.8	April 11

The above values represent the peak value of the ice pressure on one of the long faces of the structure. For these three events, the ice thickness was 0.6 - 0.7 m. The first event took place in mid-winter when the ice was cold and strong; the latter two events took place in spring when the ice was warmer and weaker. To compare this to the present tests, it is necessary to make a few statements about the type of comparison that can be made. In the present test program, there was no intention to try to scale identically the results presented by Neth on the Molikpaq. The present tests were concerned with a two-dimensional situation. For this, the individual sensing panels are quite long relative to the thickness of the ice, giving a high aspect ratio. For the field condition, the panels are small relative to the width and height of the structure, and they are comparable in size to the thickness of the ice. More importantly, they only cover approximately one-tenth of the face of the structure. Thus, in the model test, the full global load was measured, whereas in the full-scale situation, the load was measured over a small part of the structure, and the load was extrapolated to represent the load on the full face of the structure.

To compare to the first Molikpaq event, which had a strong ice sheet, five tests have similar conditions (TN_006, TN_012, TN_016, TN_018). For the loading events in April, the ice would be relatively weak. Three of the tests from the present series can be used in this comparison (TN_020, TN_021, TN_022).

To scale these results, it is necessary to choose a scale factor. A simple approach would be to choose a scale factor based on the thickness of the ice. Thus, the scale factor (λ) would be

$$\lambda = h_i(\text{full scale}) \,/\, h_i(\text{model scale}). \tag{8}$$

For example, for test TN_018, the model ice had a thickness of 3 cm. Since the full-scale ice thickness was 0.7 m (70 cm), this would give a scale factor of (70 cm/ 3 cm) = 23.3. Scaling of the model ice strength by this factor would give a full-scale flexural strength of (61 * 23.3) = 1.4 MPa and a full-scale compressive strength of 3.0 MPa. These strength values are representative of a strong sheet of ice, so the strength comparison is reasonable. For this test in the ice tank, the peak load on the whole structure was 1.1 kN. From this value, the peak global pressure can be determined from

$$P = F_{N\_tot} \,/\, (\, w * h_i) \tag{9}$$

where F_{N_tot} is the peak force on the structure, w is the width of the structure (= 0.95 m) and h_i is the thickness of the ice. This is the definition used by Neth in calculating the global pressure on the face of the Molikpaq. For test TN_018, the peak pressure was 38.6 kPa. If this measured pressure is scaled according to the Froude scaling laws, directly with λ, the predicted peak pressures in the full-scale situation would be 0.9 MPa. This is in excellent agreement with the full-scale peak pressures of 0.9 and 1.2 MPa. Similarly, the other six tests can be used to predict the full-scale pressure values:

MODEL TESTS						FULL SCALE			
							PREDICTED		MEASURED
TEST NUMBER	h_i	σ_F	PEAK FORCE	PEAK PRESSURE	SCALE FACTOR	σ_F	PEAK PRESSURE	EVENT #	PEAK PRESSURE
	cm	kPa	kN	kPa		MPa	MPa		MPa
TN_006	3.2	64	1.3	42.8	21.9	1.4	0.94	33R	0.9, 1.2
TN_012	3.2	58	2.1	69.1	21.9	1.3	1.51	33R	0.9, 1.2
TN_016	3.3	64	1.6	51.0	21.2	1.4	1.08	33R	0.9, 1.2
TN_018	3.0	61	1.1	38.6	23.3	1.4	0.90	33R	0.9, 1.2
TN_020	3.6	15	0.83	24.3	16.7	0.25	0.40	44R,45R	0.5, 0.8
TN_021	2.6	24	0.57	23.1	23.1	0.55	0.53	44R,45R	0.5, 0.8
TN_022	3.8	21	1.3	36.0	15.8	0.33	0.57	44R,45R	0.5, 0.8

The comparison between the measured and predicted values in the above table shows quite remarkable agreement. The excellent agreement in the present tests, both in terms of the qualitative description of the rubble-building events and the predicted global pressures on the structure, gives confidence in the measured results.

5.0 SUMMARY

A test program has been carried out to investigate the behaviour of load transmission to a structure through pressured broken ice. This involved a test series in an ice modelling basin. The problem was investigated by simplifying it to a two-dimensional situation. A horizontally segmented model was constructed, and the ice loads on each of the six segments were measured for different loading situations. The parameters that were varied include ice strength, ice thickness, the ice density, the ice structure friction and the angle of inclination of the structure with respect to the ice. The test results are reported in full in this report. Because of the complexity of the situation, the data are presented in various formats to make them more readily useable. The data are meant to serve as a basis for evaluating analytical models that describe the situation of ice-loading through broken, pressured ice. Analysis of these data suggests that pressured ice generates a righting moment to a listing vessel. This is an indication from fixed structure tests and should be verified with floating model tests. A comparison with the available data for the Molikpaq shows excellent agreement.

6.0 ACKNOWLEDGEMENTS

The author thanks Ed Funke for the design concepts and the time and effort spent in overseeing the design of the test apparatus. Ed Arambarri, Janet Williams and Ruth Abraham, three engineering students from Memorial University, were instrumental in helping to design, build and test the structure, and the author thanks them for their efforts in this area. Finally, the author thanks Jeff Farnand for his usual high standard of technical assistance during the course of this test program.

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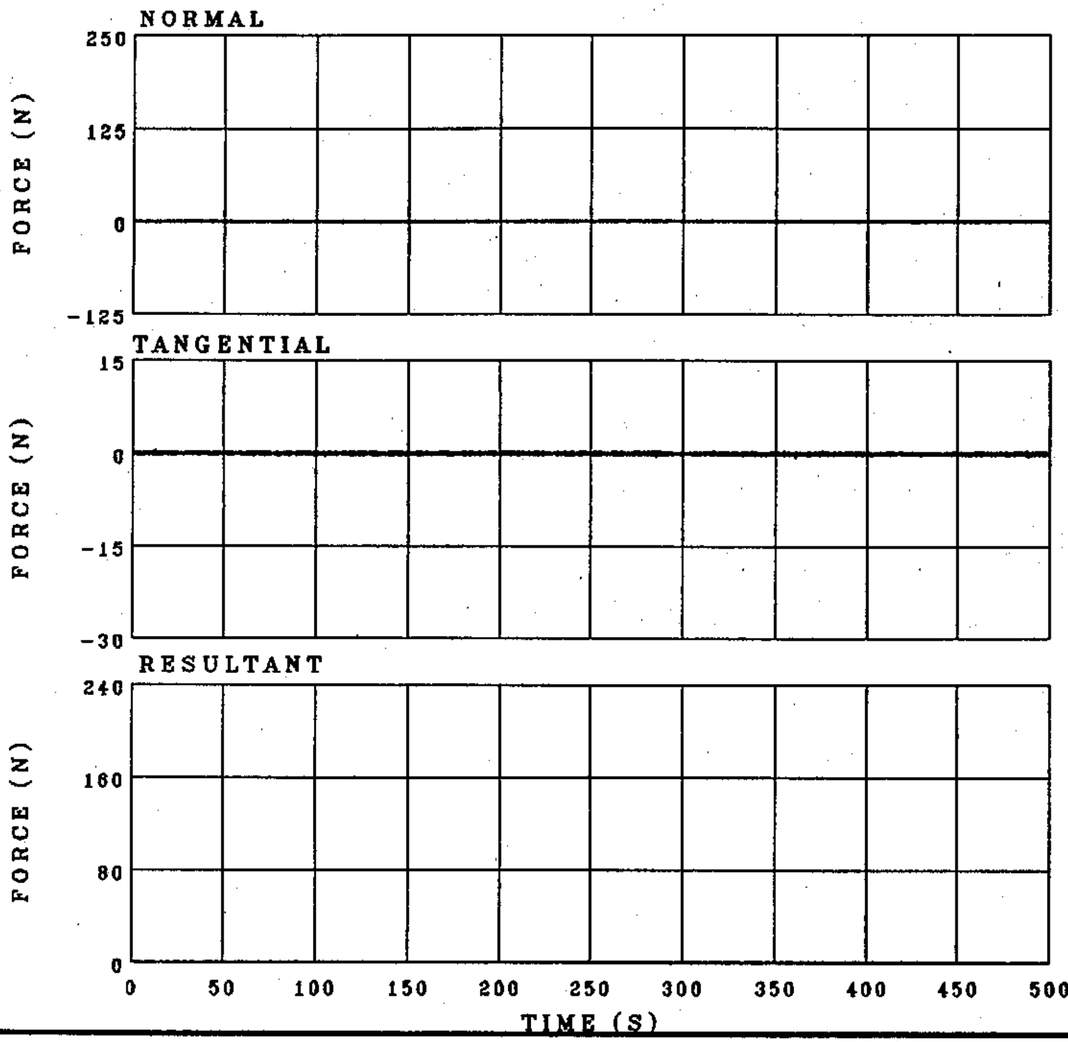
APPENDIX A

Full Time series Test Results

- 22 Tests -



FILE TN←001

PLATE #1

NORMAL

MEAN FORCE = -0.07665 N
MAX FORCE = 0.4526 N
MIN FORCE = -0.8093 N

TANGENTIAL

MEAN FORCE = -0.003988 N
MAX FORCE = 0.3372 N
MIN FORCE = -0.3613 N

RESULTANT

MEAN FORCE = 0.1719 N
MAX FORCE = 0.8233 N
MIN FORCE = 0.08503 N
AVERAGE ANGLE = -18.94 O

TEST CONDITIONS

BOARD ANGLE = -23.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 106.0 kPa
ICE THICKNESS = 3.100 cm
ICE DENSITY = 0.9300 g/cc

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ICE PILEUP STUDY
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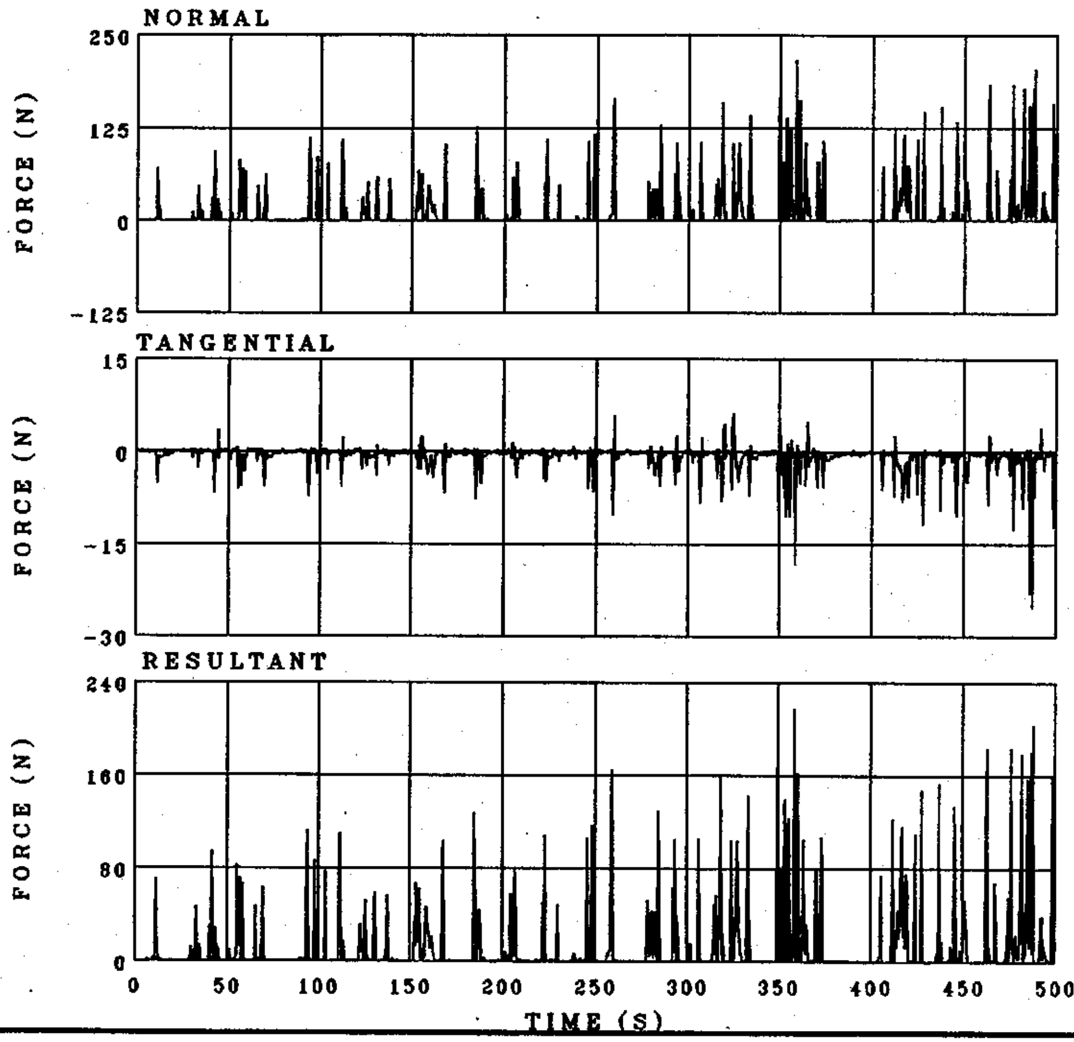

FILE TN←001

PLATE #2

NORMAL

MEAN FORCE = 7.913 N
MAX FORCE = 216.6 N
MIN FORCE = -2.800 N

TANGENTIAL

MEAN FORCE = -0.7563 N
MAX FORCE = 6.266 N
MIN FORCE = -25.37 N

RESULTANT

MEAN FORCE = 8.304 N
MAX FORCE = 217.2 N
MIN FORCE = 0.01716 N
AVERAGE ANGLE = -35.34 O

TEST CONDITIONS

BOARD ANGLE = -23.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 106.0 kPa
ICE THICKNESS = 3.100 cm
ICE DENSITY = 0.9300 g/cc

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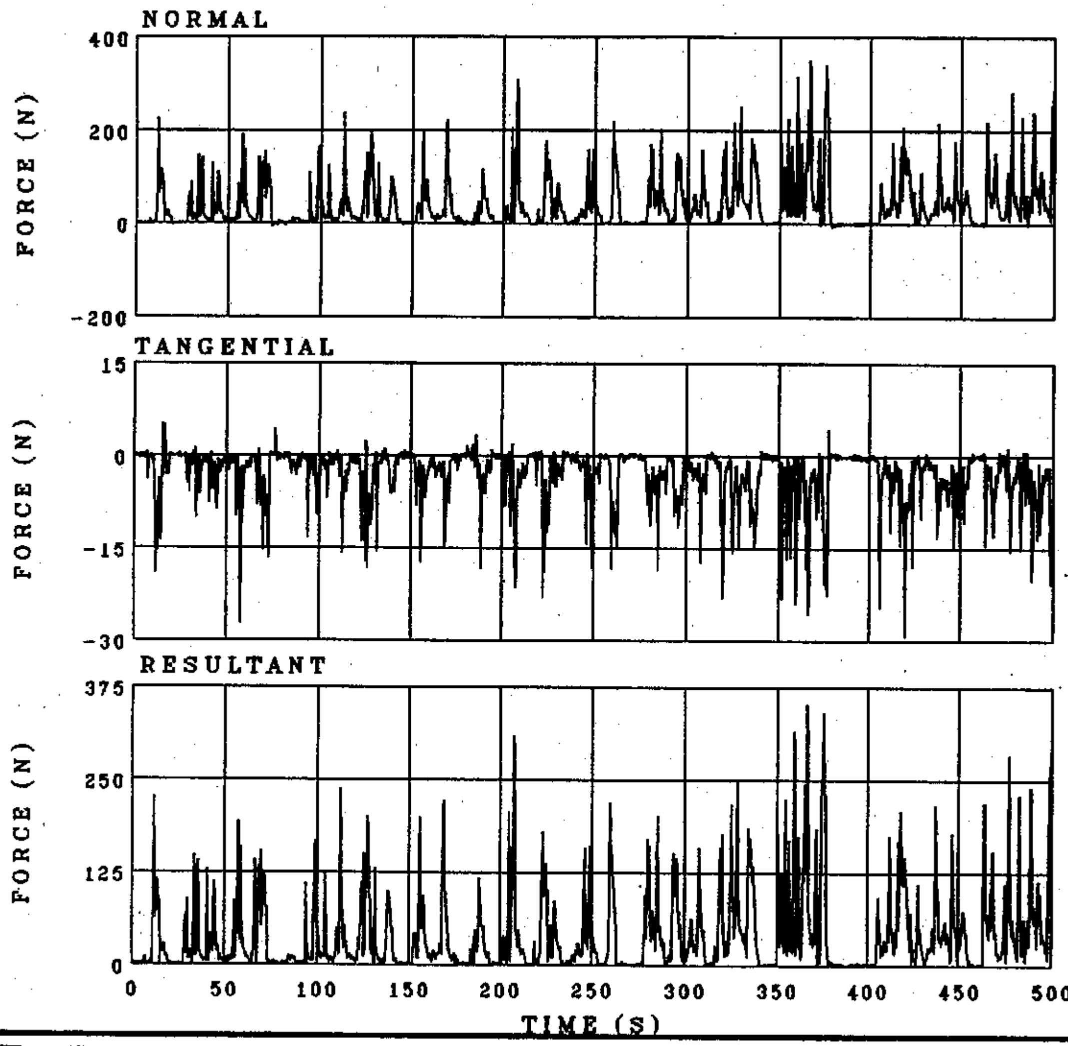

FILE TN←001

PLATE #3

NORMAL

MEAN FORCE = 37.86 N
MAX FORCE = 351.3 N
MIN FORCE = -8.310 N

TANGENTIAL

MEAN FORCE = -2.878 N
MAX FORCE = 5.217 N
MIN FORCE = -29.27 N

RESULTANT

MEAN FORCE = 38.27 N
MAX FORCE = 352.2 N
MIN FORCE = 0.04510 N
AVERAGE ANGLE = 4.820 D

TEST CONDITIONS

BOARD ANGLE = -23.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 106.0 kPa
ICE THICKNESS = 3.100 cm
ICE DENSITY = 0.9300 g/cc

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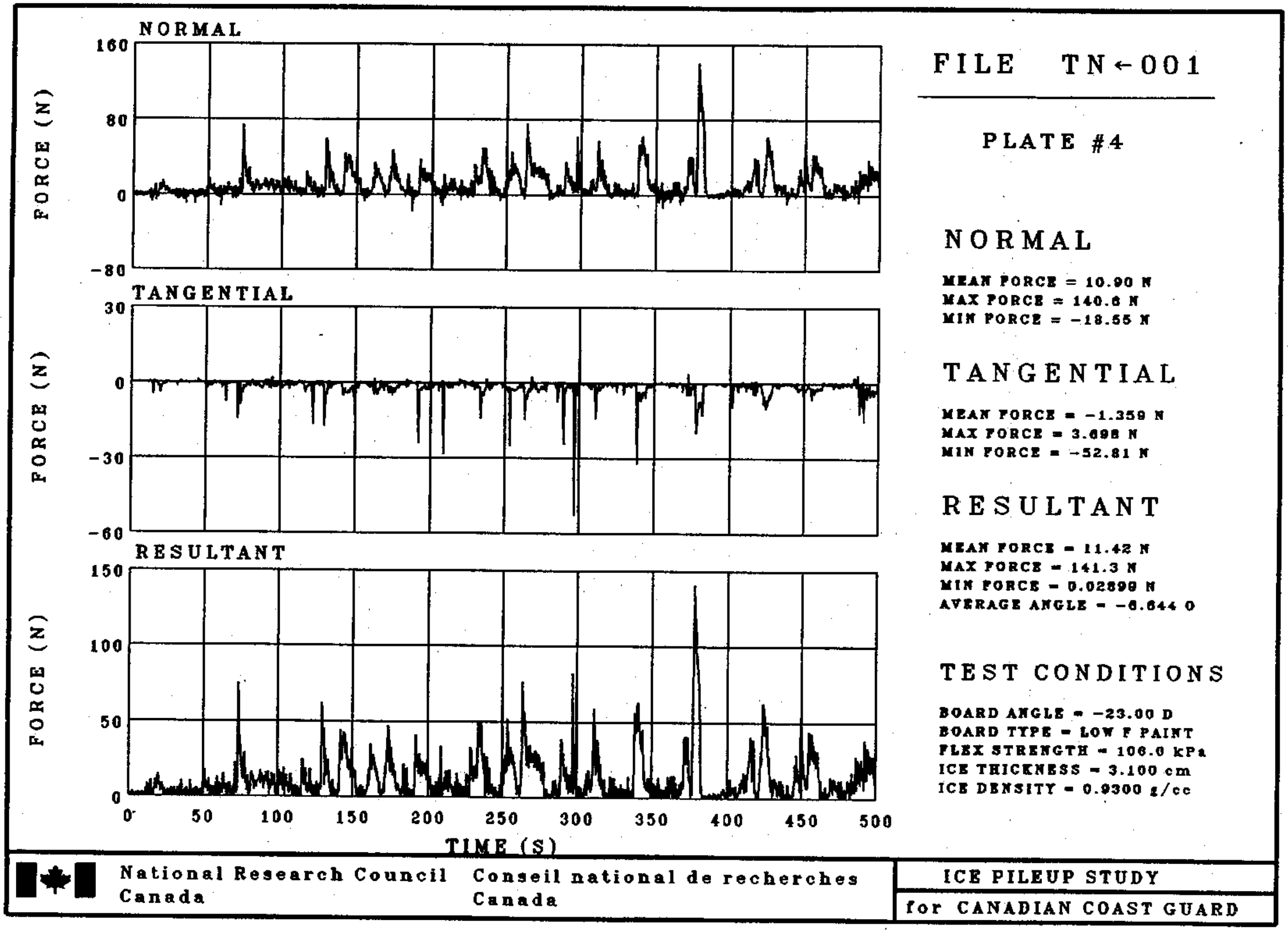
NORMAL
160
80
0
-80
FORCE (N)
TANGENTIAL
30
0
-30
-60
FORCE (N)
RESULTANT
150
100
50
0
FORCE (N)
0 50 100 150 200 250 300 350 400 450 500
TIME (S)
FILE TN←001
PLATE #4
NORMAL
MEAN FORCE = 10.90 N
MAX FORCE = 140.6 N
MIN FORCE = -18.55 N
TANGENTIAL
MEAN FORCE = -1.359 N
MAX FORCE = 3.698 N
MIN FORCE = -52.81 N
RESULTANT
MEAN FORCE = 11.42 N
MAX FORCE = 141.3 N
MIN FORCE = 0.02899 N
AVERAGE ANGLE = -6.644 O
TEST CONDITIONS
BOARD ANGLE = -23.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 106.0 kPa
ICE THICKNESS = 3.100 cm
ICE DENSITY = 0.9300 g/cc
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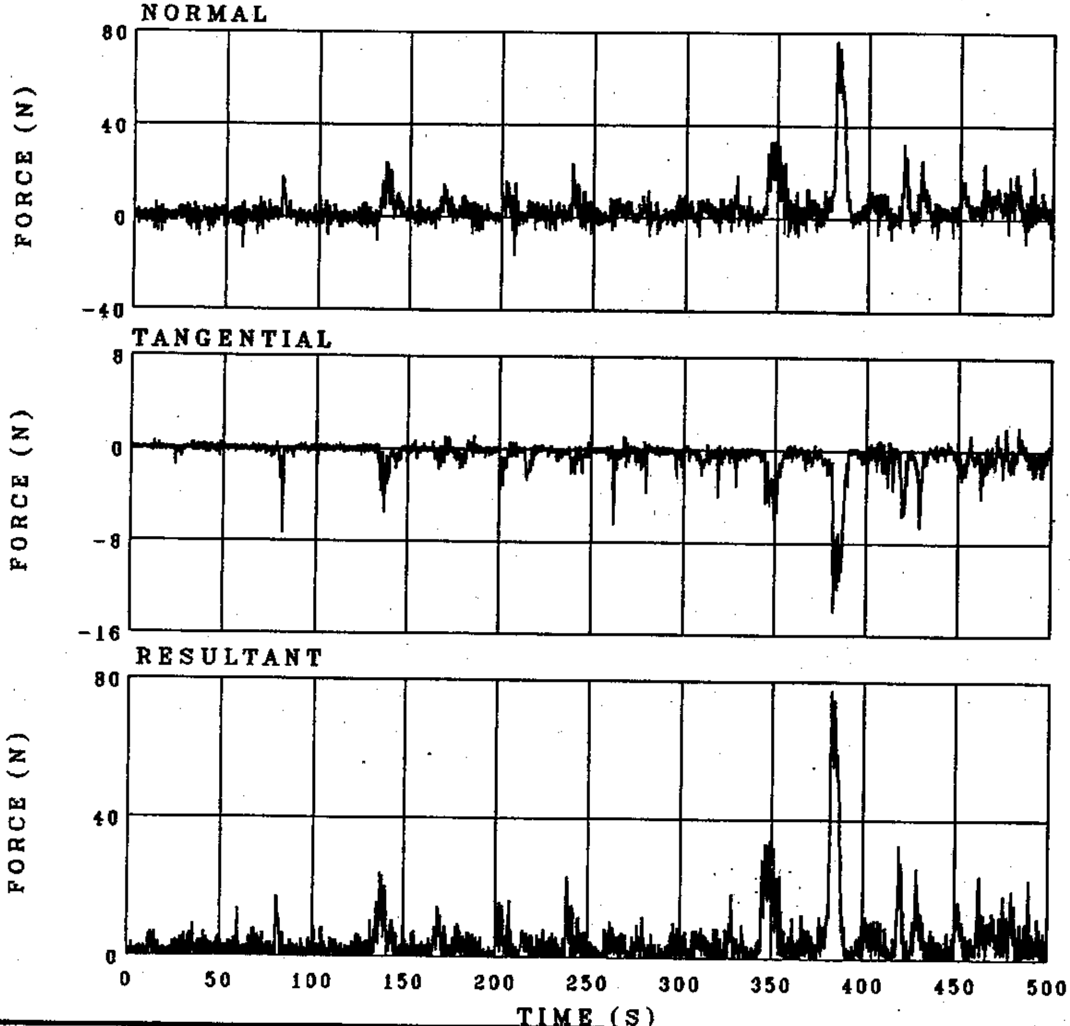

FILE TN←001

PLATE #5

NORMAL

MEAN FORCE = 3.506 N
MAX FORCE = 76.61 N
MIN FORCE = −16.26 N

TANGENTIAL

MEAN FORCE = −0.5364 N
MAX FORCE = 2.126 N
MIN FORCE = −13.96 N

RESULTANT

MEAN FORCE = 4.347 N
MAX FORCE = 77.38 N
MIN FORCE = 0.02803 N
AVERAGE ANGLE = −9.588 O

TEST CONDITIONS

BOARD ANGLE = −23.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 106.0 kPa
ICE THICKNESS = 3.100 cm
ICE DENSITY = 0.9300 g/cc

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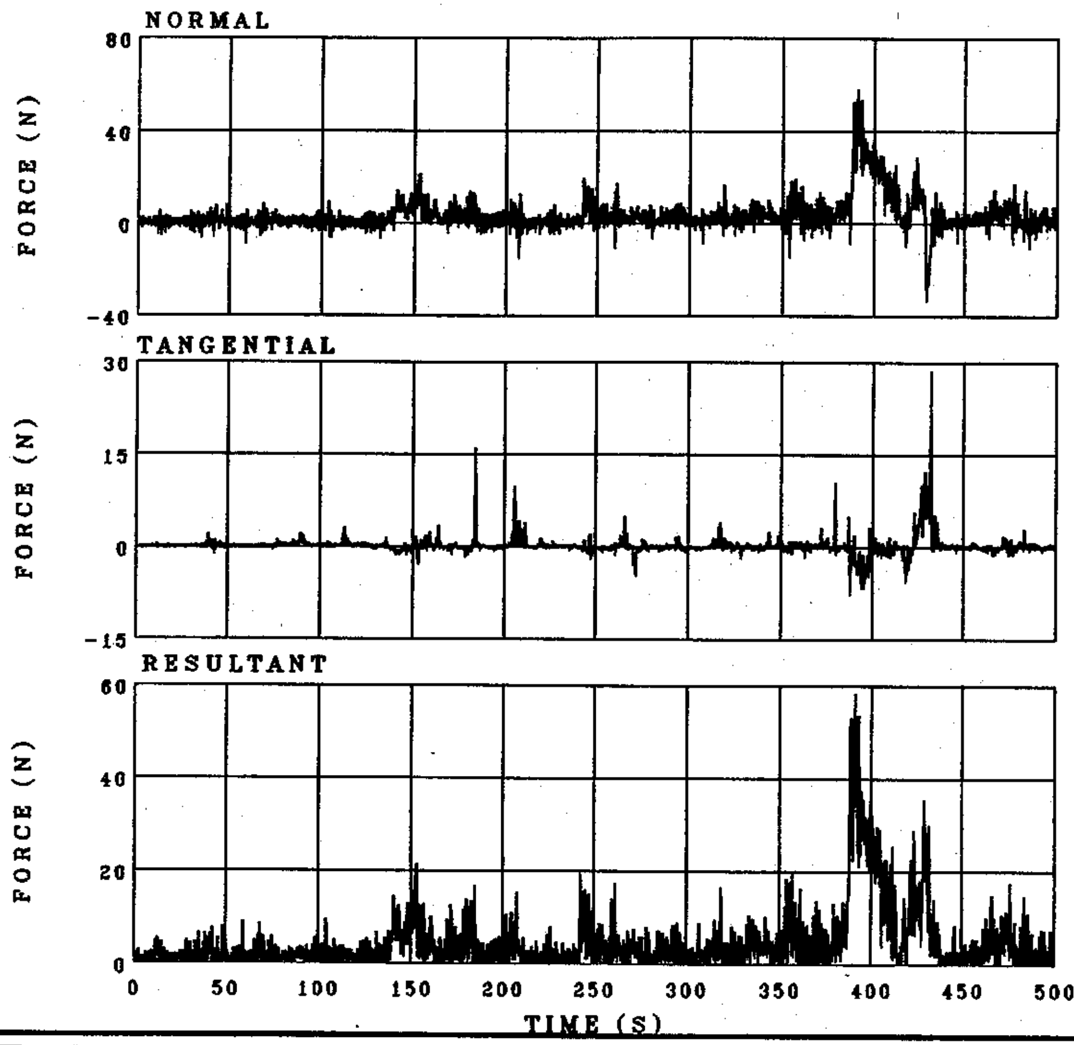

FILE TN←001

PLATE #6

NORMAL

MEAN FORCE = 3.252 N
MAX FORCE = 58.34 N
MIN FORCE = -33.59 N

TANGENTIAL

MEAN FORCE = 0.1375 N
MAX FORCE = 28.66 N
MIN FORCE = -7.773 N

RESULTANT

MEAN FORCE = 4.156 N
MAX FORCE = 58.41 N
MIN FORCE = 0.07007 N
AVERAGE ANGLE = 14.01 O

TEST CONDITIONS

BOARD ANGLE = -23.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 106.0 kPa
ICE THICKNESS = 3.100 cm
ICE DENSITY = 0.9300 g/cc

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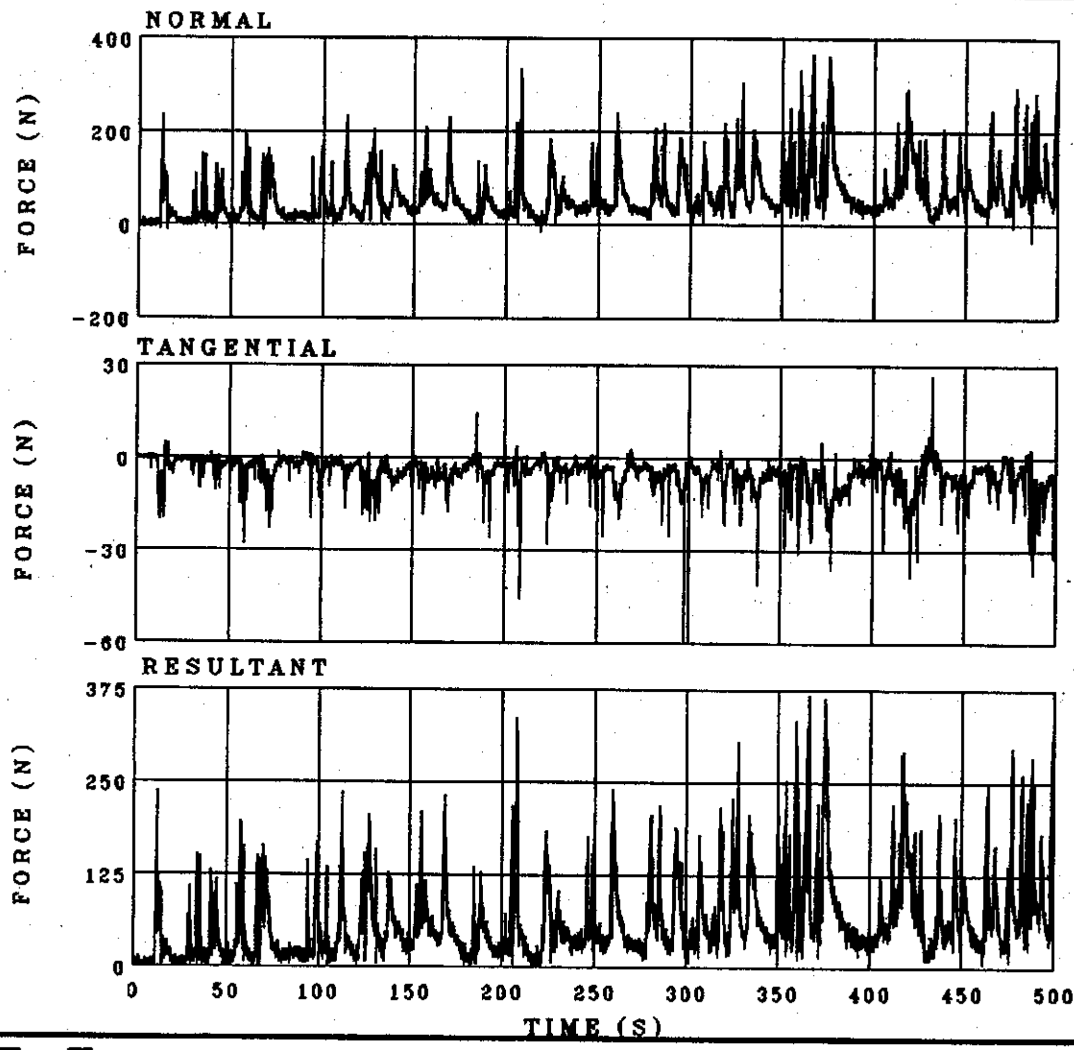

FILE TN←001

TOTAL

NORMAL

MEAN FORCE = 63.35 N
MAX FORCE = 368.5 N
MIN FORCE = -35.37 N

TANGENTIAL

MEAN FORCE = -5.396 N
MAX FORCE = 26.86 N
MIN FORCE = -59.67 N

RESULTANT

MEAN FORCE = 63.80 N
MAX FORCE = 369.5 N
MIN FORCE = 0.08362 N
AVERAGE ANGLE = -5.423 0

TEST CONDITIONS

BOARD ANGLE = -23.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 106.0 kPa
ICE THICKNESS = 3.100 cm
ICE DENSITY = 0.9300 g/cc

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ICE PILEUP STUDY
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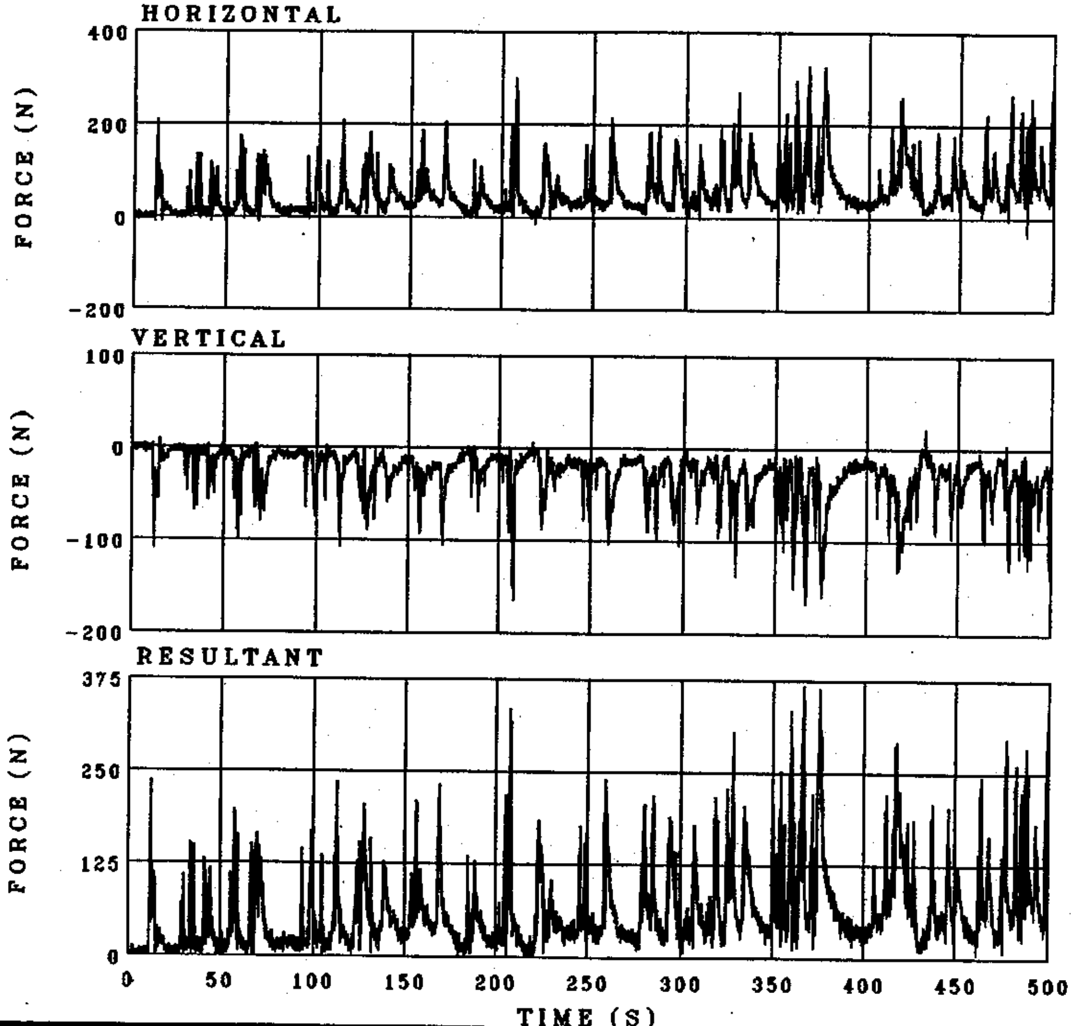

FILE TN←001

TOTAL

HORIZONTAL

MEAN FORCE = -5.396 N
MAX FORCE = 26.86 N
MIN FORCE = -59.67 N

VERTICAL

MEAN FORCE = -5.396 N
MAX FORCE = 26.86 N
MIN FORCE = -59.67 N

RESULTANT

MEAN FORCE = -5.396 N
MAX FORCE = 26.86 N
MIN FORCE = -59.67 N
AVERAGE ANGLE = -5.396 O

TEST CONDITIONS

BOARD ANGLE = -23.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 106.0 kPa
ICE THICKNESS = 3.100 cm
ICE DENSITY = 0.9300 g/cc

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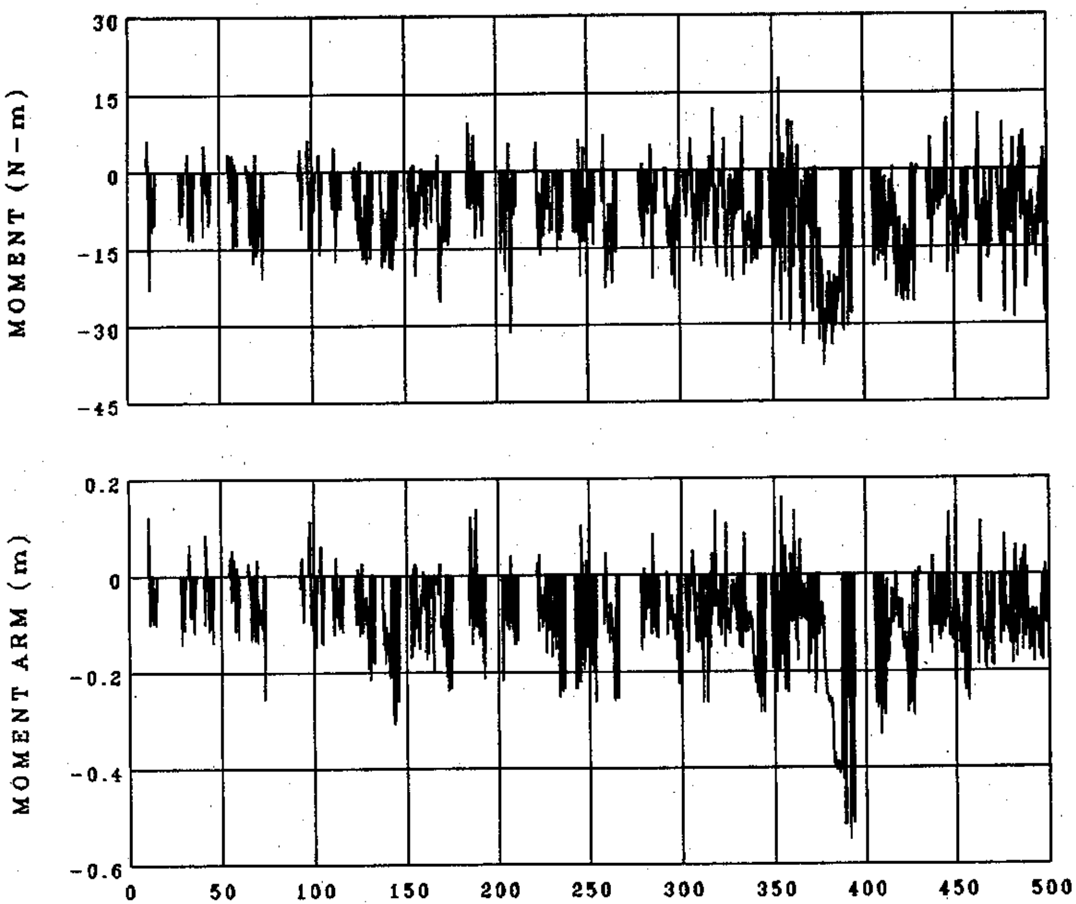
FILE TN←001

MOMENT



MOMENT

MEAN MOMENT = -4.727 N-m
MAX MOMENT = 17.86 N-m
MIN MOMENT = -38.00 N-m

MOMENT ARM

MEAN ARM = -0.04968 m
MAX ARM = 0.1627 m
MIN ARM = -0.5511 m

TEST CONDITIONS

BOARD ANGLE = -23.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 106.0 kPa
ICE THICKNESS = 3.100 cm
ICE DENSITY = 0.9300 g/cc

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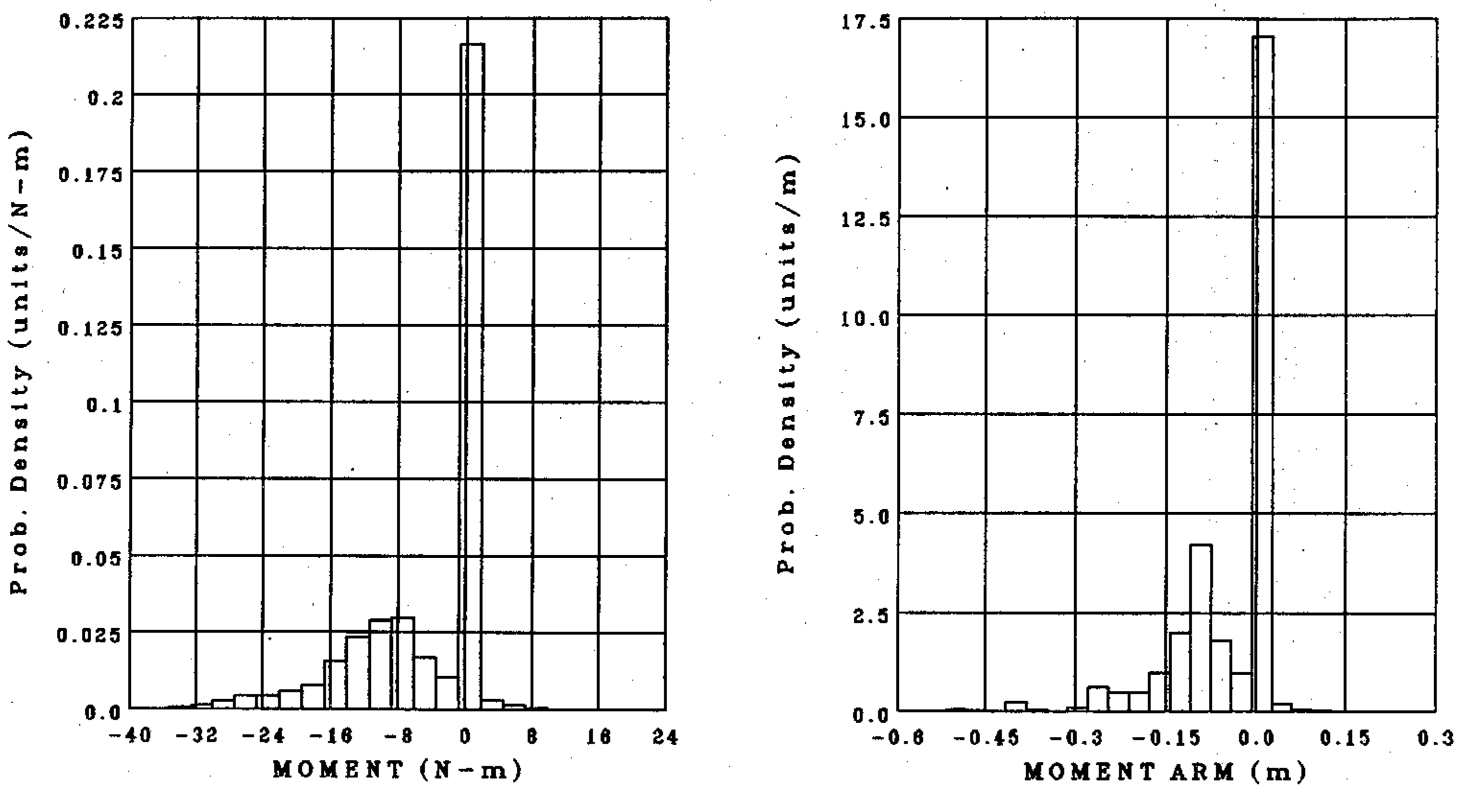
T N ← 0 0 1



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ICE PILEUP STUDY
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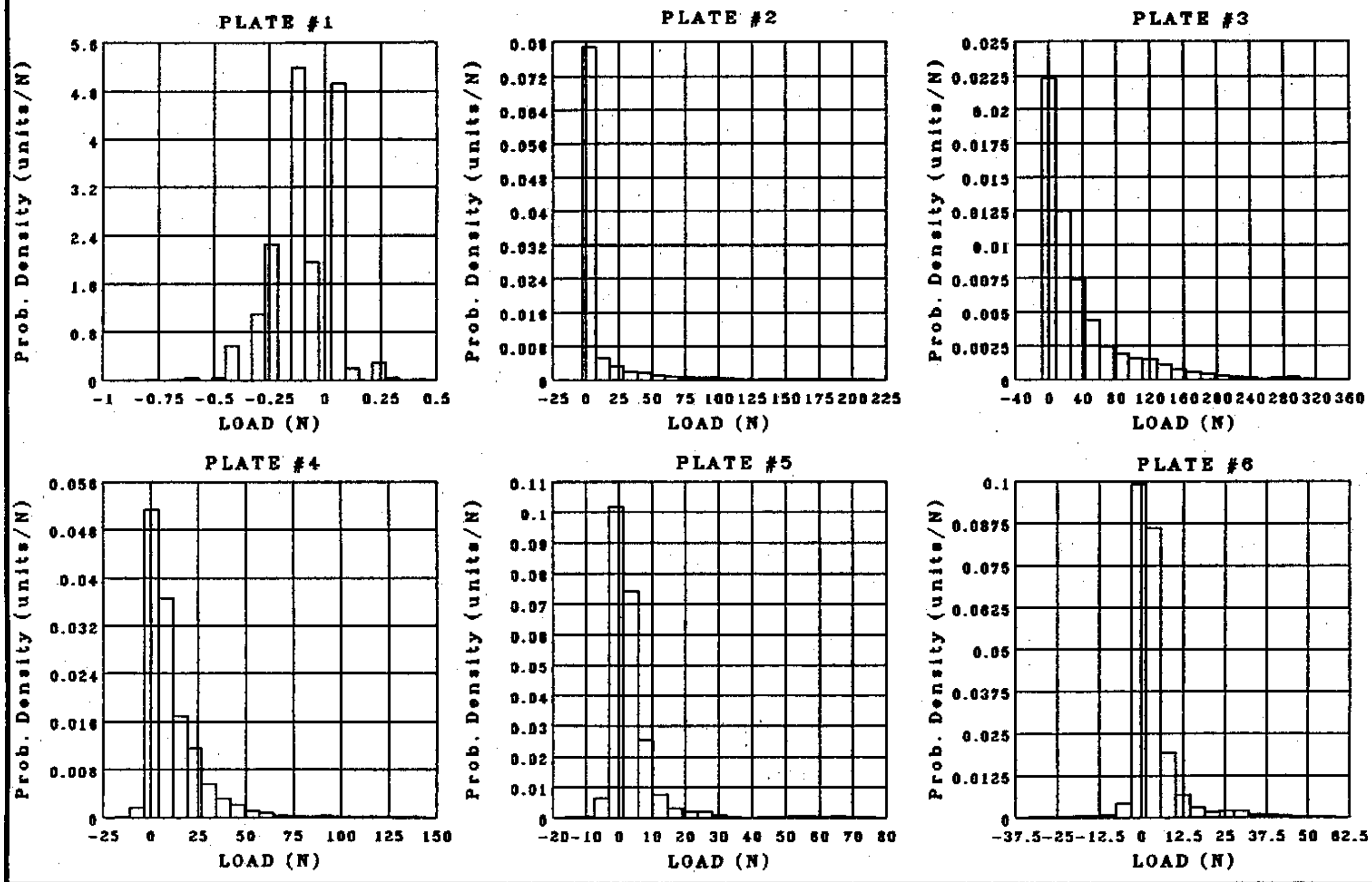
TN←001
NORMAL LOAD



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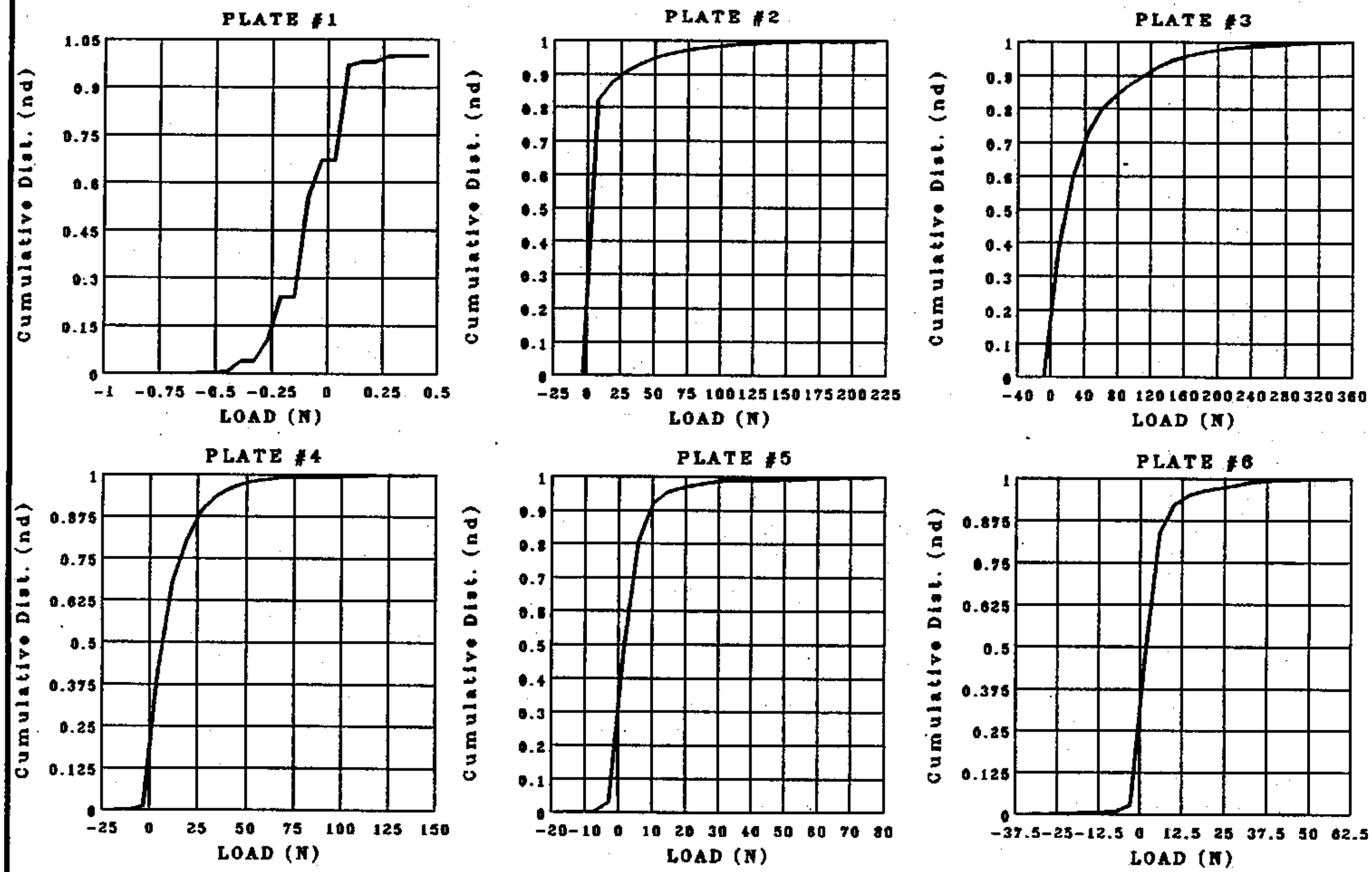
TN←001
NORMAL LOAD



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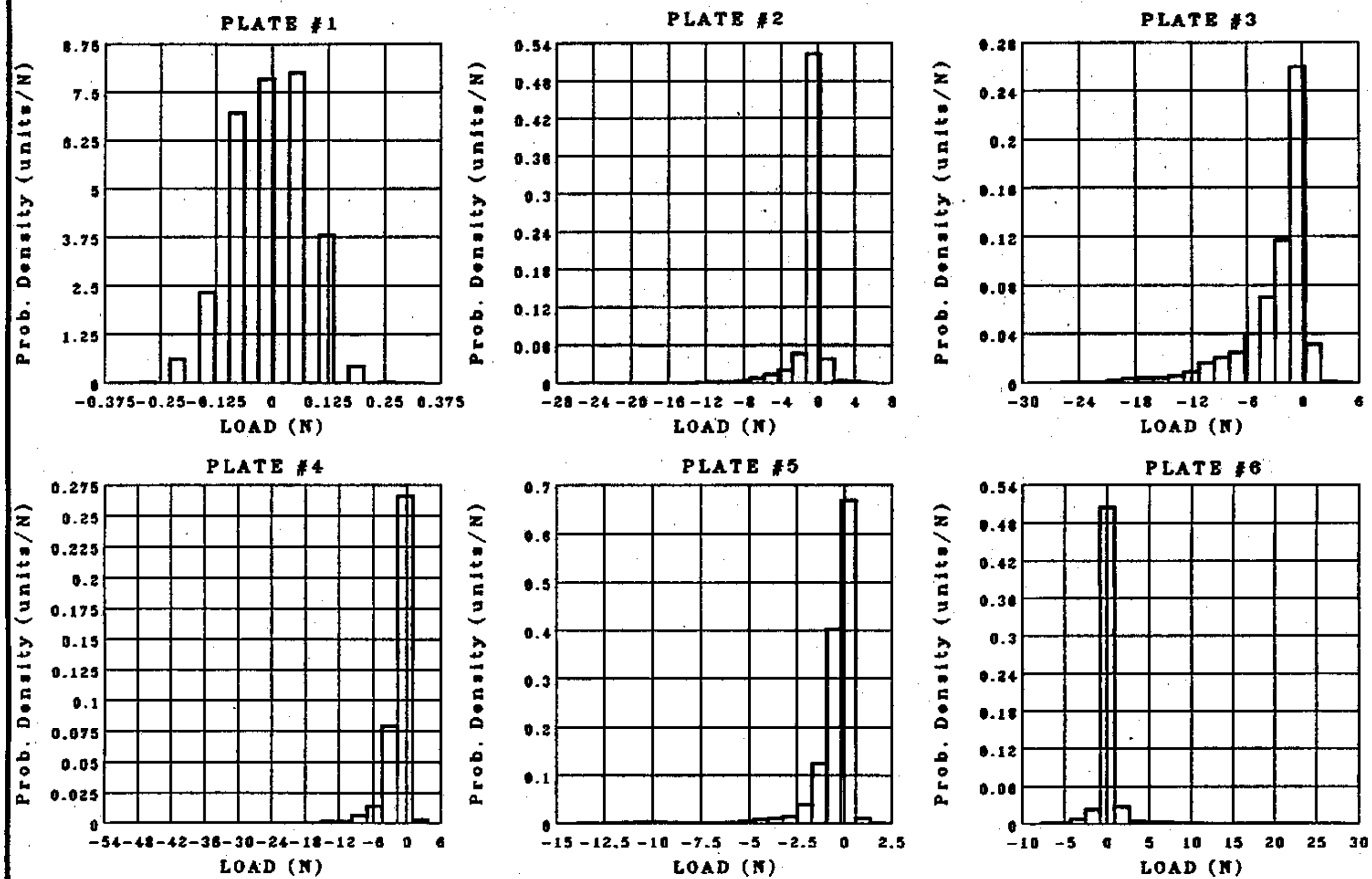
TN←001

TANGENTIAL LOAD



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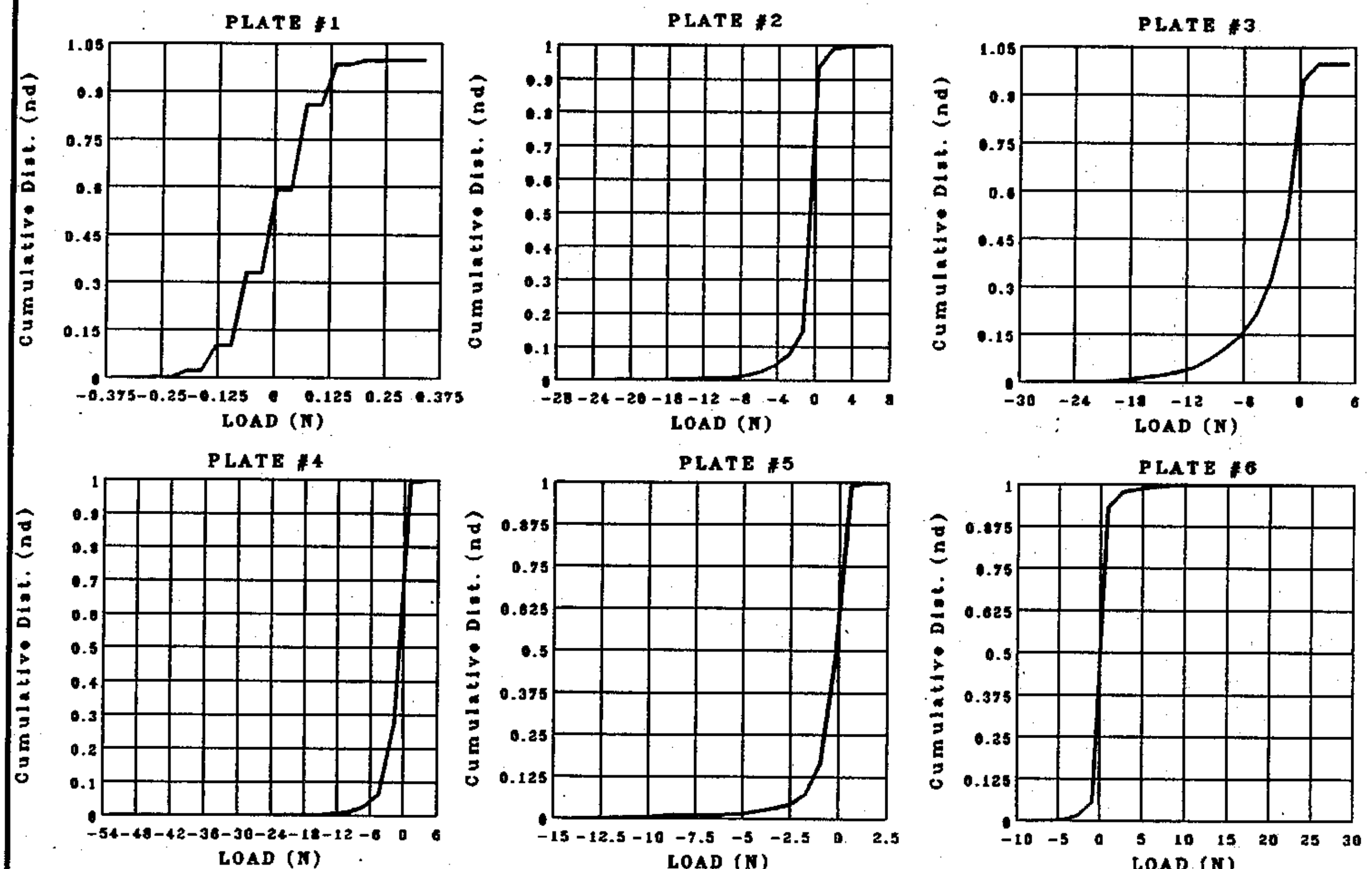
ICE PILEUP STUDY for CANADIAN COAST GUARD

TN←001
TANGENTIAL LOAD



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ICE PILEUP STUDY
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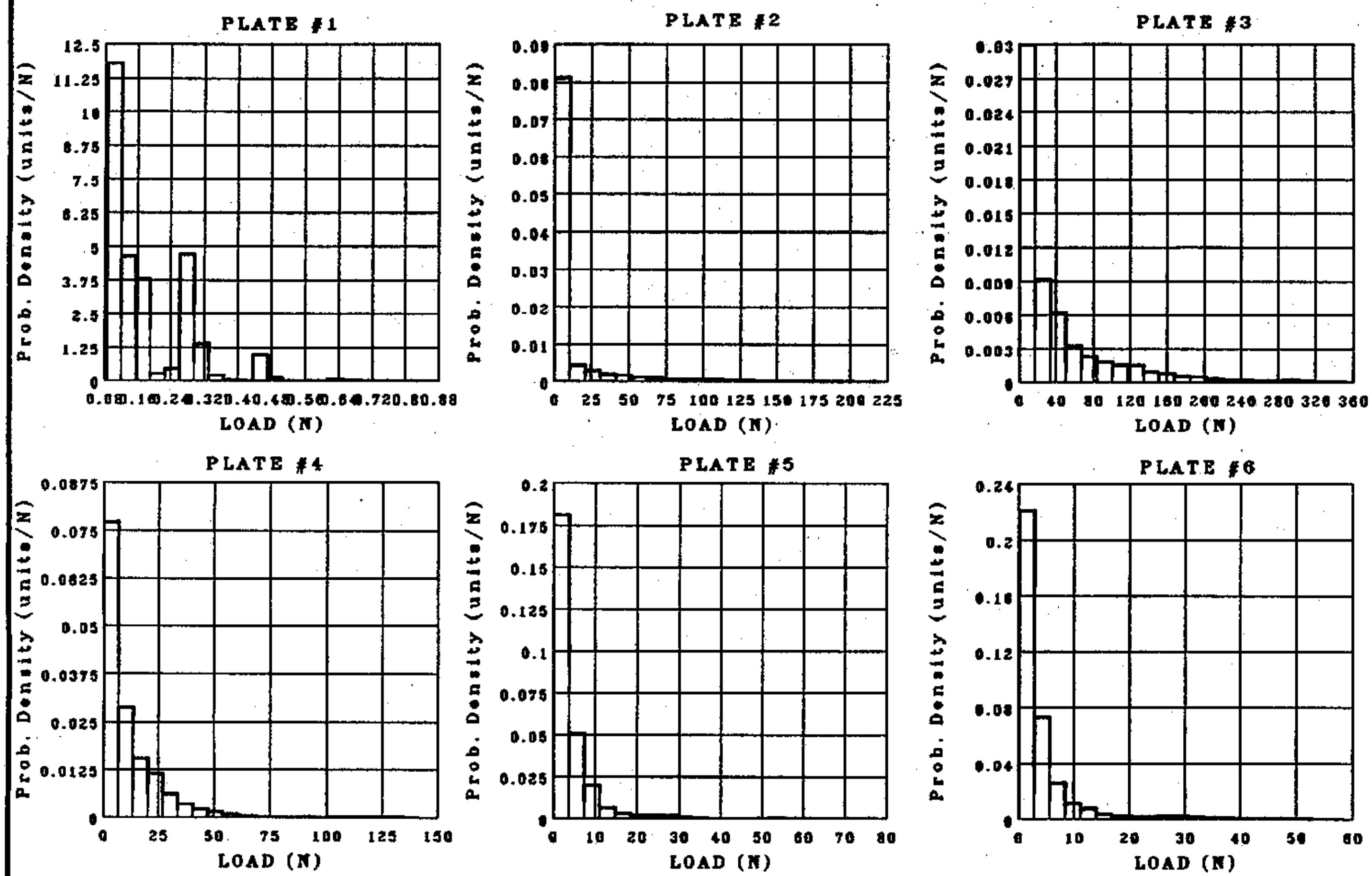
TN←001
RESULTANT



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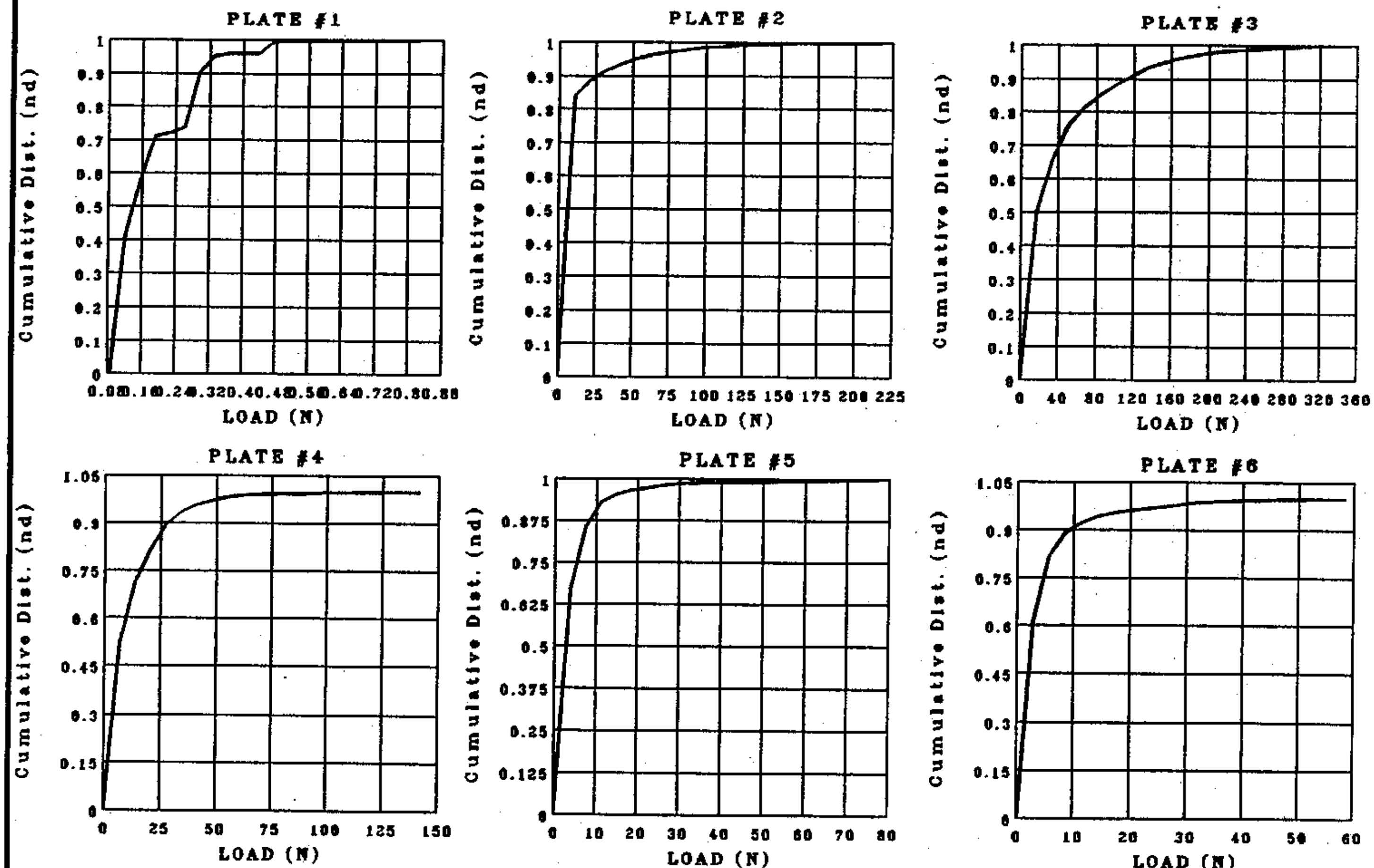
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←001
RESULTANT



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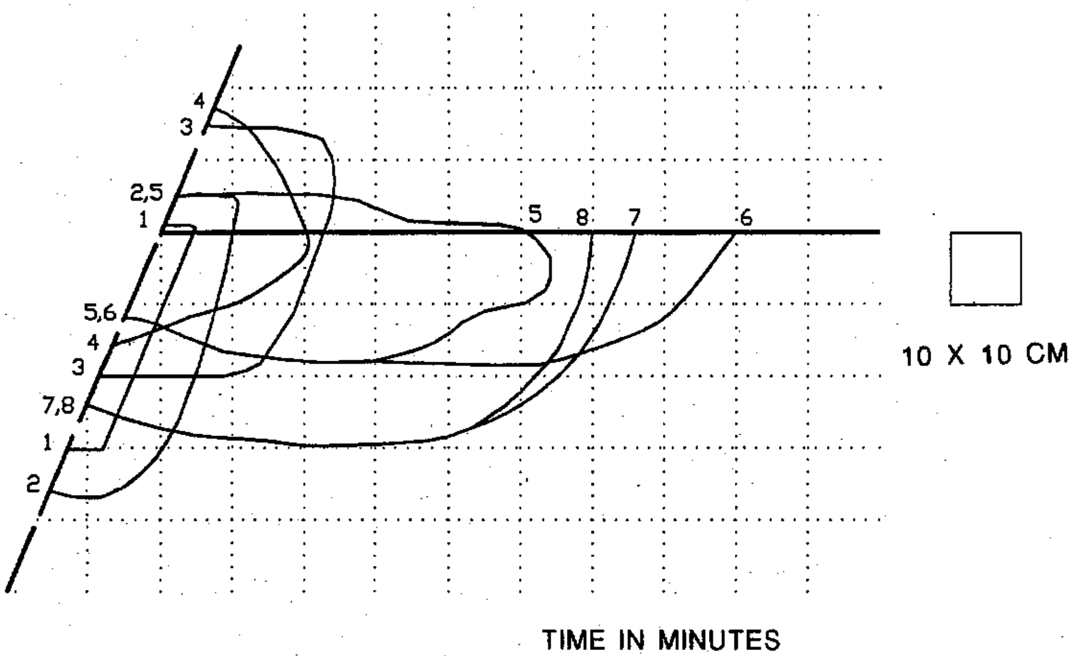
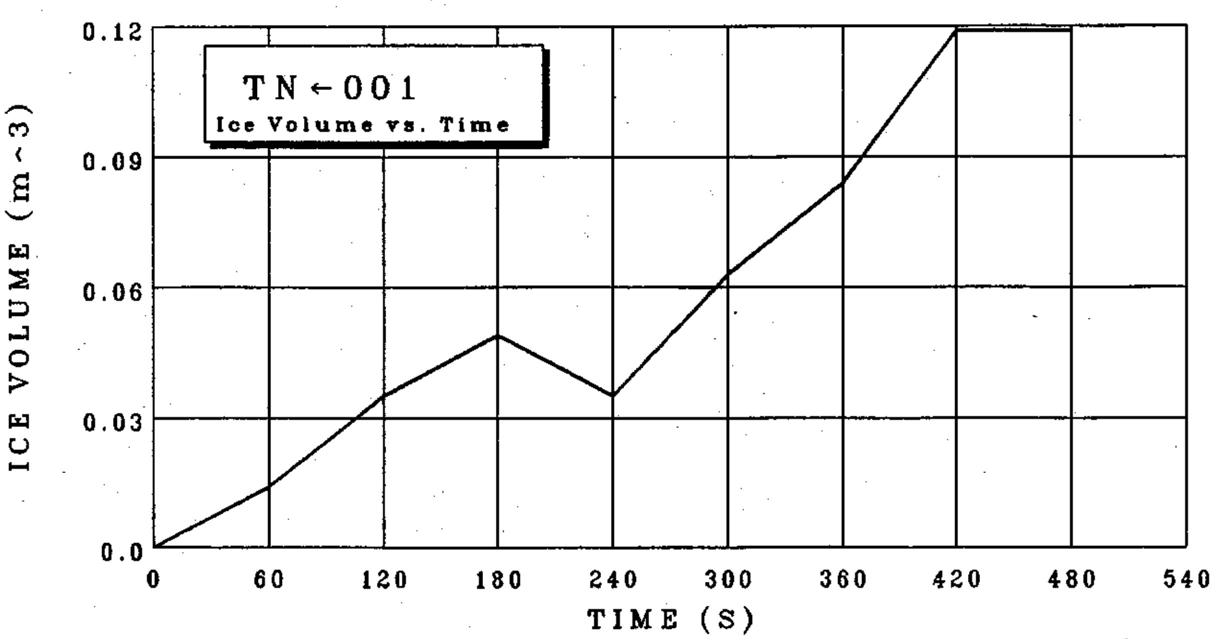
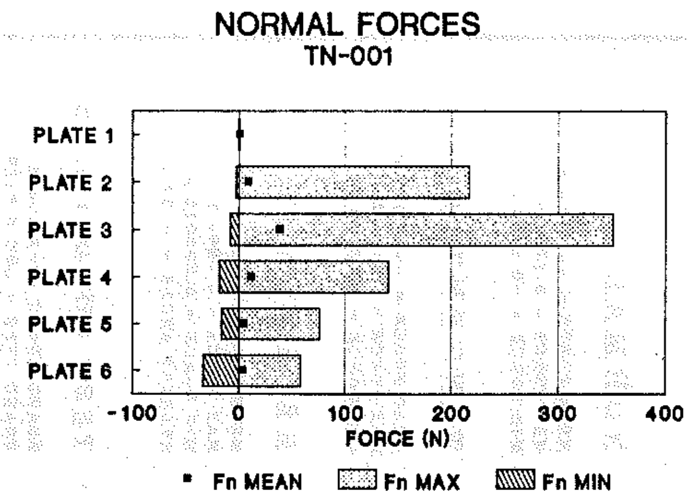
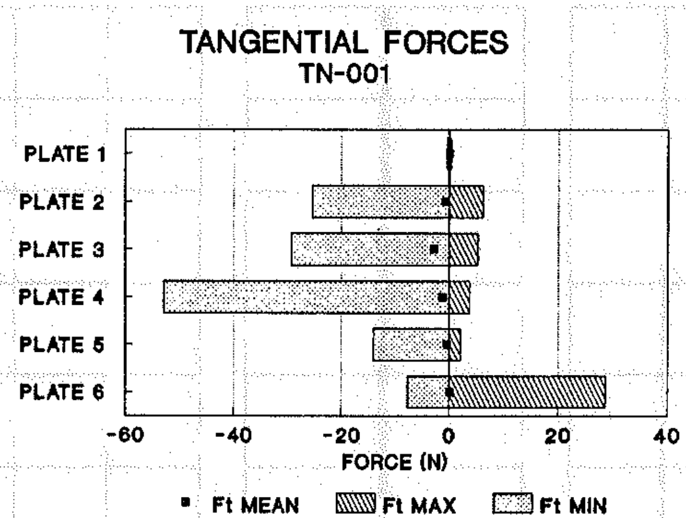
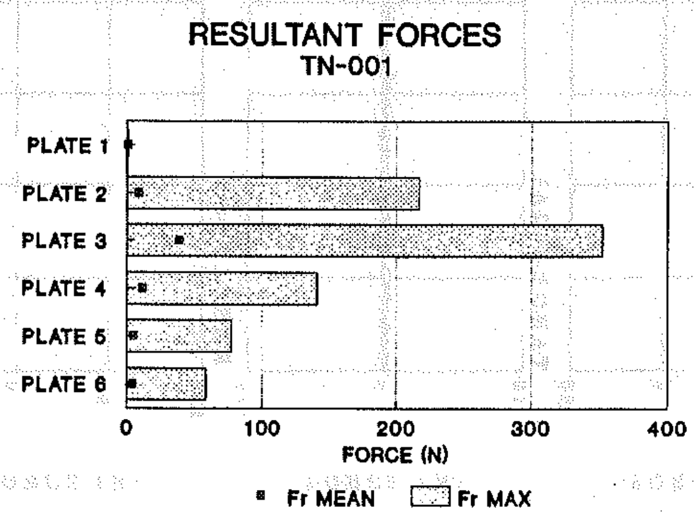
ICE PILEUP STUDY
for CANADIAN COAST GUARD

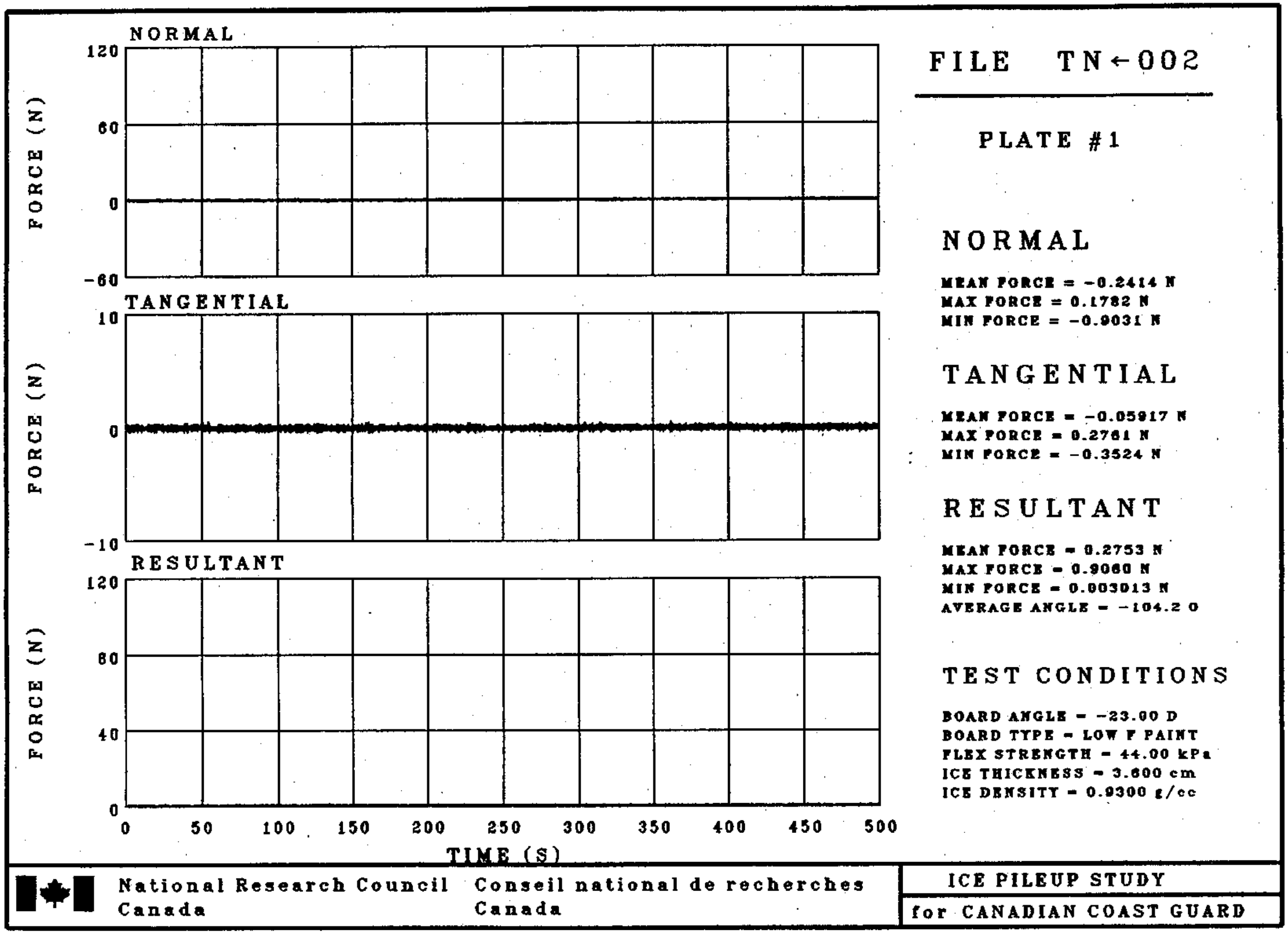

4
3
2,5
1
5
8
7
6
5,6
4
3
7,8
1
2
10 X 10 CM
TIME IN MINUTES


TN ← 001
Ice Volume vs. Time
ICE VOLUME (m ^ 3)
0.12
0.09
0.06
0.03
0.0
0
60
120
180
240
300
360
420
480
540
TIME (S)


NORMAL FORCES
TN-001
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-100
0
100
200
300
400
FORCE (N)
Fn MEAN
Fn MAX
Fn MIN


TANGENTIAL FORCES
TN-001
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-60
-40
-20
0
20
40
FORCE (N)
Ft MEAN
Ft MAX
Ft MIN


RESULTANT FORCES
TN-001
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
0
100
200
300
400
FORCE (N)
Fr MEAN
Fr MAX


NORMAL
TANGENTIAL
RESULTANT
FORCE (N)
TIME (S)
FILE TN←002
PLATE #1
NORMAL
MEAN FORCE = −0.2414 N
MAX FORCE = 0.1782 N
MIN FORCE = −0.9031 N
TANGENTIAL
MEAN FORCE = −0.05917 N
MAX FORCE = 0.2761 N
MIN FORCE = −0.3524 N
RESULTANT
MEAN FORCE = 0.2753 N
MAX FORCE = 0.9060 N
MIN FORCE = 0.003013 N
AVERAGE ANGLE = −104.2 O
TEST CONDITIONS
BOARD ANGLE = −23.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 44.00 kPa
ICE THICKNESS = 3.600 cm
ICE DENSITY = 0.9300 g/cc
National Research Council Canada
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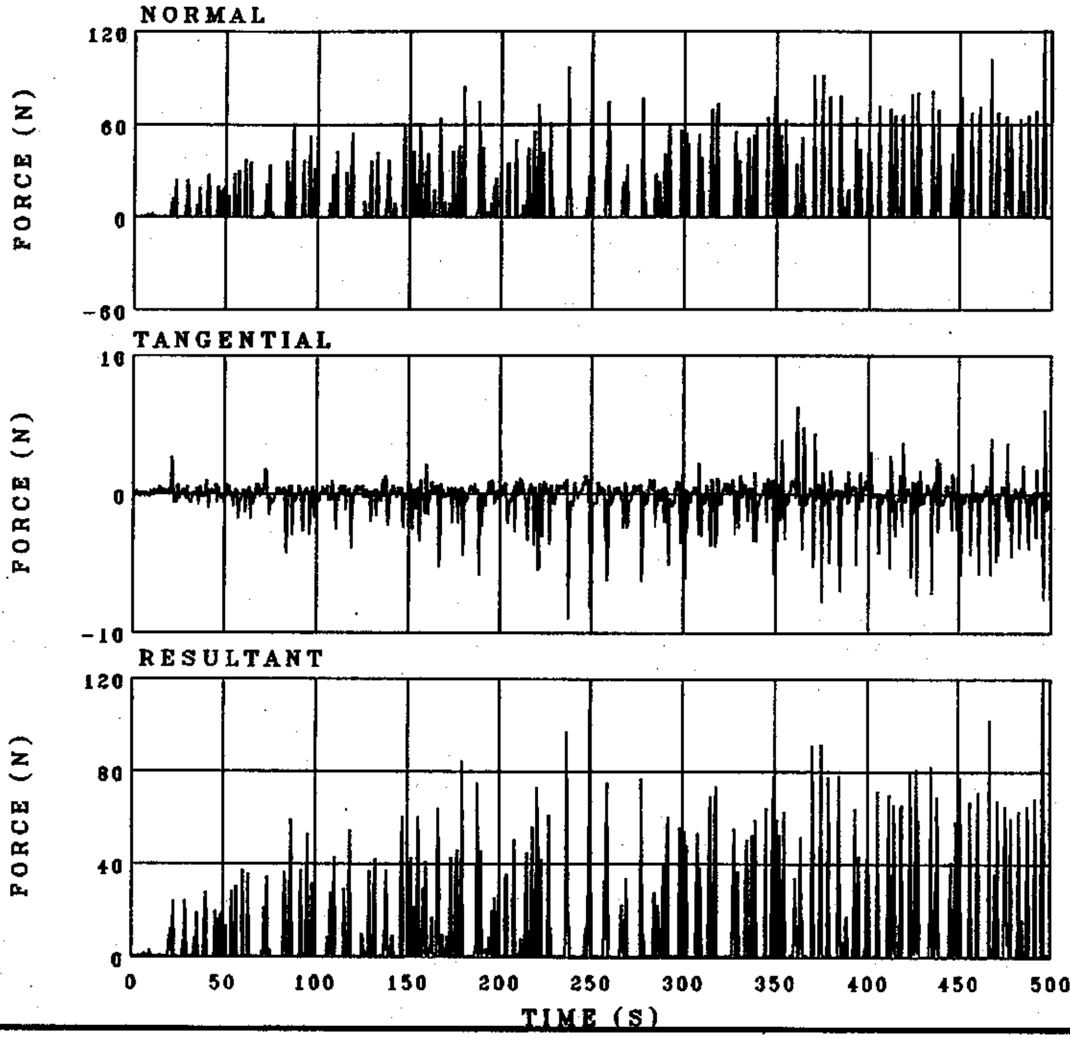
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←002

PLATE #2

NORMAL

MEAN FORCE = 5.205 N
MAX FORCE = 119.1 N
MIN FORCE = -0.8271 N

TANGENTIAL

MEAN FORCE = -0.1975 N
MAX FORCE = 6.334 N
MIN FORCE = -8.966 N

RESULTANT

MEAN FORCE = 5.568 N
MAX FORCE = 119.3 N
MIN FORCE = 0.05925 N
AVERAGE ANGLE = -5.154 O

TEST CONDITIONS

BOARD ANGLE = -23.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 44.00 kPa
ICE THICKNESS = 3.600 cm
ICE DENSITY = 0.9300 g/cc

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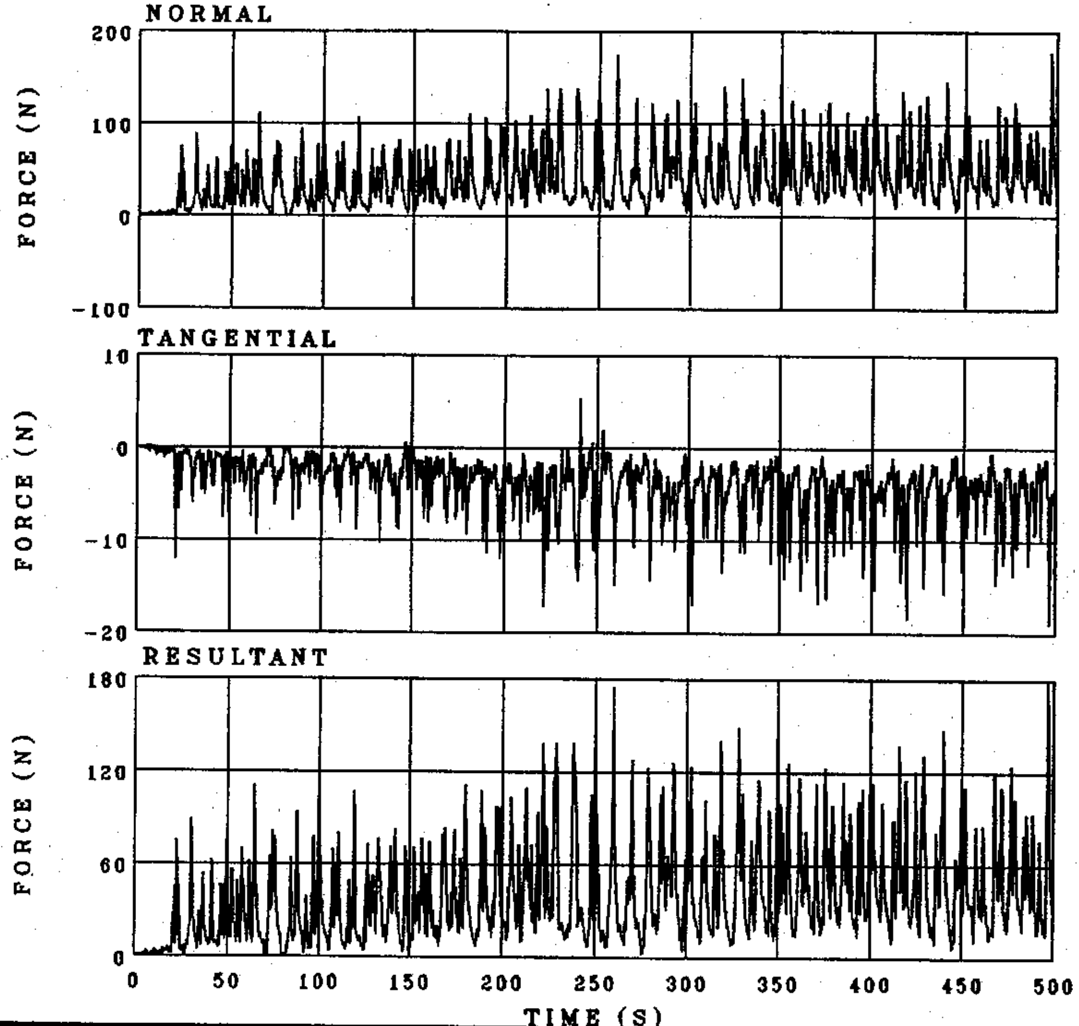
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←002

PLATE #3

NORMAL

MEAN FORCE = 39.57 N
MAX FORCE = 178.4 N
MIN FORCE = -1.798 N

TANGENTIAL

MEAN FORCE = -3.785 N
MAX FORCE = 5.413 N
MIN FORCE = -19.04 N

RESULTANT

MEAN FORCE = 39.79 N
MAX FORCE = 179.3 N
MIN FORCE = 0.04695 N
AVERAGE ANGLE = -6.544 0

TEST CONDITIONS

BOARD ANGLE = -23.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 44.00 kPa
ICE THICKNESS = 3.600 cm
ICE DENSITY = 0.9300 g/cc

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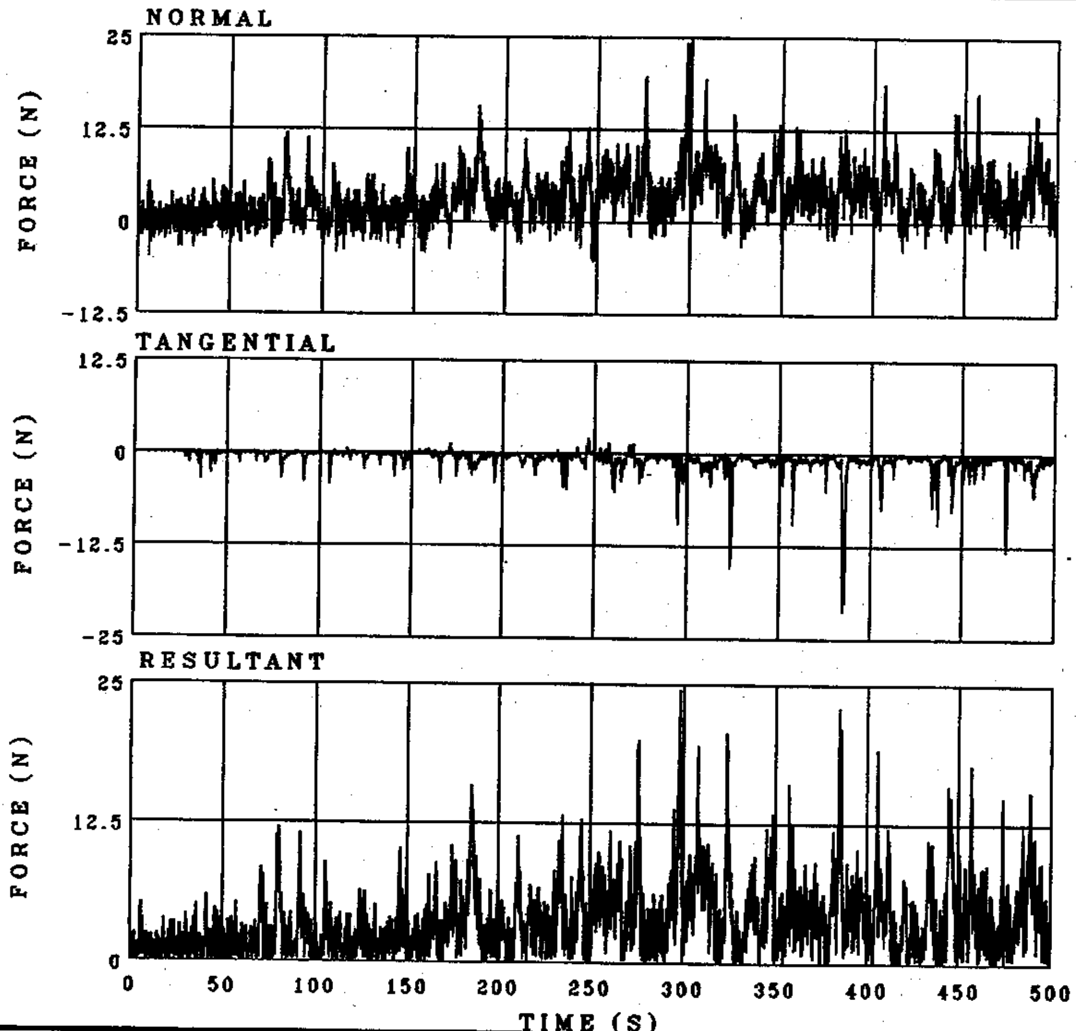

FILE TN←002

PLATE #4

NORMAL

MEAN FORCE = 3.157 N
MAX FORCE = 24.36 N
MIN FORCE = -5.356 N

TANGENTIAL

MEAN FORCE = -0.7186 N
MAX FORCE = 2.087 N
MIN FORCE = -21.33 N

RESULTANT

MEAN FORCE = 3.604 N
MAX FORCE = 24.57 N
MIN FORCE = 0.02128 N
AVERAGE ANGLE = -17.78 O

TEST CONDITIONS

BOARD ANGLE = -23.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 44.00 kPa
ICE THICKNESS = 3.600 cm
ICE DENSITY = 0.9300 g/cc

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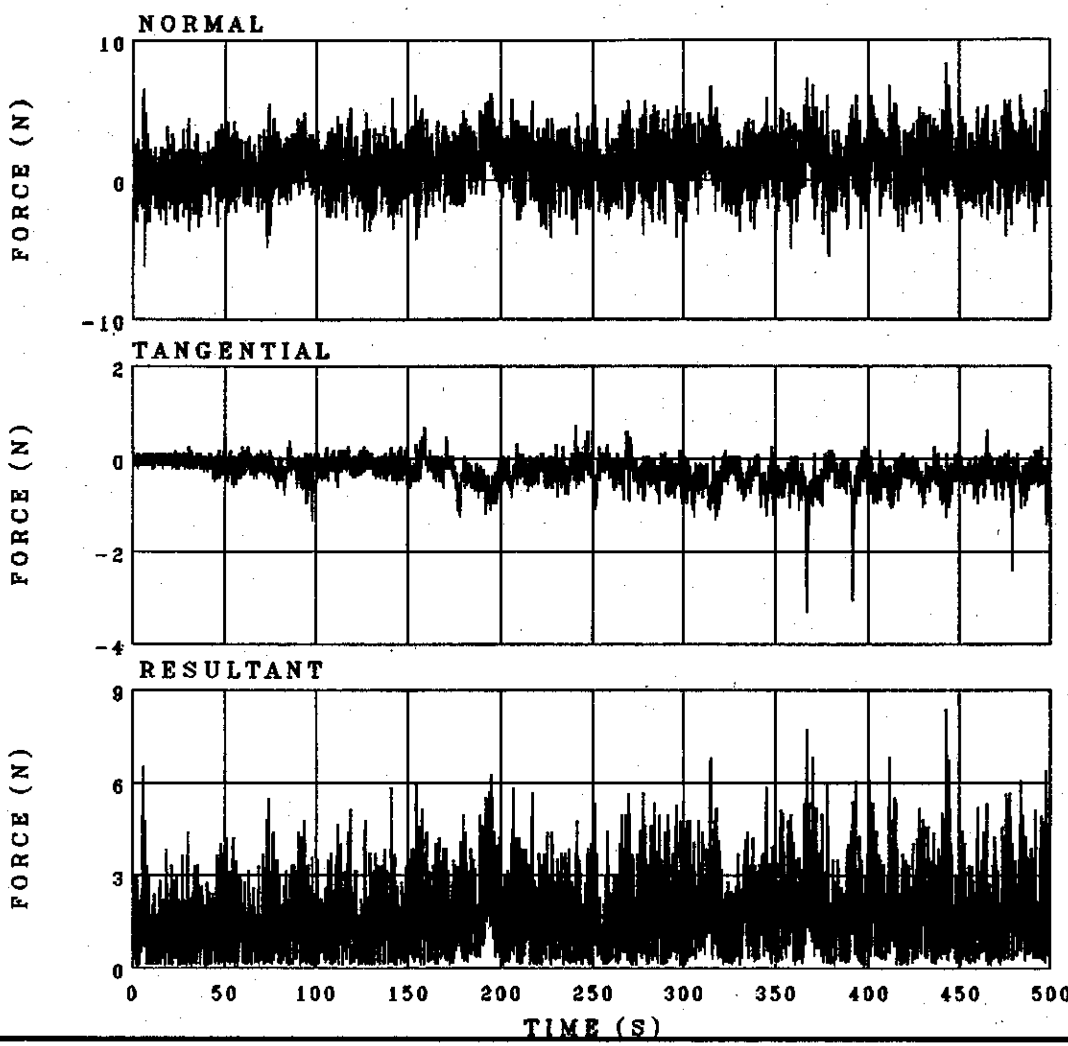
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←002

PLATE #5

NORMAL

MEAN FORCE = 1.042 N
MAX FORCE = 8.341 N
MIN FORCE = -6.233 N

TANGENTIAL

MEAN FORCE = -0.2849 N
MAX FORCE = 0.7313 N
MIN FORCE = -3.311 N

RESULTANT

MEAN FORCE = 1.557 N
MAX FORCE = 8.399 N
MIN FORCE = 0.05859 N
AVERAGE ANGLE = -34.05 O

TEST CONDITIONS

BOARD ANGLE = -23.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 44.00 kPa
ICE THICKNESS = 3.600 cm
ICE DENSITY = 0.9300 g/cc

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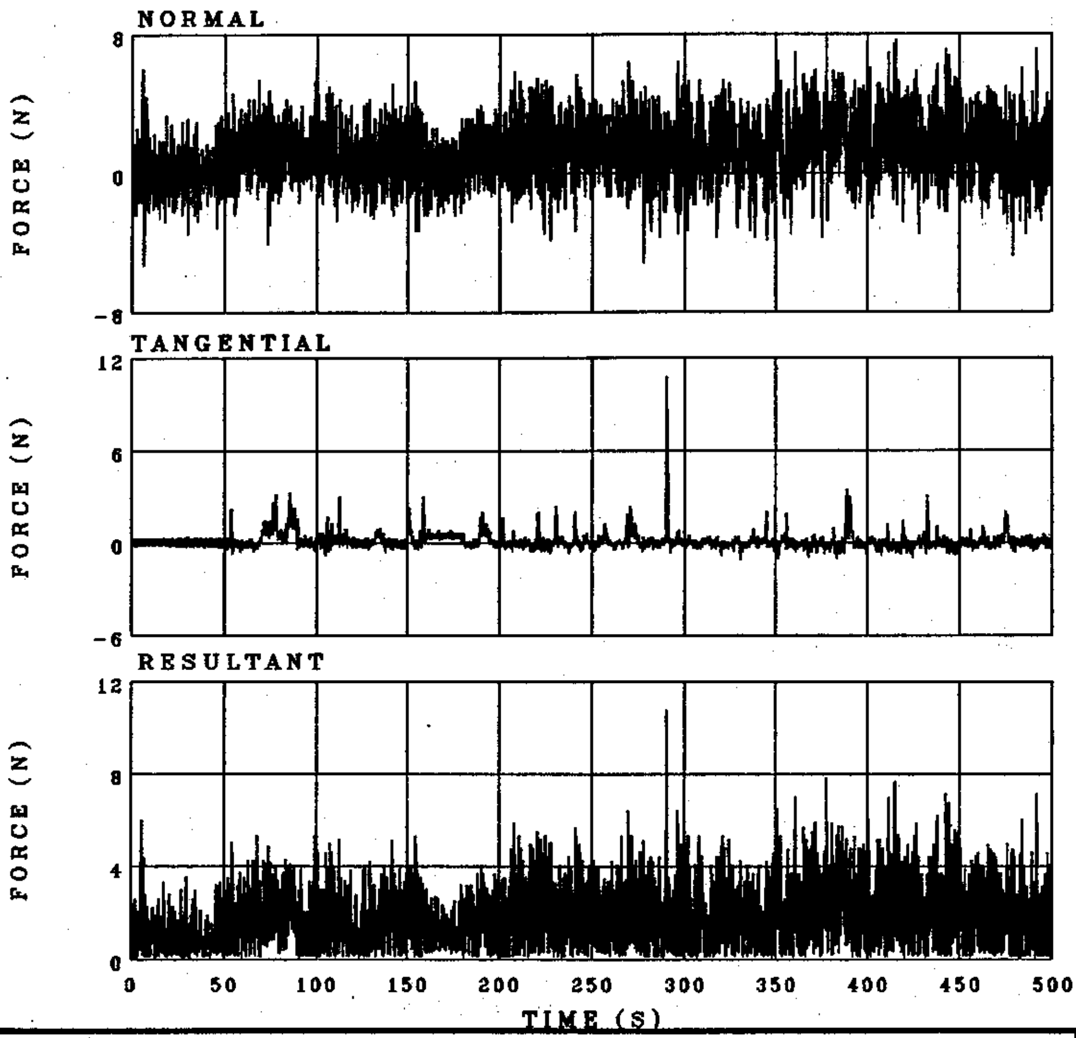
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←002

PLATE #6

NORMAL

MEAN FORCE = 1.199 N
MAX FORCE = 7.883 N
MIN FORCE = −5.337 N

TANGENTIAL

MEAN FORCE = 0.08308 N
MAX FORCE = 10.79 N
MIN FORCE = −1.107 N

RESULTANT

MEAN FORCE = 1.630 N
MAX FORCE = 10.79 N
MIN FORCE = 0.08133 N
AVERAGE ANGLE = 5.420 O

TEST CONDITIONS

BOARD ANGLE = −23.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 44.00 kPa
ICE THICKNESS = 3.600 cm
ICE DENSITY = 0.9300 g/cc

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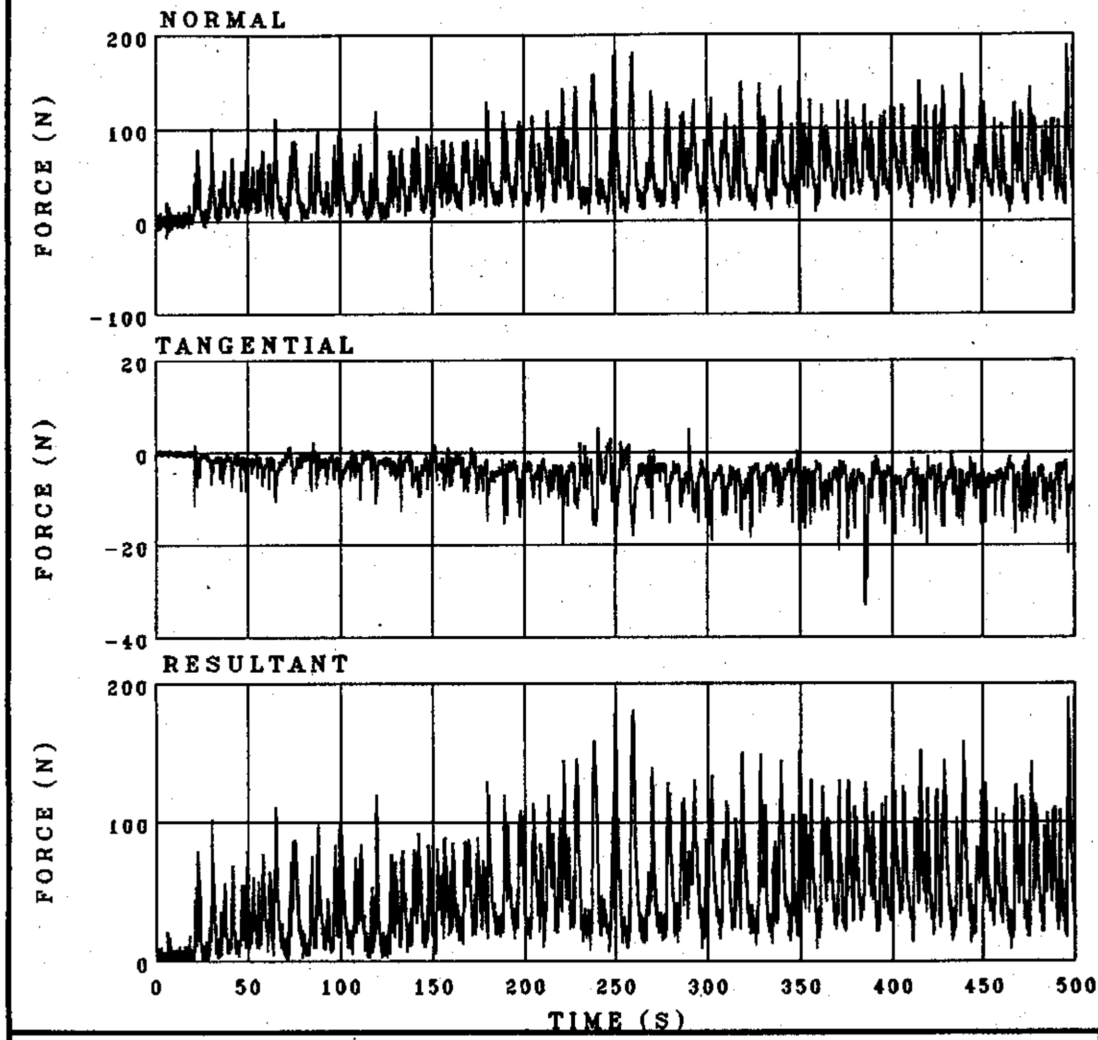
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←002

TOTAL

NORMAL

MEAN FORCE = 49.94 N
MAX FORCE = 186.8 N
MIN FORCE = −16.45 N

TANGENTIAL

MEAN FORCE = −4.962 N
MAX FORCE = 5.378 N
MIN FORCE = −33.17 N

RESULTANT

MEAN FORCE = 50.34 N
MAX FORCE = 189.4 N
MIN FORCE = 0.06580 N
AVERAGE ANGLE = −6.453 O

TEST CONDITIONS

BOARD ANGLE = −23.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 44.00 kPa
ICE THICKNESS = 3.600 cm
ICE DENSITY = 0.9300 g/cc

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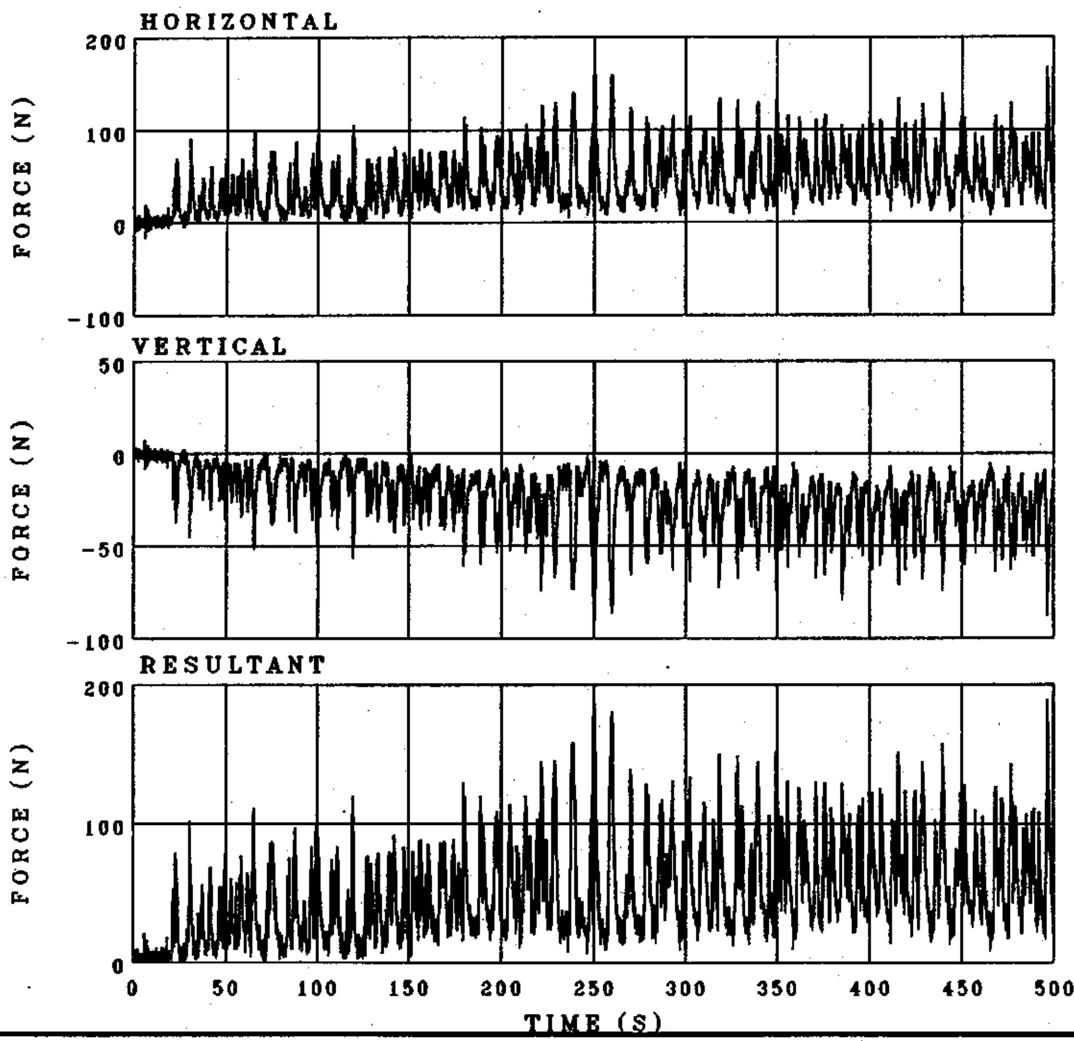
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←002

TOTAL

HORIZONTAL

MEAN FORCE = -4.962 N
MAX FORCE = 5.378 N
MIN FORCE = -33.17 N

VERTICAL

MEAN FORCE = -4.962 N
MAX FORCE = 5.378 N
MIN FORCE = -33.17 N

RESULTANT

MEAN FORCE = -4.962 N
MAX FORCE = 5.378 N
MIN FORCE = -33.17 N
AVERAGE ANGLE = -4.962 O

TEST CONDITIONS

BOARD ANGLE = -23.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 44.00 kPa
ICE THICKNESS = 3.600 cm
ICE DENSITY = 0.9300 g/cc

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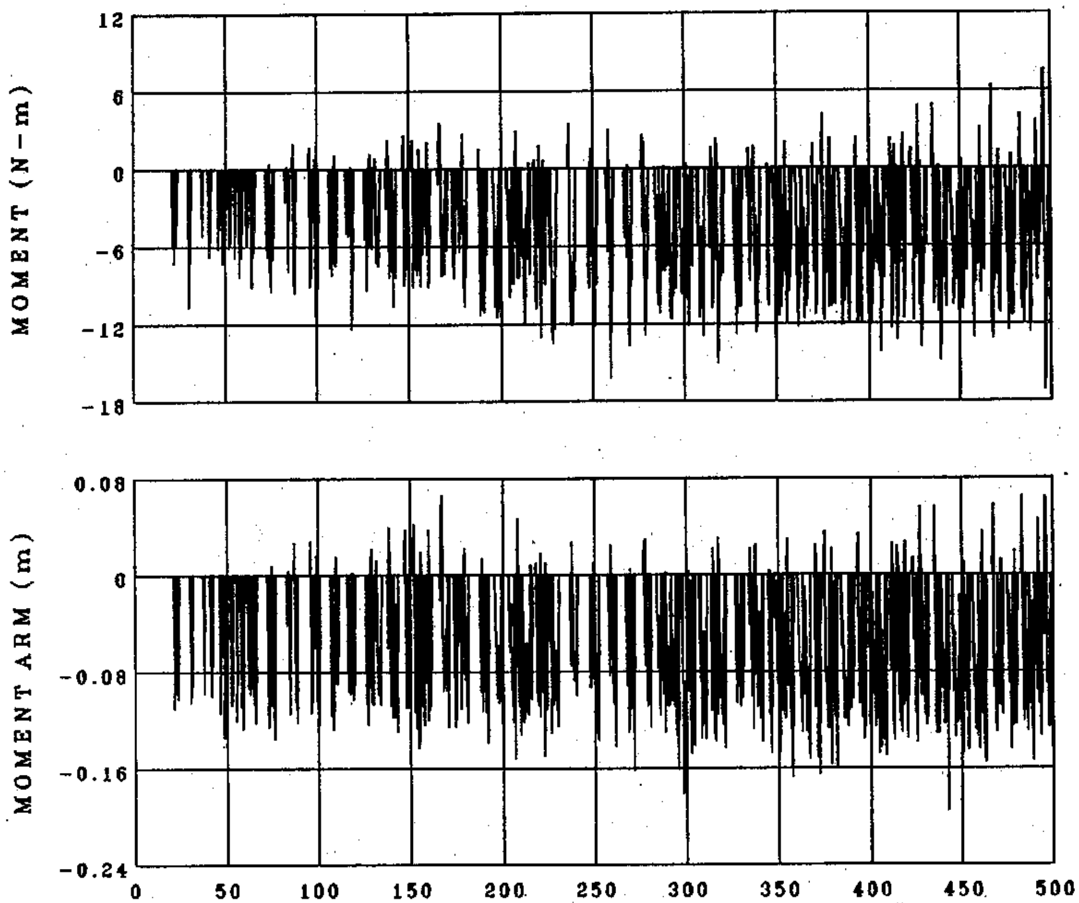
ICE PILEUP STUDY
for CANADIAN COAST GUARD

FILE TN←002

MOMENT



MOMENT

MEAN MOMENT = -2.665 N-m
MAX MOMENT = 7.636 N-m
MIN MOMENT = -17.23 N-m

MOMENT ARM

MEAN ARM = -0.03306 m
MAX ARM = 0.06672 m
MIN ARM = -0.1956 m

TEST CONDITIONS

BOARD ANGLE = -23.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 44.00 kPa
ICE THICKNESS = 3.600 cm
ICE DENSITY = 0.9300 g/cc

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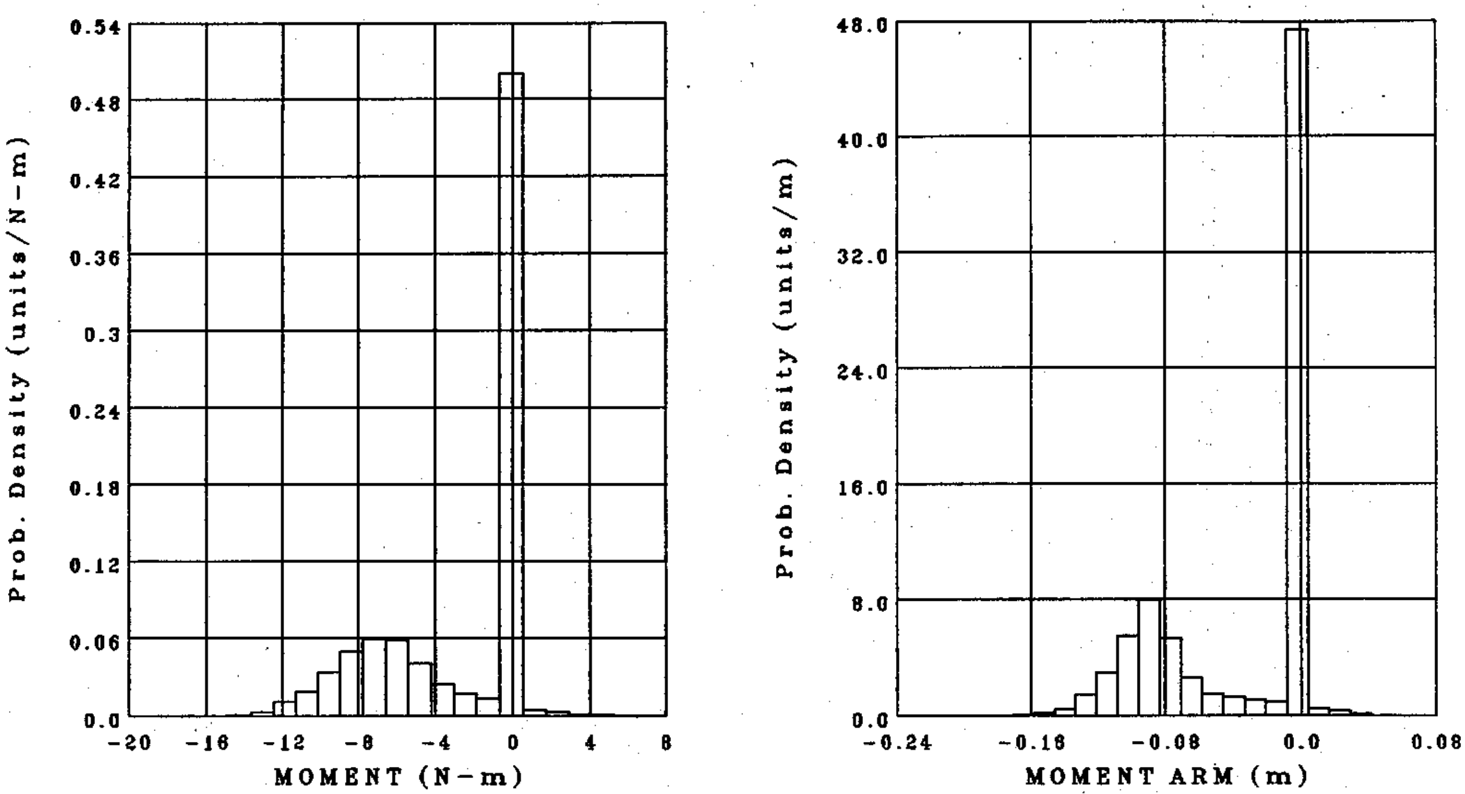
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←002



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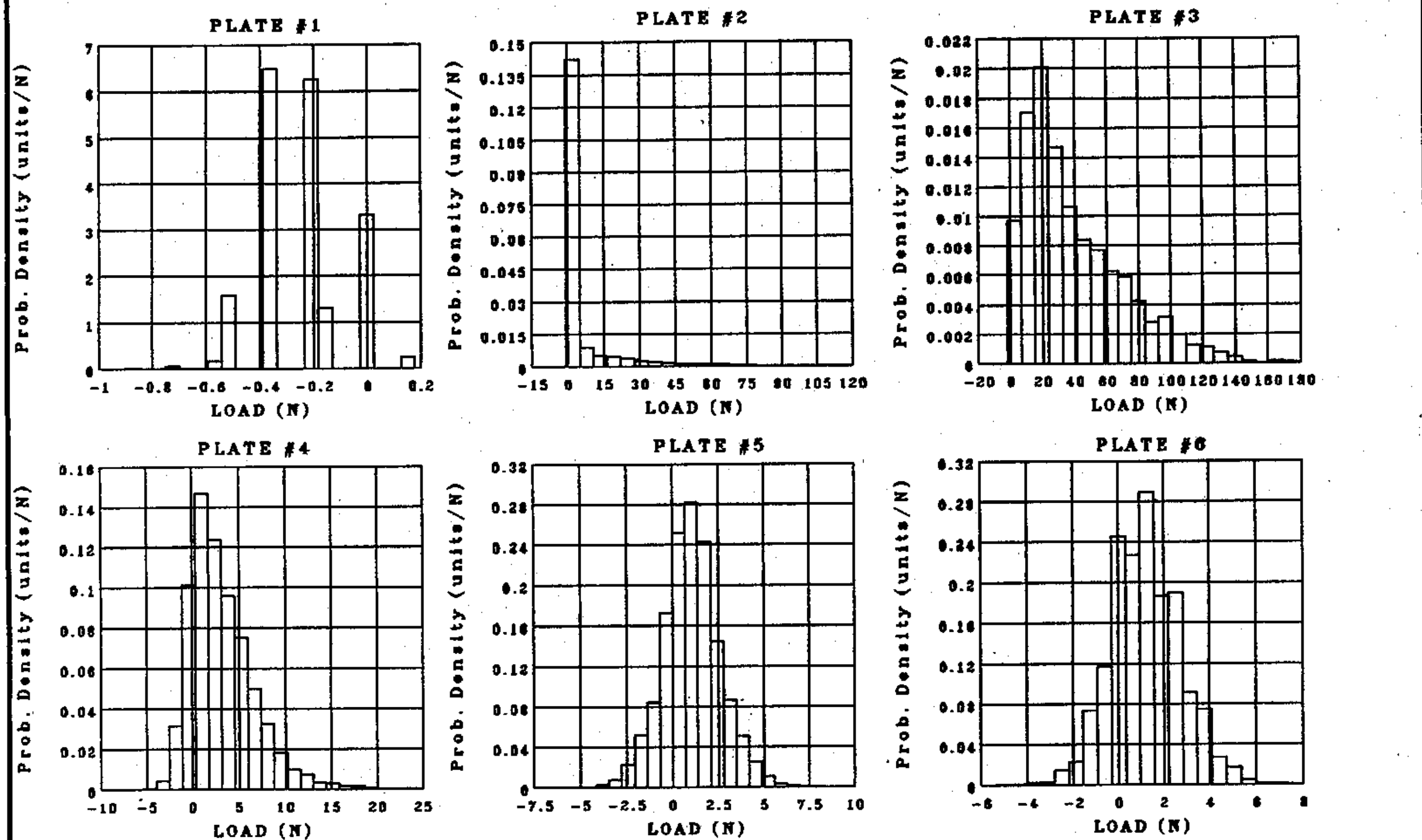
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←002
NORMAL LOAD



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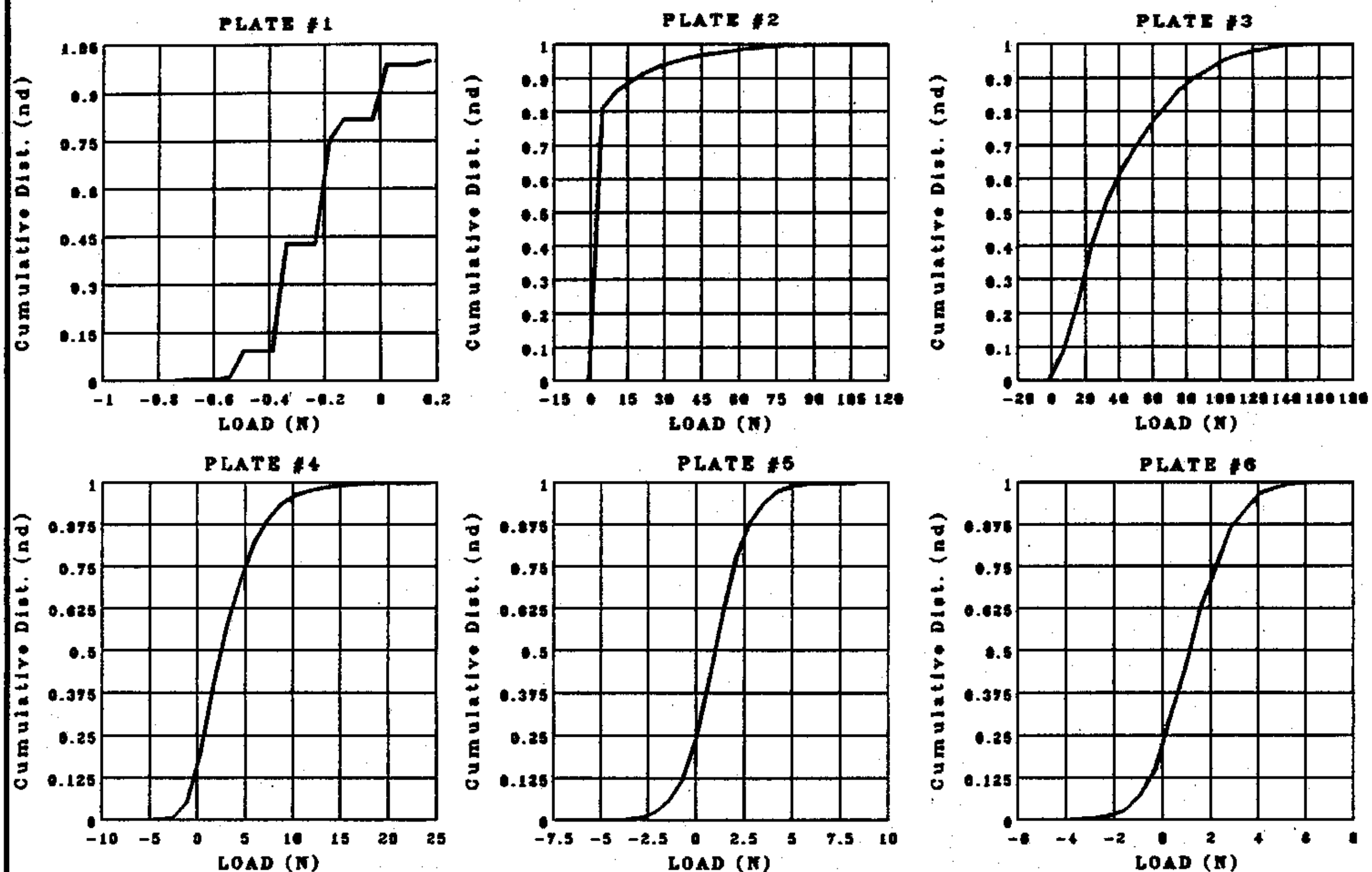
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←002
NORMAL LOAD



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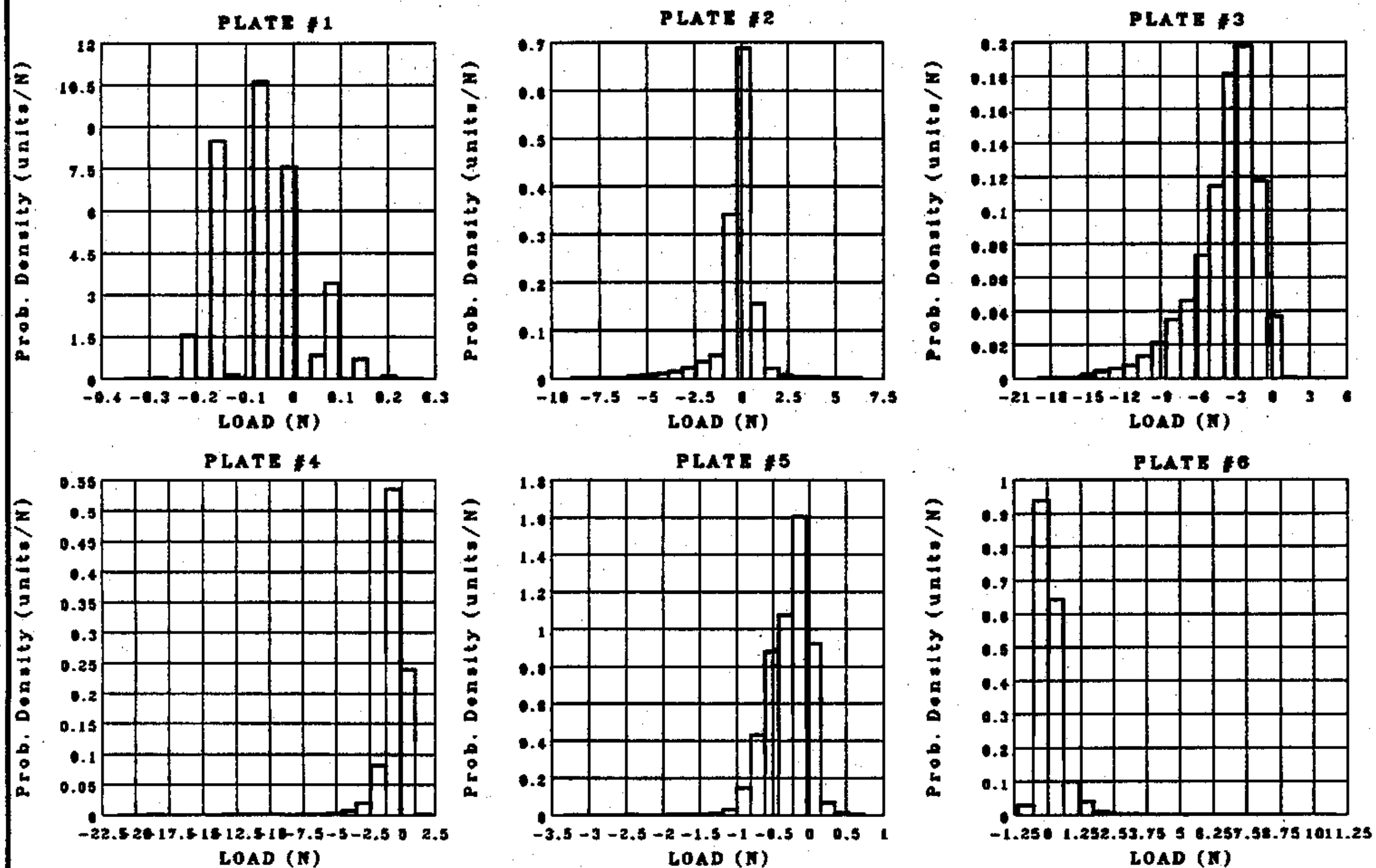
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←002
TANGENTIAL LOAD



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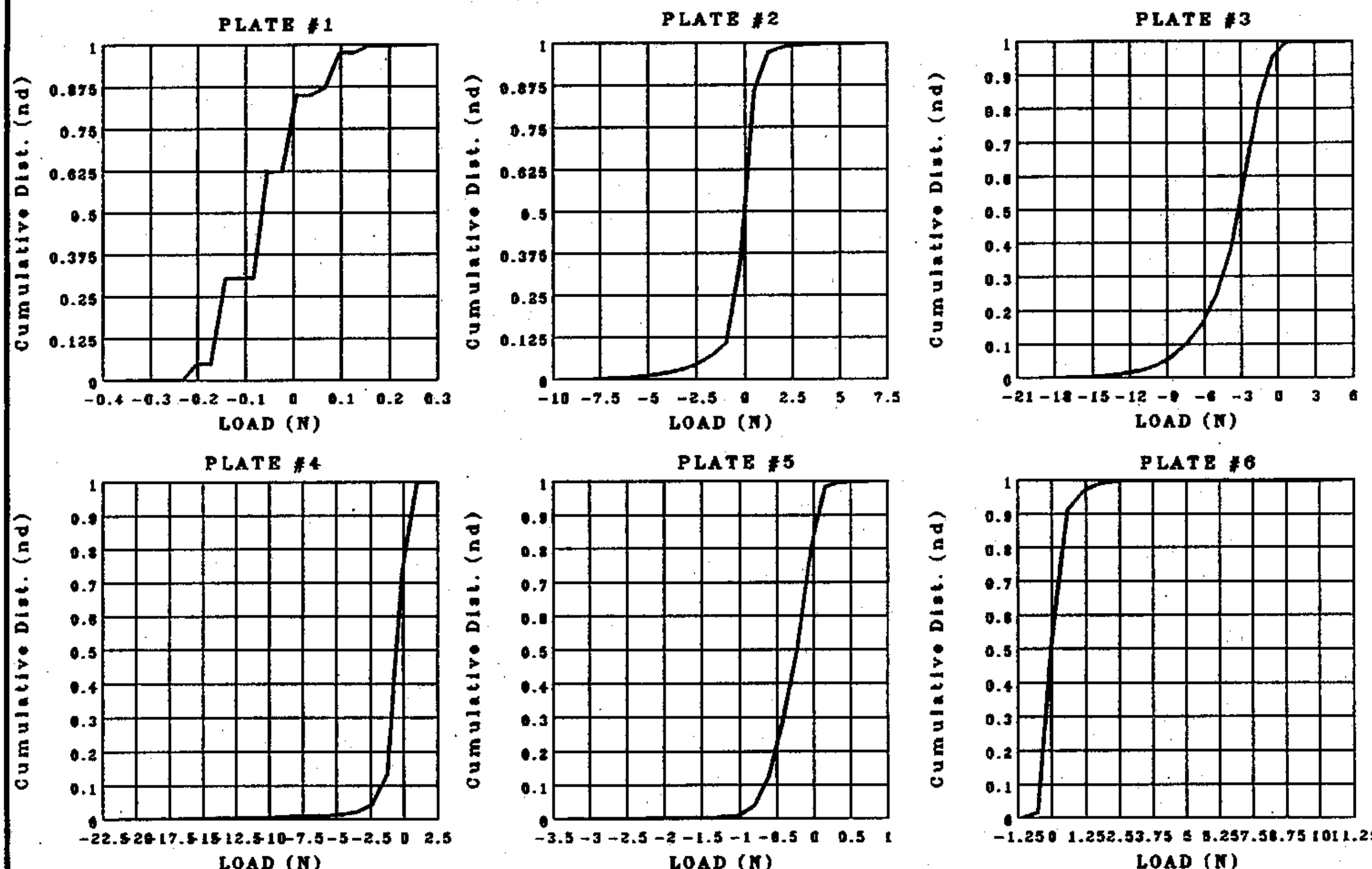
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←002
TANGENTIAL LOAD



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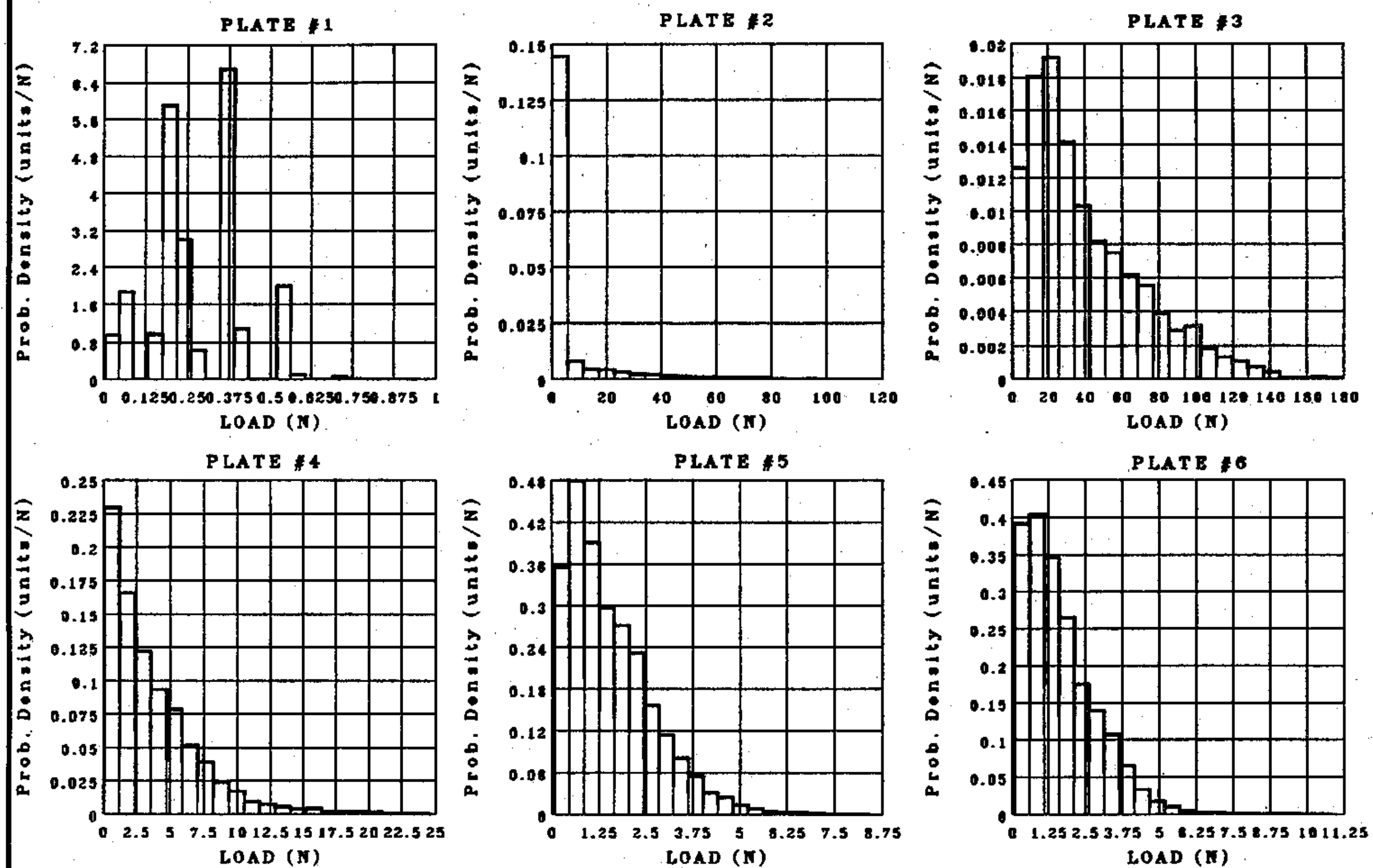
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←002
RESULTANT



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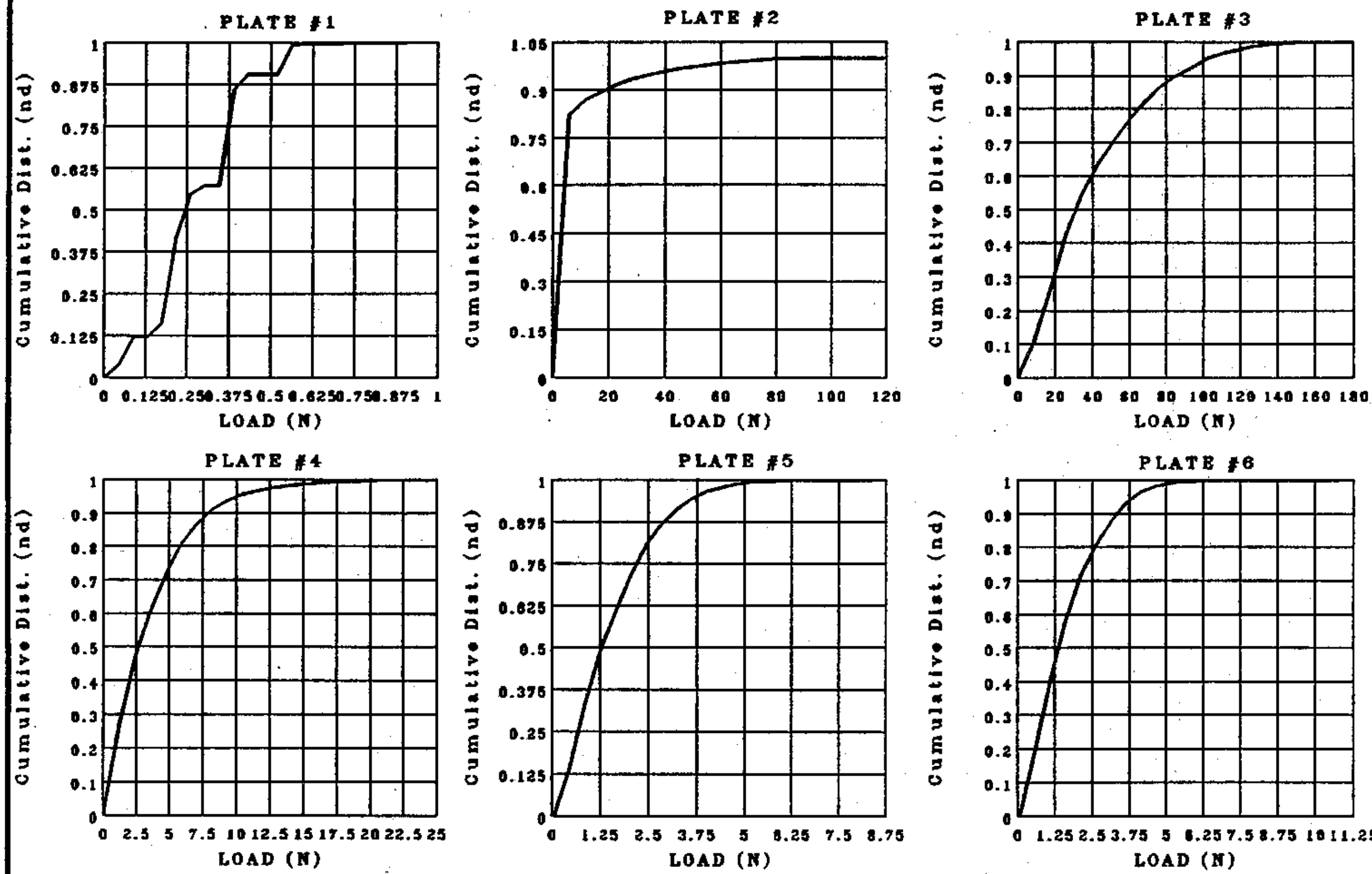
TN←002
RESULTANT



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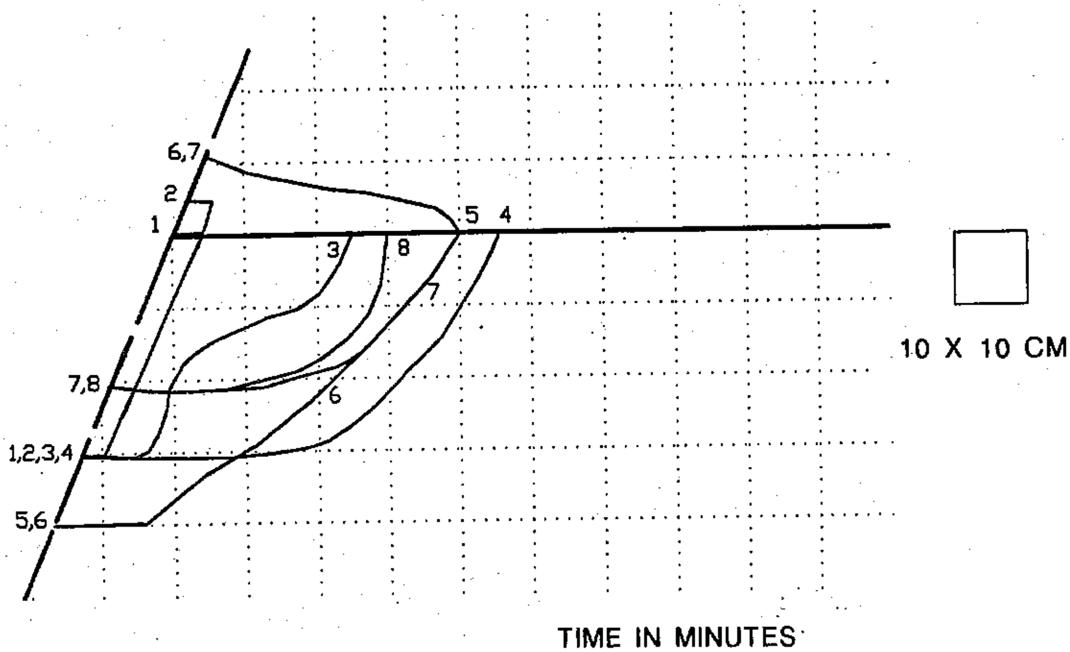
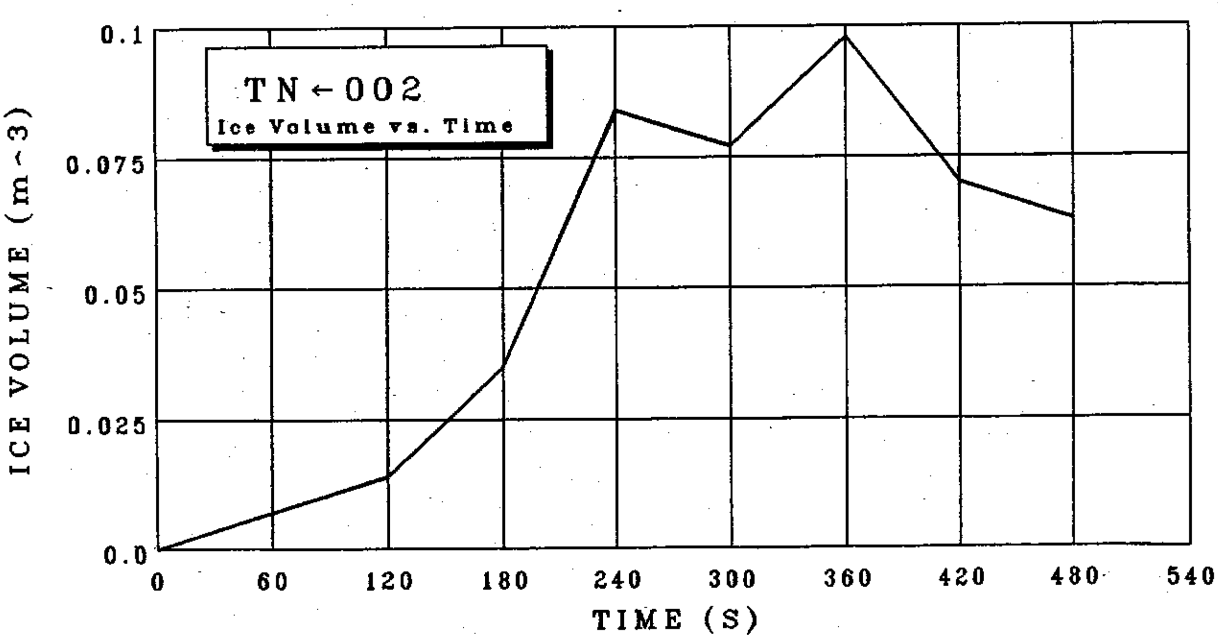
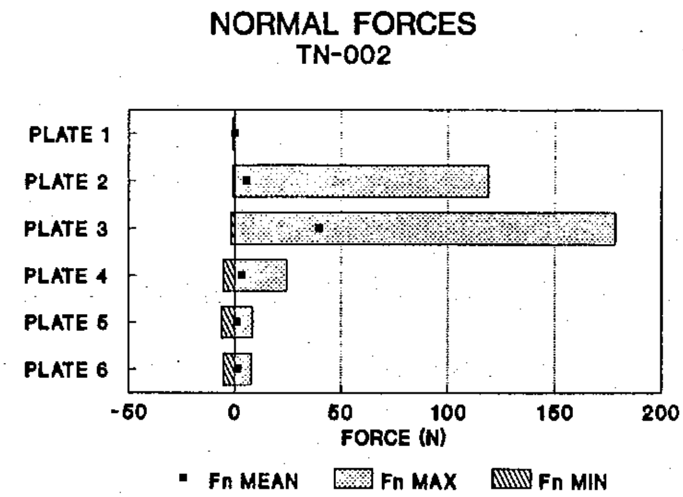
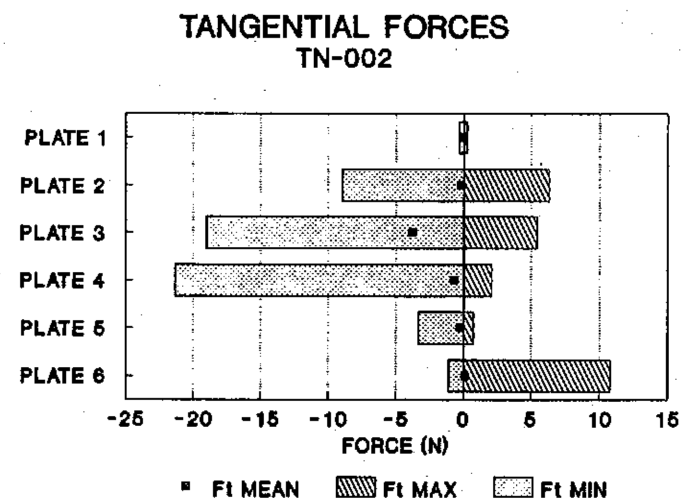
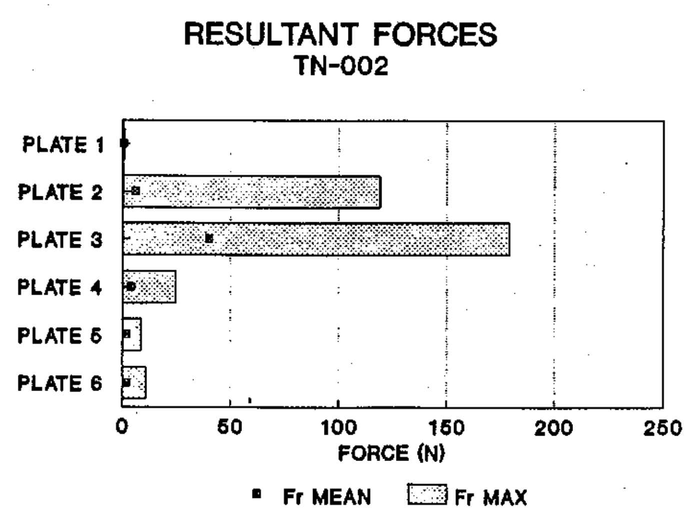
ICE PILEUP STUDY
for CANADIAN COAST GUARD

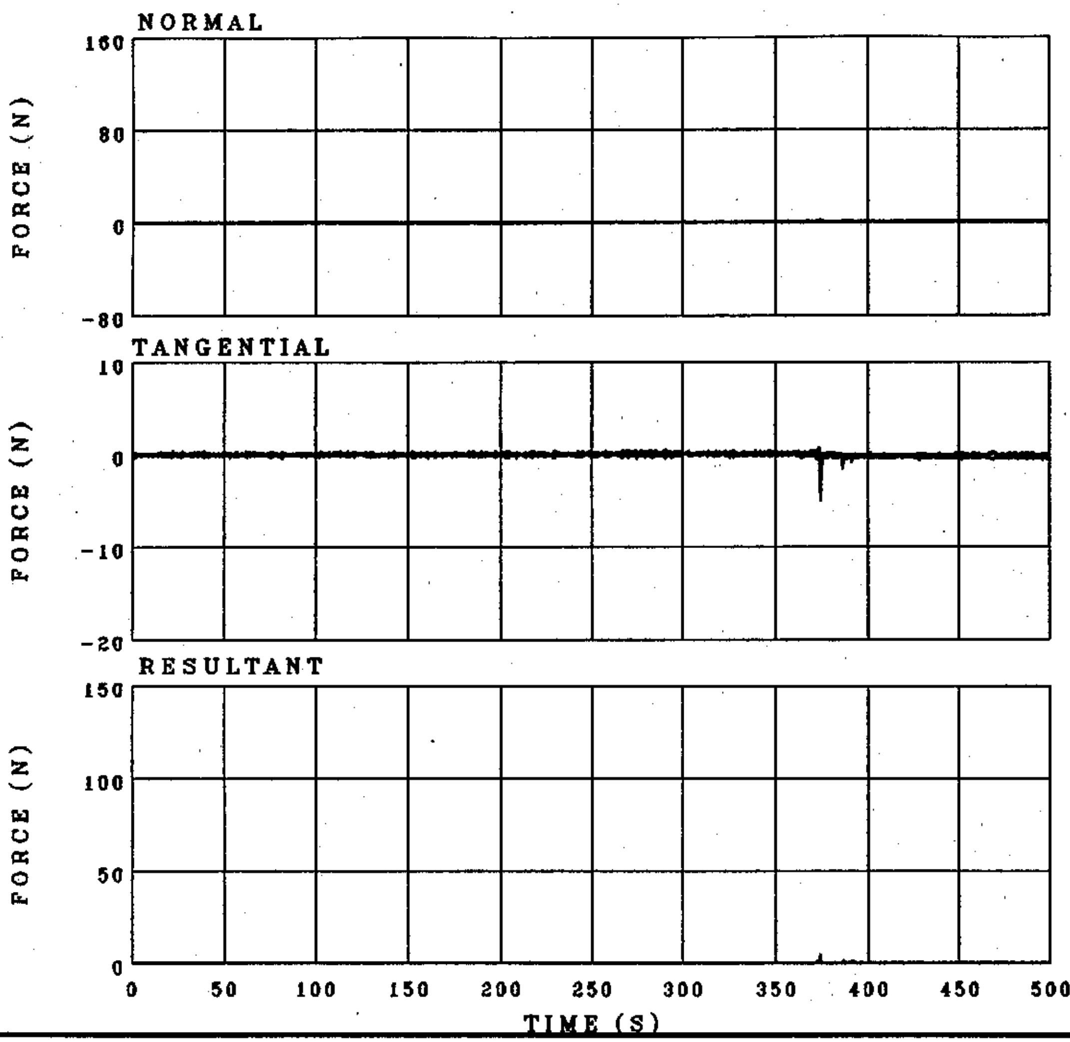

6,7
2
1
5
4
3
8
7
7,8
6
1,2,3,4
5,6
10 X 10 CM
TIME IN MINUTES


TN←002
Ice Volume vs. Time
ICE VOLUME (m^3)
0.1
0.075
0.05
0.025
0.0
0
60
120
180
240
300
360
420
480
540
TIME (S)


NORMAL FORCES
TN-002
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-50
0
50
100
150
200
FORCE (N)
Fn MEAN
Fn MAX
Fn MIN


TANGENTIAL FORCES
TN-002
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-25
-20
-15
-10
-5
0
5
10
15
FORCE (N)
Ft MEAN
Ft MAX
Ft MIN


RESULTANT FORCES
TN-002
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
0
50
100
150
200
250
FORCE (N)
Fr MEAN
Fr MAX



FILE TN←003

PLATE #1

NORMAL

MEAN FORCE = 0.1159 N
MAX FORCE = 1.276 N
MIN FORCE = -0.5212 N

TANGENTIAL

MEAN FORCE = -0.03805 N
MAX FORCE = 0.4682 N
MIN FORCE = -2.887 N

RESULTANT

MEAN FORCE = 0.1937 N
MAX FORCE = 3.156 N
MIN FORCE = 0.02561 N
AVERAGE ANGLE = -13.83 O

TEST CONDITIONS

BOARD ANGLE = -23.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 83.00 kPa
ICE THICKNESS = 2.800 cm
ICE DENSITY = 0.9300 g/cc

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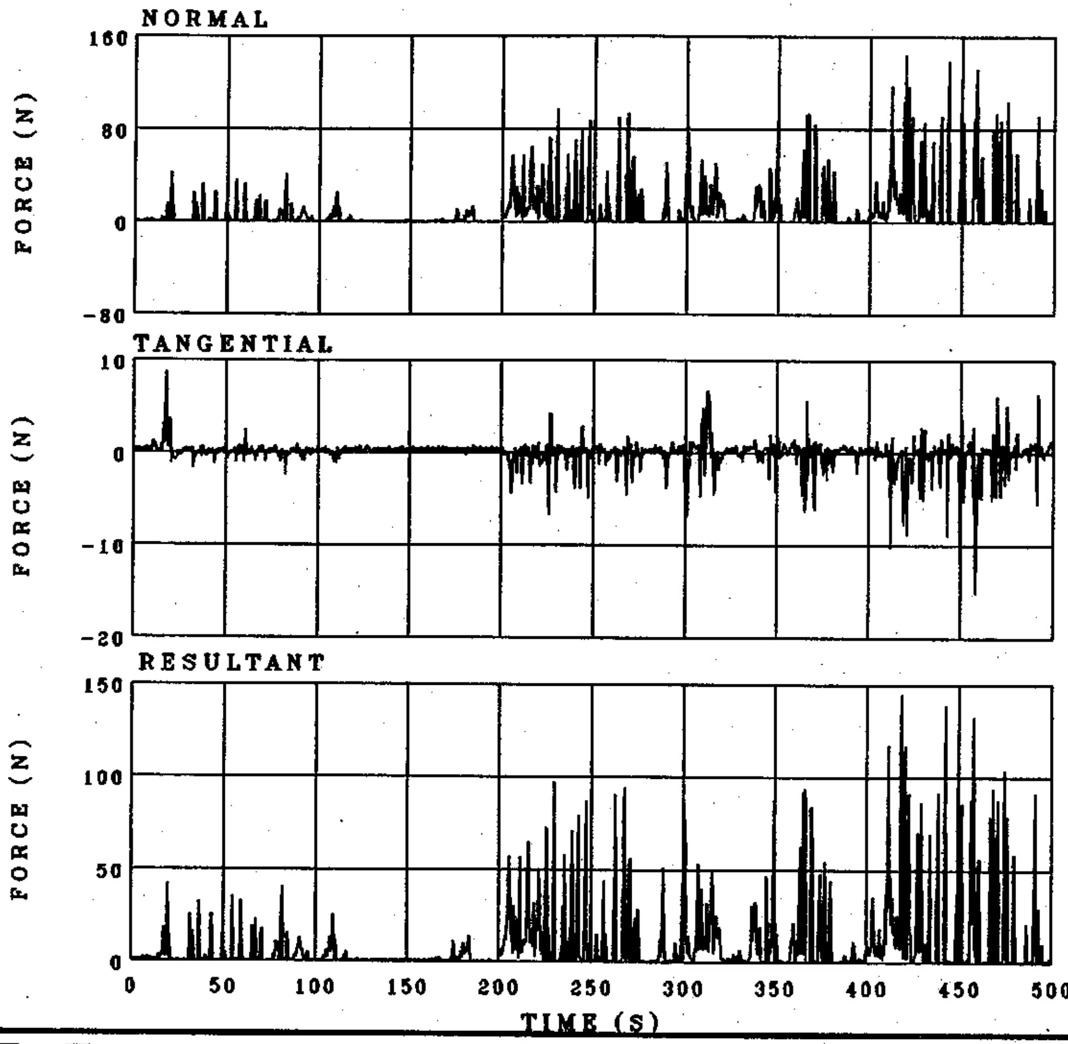
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←003

PLATE #2

NORMAL

MEAN FORCE = 6.960 N
MAX FORCE = 144.8 N
MIN FORCE = -0.8546 N

TANGENTIAL

MEAN FORCE = 0.003909 N
MAX FORCE = 8.770 N
MIN FORCE = -15.19 N

RESULTANT

MEAN FORCE = 7.190 N
MAX FORCE = 144.9 N
MIN FORCE = 0.01470 N
AVERAGE ANGLE = 20.30 D

TEST CONDITIONS

BOARD ANGLE = -23.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 83.00 kPa
ICE THICKNESS = 2.600 cm
ICE DENSITY = 0.9300 g/cc

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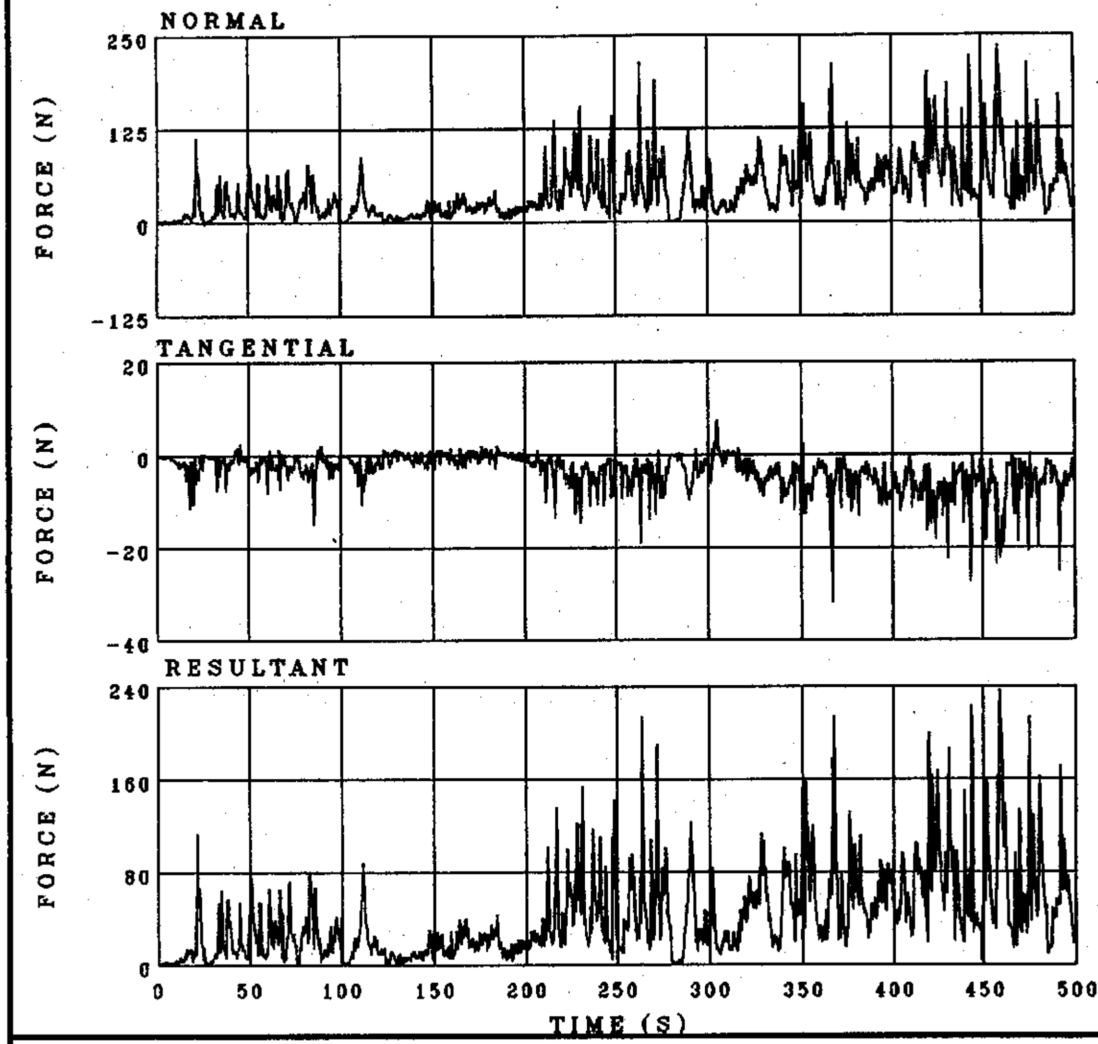
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←003

PLATE #3

NORMAL

MEAN FORCE = 40.90 N
MAX FORCE = 236.3 N
MIN FORCE = -3.769 N

TANGENTIAL

MEAN FORCE = -3.648 N
MAX FORCE = 7.507 N
MIN FORCE = -31.96 N

RESULTANT

MEAN FORCE = 41.13 N
MAX FORCE = 237.2 N
MIN FORCE = 0.08354 N
AVERAGE ANGLE = -5.553 0

TEST CONDITIONS

BOARD ANGLE = -23.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 83.00 kPa
ICE THICKNESS = 2.800 cm
ICE DENSITY = 0.9300 g/cc

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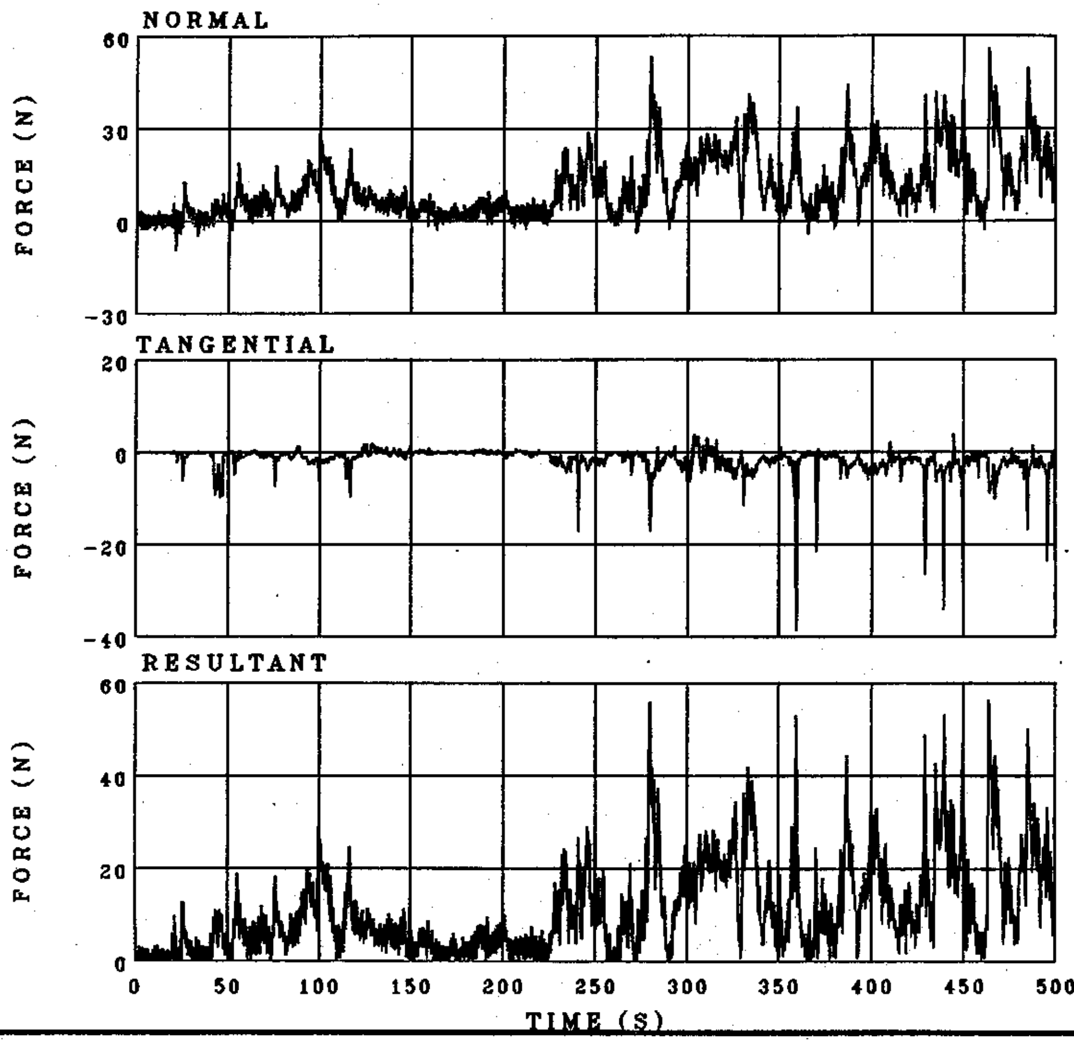
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←003

PLATE #4

NORMAL

MEAN FORCE = 10.67 N
MAX FORCE = 55.79 N
MIN FORCE = -9.687 N

TANGENTIAL

MEAN FORCE = -1.550 N
MAX FORCE = 3.975 N
MIN FORCE = -38.75 N

RESULTANT

MEAN FORCE = 10.99 N
MAX FORCE = 56.39 N
MIN FORCE = 0.01447 N
AVERAGE ANGLE = -7.797 O

TEST CONDITIONS

BOARD ANGLE = -23.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 83.00 kPa
ICE THICKNESS = 2.800 cm
ICE DENSITY = 0.9300 g/cc

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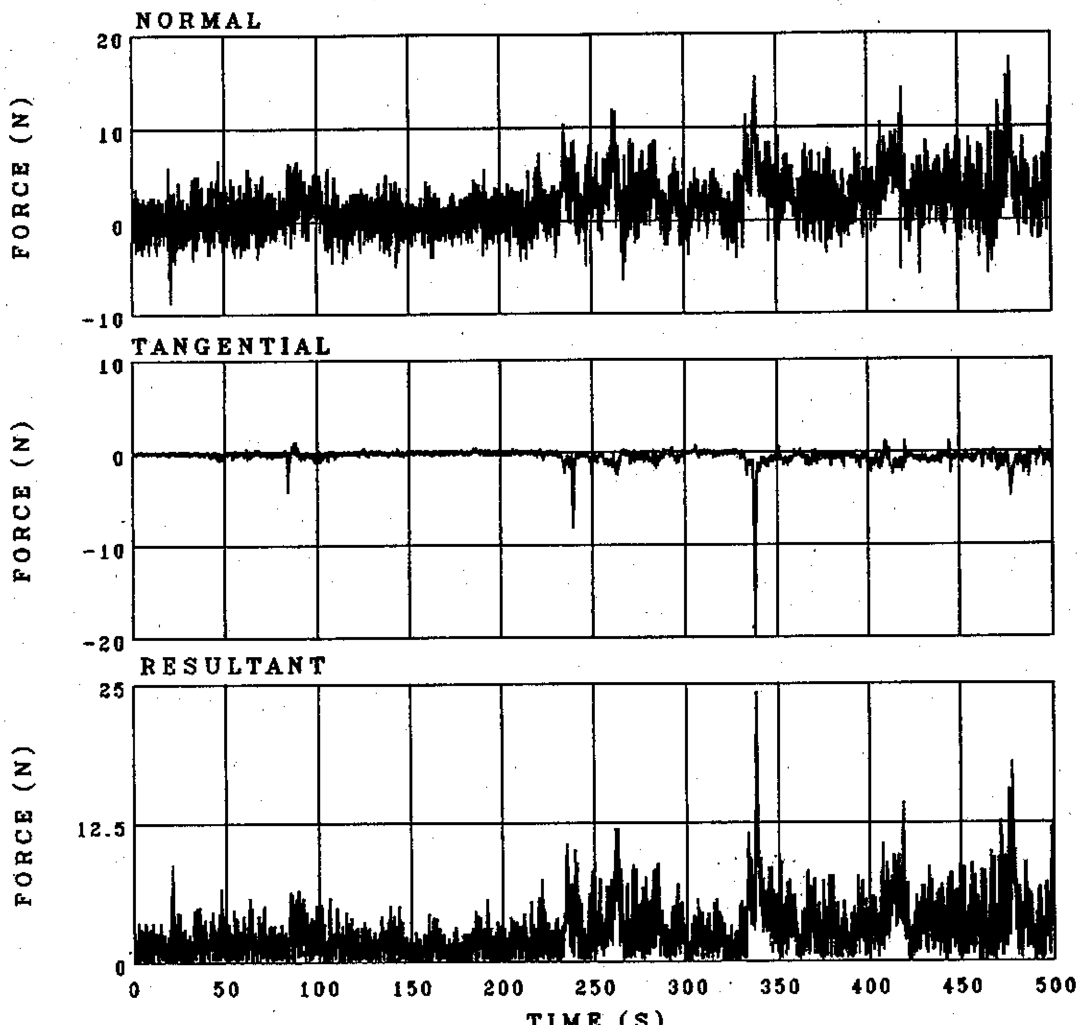
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←003

PLATE #5

NORMAL

MEAN FORCE = 1.873 N
MAX FORCE = 17.43 N
MIN FORCE = -8.830 N

TANGENTIAL

MEAN FORCE = -0.4250 N
MAX FORCE = 1.210 N
MIN FORCE = -19.96 N

RESULTANT

MEAN FORCE = 2.466 N
MAX FORCE = 24.27 N
MIN FORCE = 0.01248 N
AVERAGE ANGLE = -10.87 O

TEST CONDITIONS

BOARD ANGLE = -23.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 63.00 kPa
ICE THICKNESS = 2.800 cm
ICE DENSITY = 0.9300 g/cc

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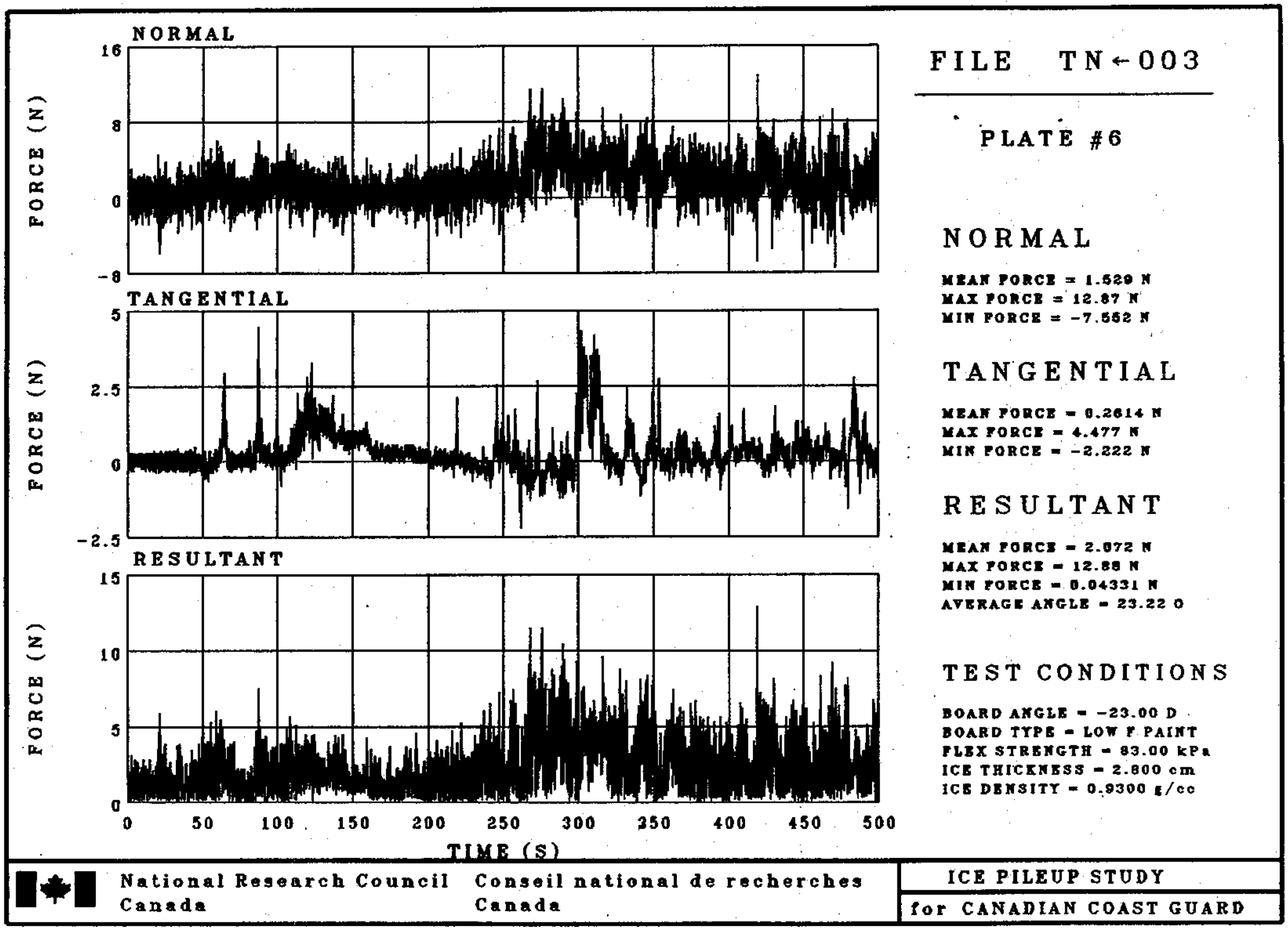
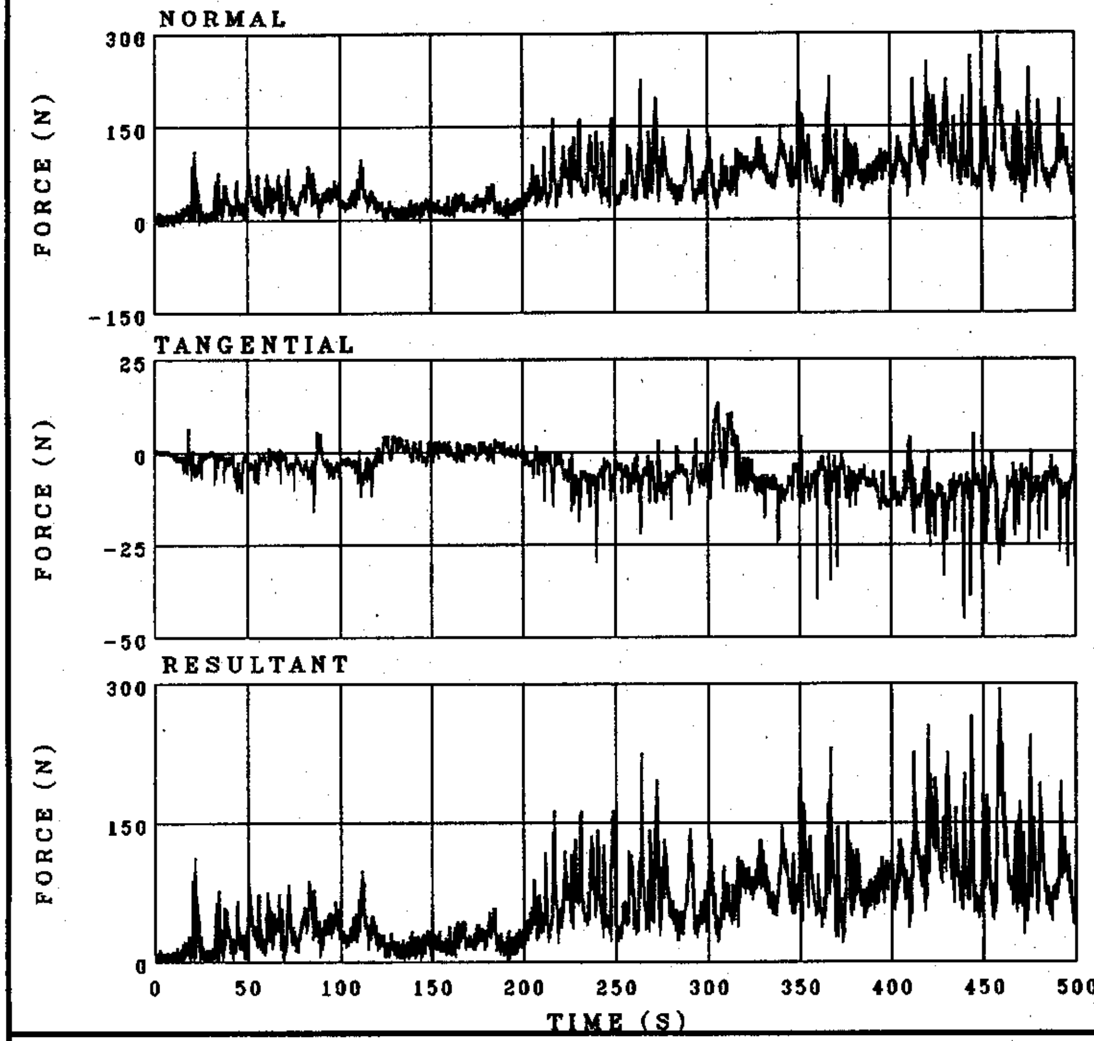
ICE PILEUP STUDY
for CANADIAN COAST GUARD


NORMAL
FORCE (N)
16
8
0
-8
TANGENTIAL
FORCE (N)
5
2.5
0
-2.5
RESULTANT
FORCE (N)
15
10
5
0
0 50 100 150 200 250 300 350 400 450 500
TIME (S)
FILE TN-003
PLATE #6
NORMAL
MEAN FORCE = 1.529 N
MAX FORCE = 12.87 N
MIN FORCE = -7.552 N
TANGENTIAL
MEAN FORCE = 0.2614 N
MAX FORCE = 4.477 N
MIN FORCE = -2.222 N
RESULTANT
MEAN FORCE = 2.072 N
MAX FORCE = 12.88 N
MIN FORCE = 0.04331 N
AVERAGE ANGLE = 23.22 O
TEST CONDITIONS
BOARD ANGLE = -23.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 83.00 kPa
ICE THICKNESS = 2.800 cm
ICE DENSITY = 0.9300 g/cc
National Research Council Canada
Conseil national de recherches Canada
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←003

TOTAL

NORMAL

MEAN FORCE = 62.05 N
MAX FORCE = 293.6 N
MIN FORCE = -9.787 N

TANGENTIAL

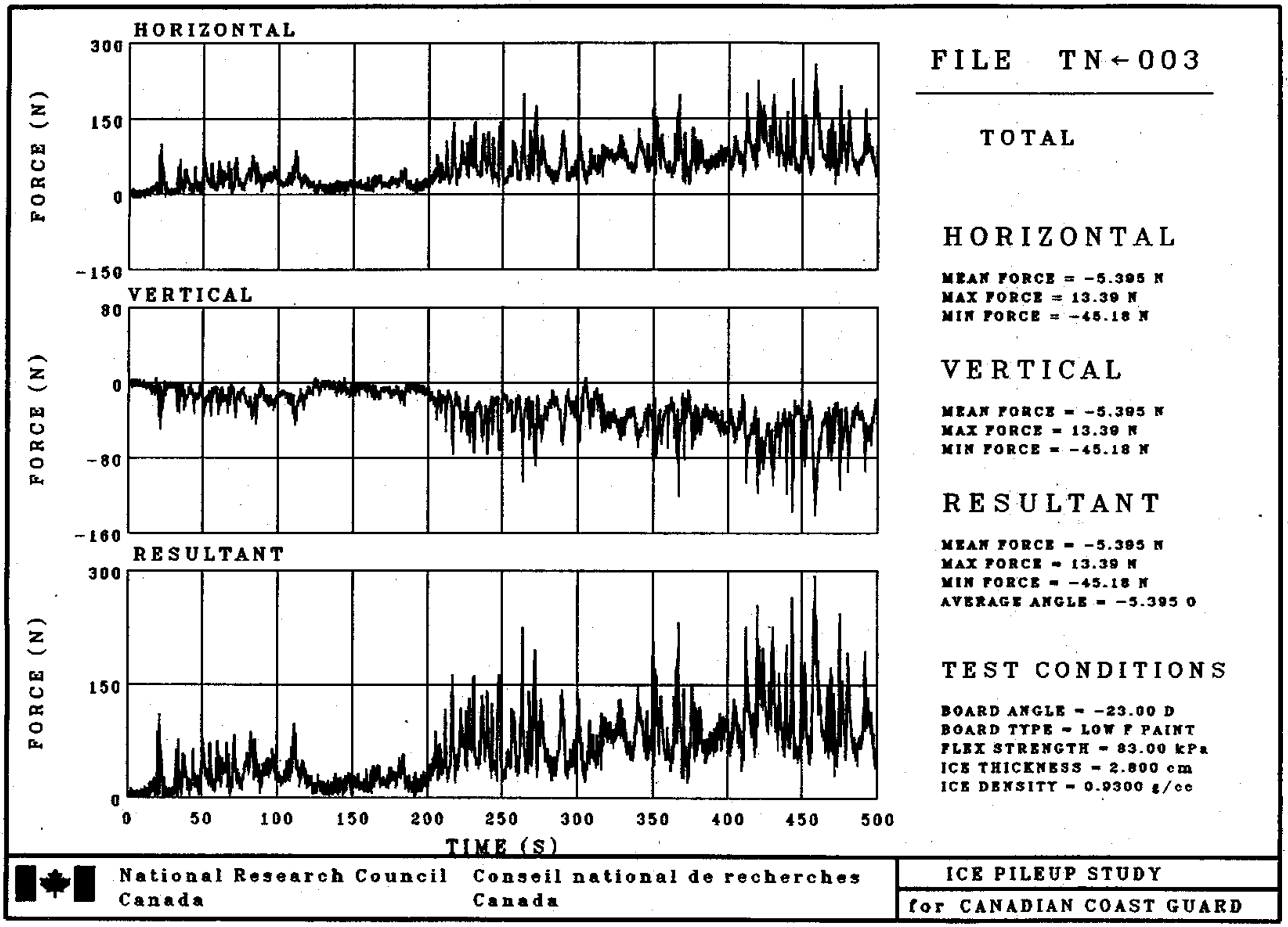
MEAN FORCE = -5.395 N
MAX FORCE = 13.39 N
MIN FORCE = -45.18 N

RESULTANT

MEAN FORCE = 62.48 N
MAX FORCE = 295.1 N
MIN FORCE = 0.03900 N
AVERAGE ANGLE = -4.110 D

TEST CONDITIONS

BOARD ANGLE = -23.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 63.00 kPa
ICE THICKNESS = 2.800 cm
ICE DENSITY = 0.9300 g/cc


HORIZONTAL
300
150
0
-150
FORCE (N)
VERTICAL
80
0
-80
-160
FORCE (N)
RESULTANT
300
150
0
FORCE (N)
0 50 100 150 200 250 300 350 400 450 500
TIME (S)
FILE TN←003
TOTAL
HORIZONTAL
MEAN FORCE = -5.395 N
MAX FORCE = 13.39 N
MIN FORCE = -45.18 N
VERTICAL
MEAN FORCE = -5.395 N
MAX FORCE = 13.39 N
MIN FORCE = -45.18 N
RESULTANT
MEAN FORCE = -5.395 N
MAX FORCE = 13.39 N
MIN FORCE = -45.18 N
AVERAGE ANGLE = -5.395 O
TEST CONDITIONS
BOARD ANGLE = -23.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 83.00 kPa
ICE THICKNESS = 2.800 cm
ICE DENSITY = 0.9300 g/cc
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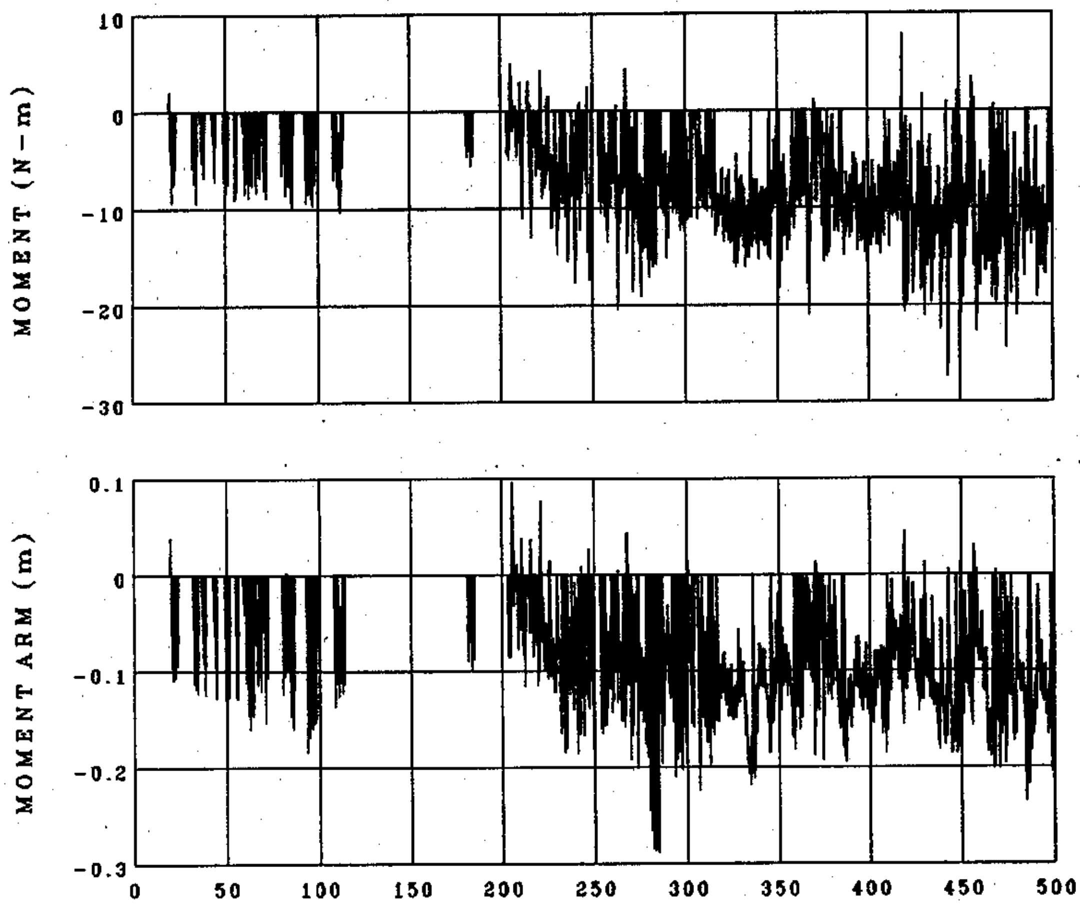
for CANADIAN COAST GUARD

FILE TN←003

MOMENT



MOMENT

MEAN MOMENT = -5.017 N-m
MAX MOMENT = 7.926 N-m
MIN MOMENT = -27.48 N-m

MOMENT ARM

MEAN ARM = -0.05758 m
MAX ARM = 0.09687 m
MIN ARM = -0.2899 m

TEST CONDITIONS

BOARD ANGLE = -23.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 63.00 kPa
ICE THICKNESS = 2.800 cm
ICE DENSITY = 0.9300 g/cc

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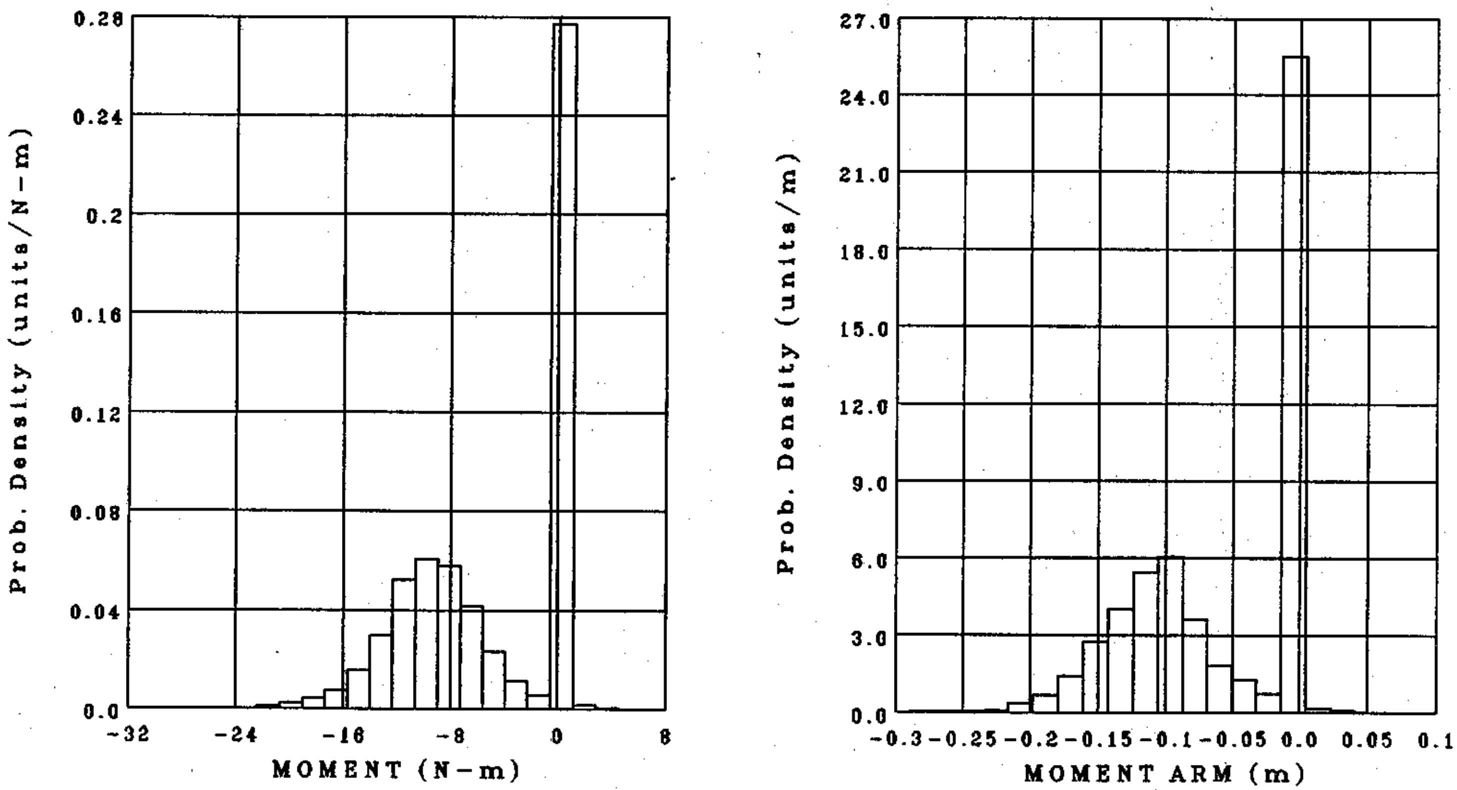
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←003



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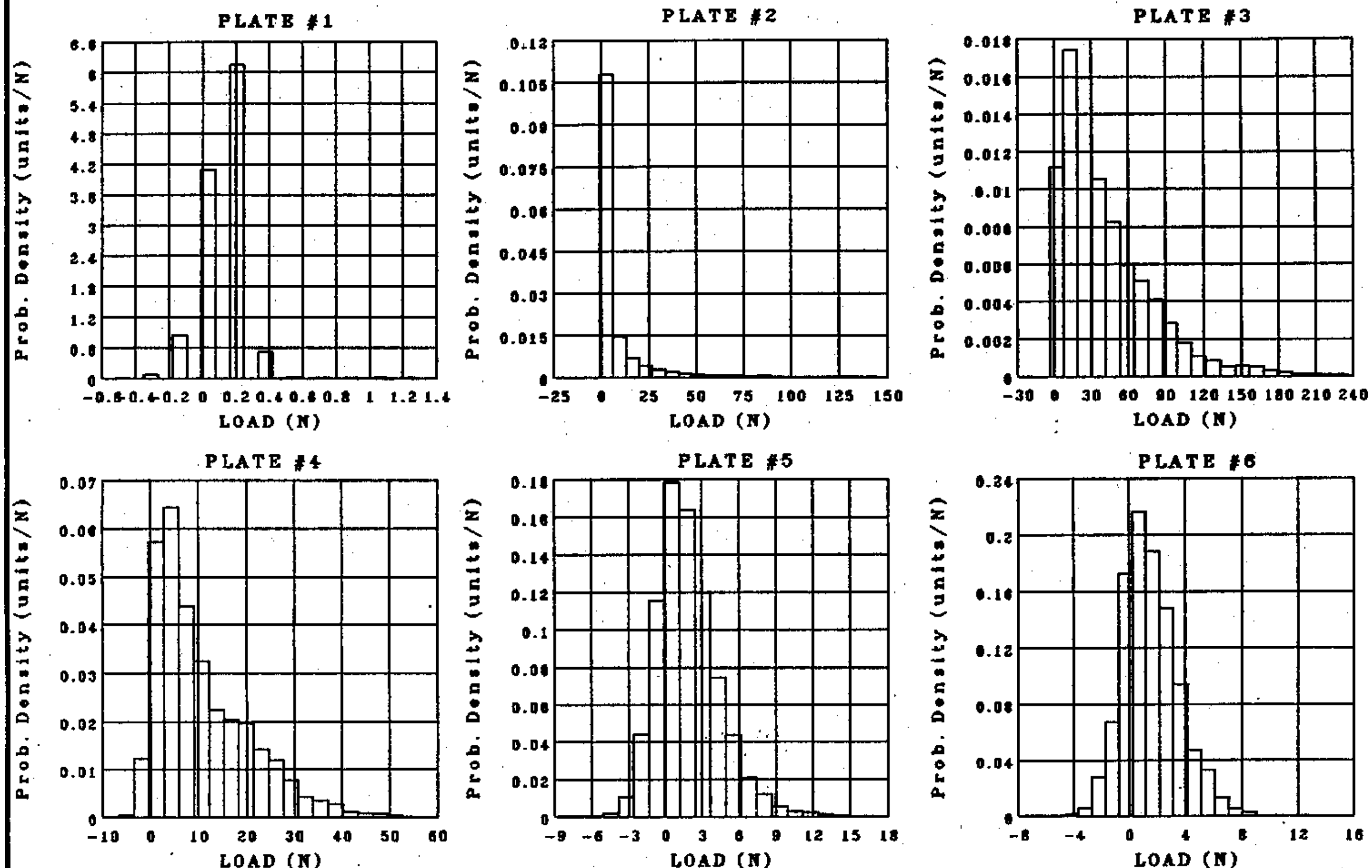
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←003
NORMAL LOAD



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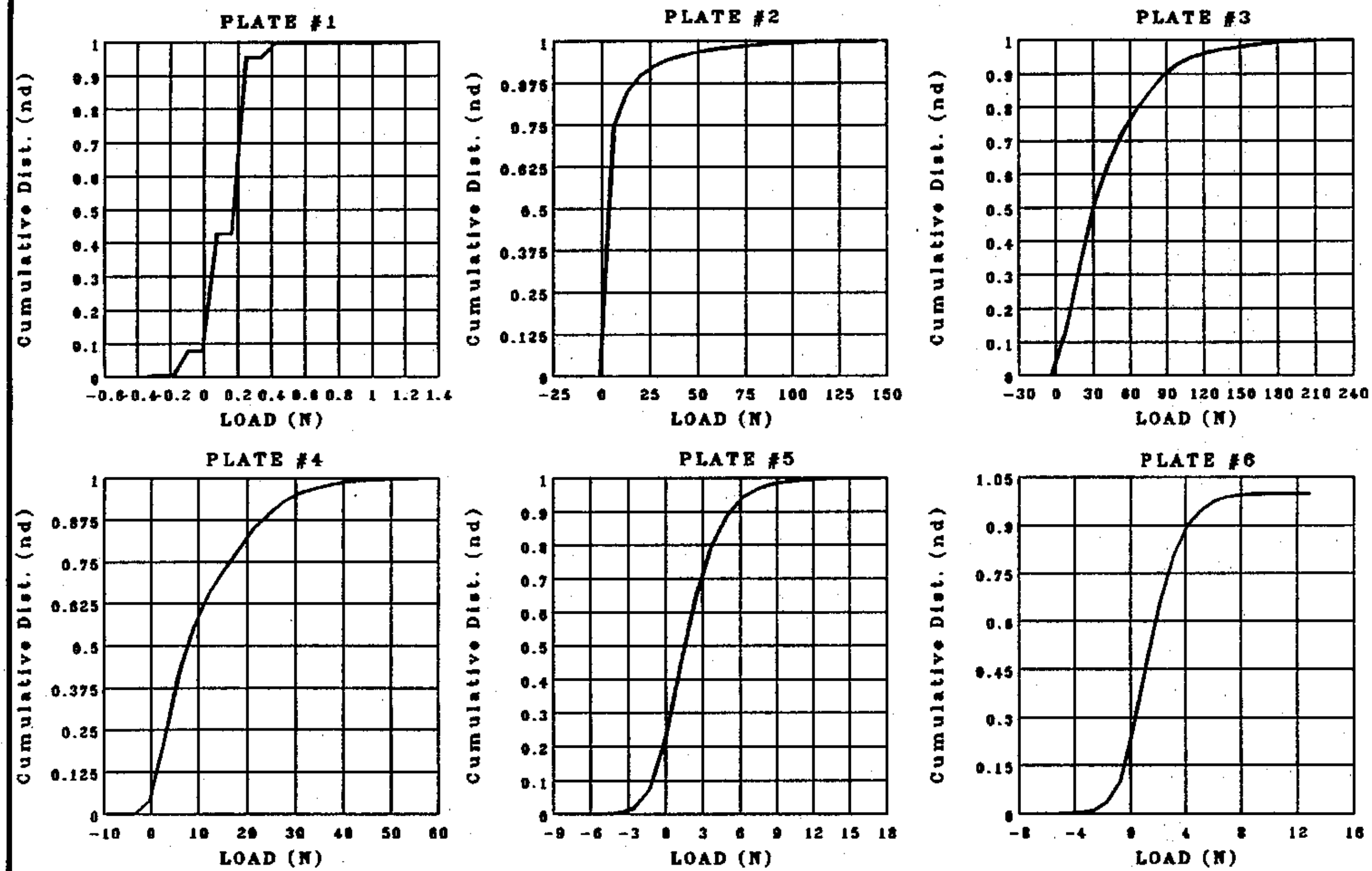
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN ← 003
NORMAL LOAD



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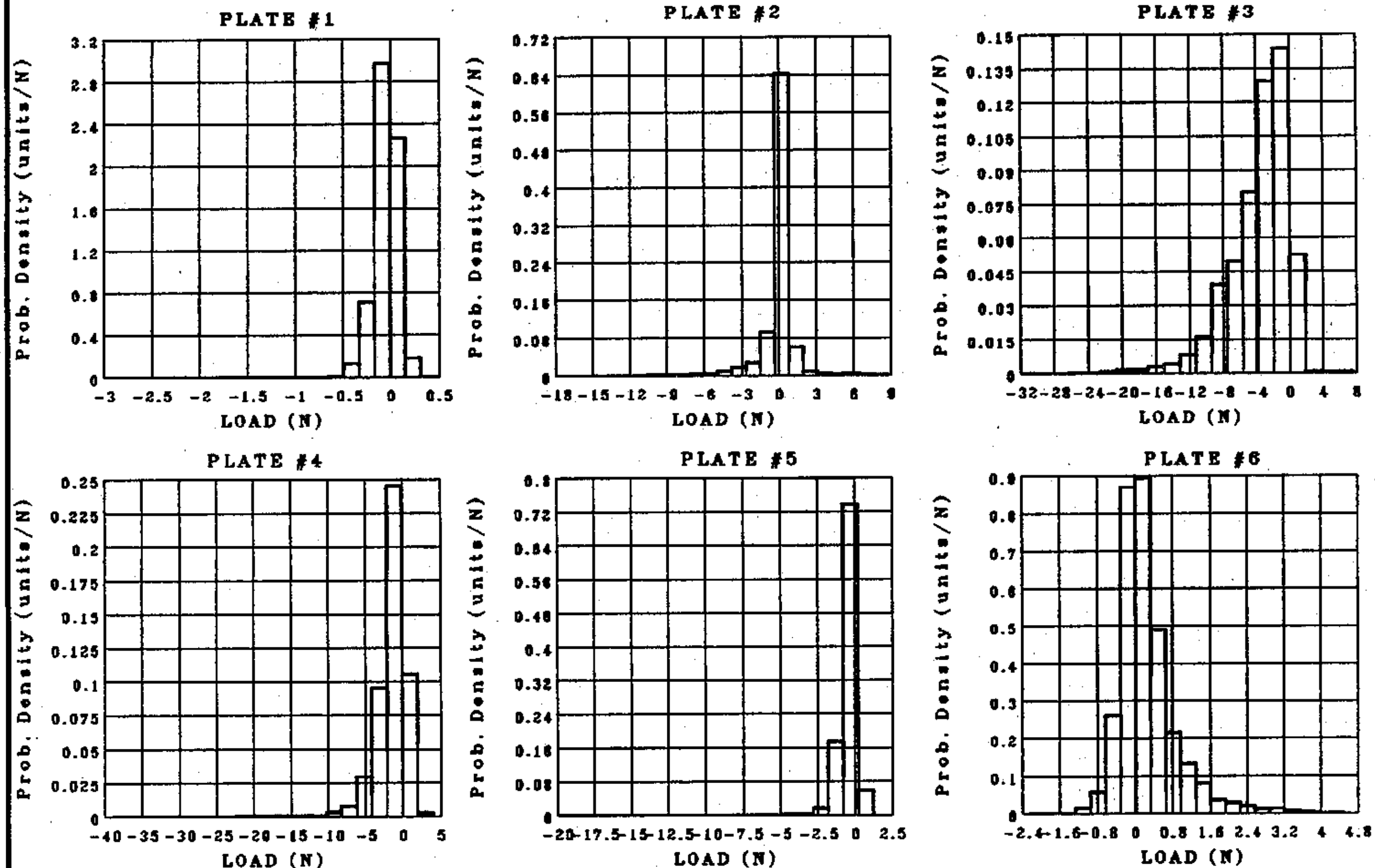
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←003
TANGENTIAL LOAD



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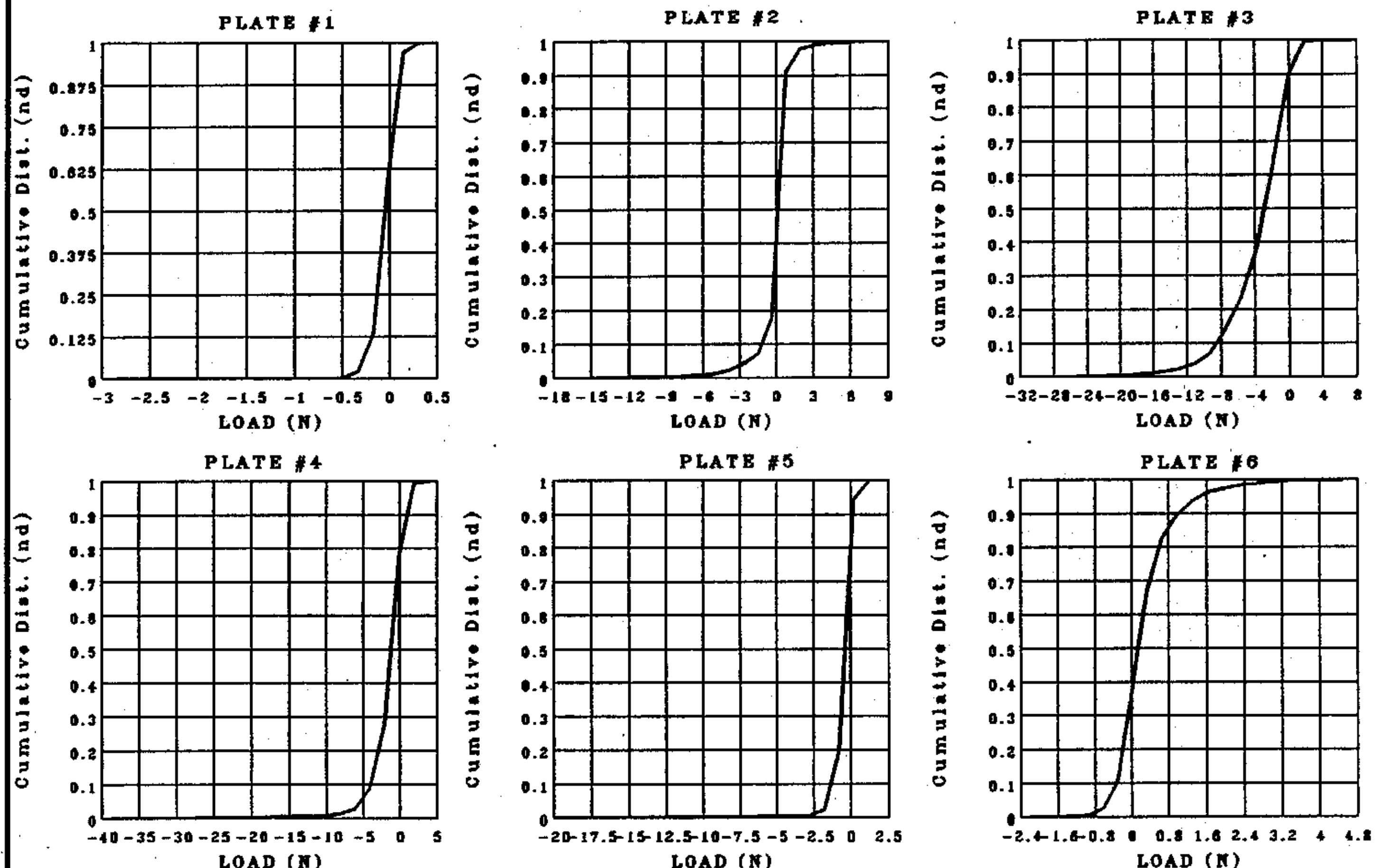
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN ← 003
TANGENTIAL LOAD



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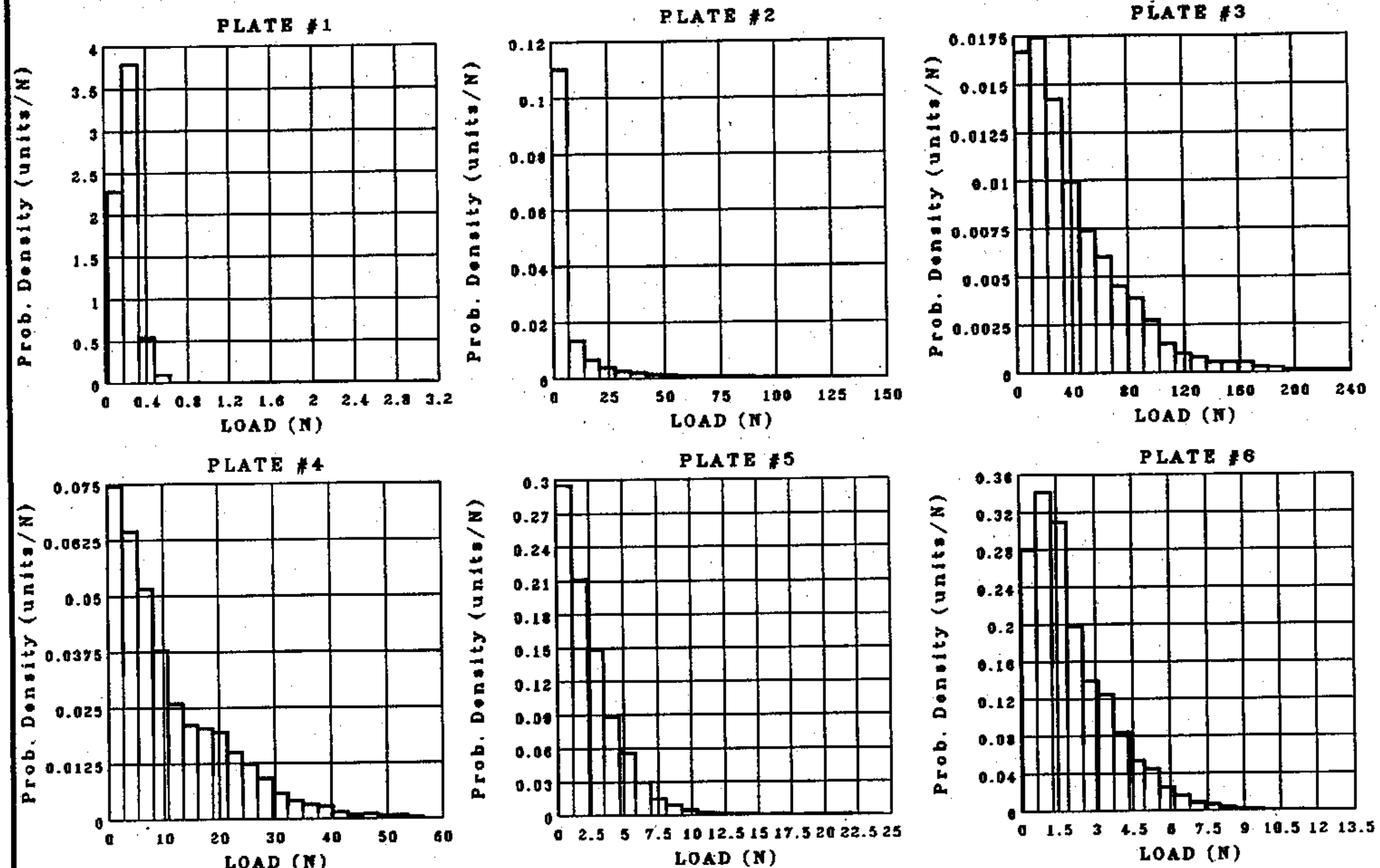
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN ← 003
RESULTANT



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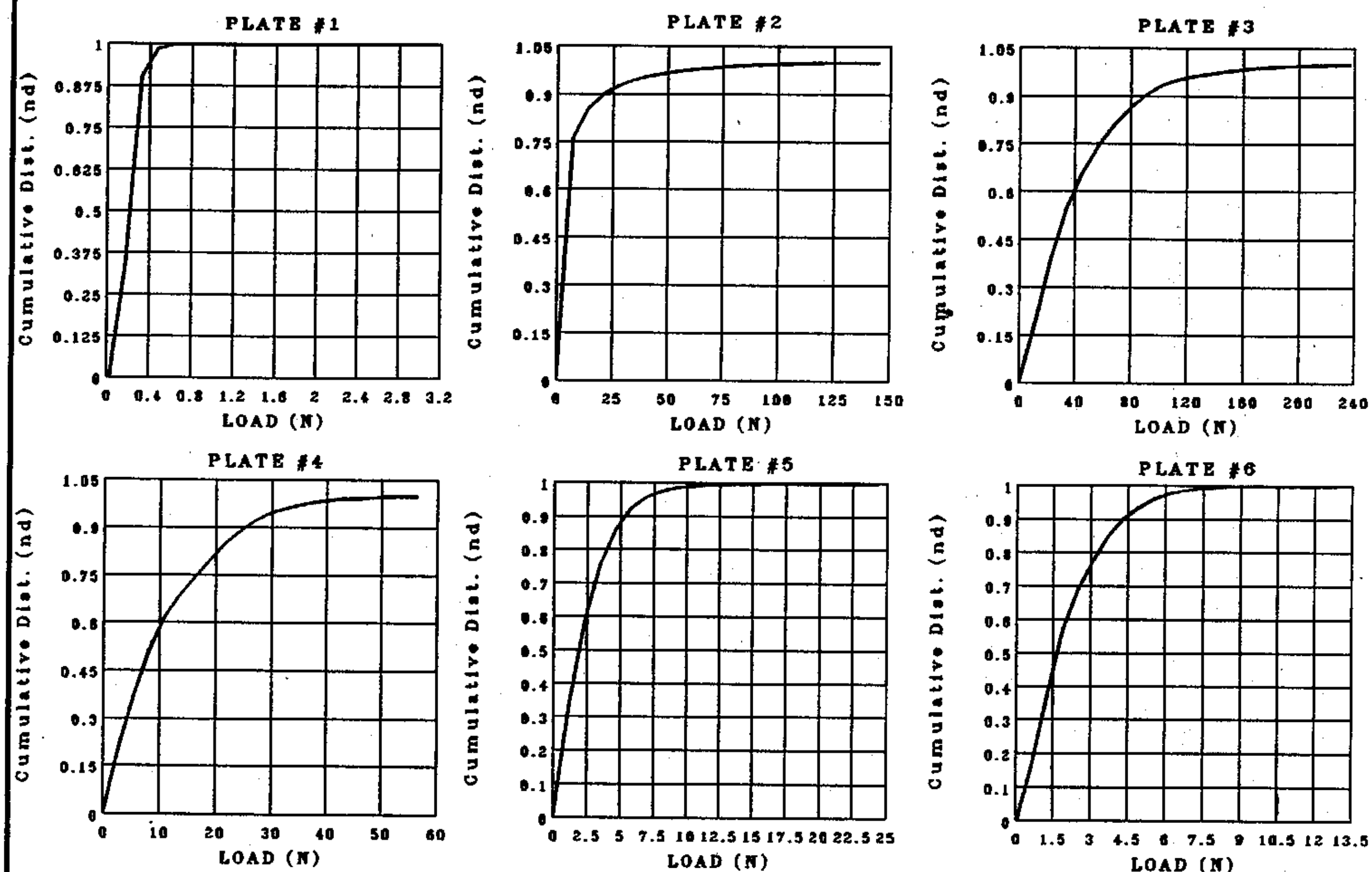
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←003
RESULTANT



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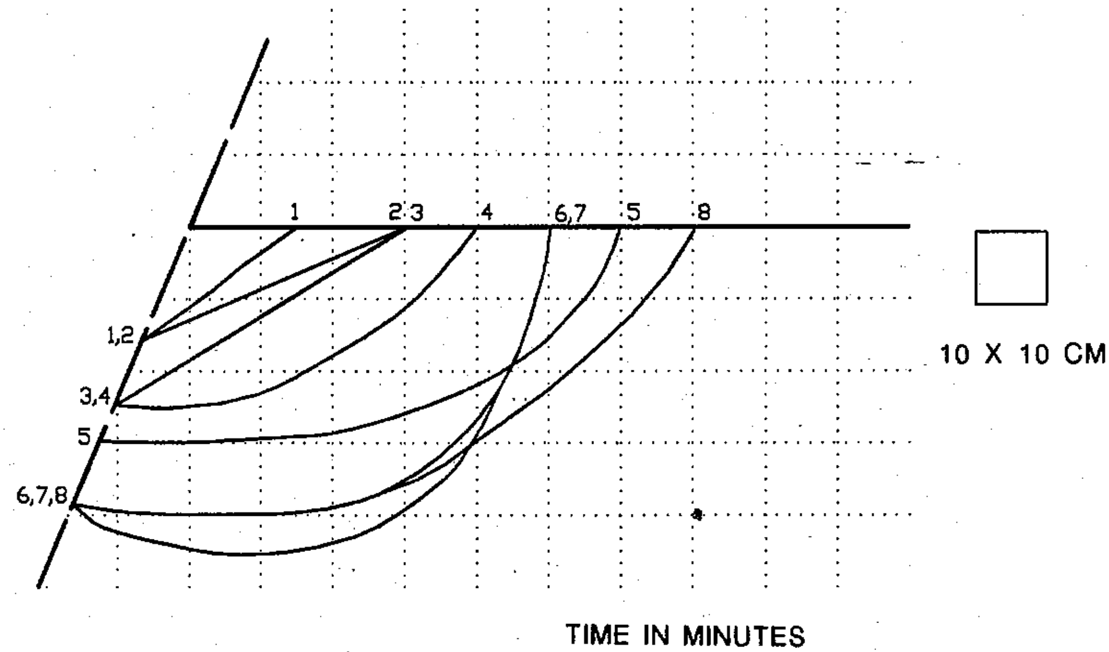
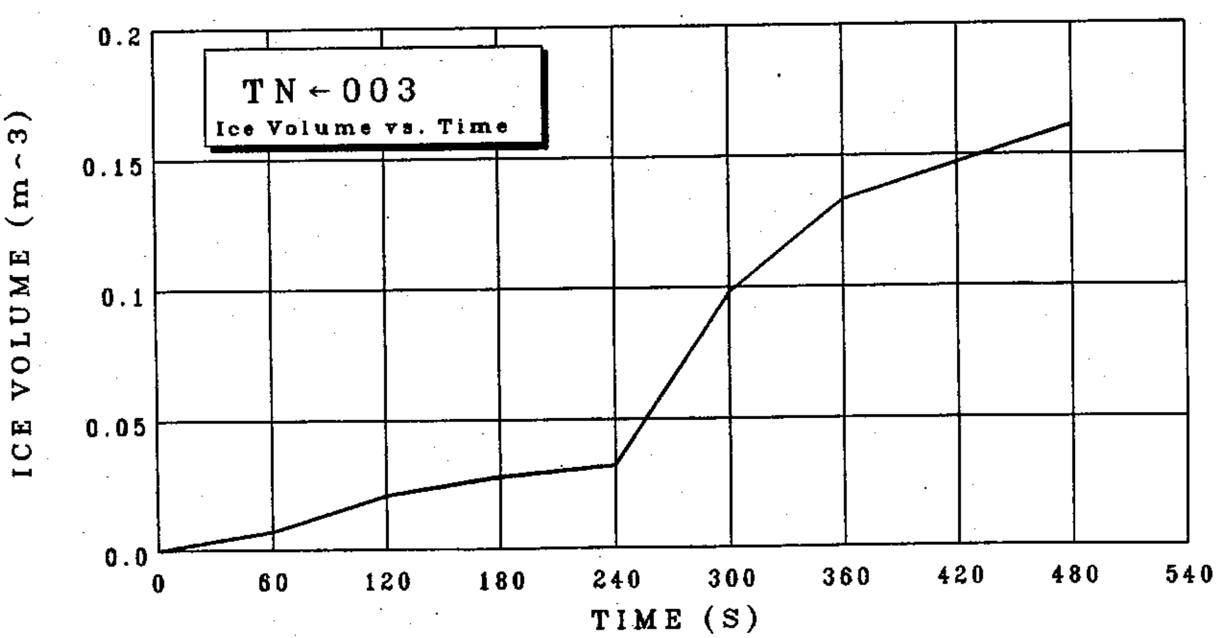
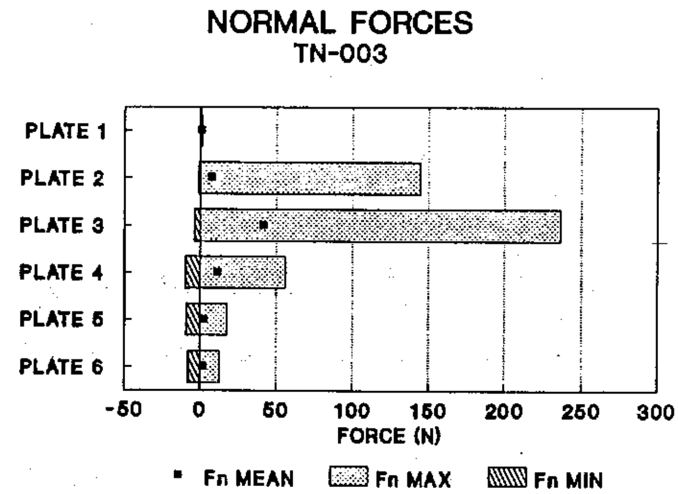
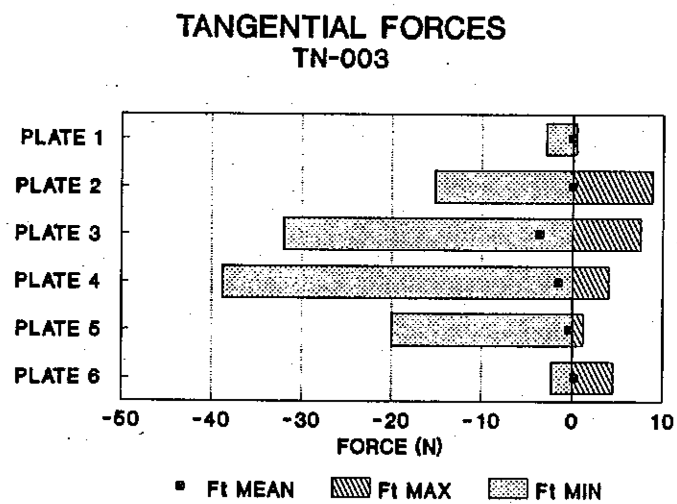
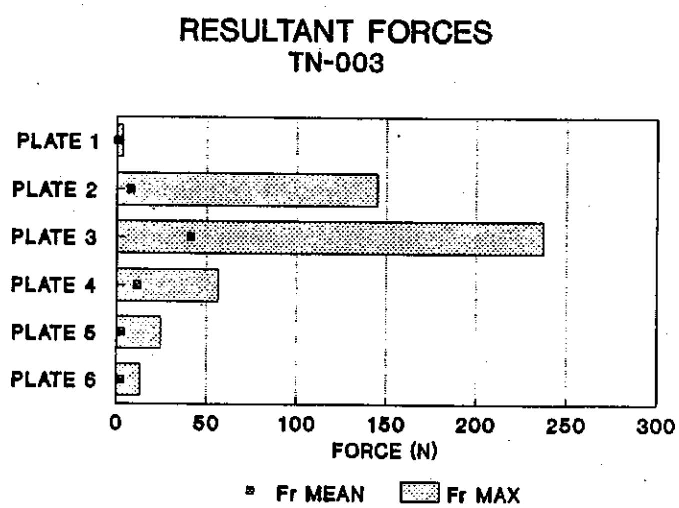
ICE PILEUP STUDY
for CANADIAN COAST GUARD

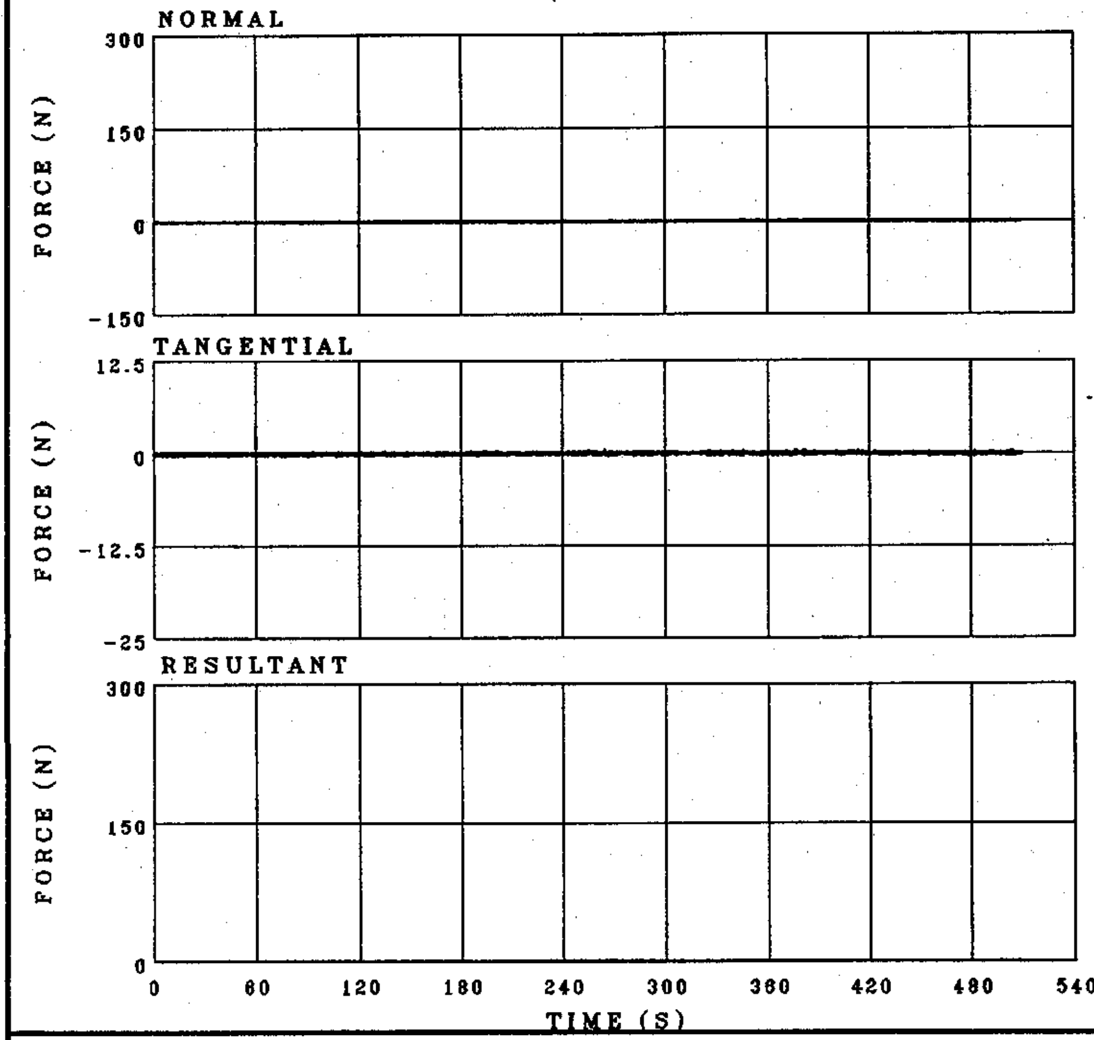

1
2 3
4
6,7
5
8
1,2
3,4
5
6,7,8
10 X 10 CM
TIME IN MINUTES


TN←003
Ice Volume vs. Time
ICE VOLUME (m^3)
0.2
0.15
0.1
0.05
0.0
0
60
120
180
240
300
360
420
480
540
TIME (S)


NORMAL FORCES
TN-003
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-50
0
50
100
150
200
250
300
FORCE (N)
Fn MEAN
Fn MAX
Fn MIN


TANGENTIAL FORCES
TN-003
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-50
-40
-30
-20
-10
0
10
FORCE (N)
Ft MEAN
Ft MAX
Ft MIN


RESULTANT FORCES
TN-003
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
0
50
100
150
200
250
300
FORCE (N)
Fr MEAN
Fr MAX



FILE TN←004

PLATE #1

NORMAL

MEAN FORCE = 0.06562 N
MAX FORCE = 0.7857 N
MIN FORCE = −0.6572 N

TANGENTIAL

MEAN FORCE = 0.006219 N
MAX FORCE = 0.3411 N
MIN FORCE = −0.2873 N

RESULTANT

MEAN FORCE = 0.2026 N
MAX FORCE = 0.7869 N
MIN FORCE = 0.06091 N
AVERAGE ANGLE = −7.166 0

TEST CONDITIONS

BOARD ANGLE = −15.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 70.00 kPa
ICE THICKNESS = 3.500 cm
ICE DENSITY = 0.9300 g/cc

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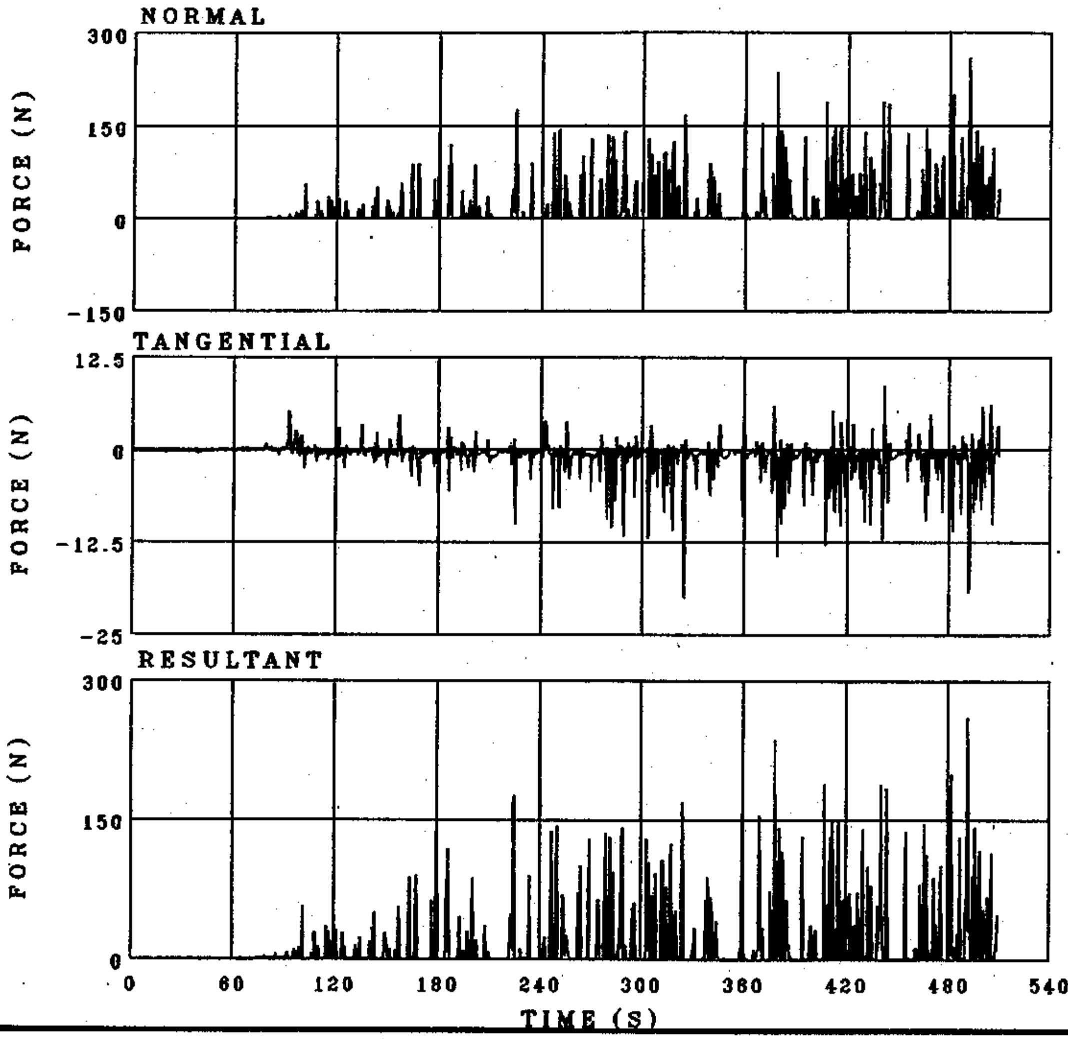
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN-004

PLATE #2

NORMAL

MEAN FORCE = 8.461 N
MAX FORCE = 259.8 N
MIN FORCE = -1.995 N

TANGENTIAL

MEAN FORCE = -0.7568 N
MAX FORCE = 8.671 N
MIN FORCE = -20.10 N

RESULTANT

MEAN FORCE = 9.049 N
MAX FORCE = 260.3 N
MIN FORCE = 0.06676 N
AVERAGE ANGLE = -45.43 O

TEST CONDITIONS

BOARD ANGLE = -15.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 70.00 kPa
ICE THICKNESS = 3.500 cm
ICE DENSITY = 0.9300 g/cc

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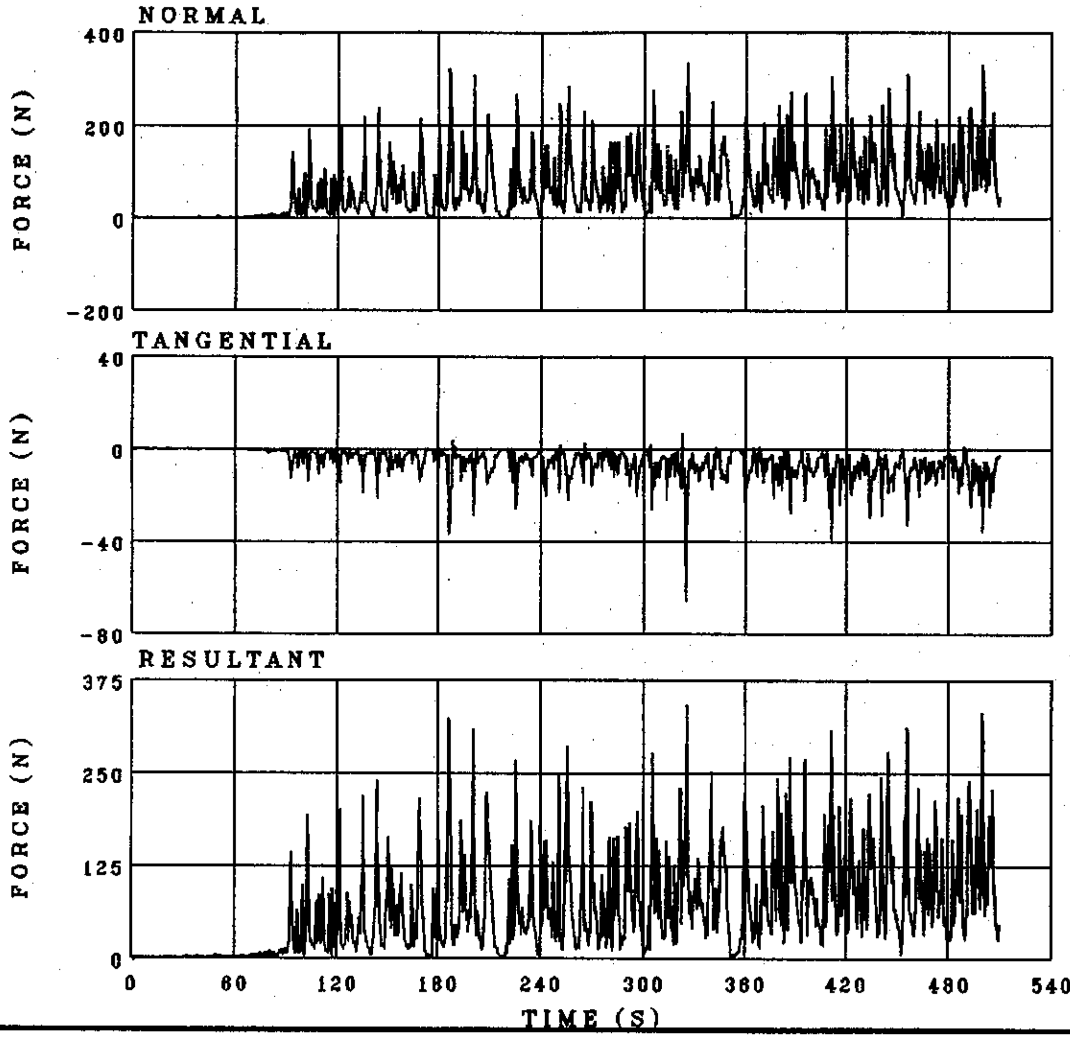
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←004

PLATE #3

NORMAL

MEAN FORCE = 63.32 N
MAX FORCE = 335.7 N
MIN FORCE = -4.530 N

TANGENTIAL

MEAN FORCE = -5.496 N
MAX FORCE = 7.149 N
MIN FORCE = -65.88 N

RESULTANT

MEAN FORCE - 63.64 N
MAX FORCE - 341.8 N
MIN FORCE - 0.06628 N
AVERAGE ANGLE - -5.862 O

TEST CONDITIONS

BOARD ANGLE - -15.00 D
BOARD TYPE - LOW F PAINT
FLEX STRENGTH - 70.00 kPa
ICE THICKNESS = 3.500 cm
ICE DENSITY - 0.9300 g/cc

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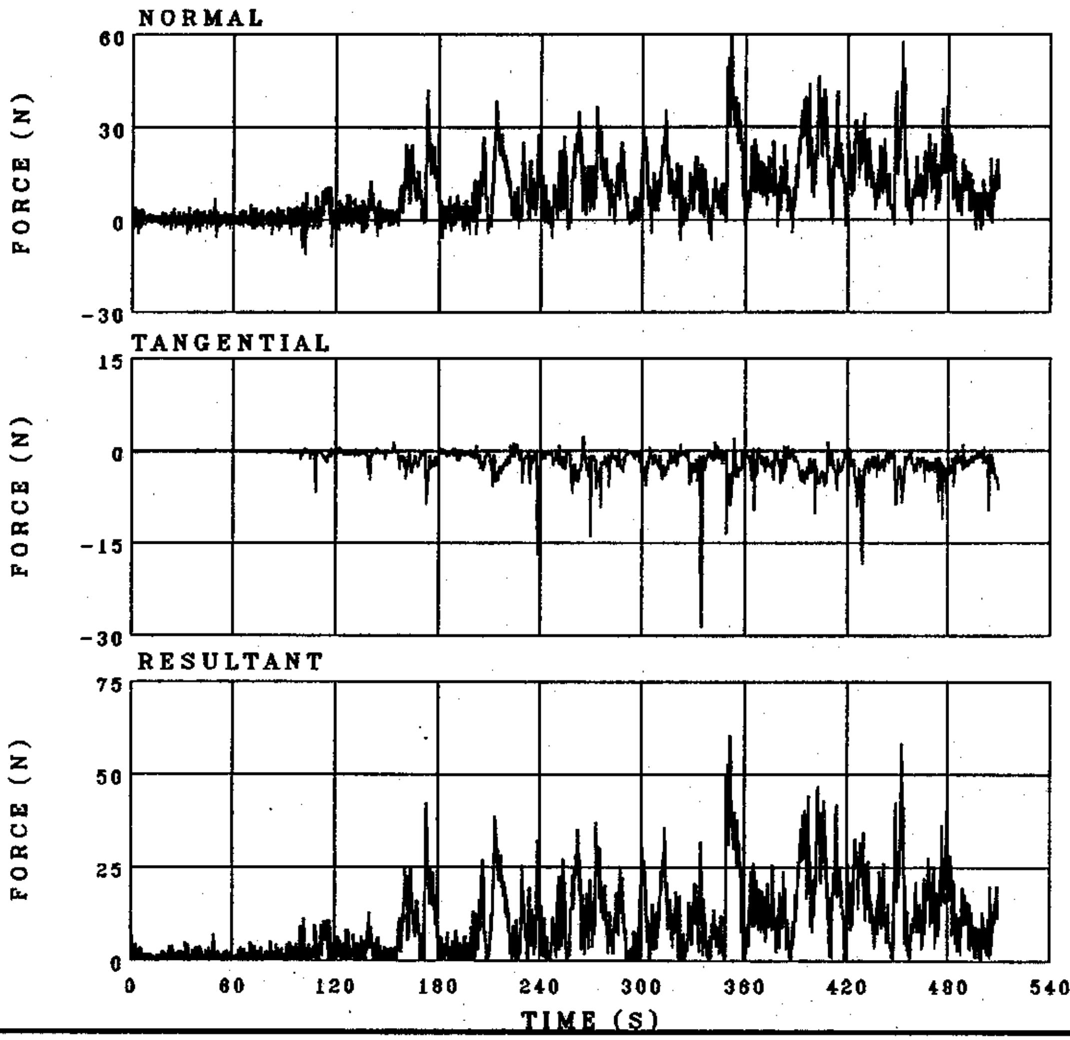
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←004

PLATE #4

NORMAL

MEAN FORCE = 9.061 N
MAX FORCE = 59.88 N
MIN FORCE = -11.29 N

TANGENTIAL

MEAN FORCE = -1.488 N
MAX FORCE = 2.427 N
MIN FORCE = -28.59 N

RESULTANT

MEAN FORCE = 9.561 N
MAX FORCE = 60.54 N
MIN FORCE = 0.05887 N
AVERAGE ANGLE = -9.837 O

TEST CONDITIONS

BOARD ANGLE = -15.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 70.00 kPa
ICE THICKNESS = 3.500 cm
ICE DENSITY = 0.9300 g/cc

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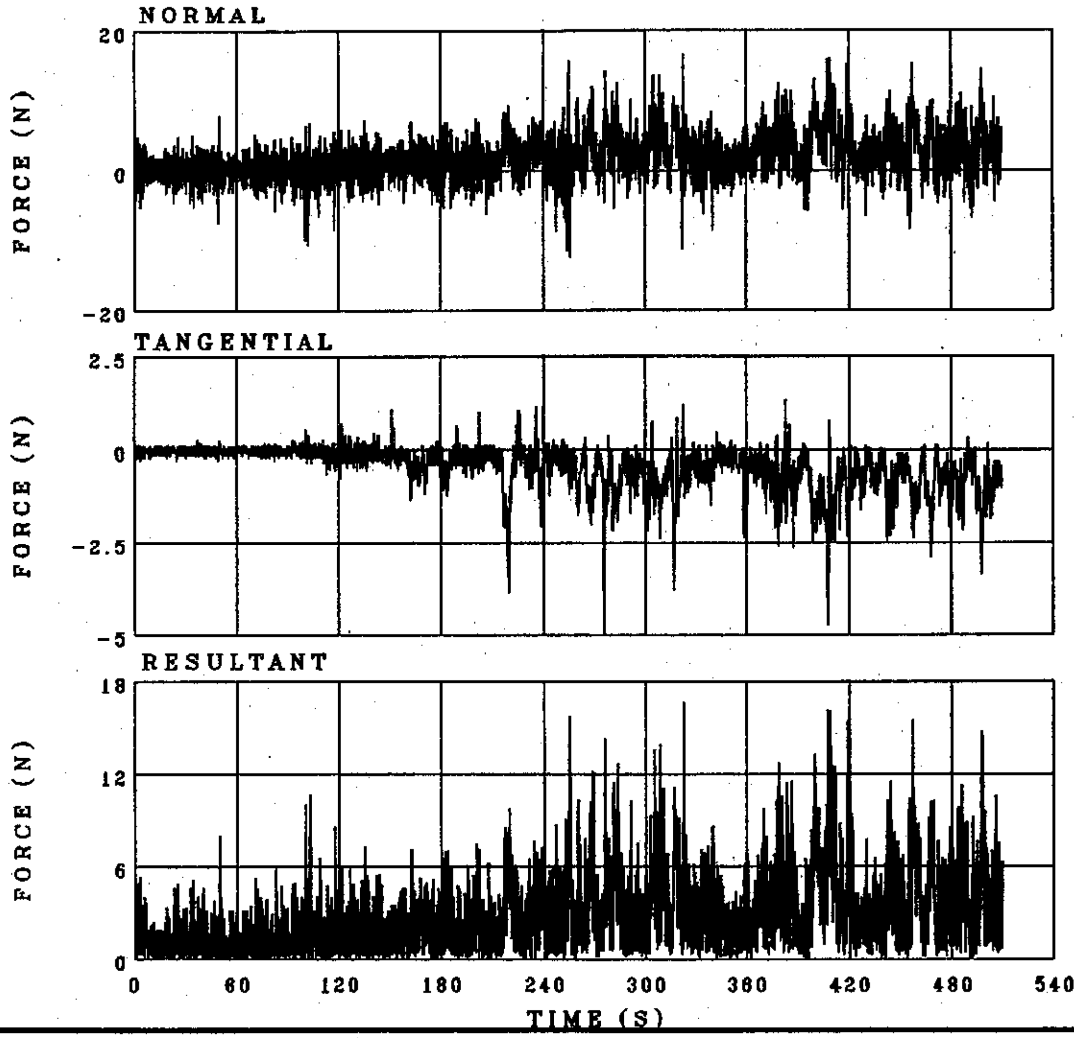
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←004

PLATE #5

NORMAL

MEAN FORCE = 1.917 N
MAX FORCE = 16.65 N
MIN FORCE = -12.54 N

TANGENTIAL

MEAN FORCE = -0.4925 N
MAX FORCE = 1.325 N
MIN FORCE = -4.976 N

RESULTANT

MEAN FORCE = 2.718 N
MAX FORCE = 16.66 N
MIN FORCE = 0.01735 N
AVERAGE ANGLE = -29.59 O

TEST CONDITIONS

BOARD ANGLE = -15.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 70.00 kPa
ICE THICKNESS = 3.500 cm
ICE DENSITY = 0.9300 g/cc

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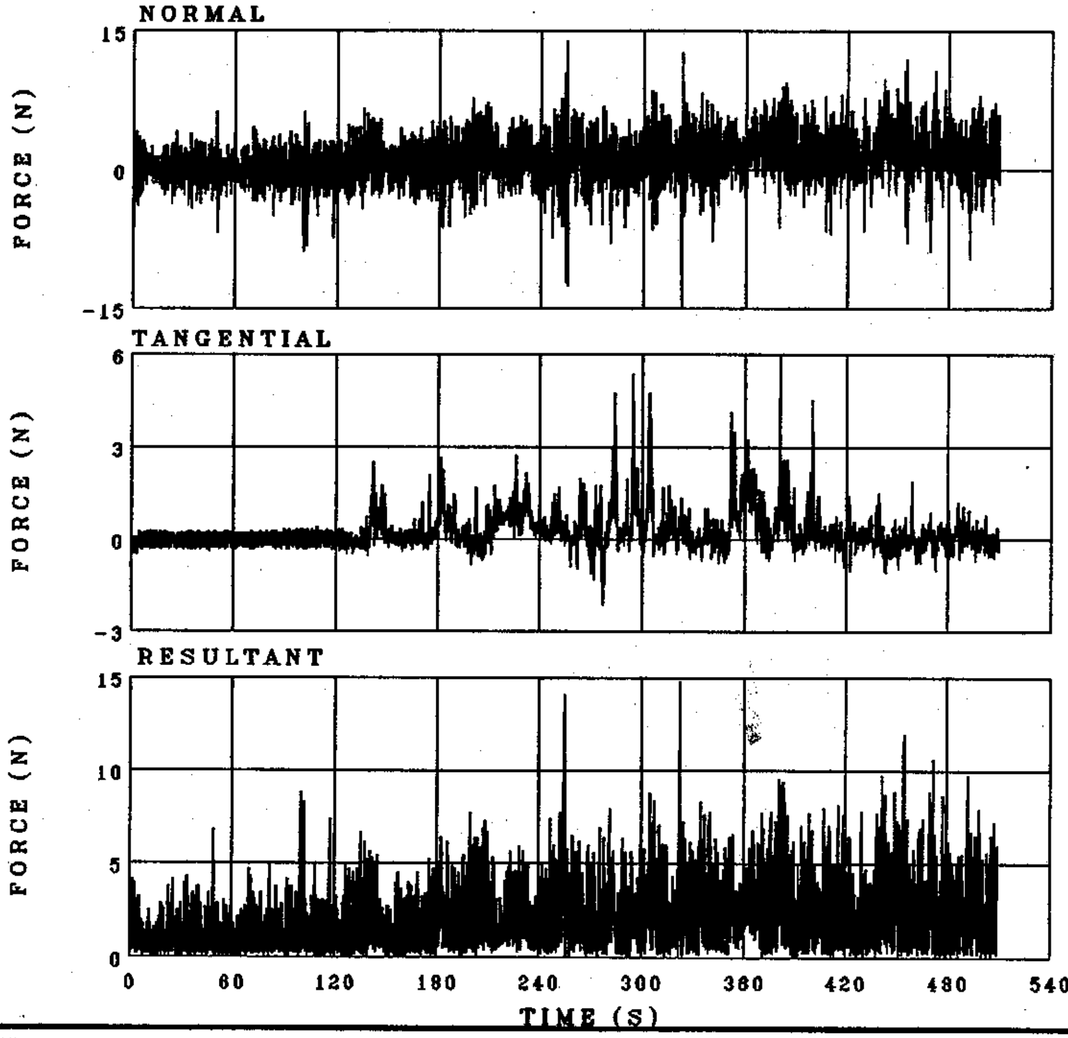
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←004

PLATE #6

NORMAL

MEAN FORCE = 1.092 N
MAX FORCE = 14.09 N
MIN FORCE = -14.83 N

TANGENTIAL

MEAN FORCE = 0.2032 N
MAX FORCE = 5.972 N
MIN FORCE = -2.172 N

RESULTANT

MEAN FORCE = 1.958 N
MAX FORCE = 14.83 N
MIN FORCE = 0.01376 N
AVERAGE ANGLE = 7.677 O

TEST CONDITIONS

BOARD ANGLE = -15.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 70.00 kPa
ICE THICKNESS = 3.500 cm
ICE DENSITY = 0.9300 g/cc

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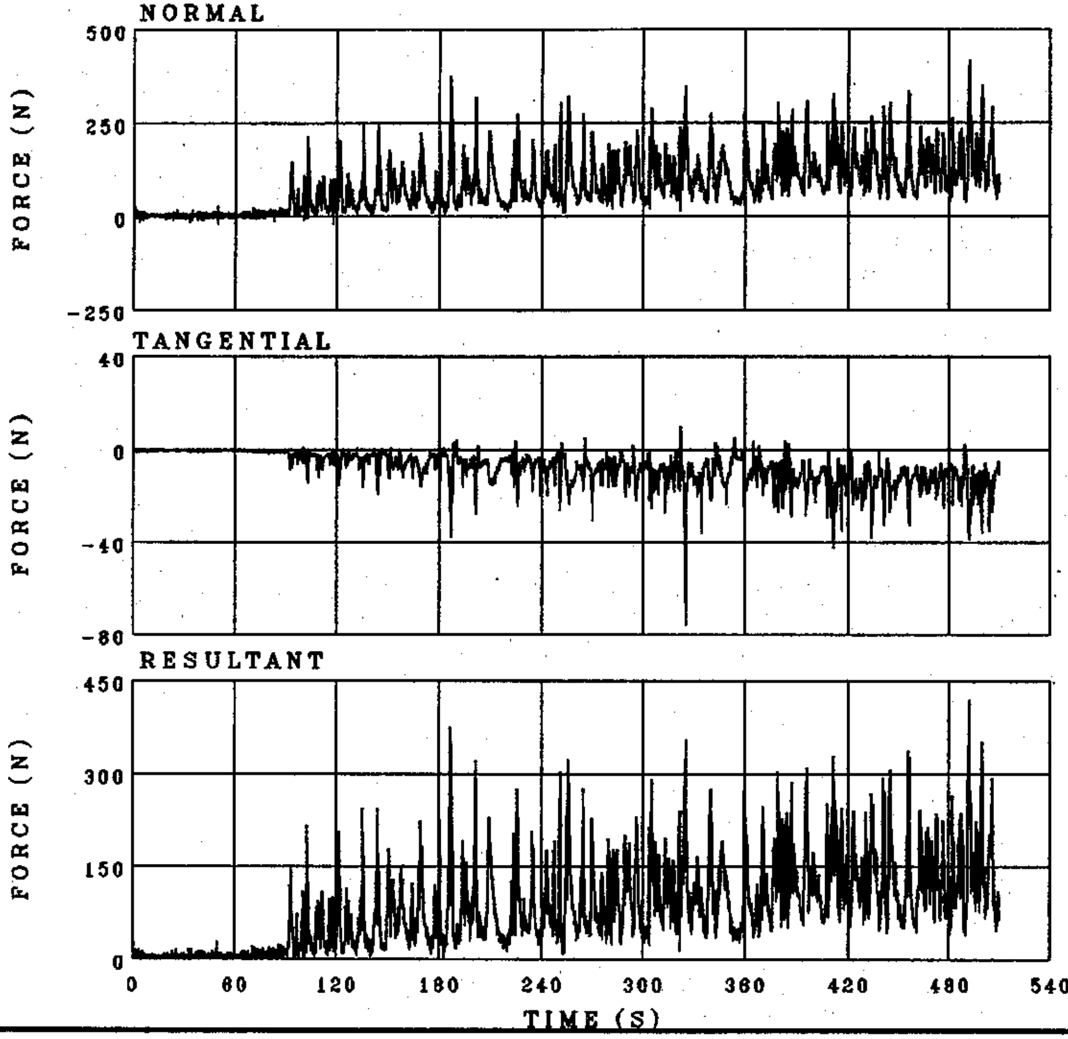
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←004

TOTAL

NORMAL

MEAN FORCE = 83.92 N
MAX FORCE = 418.9 N
MIN FORCE = -23.55 N

TANGENTIAL

MEAN FORCE = -8.024 N
MAX FORCE = 9.794 N
MIN FORCE = -76.18 N

RESULTANT

MEAN FORCE = 84.81 N
MAX FORCE = 420.6 N
MIN FORCE = 0.09283 N
AVERAGE ANGLE = -10.52 O

TEST CONDITIONS

BOARD ANGLE = -15.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 70.00 kPa
ICE THICKNESS = 3.500 cm
ICE DENSITY = 0.9300 g/cc

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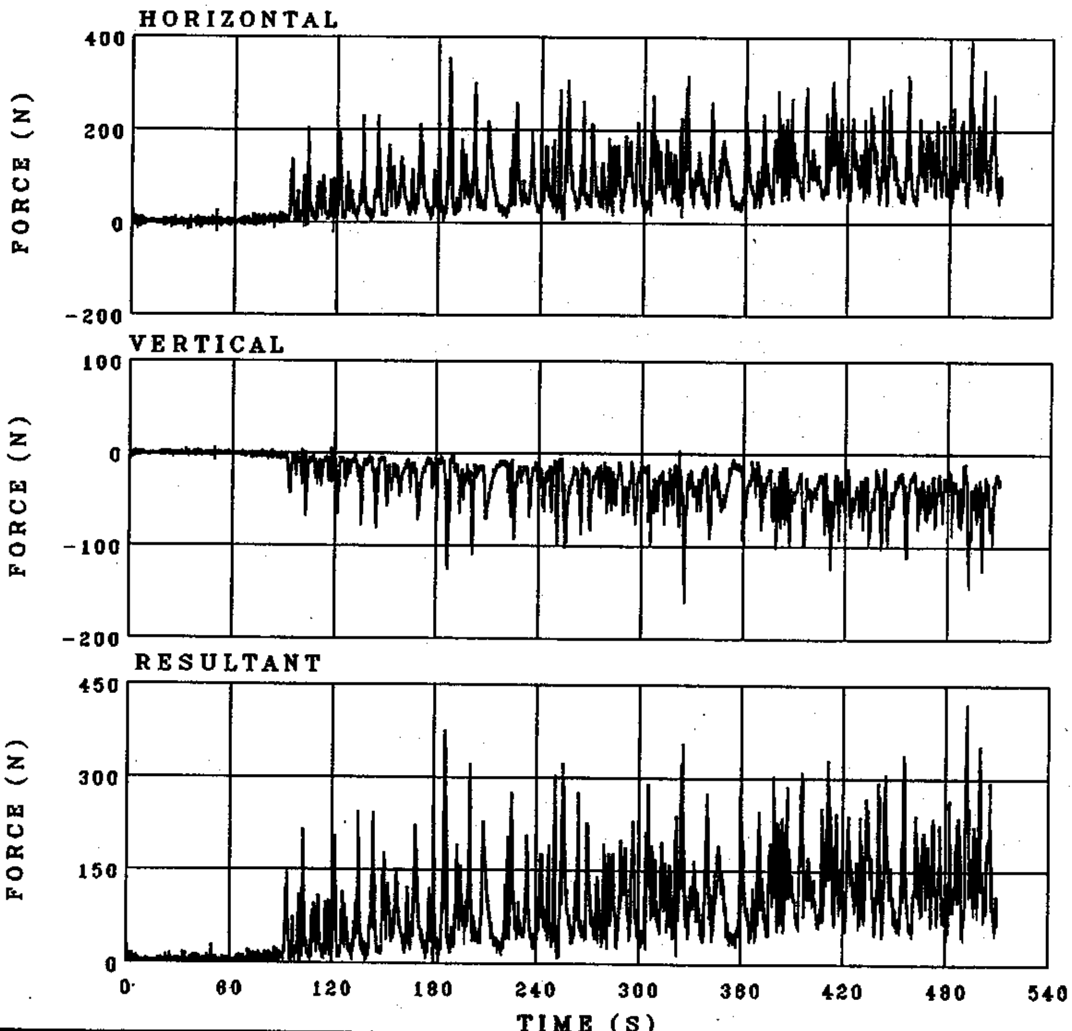
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←004

TOTAL

HORIZONTAL

MEAN FORCE = -8.024 N
MAX FORCE = 9.794 N
MIN FORCE = -76.18 N

VERTICAL

MEAN FORCE = -8.024 N
MAX FORCE = 9.794 N
MIN FORCE = -76.18 N

RESULTANT

MEAN FORCE = -8.024 N
MAX FORCE = 9.794 N
MIN FORCE = -76.18 N
AVERAGE ANGLE = -8.024 O

TEST CONDITIONS

BOARD ANGLE = -15.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 70.00 kPa
ICE THICKNESS = 3.500 cm
ICE DENSITY = 0.9300 g/cc

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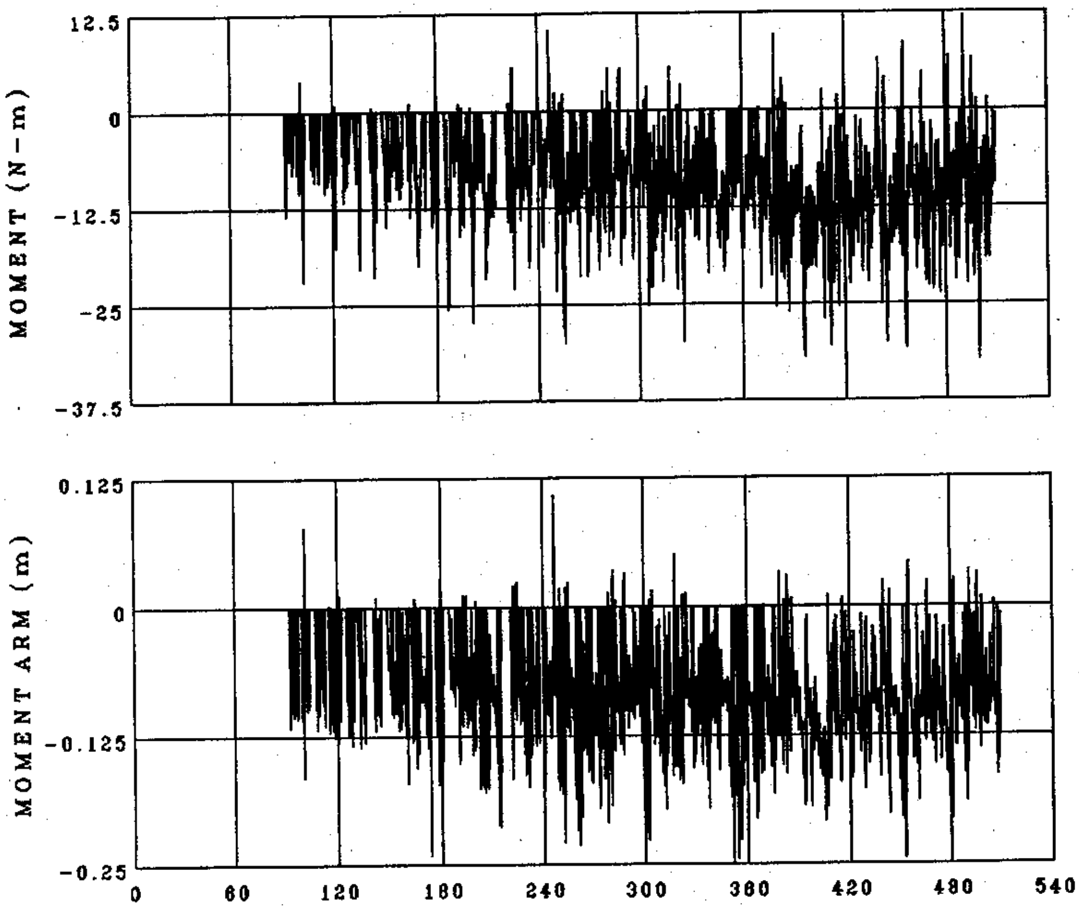
ICE PILEUP STUDY
for CANADIAN COAST GUARD

FILE TN←004



MOMENT

MOMENT

MEAN MOMENT = -6.560 N-m
MAX MOMENT = 12.09 N-m
MIN MOMENT = -32.47 N-m

MOMENT ARM

MEAN ARM = -0.05886 m
MAX ARM = 0.1085 m
MIN ARM = -0.2487 m

TEST CONDITIONS

BOARD ANGLE = -15.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 70.00 kPa
ICE THICKNESS = 3.500 cm
ICE DENSITY = 0.9300 g/cc

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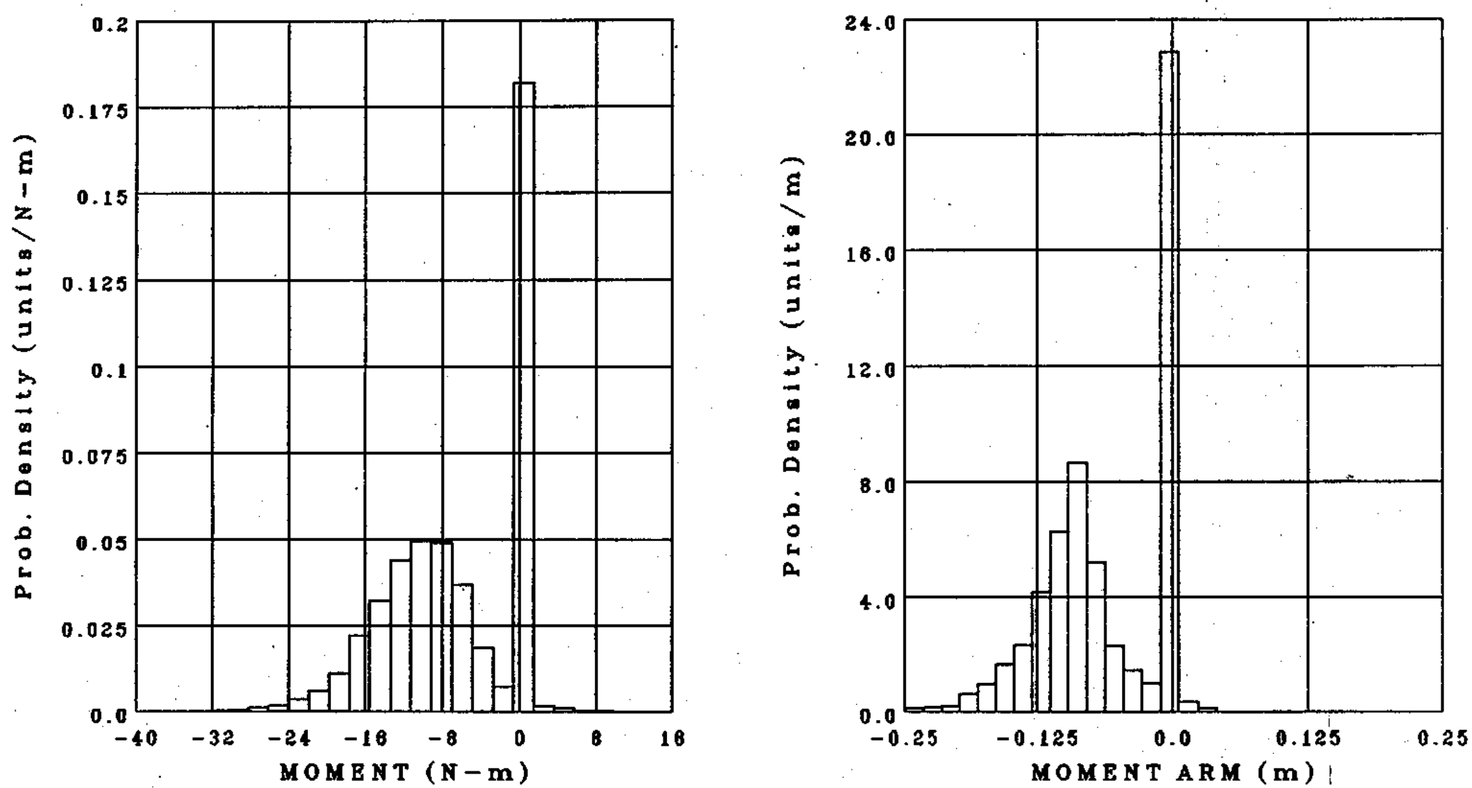
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←004



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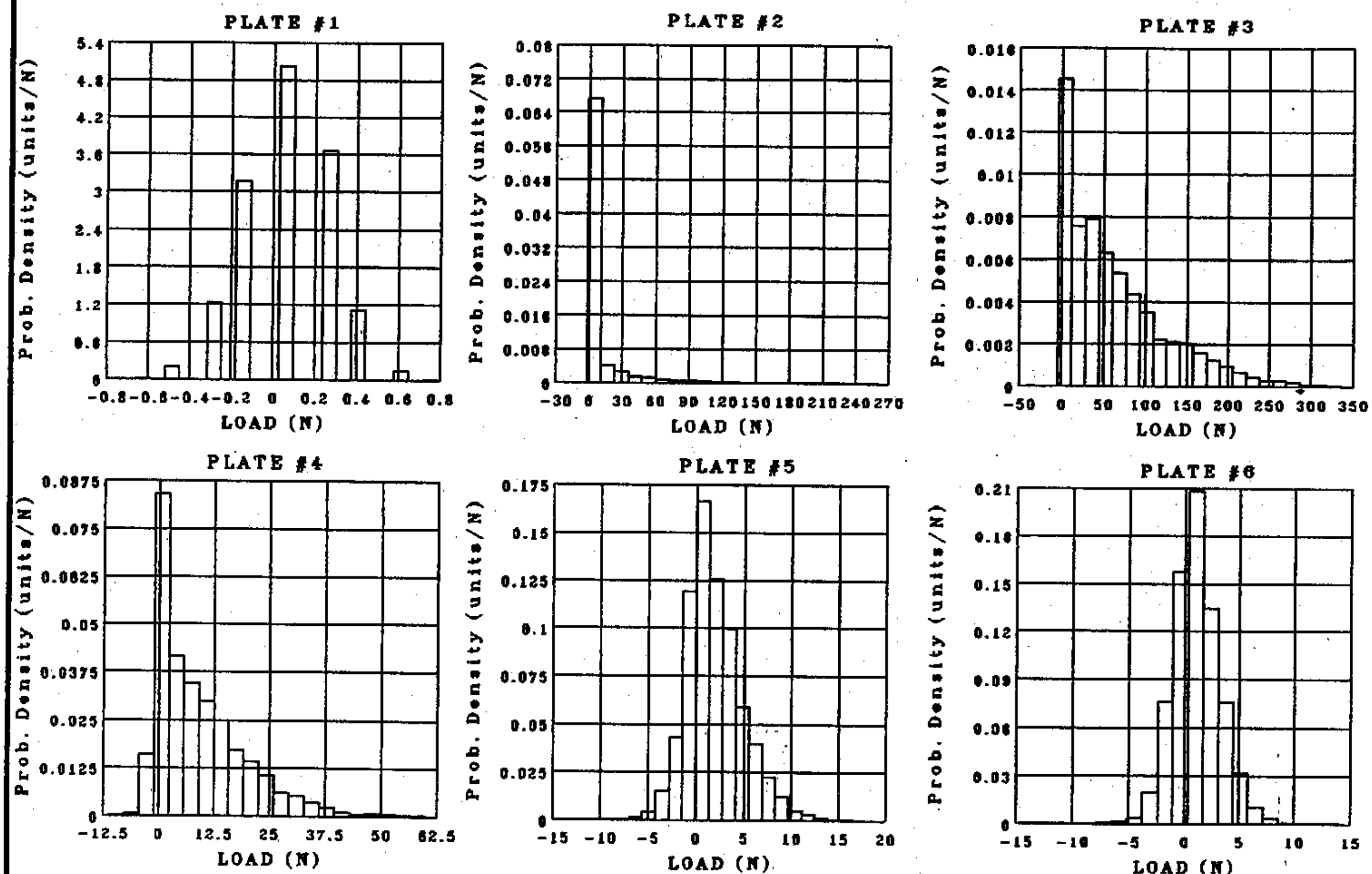
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←004
NORMAL LOAD



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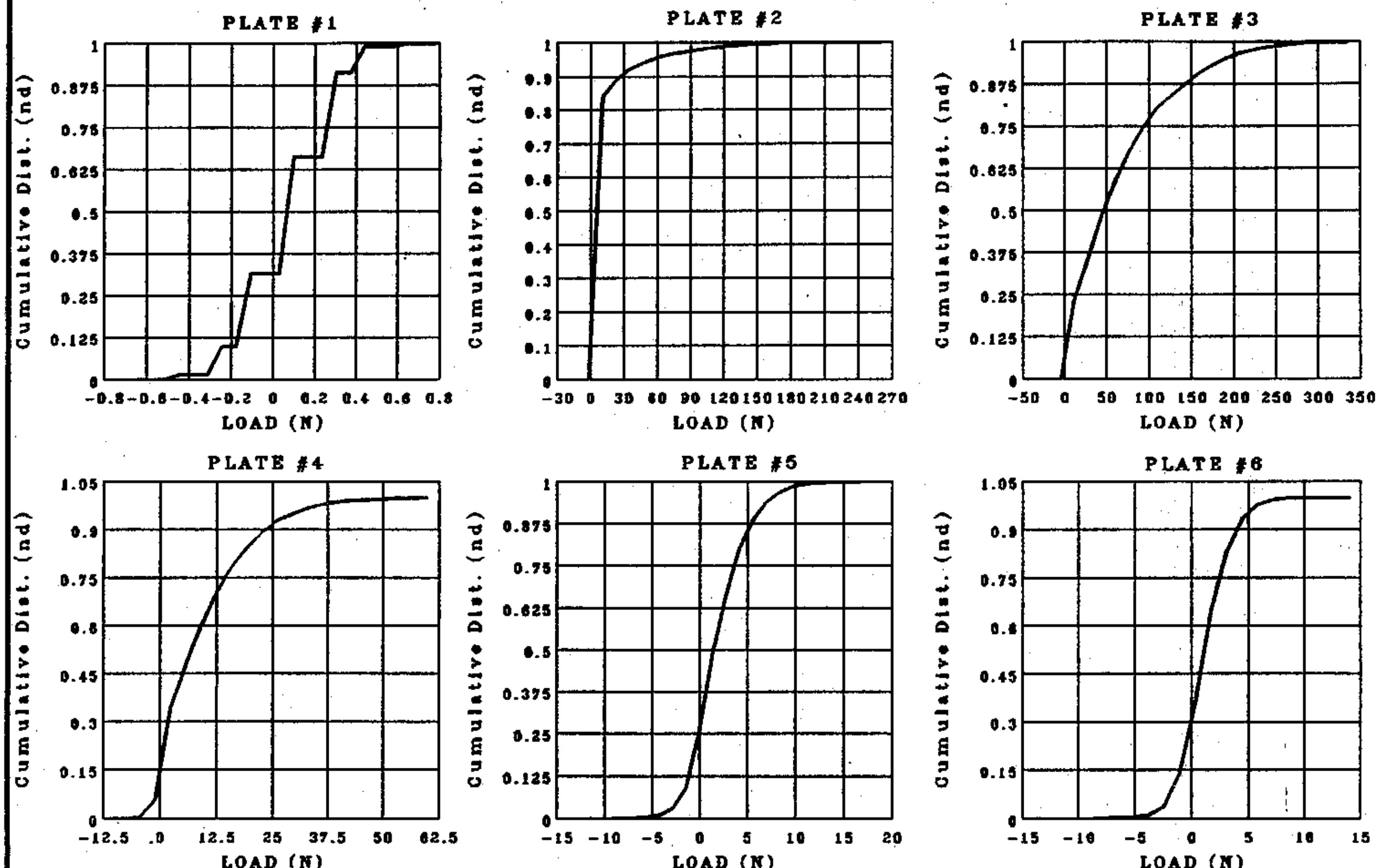
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←004
NORMAL LOAD



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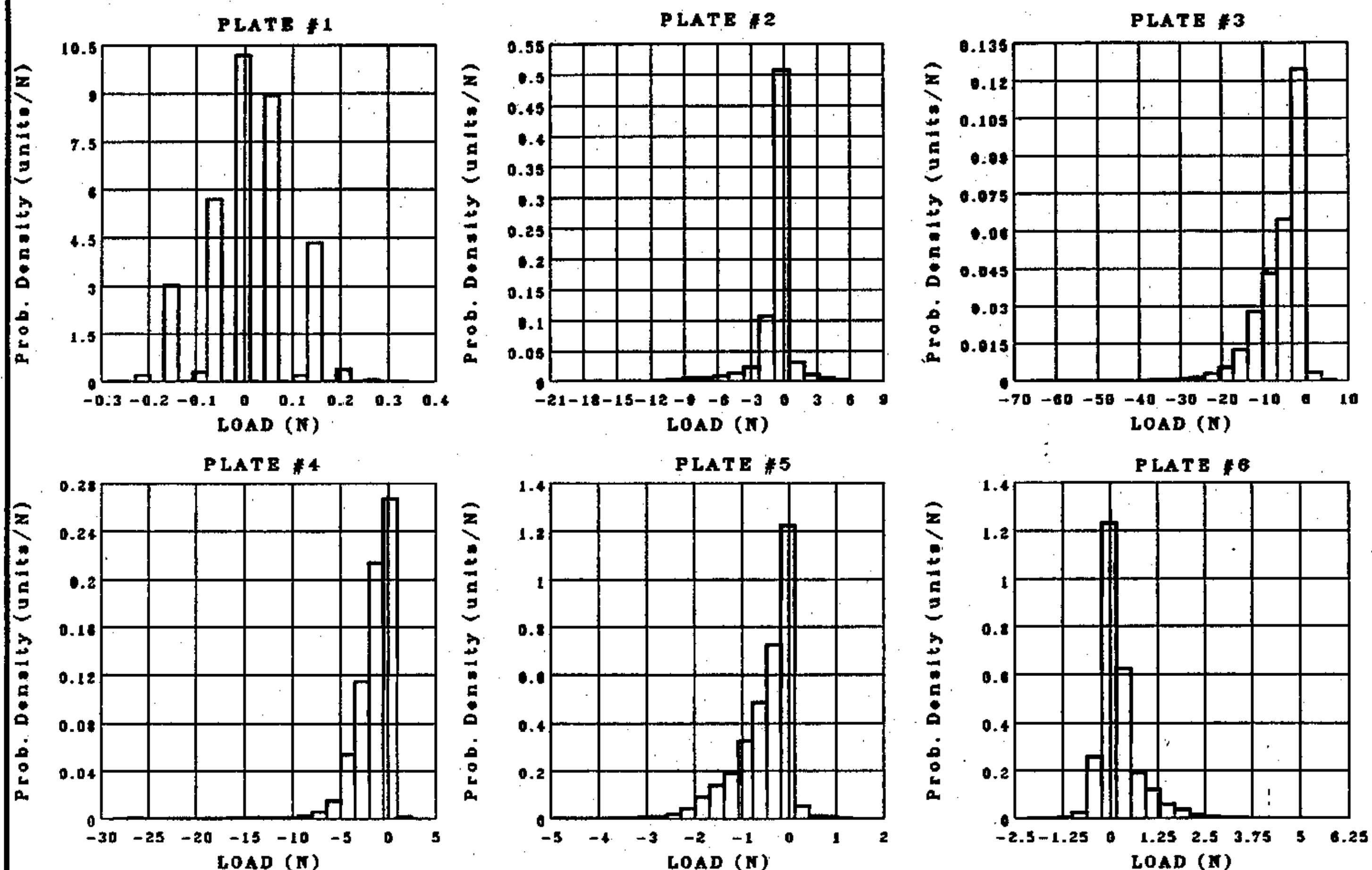
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←004
TANGENTIAL LOAD



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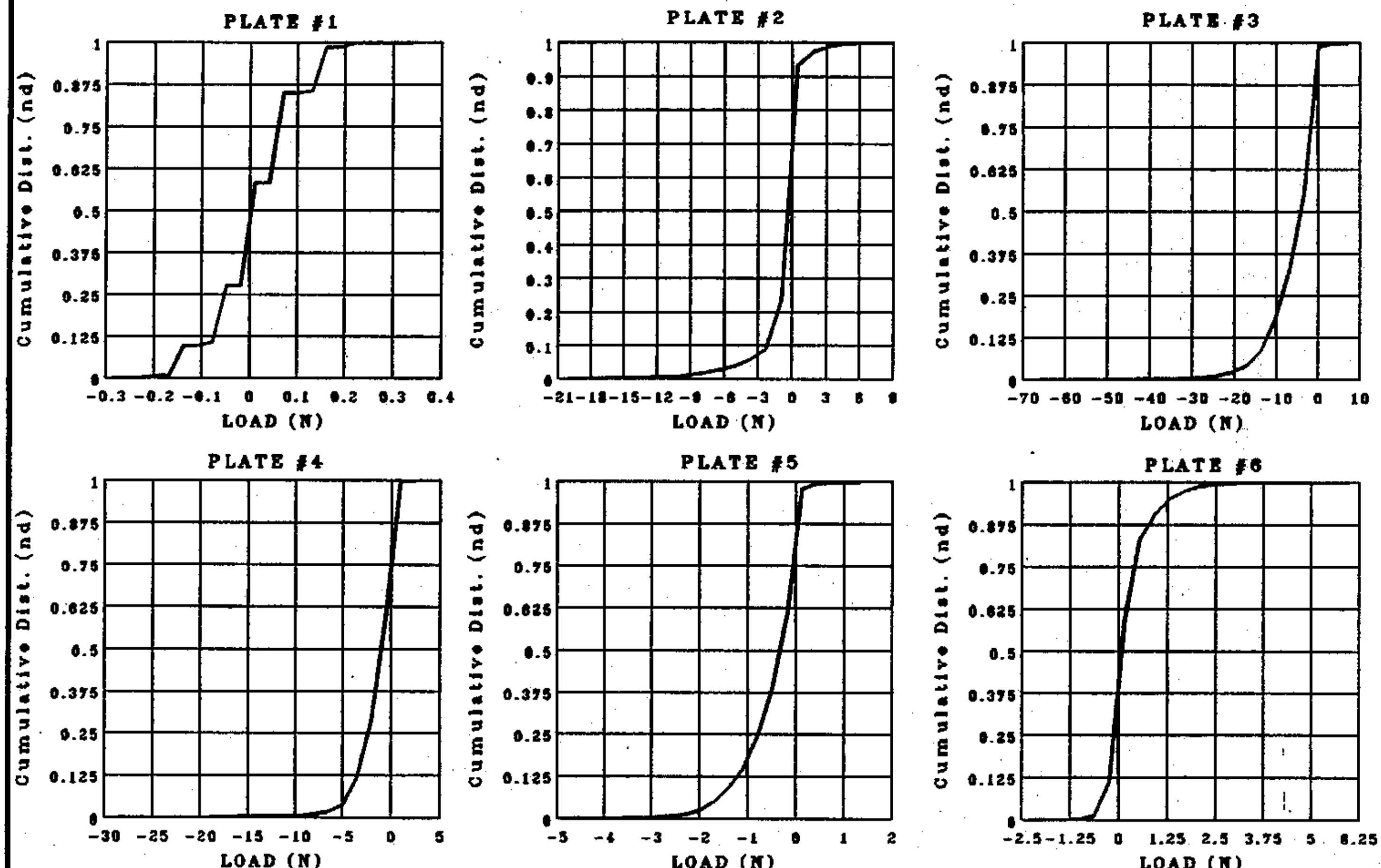
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN ← 004
TANGENTIAL LOAD



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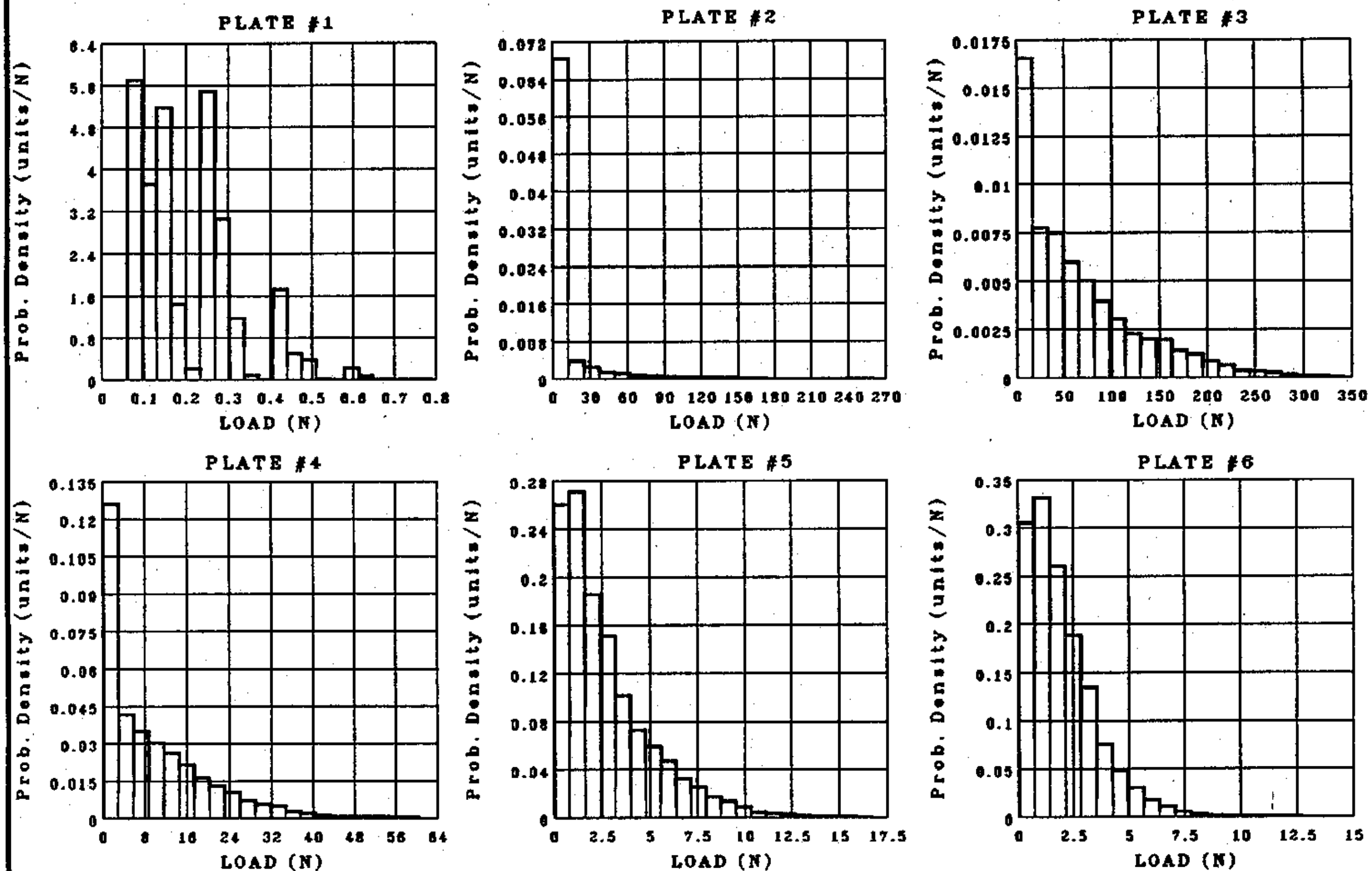
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←004
RESULTANT



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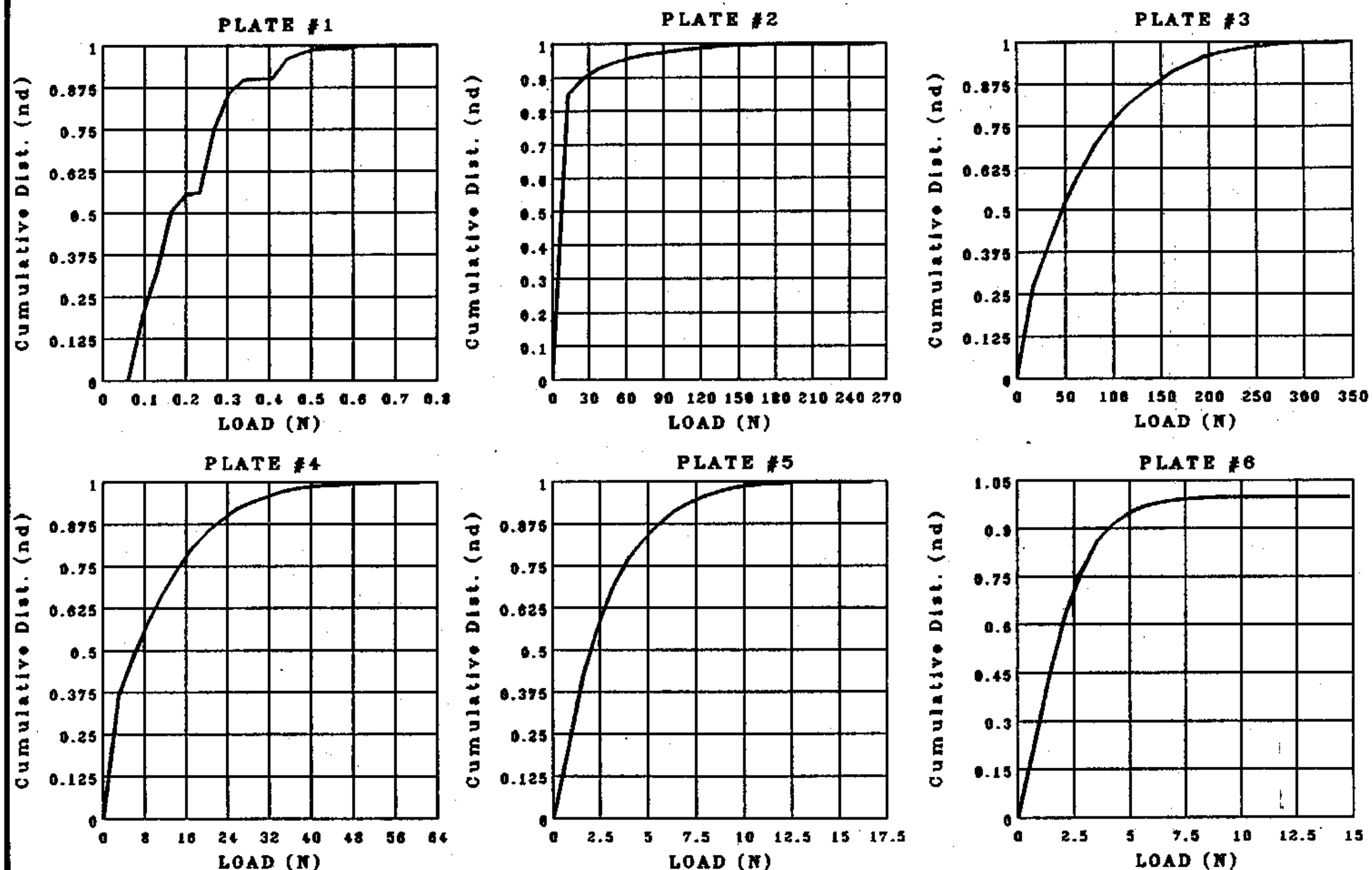
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN ← 004
RESULTANT



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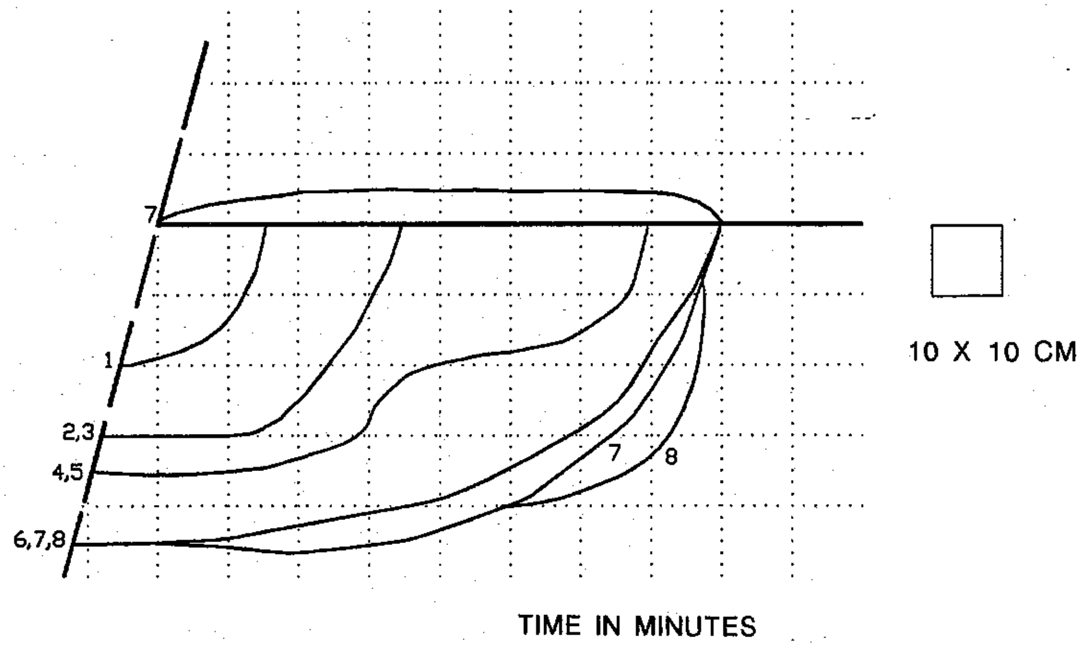
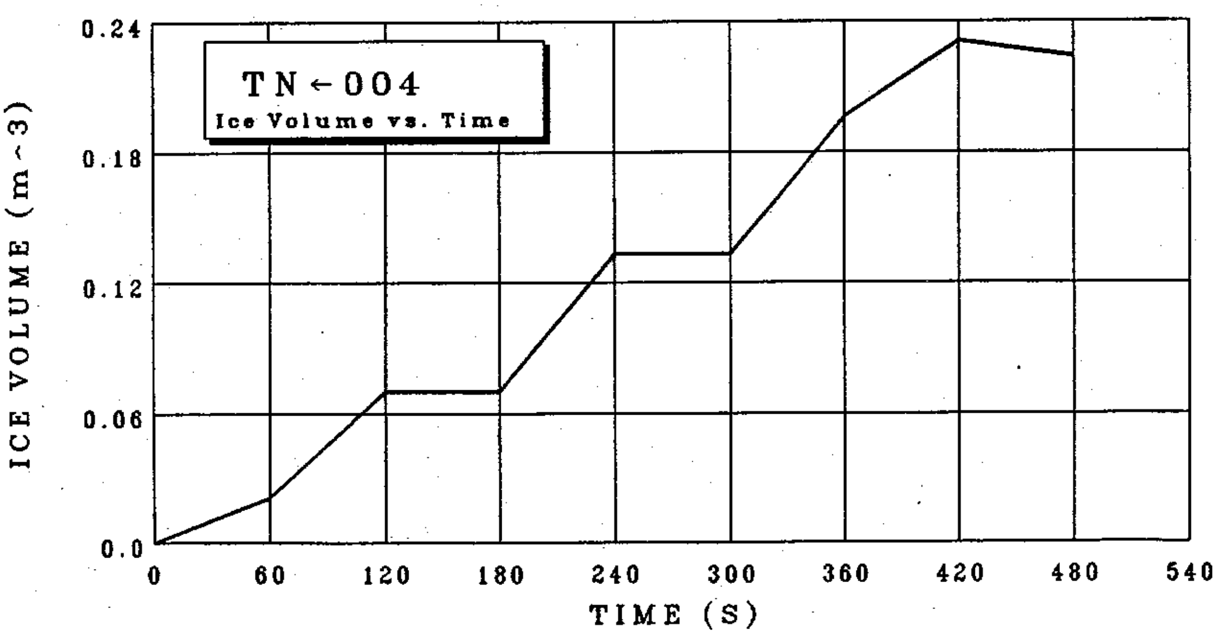
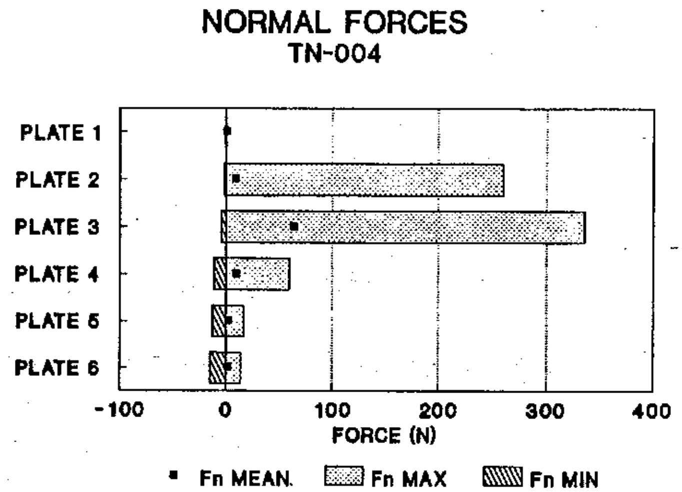
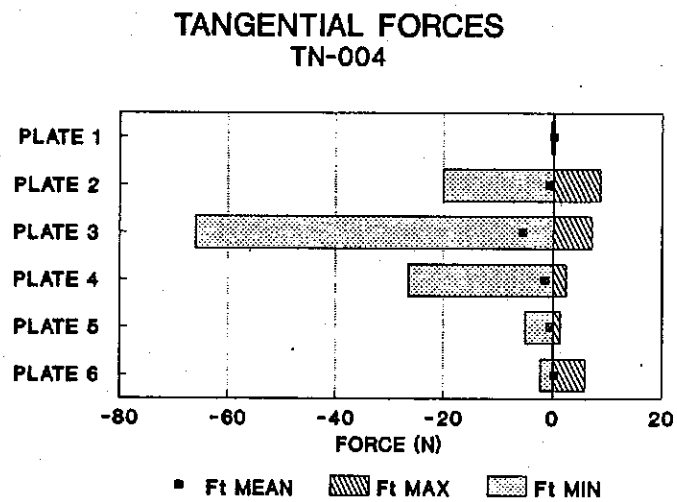
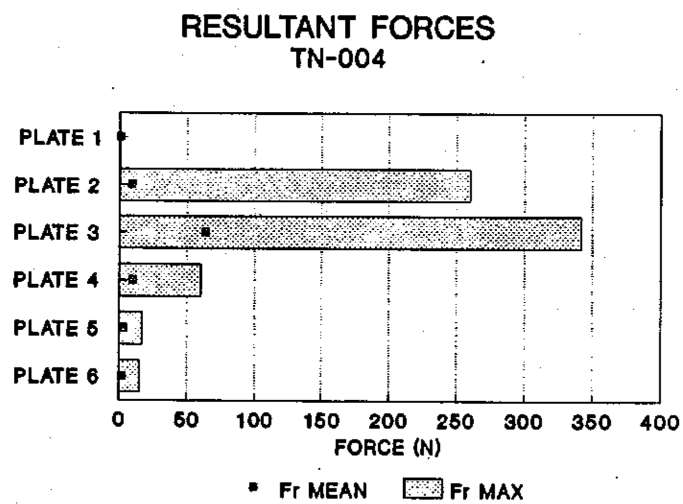
ICE PILEUP STUDY
for CANADIAN COAST GUARD

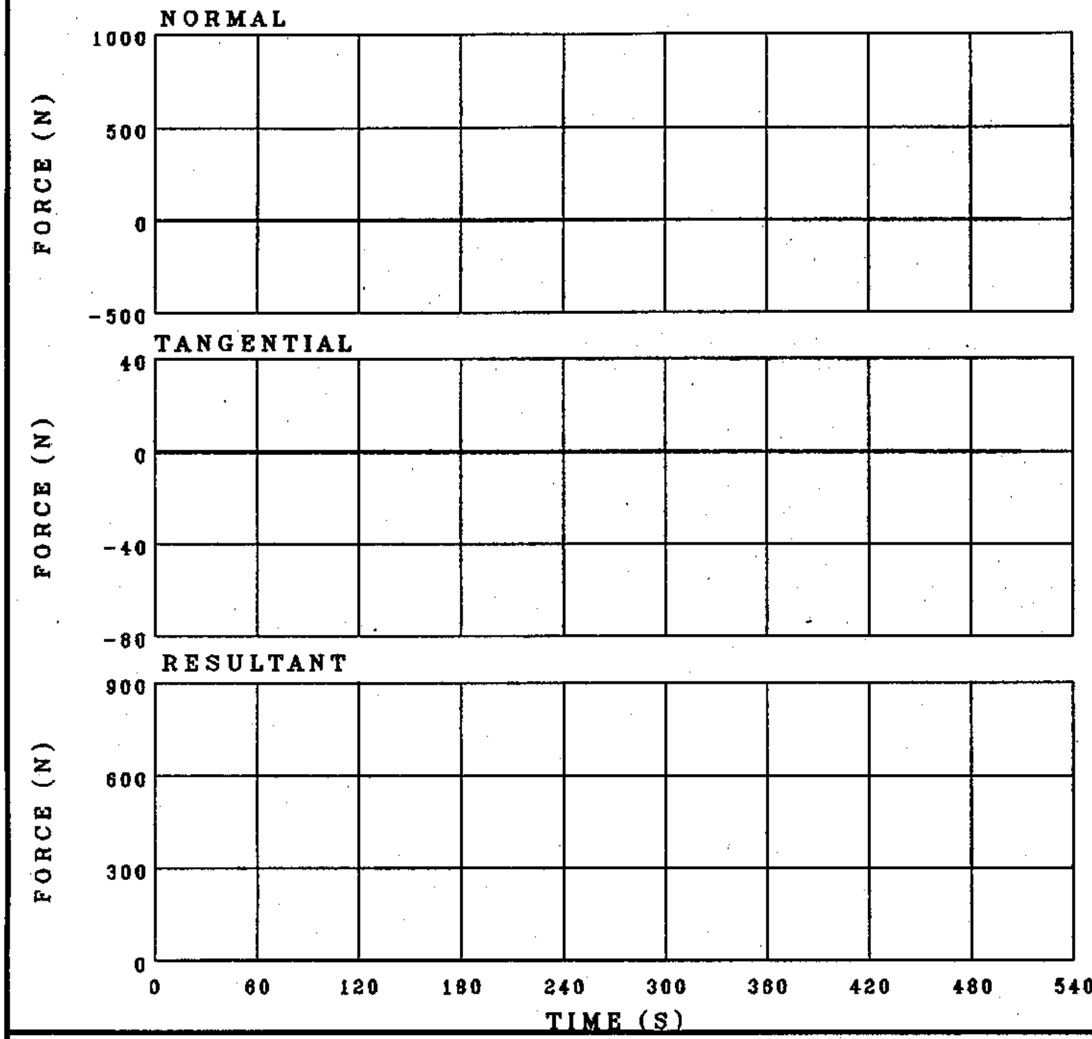

7
1
2,3
4,5
6,7,8
7
8
10 X 10 CM
TIME IN MINUTES


TN ← 004
Ice Volume vs. Time
ICE VOLUME (m ^ 3)
0.0
0.06
0.12
0.18
0.24
0
60
120
180
240
300
360
420
480
540
TIME (S)


NORMAL FORCES
TN-004
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-100
0
100
200
300
400
FORCE (N)
Fn MEAN
Fn MAX
Fn MIN


TANGENTIAL FORCES
TN-004
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-80
-60
-40
-20
0
20
FORCE (N)
Ft MEAN
Ft MAX
Ft MIN


RESULTANT FORCES
TN-004
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
0
50
100
150
200
250
300
350
400
FORCE (N)
Fr MEAN
Fr MAX



FILE TN←005

PLATE #1

NORMAL

MEAN FORCE = -0.09104 N
MAX FORCE = 1.371 N
MIN FORCE = -1.308 N

TANGENTIAL

MEAN FORCE = 0.03793 N
MAX FORCE = 0.4298 N
MIN FORCE = -0.3402 N

RESULTANT

MEAN FORCE = 0.2501 N
MAX FORCE = 1.397 N
MIN FORCE = 0.03693 N
AVERAGE ANGLE = 28.18 O

TEST CONDITIONS

BOARD ANGLE = -5.000 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 86.00 kPa
ICE THICKNESS = 3.300 cm
ICE DENSITY = 0.9300 g/cc

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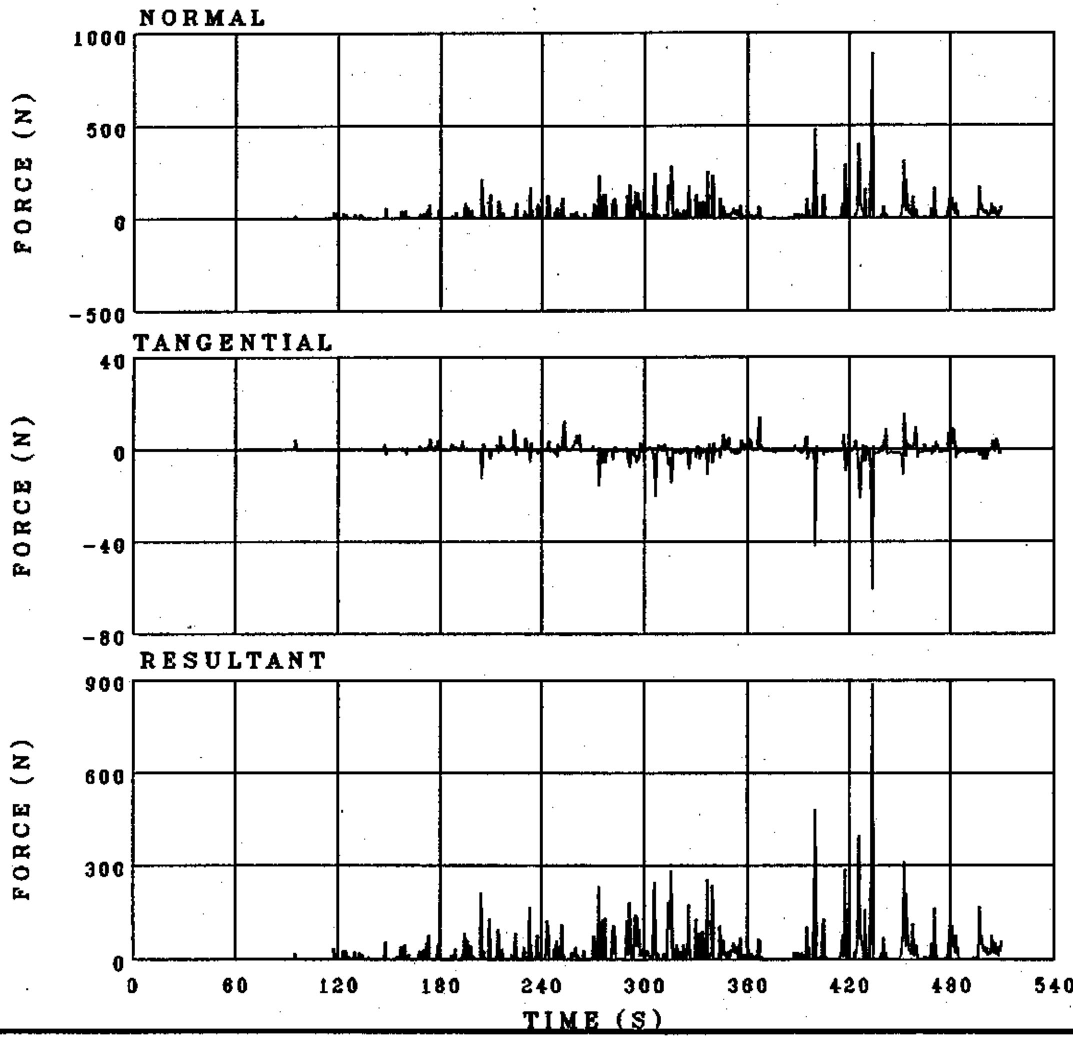
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←005

PLATE #2

NORMAL

MEAN FORCE = 13.50 N
MAX FORCE = 888.5 N
MIN FORCE = -3.606 N

TANGENTIAL

MEAN FORCE = -0.4330 N
MAX FORCE = 15.36 N
MIN FORCE = -60.57 N

RESULTANT

MEAN FORCE = 14.13 N
MAX FORCE = 890.1 N
MIN FORCE = 0.05764 N
AVERAGE ANGLE = -52.71 D

TEST CONDITIONS

BOARD ANGLE = -5.000 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 86.00 kPa
ICE THICKNESS = 3.300 cm
ICE DENSITY = 0.9300 g/cc

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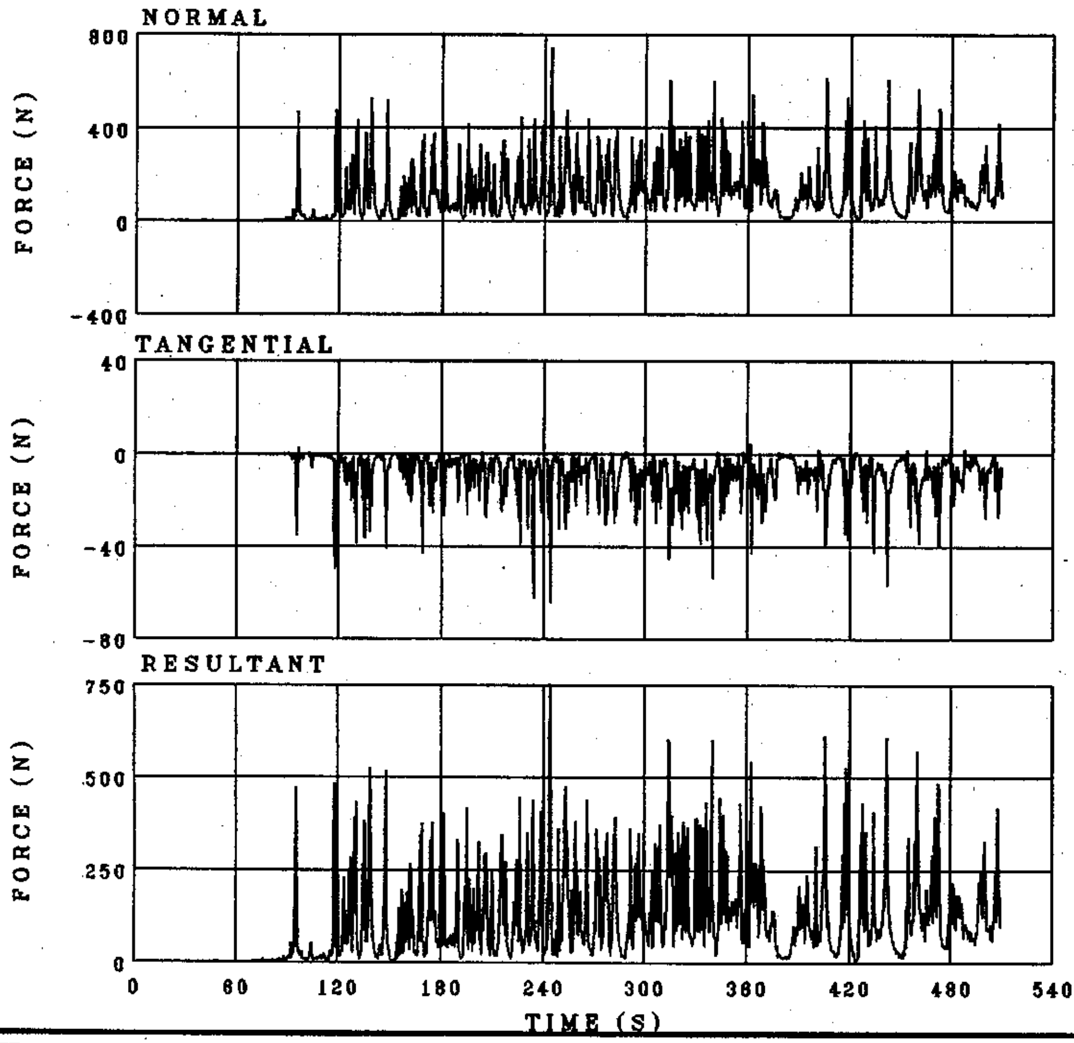
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←005

PLATE #3

NORMAL

MEAN FORCE = 103.7 N
MAX FORCE = 746.0 N
MIN FORCE = −5.515 N

TANGENTIAL

MEAN FORCE = −7.149 N
MAX FORCE = 4.464 N
MIN FORCE = −64.50 N

RESULTANT

MEAN FORCE = 104.0 N
MAX FORCE = 748.8 N
MIN FORCE = 0.03964 N
AVERAGE ANGLE = −2.331 O

TEST CONDITIONS

BOARD ANGLE = −5.000 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 86.00 kPa
ICE THICKNESS = 3.300 cm
ICE DENSITY = 0.9300 g/cc

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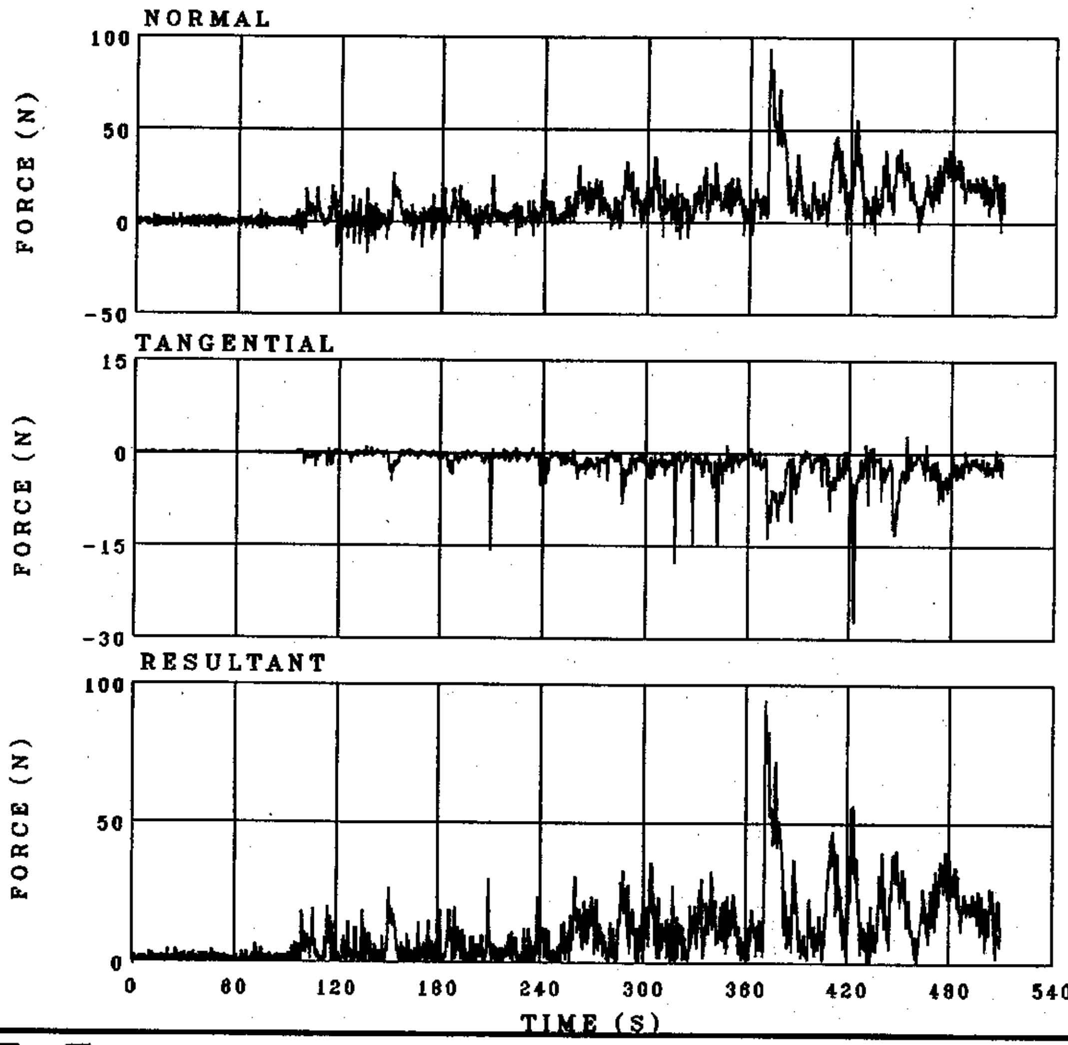
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←005

PLATE #4

NORMAL

MEAN FORCE = 9.250 N
MAX FORCE = 93.83 N
MIN FORCE = -16.87 N

TANGENTIAL

MEAN FORCE = -1.428 N
MAX FORCE = 3.051 N
MIN FORCE = -27.28 N

RESULTANT

MEAN FORCE = 9.940 N
MAX FORCE = 94.51 N
MIN FORCE = 0.02540 N
AVERAGE ANGLE = -7.554 D

TEST CONDITIONS

BOARD ANGLE = -5.000 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 86.00 kPa
ICE THICKNESS = 3.300 cm
ICE DENSITY = 0.9300 g/cc

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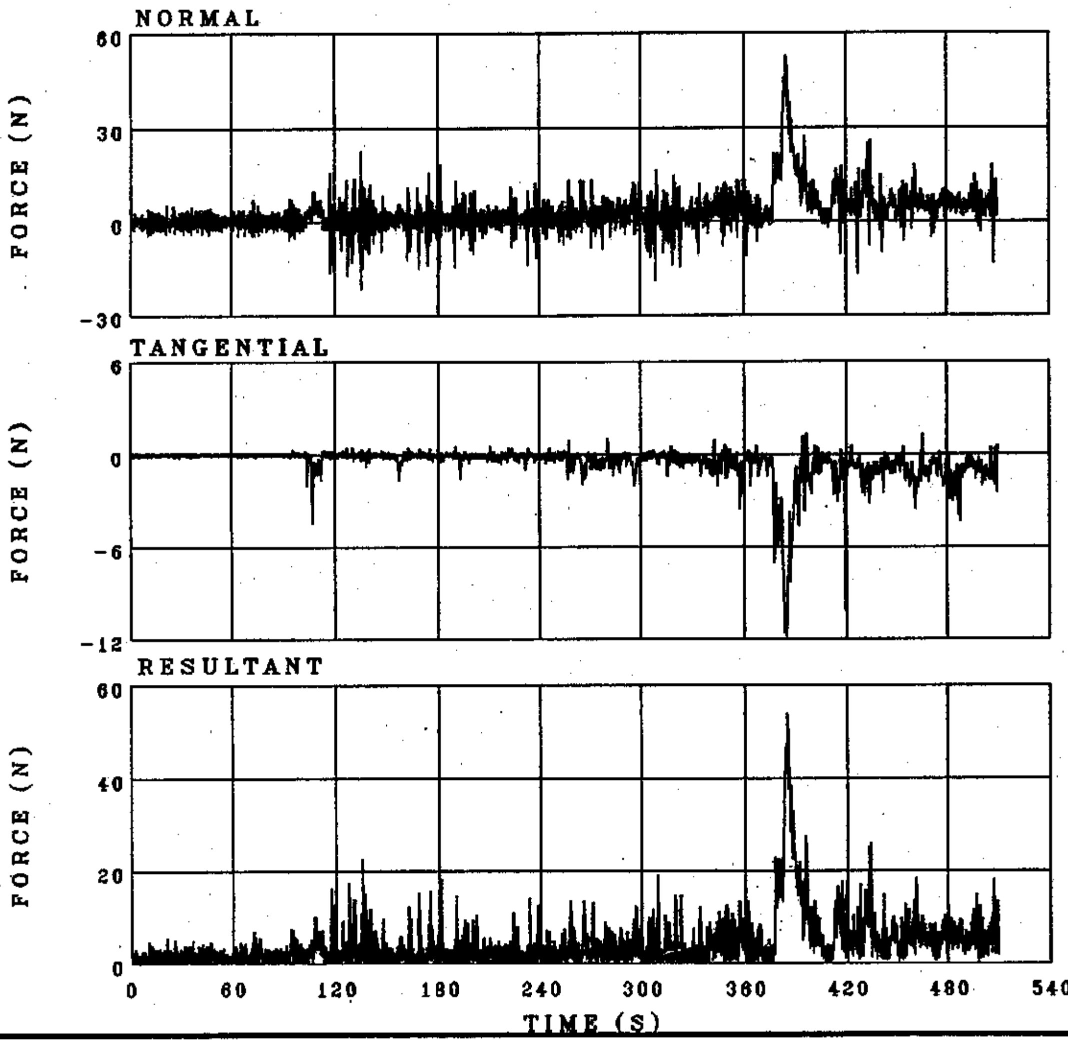
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←005

PLATE #5

NORMAL

MEAN FORCE = 2.841 N
MAX FORCE = 52.61 N
MIN FORCE = -21.70 N

TANGENTIAL

MEAN FORCE = -0.5569 N
MAX FORCE = 1.343 N
MIN FORCE = -11.82 N

RESULTANT

MEAN FORCE = 3.858 N
MAX FORCE = 53.93 N
MIN FORCE = 0.05040 N
AVERAGE ANGLE = -13.57 O

TEST CONDITIONS

BOARD ANGLE = -5.000 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 86.00 kPa
ICE THICKNESS = 3.300 cm
ICE DENSITY = 0.9300 g/cc

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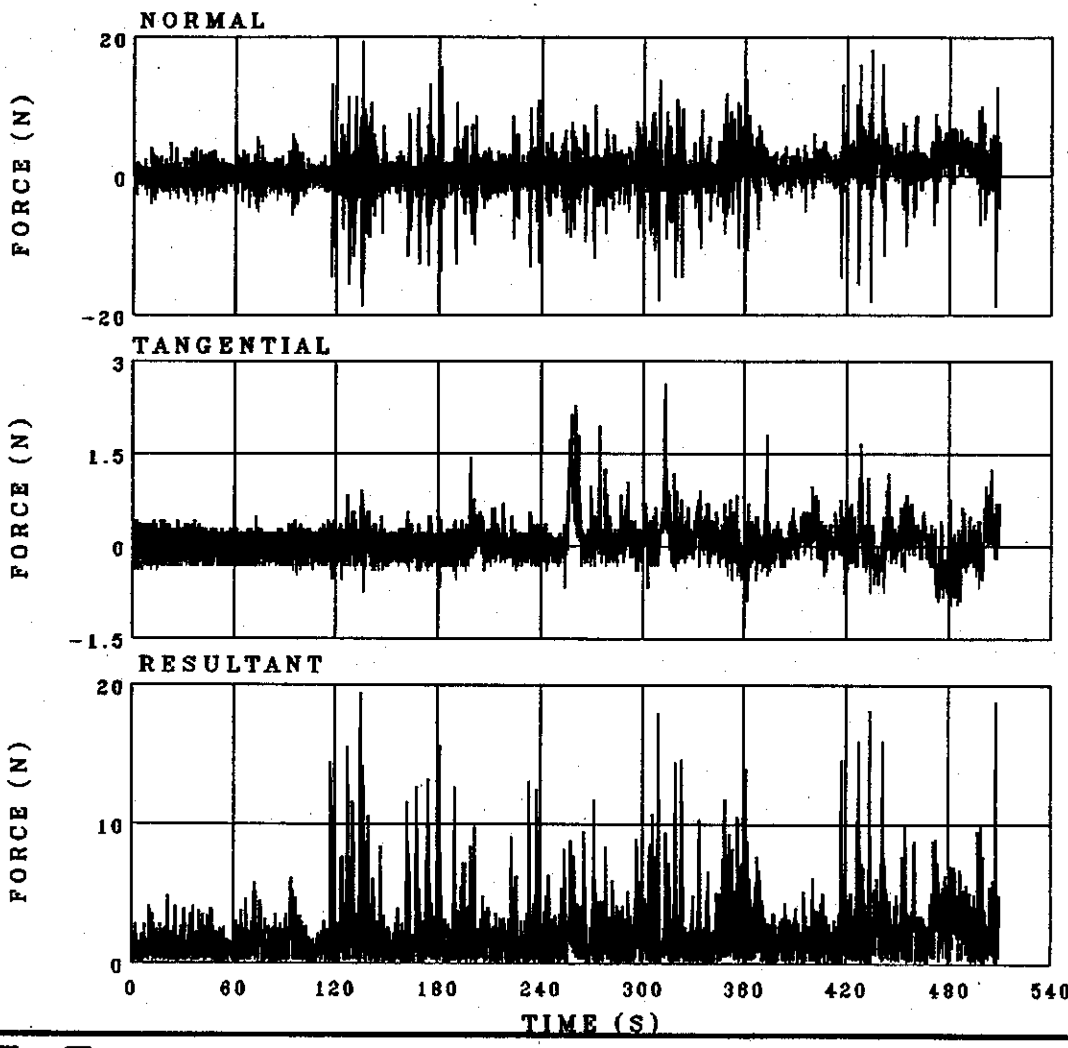
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←005

PLATE #6

NORMAL

MEAN FORCE = 0.5890 N
MAX FORCE = 19.45 N
MIN FORCE = -18.87 N

TANGENTIAL

MEAN FORCE = 0.04845 N
MAX FORCE = 2.631 N
MIN FORCE = -0.9592 N

RESULTANT

MEAN FORCE = 1.804 N
MAX FORCE = 19.46 N
MIN FORCE = 0.04569 N
AVERAGE ANGLE = 9.267 O

TEST CONDITIONS

BOARD ANGLE = -5.000 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 86.00 kPa
ICE THICKNESS = 3.300 cm
ICE DENSITY = 0.9300 g/cc

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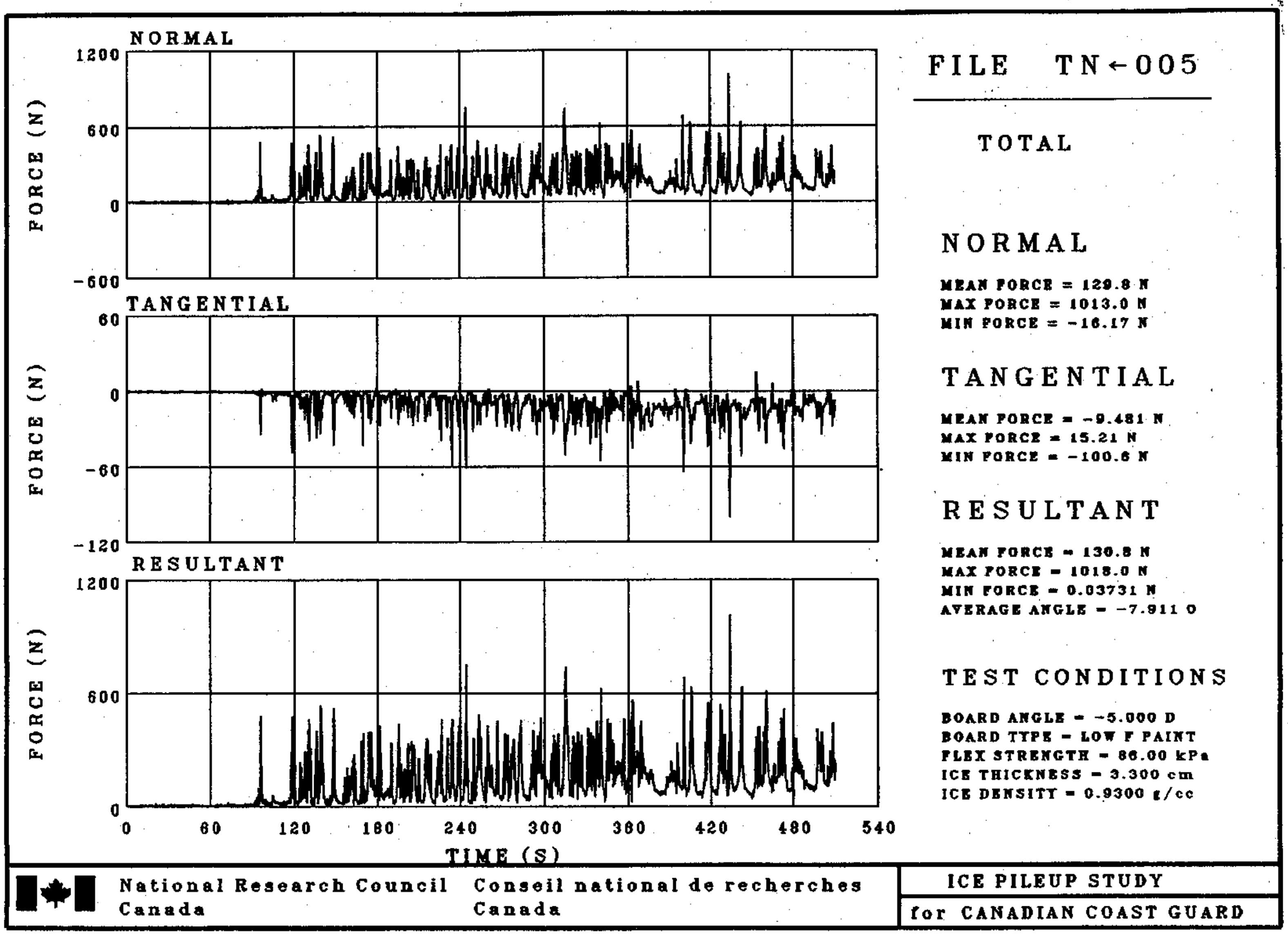
ICE PILEUP STUDY
for CANADIAN COAST GUARD


NORMAL
1200
600
0
-600
FORCE (N)
TANGENTIAL
60
0
-60
-120
FORCE (N)
RESULTANT
1200
600
0
FORCE (N)
0 60 120 180 240 300 360 420 480 540
TIME (S)
FILE TN←005
TOTAL
NORMAL
MEAN FORCE = 129.8 N
MAX FORCE = 1013.0 N
MIN FORCE = -16.17 N
TANGENTIAL
MEAN FORCE = -9.481 N
MAX FORCE = 15.21 N
MIN FORCE = -100.6 N
RESULTANT
MEAN FORCE = 130.8 N
MAX FORCE = 1018.0 N
MIN FORCE = 0.03731 N
AVERAGE ANGLE = -7.911 O
TEST CONDITIONS
BOARD ANGLE = -5.000 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 86.00 kPa
ICE THICKNESS = 3.300 cm
ICE DENSITY = 0.9300 g/cc
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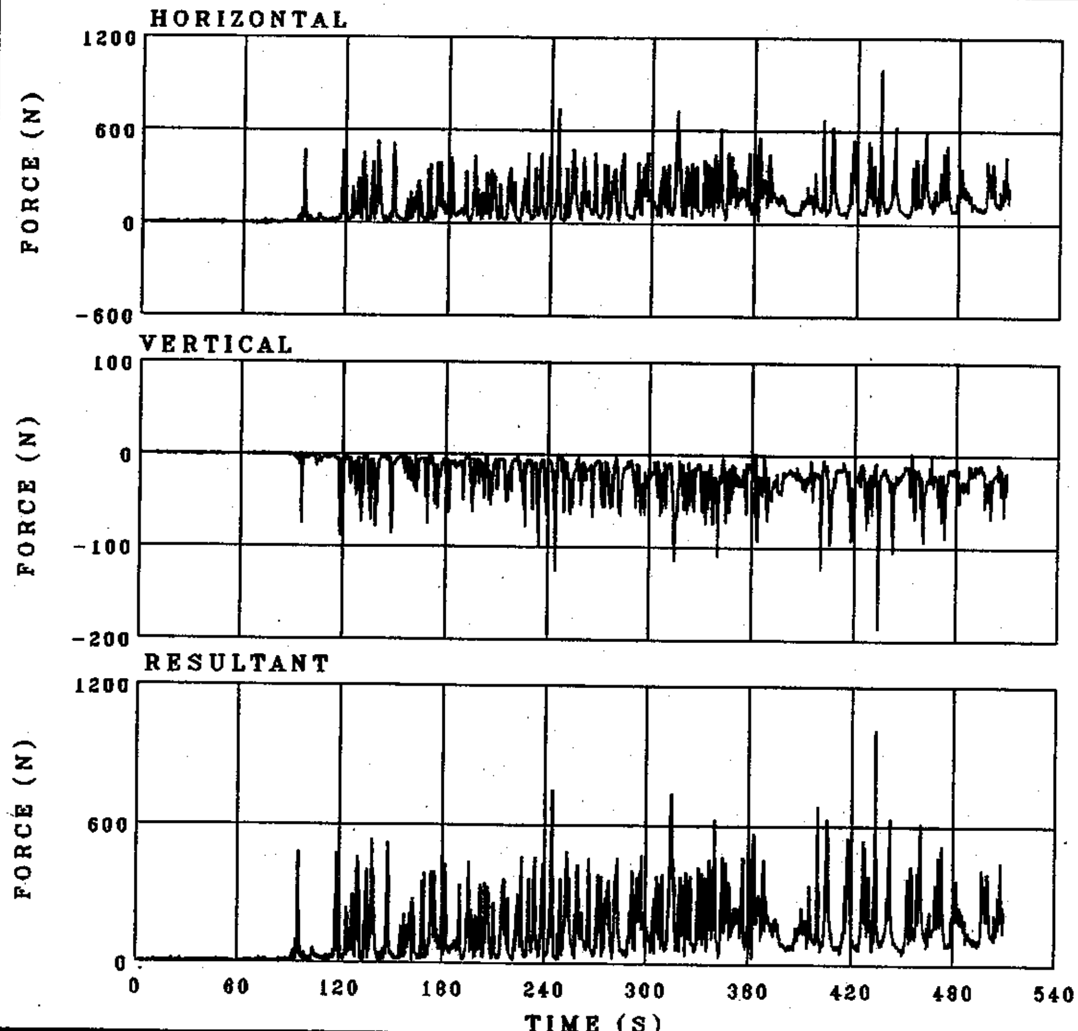
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←005

TOTAL

HORIZONTAL

MEAN FORCE = -9.481 N
MAX FORCE = 15.21 N
MIN FORCE = -100.6 N

VERTICAL

MEAN FORCE = -9.481 N
MAX FORCE = 15.21 N
MIN FORCE = -100.6 N

RESULTANT

MEAN FORCE = -9.481 N
MAX FORCE = 15.21 N
MIN FORCE = -100.6 N
AVERAGE ANGLE = -9.481 O

TEST CONDITIONS

BOARD ANGLE = -5.000 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 86.00 kPa
ICE THICKNESS = 3.300 cm
ICE DENSITY = 0.9300 g/cc

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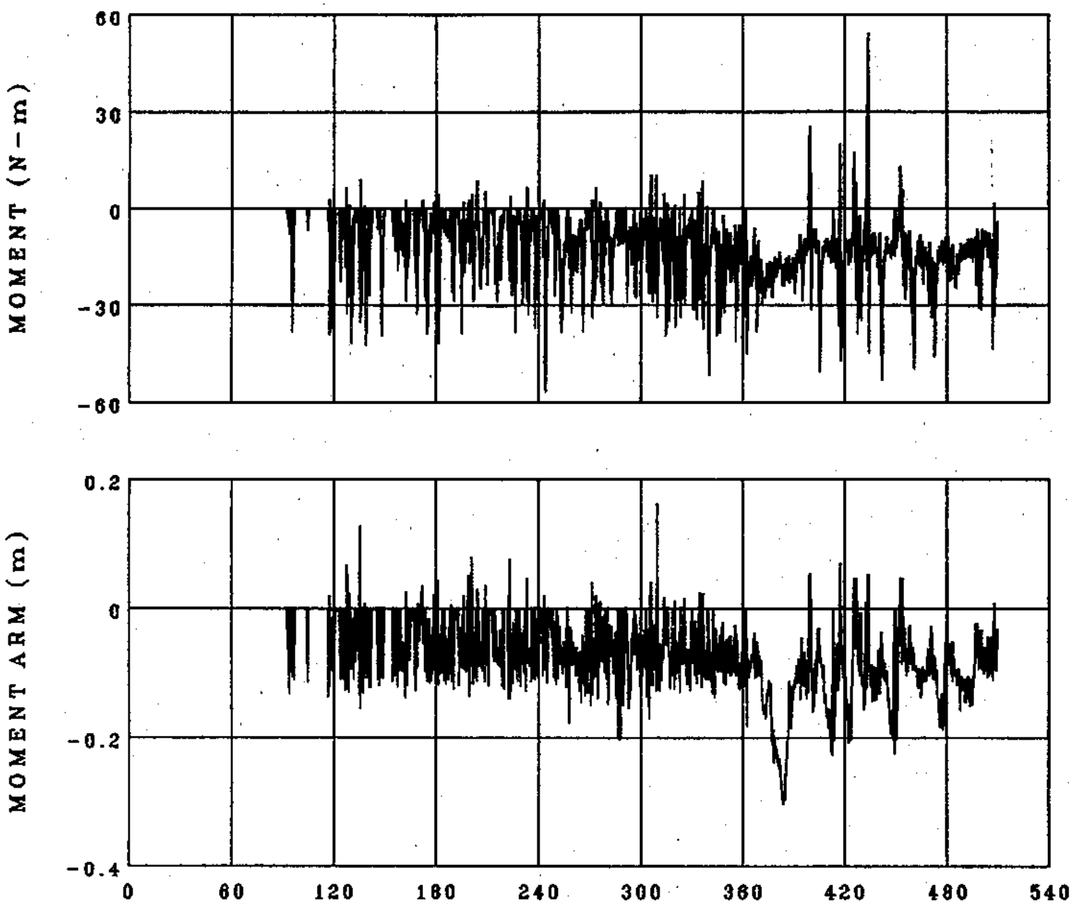
FILE TN←005

MOMENT



MOMENT

MEAN MOMENT = -9.801 N-m
MAX MOMENT = 54.16 N-m
MIN MOMENT = -56.88 N-m

MOMENT ARM

MEAN ARM = -0.06044 m
MAX ARM = 0.1628 m
MIN ARM = -0.3053 m

TEST CONDITIONS

BOARD ANGLE = -5.000 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 66.00 kPa
ICE THICKNESS = 3.300 cm
ICE DENSITY = 0.9300 g/cc

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ICE PILEUP STUDY
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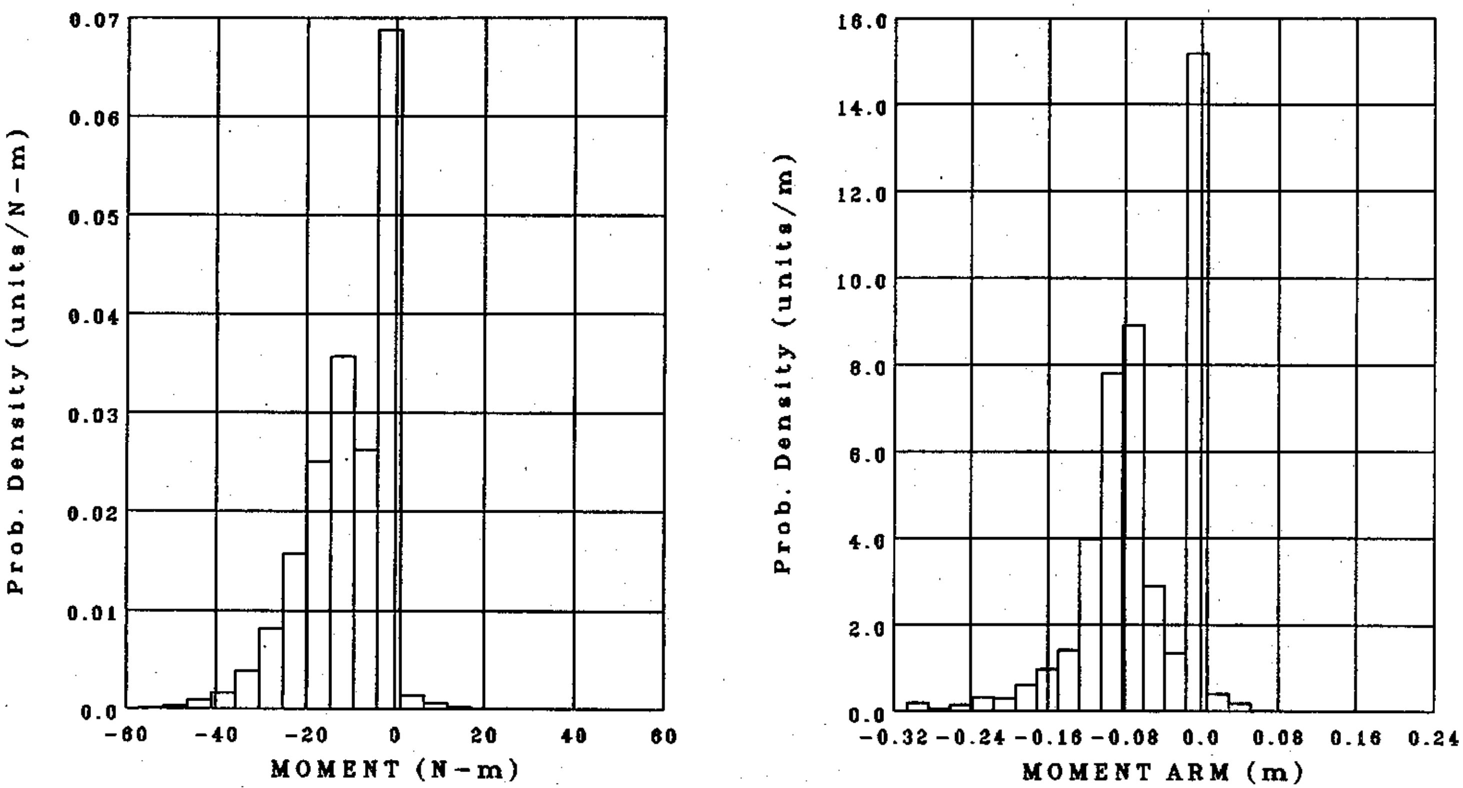
TN←005



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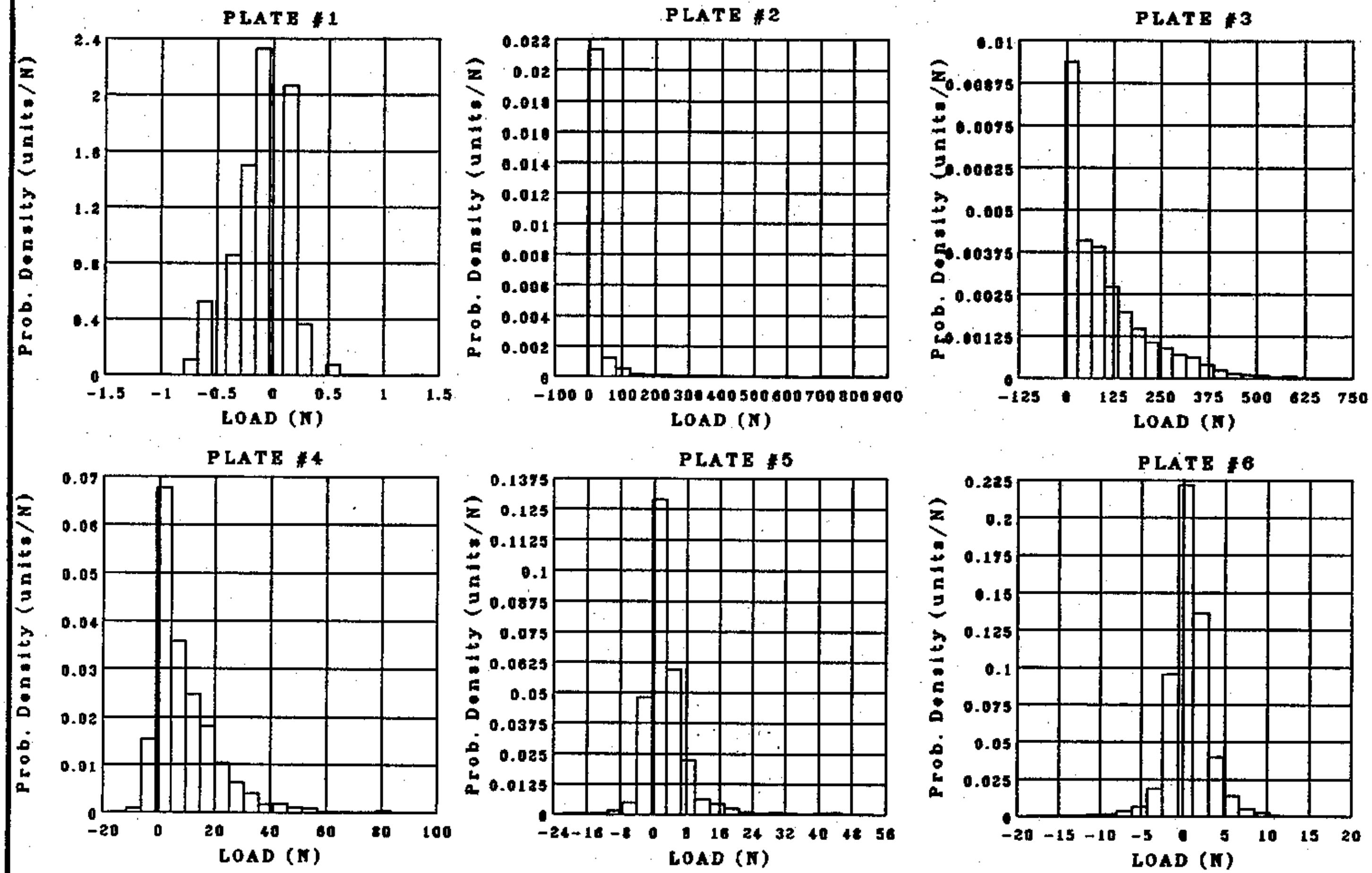
TN←005
NORMAL LOAD



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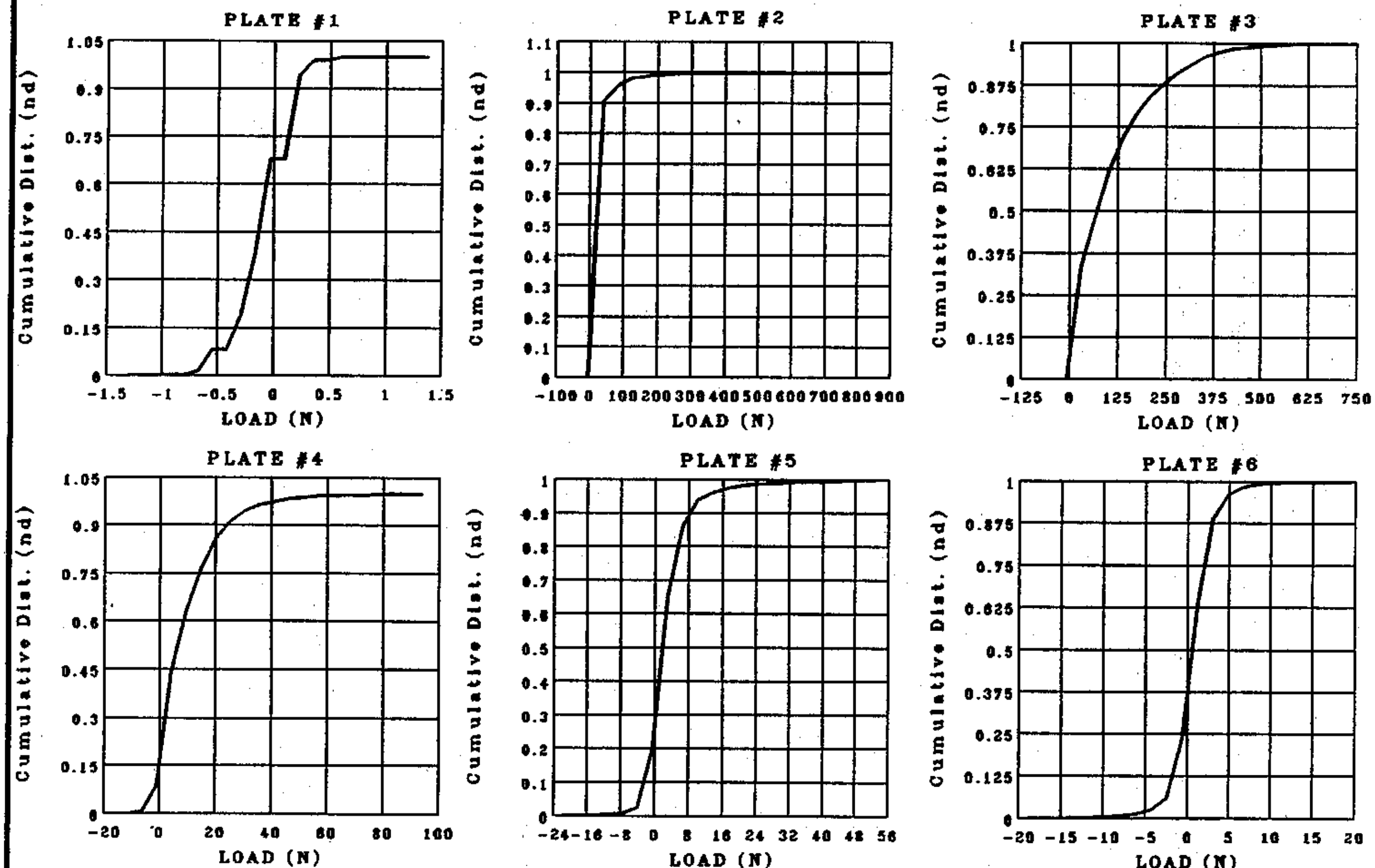
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←005
NORMAL LOAD



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ICE PILEUP STUDY
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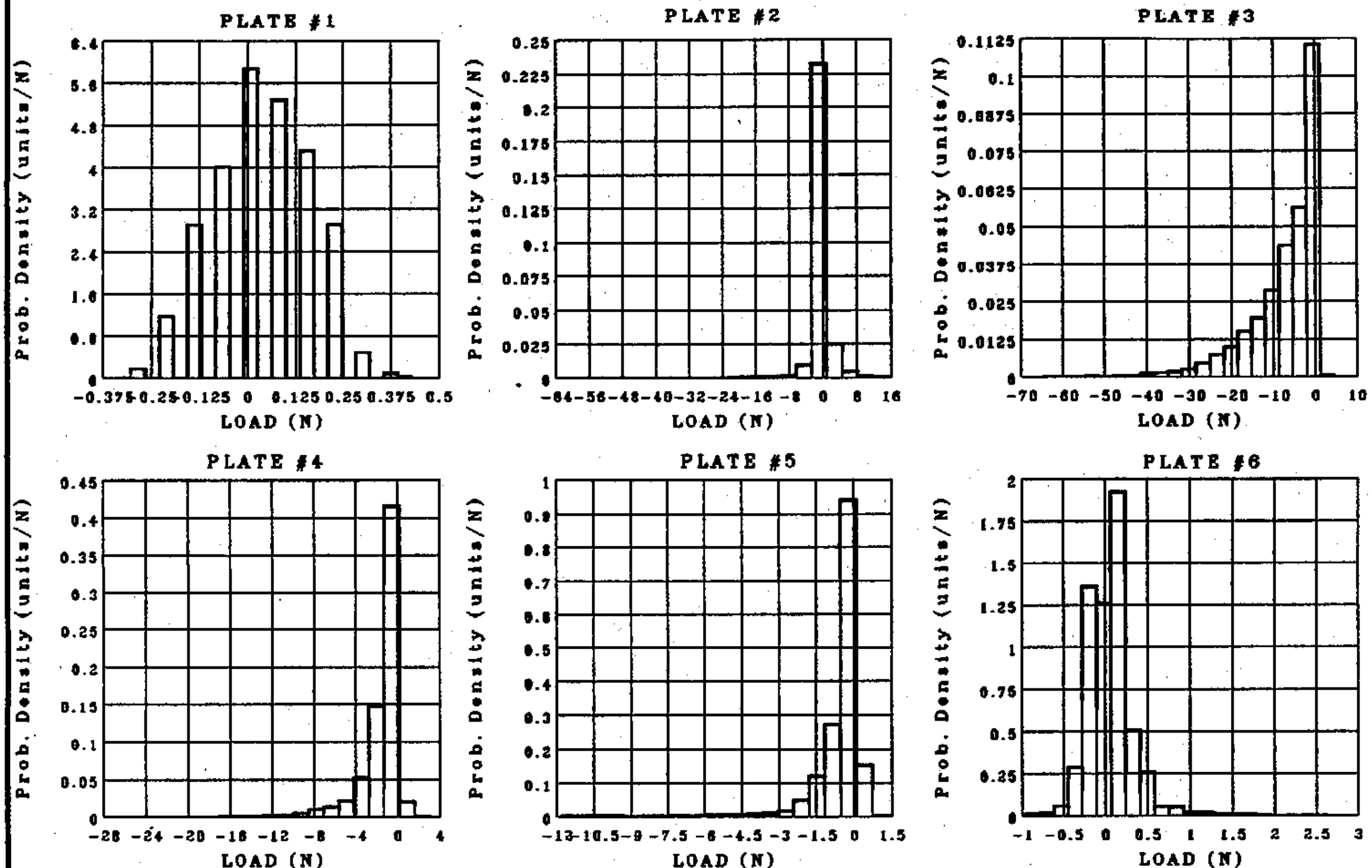
TN←005
TANGENTIAL LOAD



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ICE PILEUP STUDY
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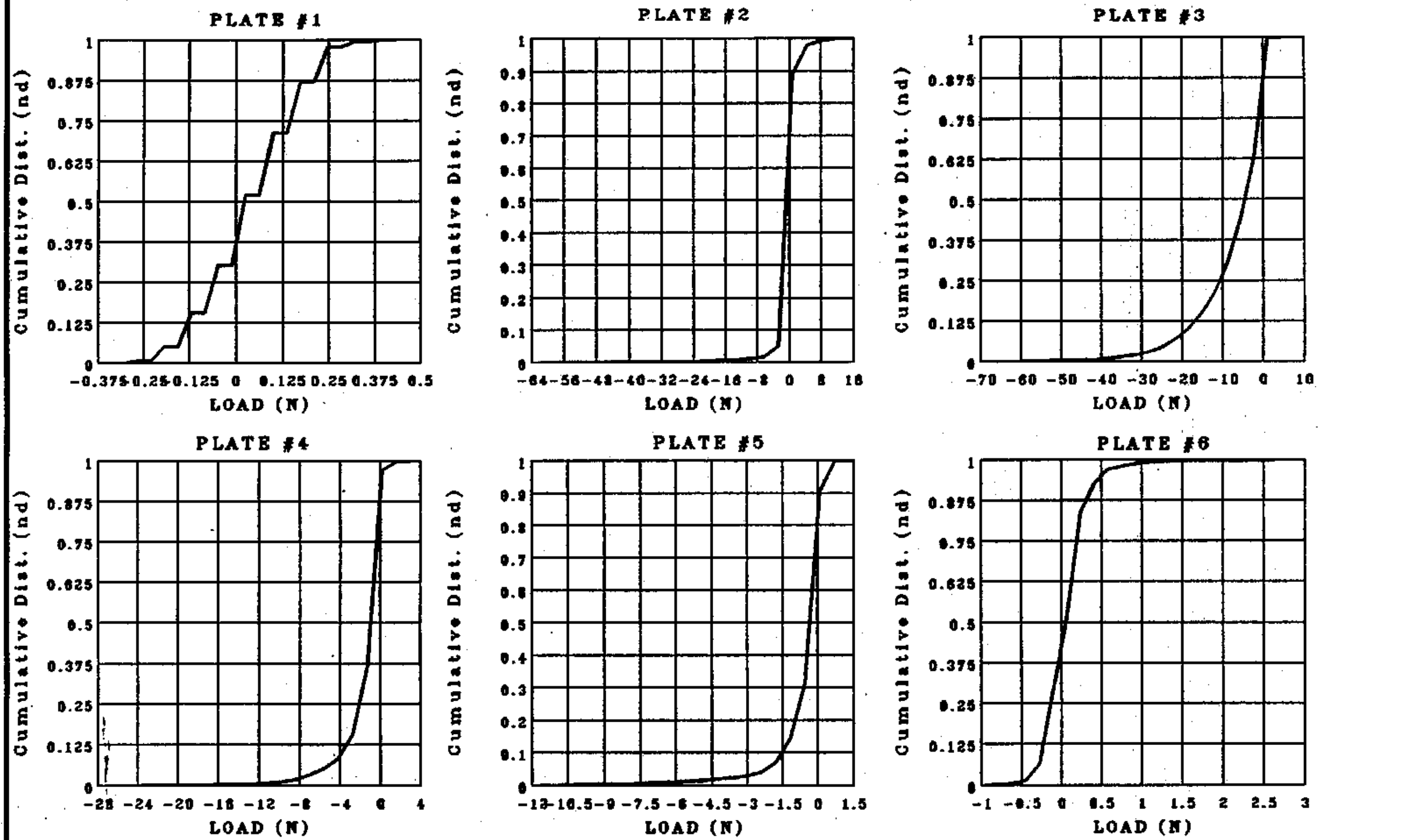
TN←005
TANGENTIAL LOAD



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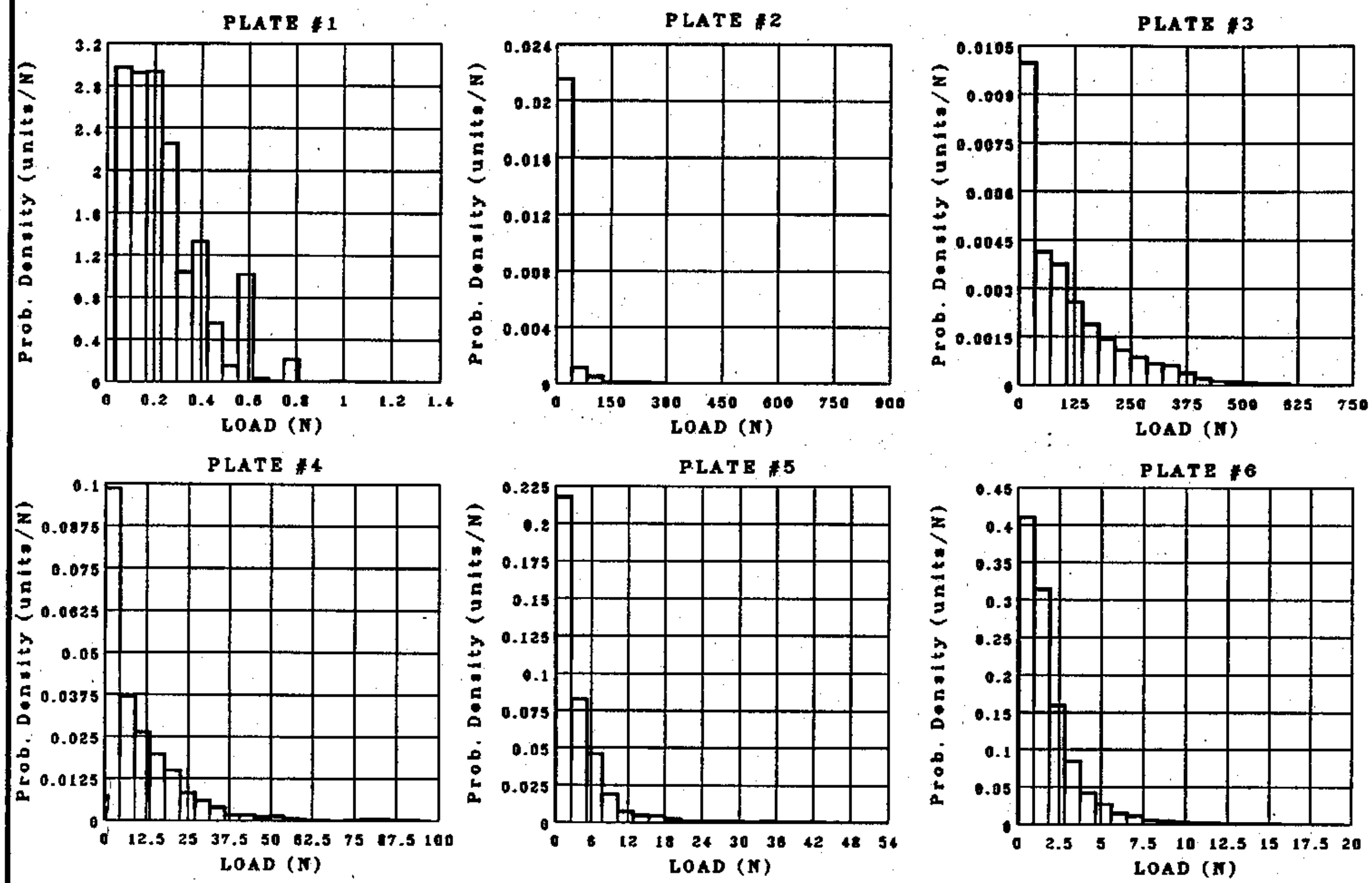
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←005
RESULTANT



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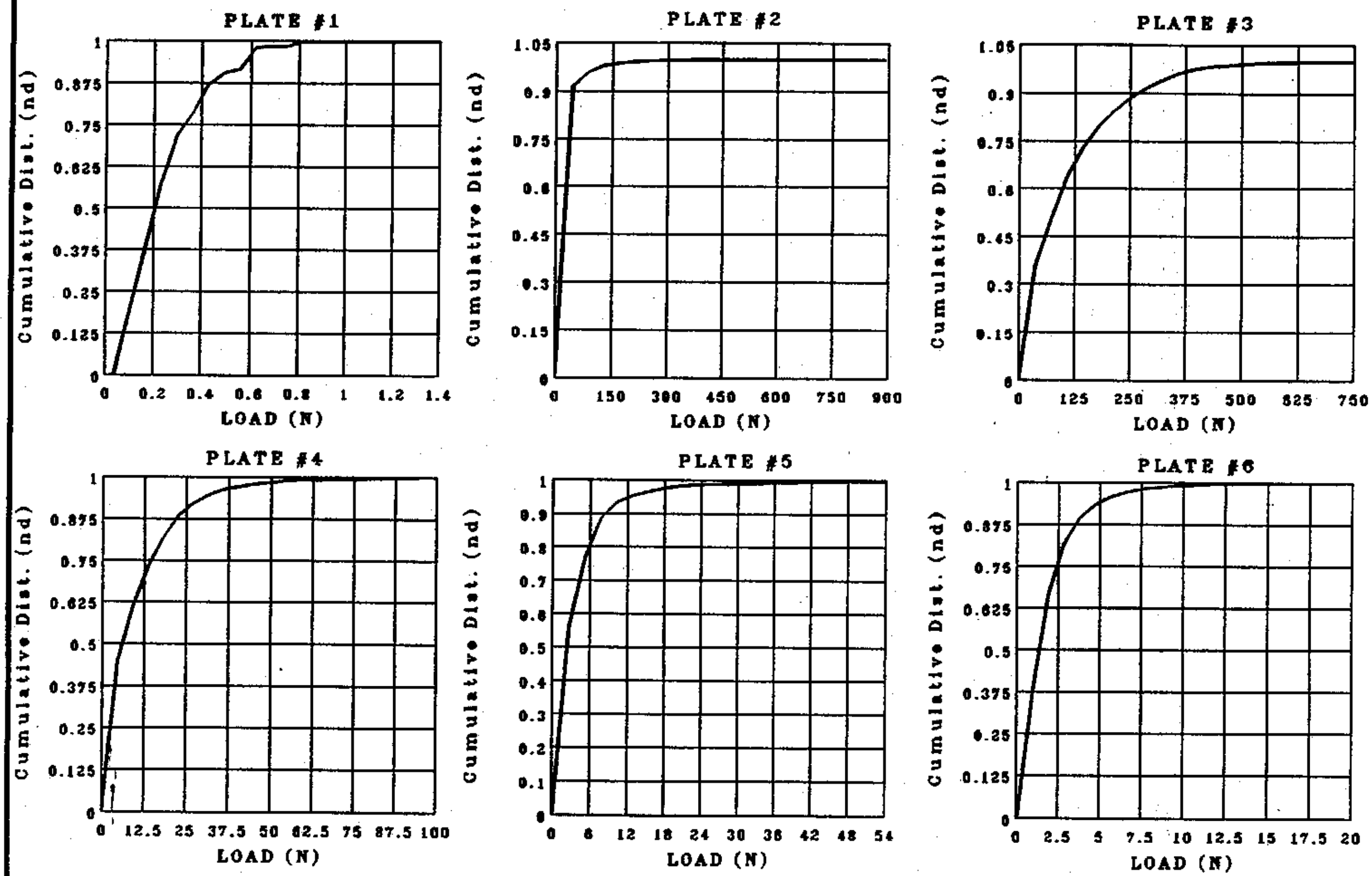
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←005
RESULTANT



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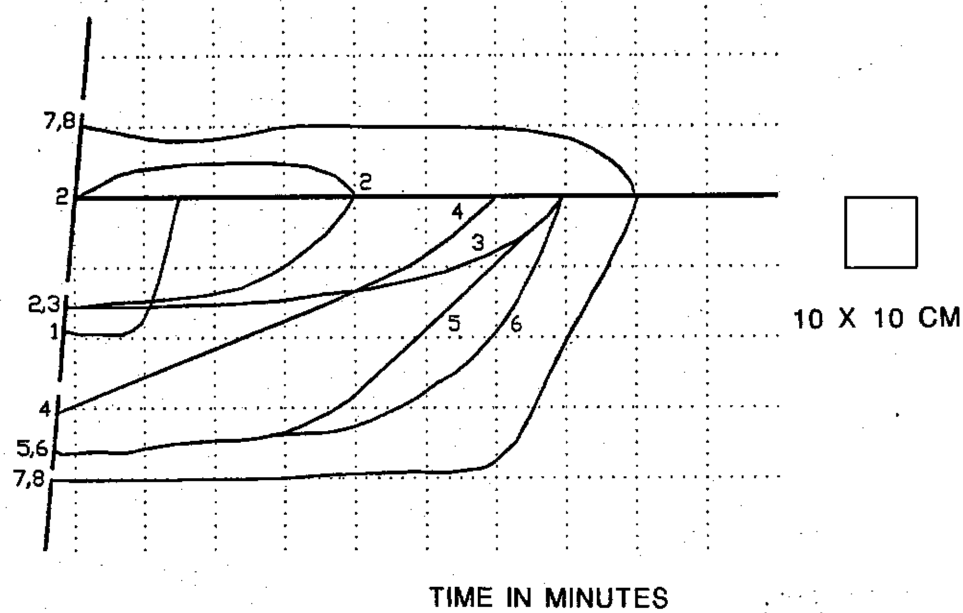
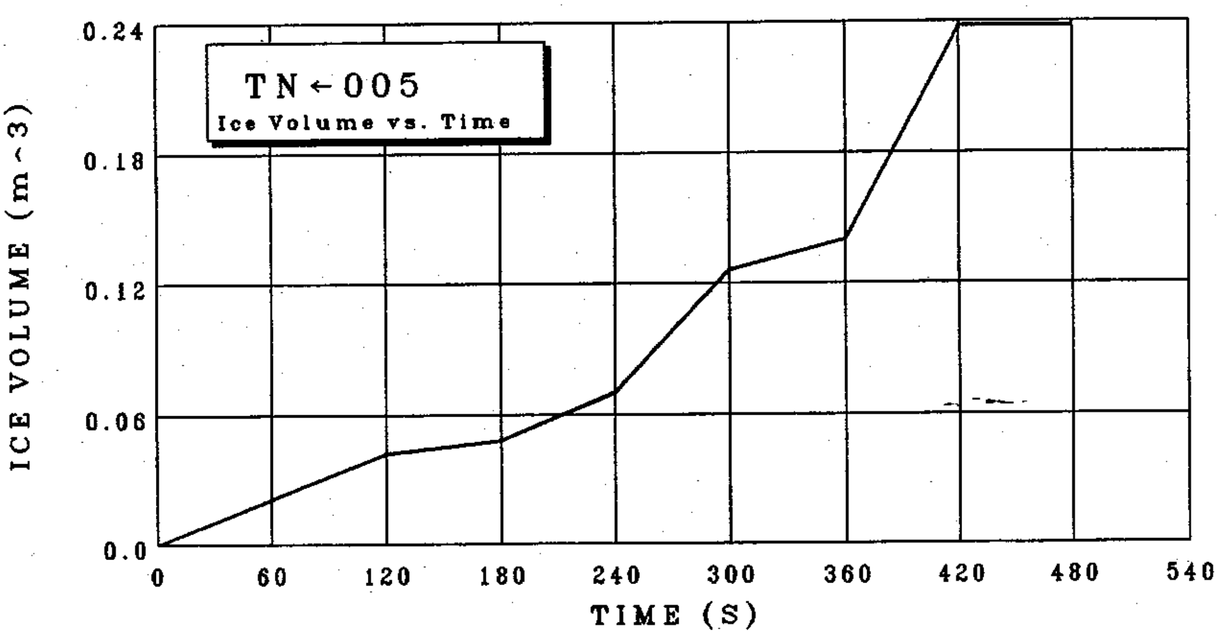
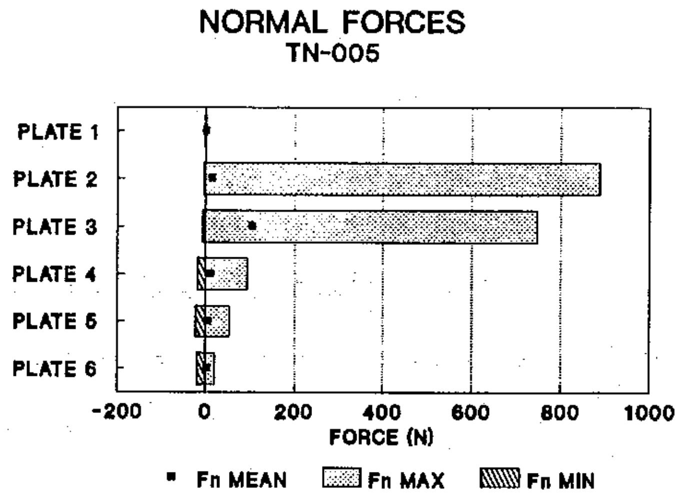
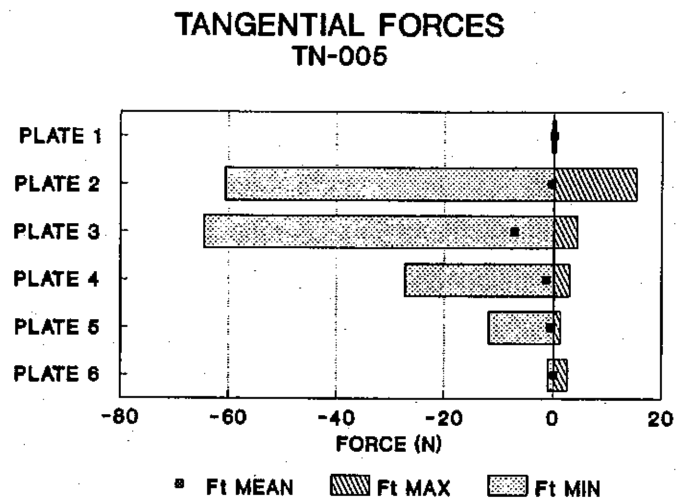
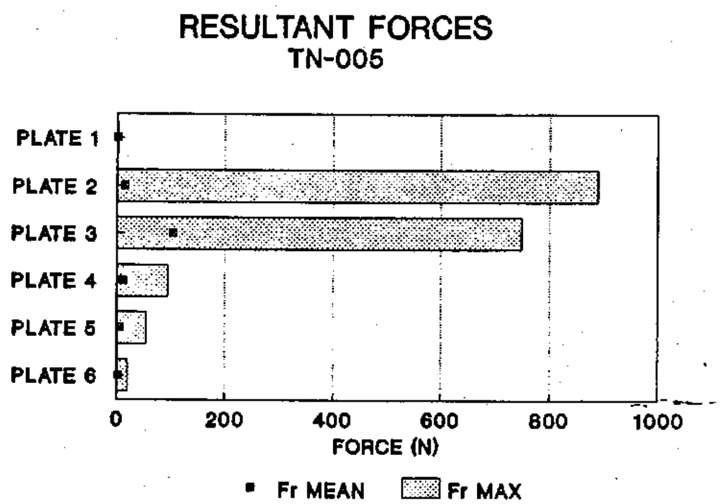
ICE PILEUP STUDY
for CANADIAN COAST GUARD

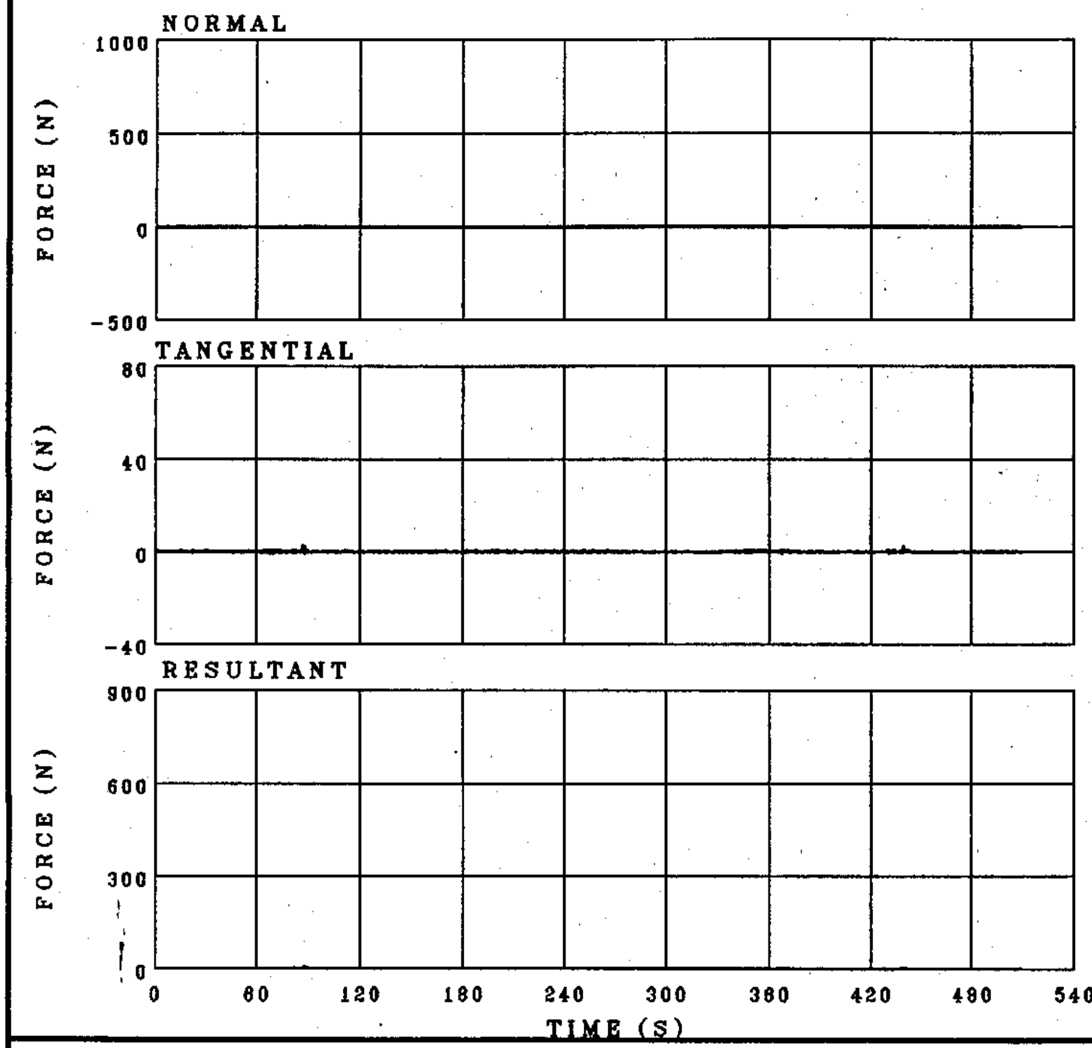

7,8
2
2
4
3
2,3
1
5
6
4
5,6
7,8
10 X 10 CM
TIME IN MINUTES


TN←005
Ice Volume vs. Time
ICE VOLUME (m^3)
0.24
0.18
0.12
0.06
0.0
0
60
120
180
240
300
360
420
480
540
TIME (S)


NORMAL FORCES
TN-005
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-200
0
200
400
600
800
1000
FORCE (N)
Fn MEAN
Fn MAX
Fn MIN


TANGENTIAL FORCES
TN-005
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-80
-60
-40
-20
0
20
FORCE (N)
Ft MEAN
Ft MAX
Ft MIN


RESULTANT FORCES
TN-005
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
0
200
400
600
800
1000
FORCE (N)
Fr MEAN
Fr MAX



FILE TN←006

PLATE #1

NORMAL

MEAN FORCE = 0.1476 N
MAX FORCE = 4.914 N
MIN FORCE = -1.216 N

TANGENTIAL

MEAN FORCE = 0.1038 N
MAX FORCE = 1.984 N
MIN FORCE = -0.5343 N

RESULTANT

MEAN FORCE = 0.3073 N
MAX FORCE = 5.002 N
MIN FORCE = 0.04518 N
AVERAGE ANGLE = 52.06 O

TEST CONDITIONS

BOARD ANGLE = 0.0 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 64.00 kPa
ICE THICKNESS = 3.200 cm
ICE DENSITY = 0.9300 g/cc

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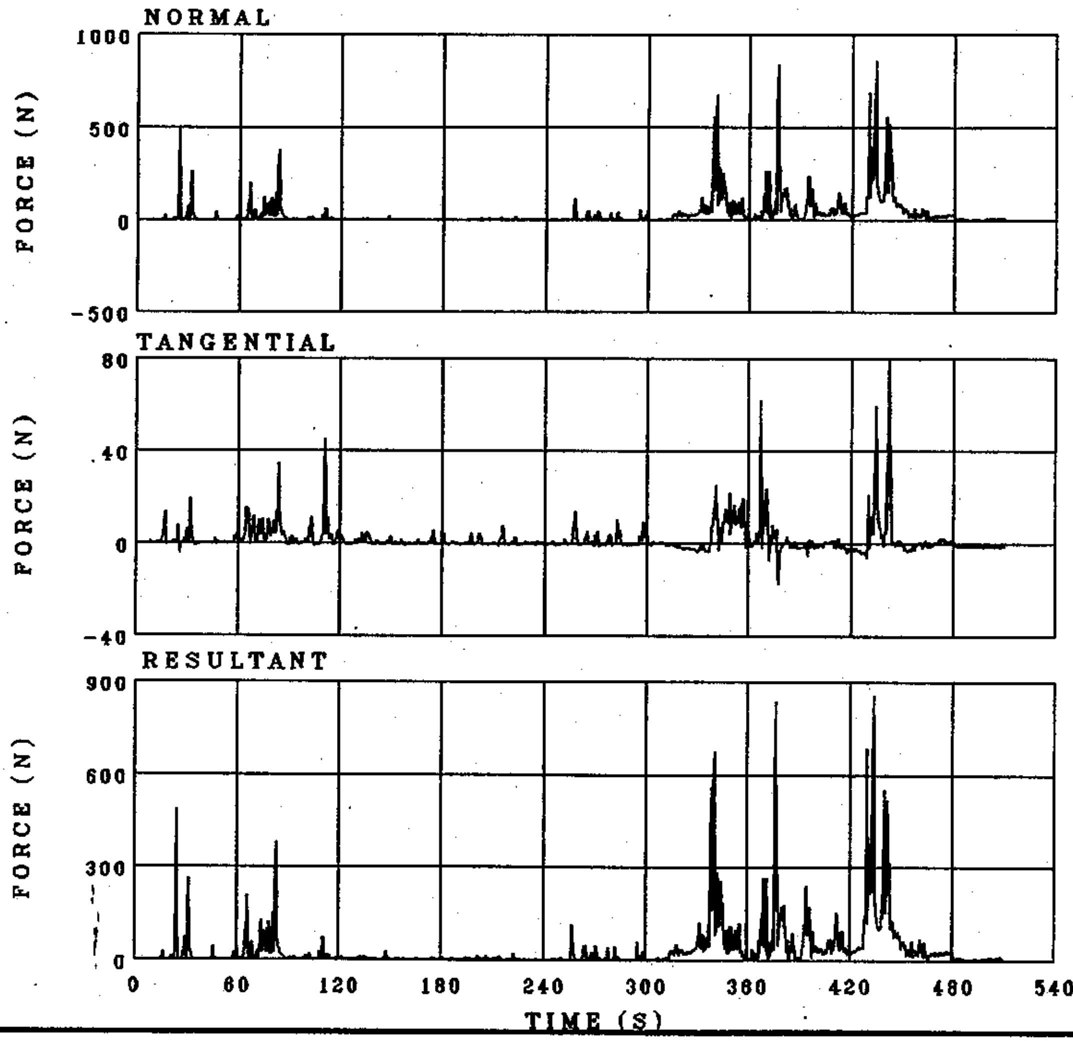
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←006

PLATE #2

NORMAL

MEAN FORCE = 31.80 N
MAX FORCE = 859.3 N
MIN FORCE = -1.951 N

TANGENTIAL

MEAN FORCE = 1.389 N
MAX FORCE = 79.69 N
MIN FORCE = -17.45 N

RESULTANT

MEAN FORCE = 32.40 N
MAX FORCE = 860.2 N
MIN FORCE = 0.02200 N
AVERAGE ANGLE = -14.55 0

TEST CONDITIONS

BOARD ANGLE = 0.0 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 64.00 kPa
ICE THICKNESS = 3.200 cm
ICE DENSITY = 0.9300 g/cc

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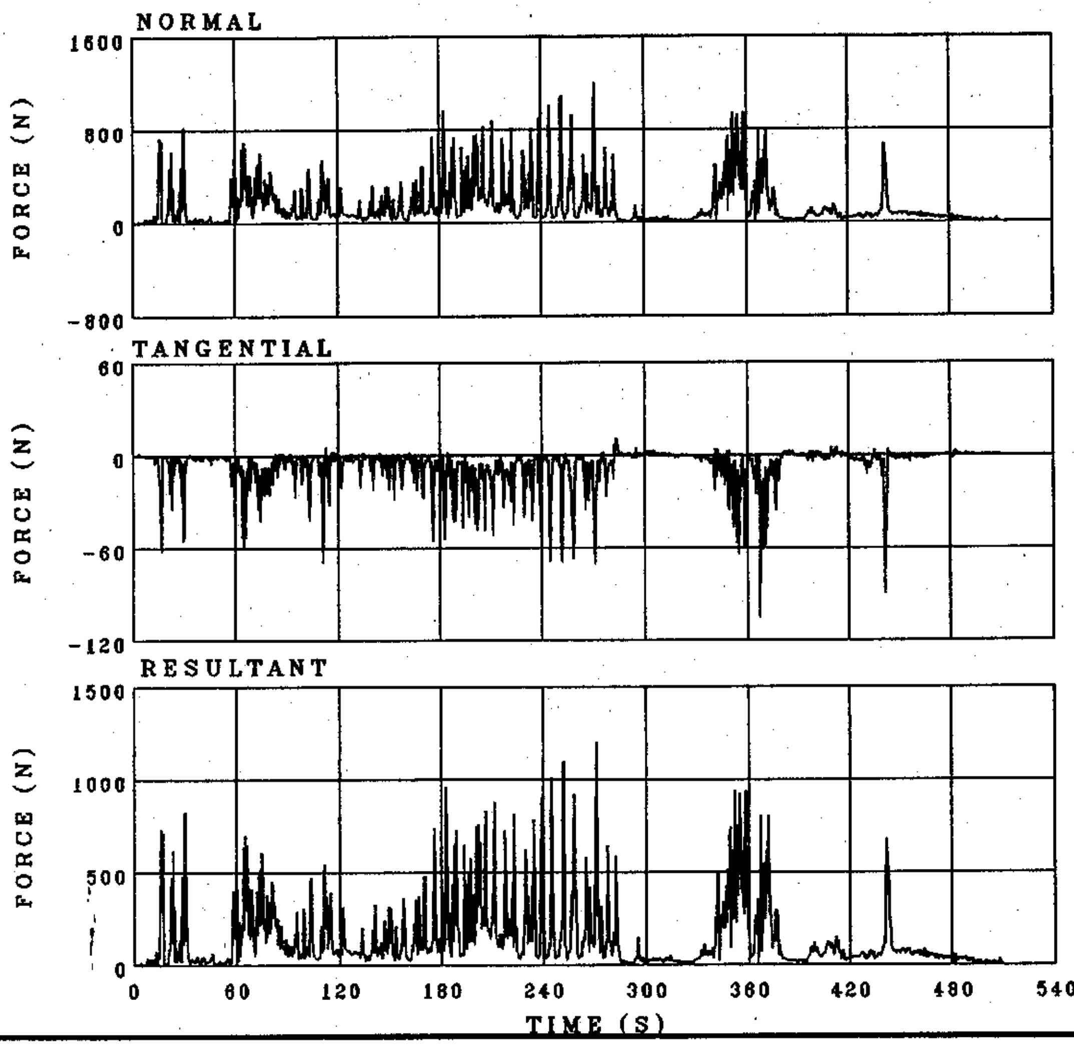
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←006

PLATE #3

NORMAL

MEAN FORCE = 132.1 N
MAX FORCE = 1201.0 N
MIN FORCE = -2.239 N

TANGENTIAL

MEAN FORCE = -6.200 N
MAX FORCE = 10.87 N
MIN FORCE = -105.3 N

RESULTANT

MEAN FORCE = 132.3 N
MAX FORCE = 1203.0 N
MIN FORCE = 0.06735 N
AVERAGE ANGLE = -1.823 0

TEST CONDITIONS

BOARD ANGLE = 0.0 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 64.00 kPa
ICE THICKNESS = 3.200 cm
ICE DENSITY = 0.9300 g/cc

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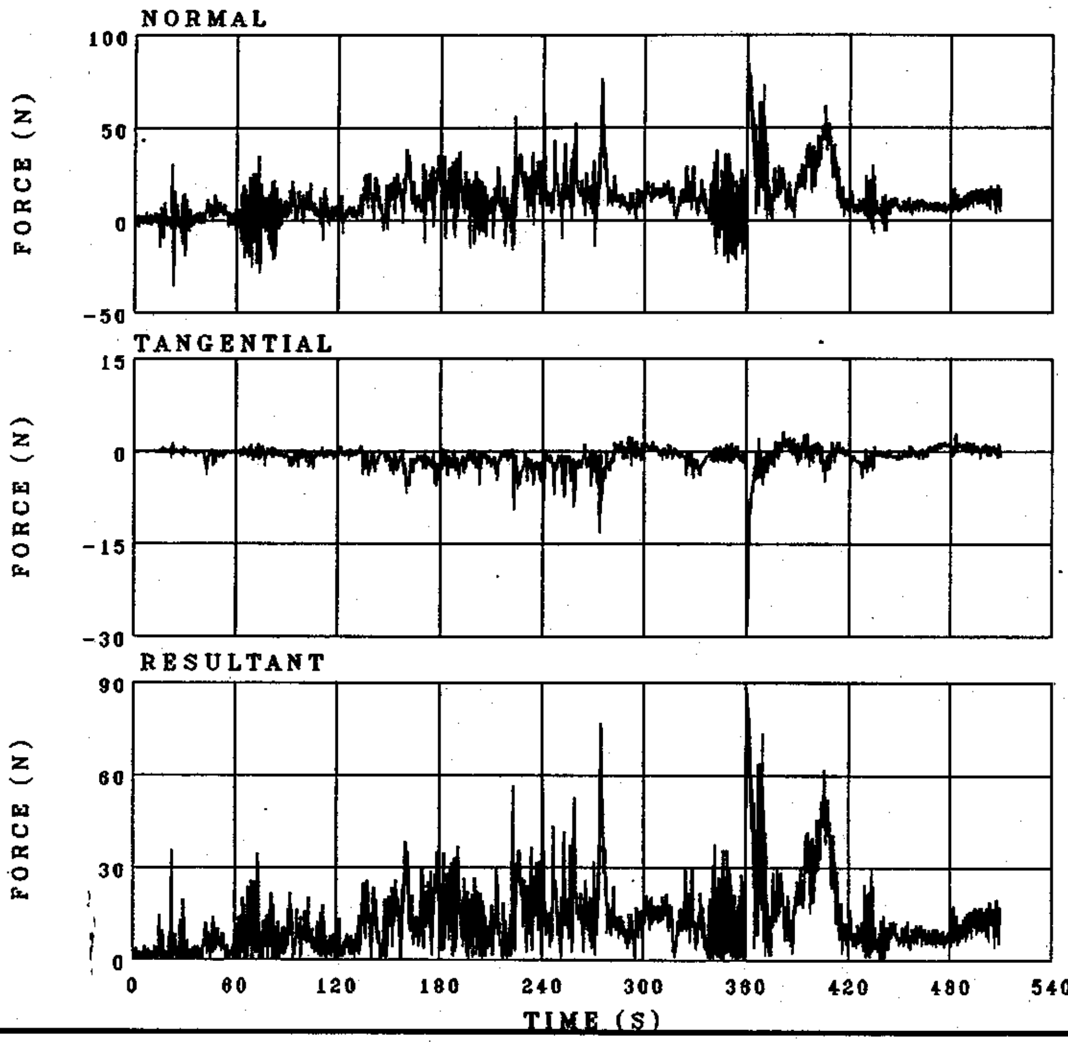
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←006

PLATE #4

NORMAL

MEAN FORCE = 11.53 N
MAX FORCE = 84.72 N
MIN FORCE = -35.54 N

TANGENTIAL

MEAN FORCE = -0.8597 N
MAX FORCE = 3.170 N
MIN FORCE = -28.23 N

RESULTANT

MEAN FORCE = 12.40 N
MAX FORCE = 86.76 N
MIN FORCE = 0.03321 N
AVERAGE ANGLE = -0.2162 D

TEST CONDITIONS

BOARD ANGLE = 0.0 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 64.00 kPa
ICE THICKNESS = 3.200 cm
ICE DENSITY = 0.9300 g/cc

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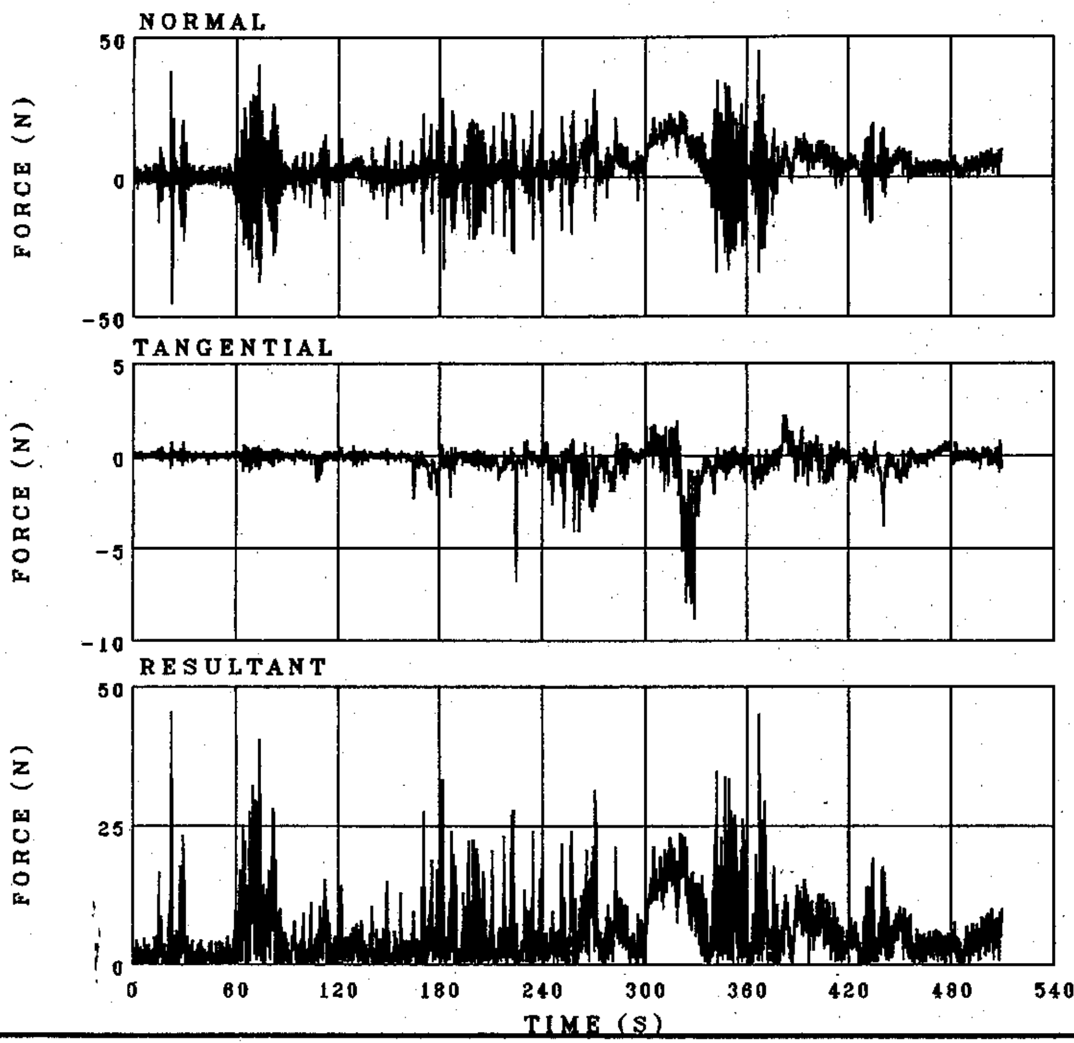
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←006

PLATE #5

NORMAL

MEAN FORCE = 3.359 N
MAX FORCE = 45.12 N
MIN FORCE = -45.70 N

TANGENTIAL

MEAN FORCE = -0.2727 N
MAX FORCE = 2.199 N
MIN FORCE = -8.832 N

RESULTANT

MEAN FORCE = 5.277 N
MAX FORCE = 45.71 N
MIN FORCE = 0.04092 N
AVERAGE ANGLE = 0.6820 D

TEST CONDITIONS

BOARD ANGLE = 0.0 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 64.00 kPa
ICE THICKNESS = 3.200 cm
ICE DENSITY = 0.9300 g/cc

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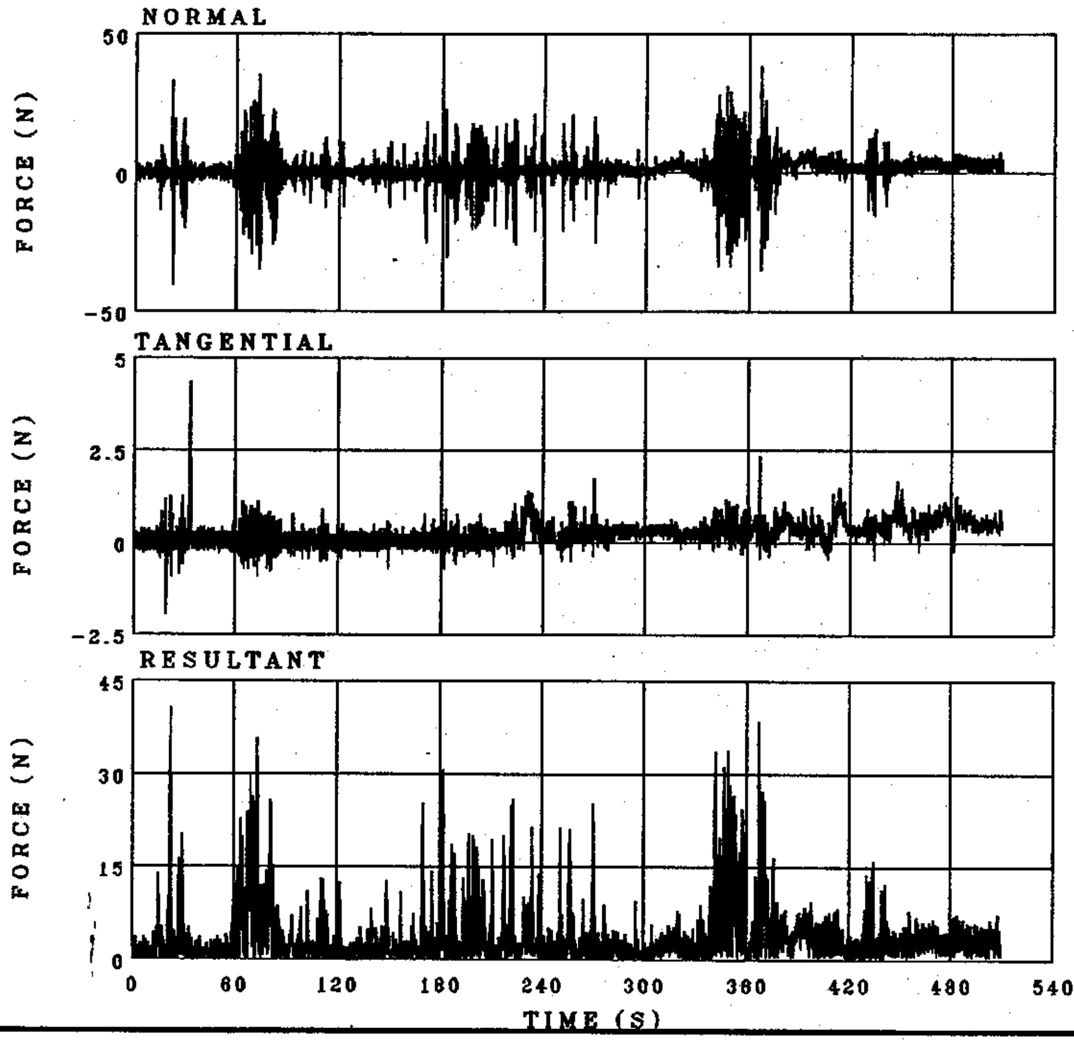
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←006

PLATE #6

NORMAL

MEAN FORCE = 1.013 N
MAX FORCE = 38.46 N
MIN FORCE = -40.69 N

TANGENTIAL

MEAN FORCE = 0.2449 N
MAX FORCE = 4.361 N
MIN FORCE = -1.959 N

RESULTANT

MEAN FORCE = 3.157 N
MAX FORCE = 40.70 N
MIN FORCE = 0.03249 N
AVERAGE ANGLE = 20.71 O

TEST CONDITIONS

BOARD ANGLE = 0.0 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 64.00 kPa
ICE THICKNESS = 3.200 cm
ICE DENSITY = 0.9300 g/cc

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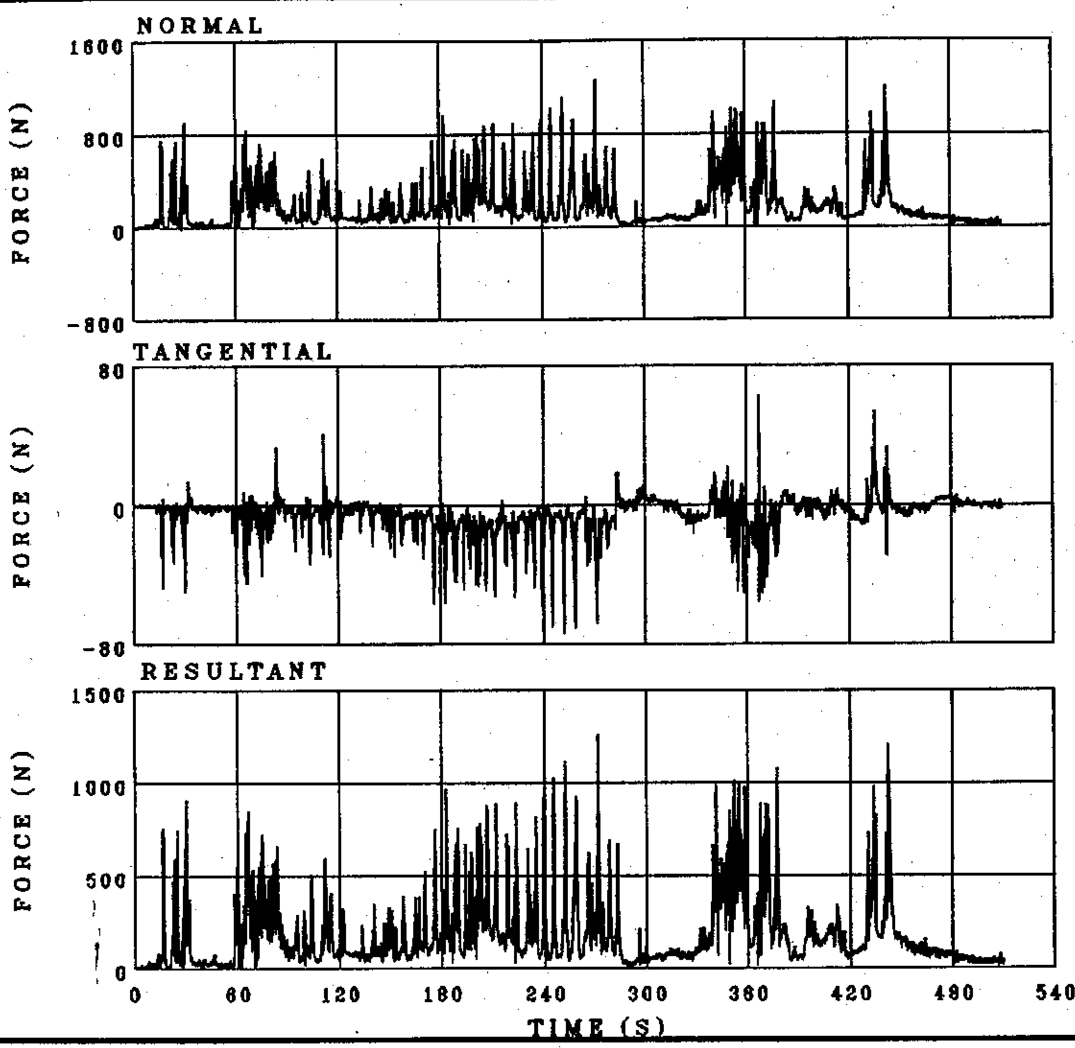
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←006

TOTAL

NORMAL

MEAN FORCE = 180.0 N
MAX FORCE = 1262.0 N
MIN FORCE = -27.45 N

TANGENTIAL

MEAN FORCE = -5.595 N
MAX FORCE = 63.03 N
MIN FORCE = -74.07 N

RESULTANT

MEAN FORCE = 180.2 N
MAX FORCE = 1264.0 N
MIN FORCE = 0.09538 N
AVERAGE ANGLE = -1.817 O

TEST CONDITIONS

BOARD ANGLE = 0.0 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 64.00 kPa
ICE THICKNESS = 3.200 cm
ICE DENSITY = 0.9300 g/cc

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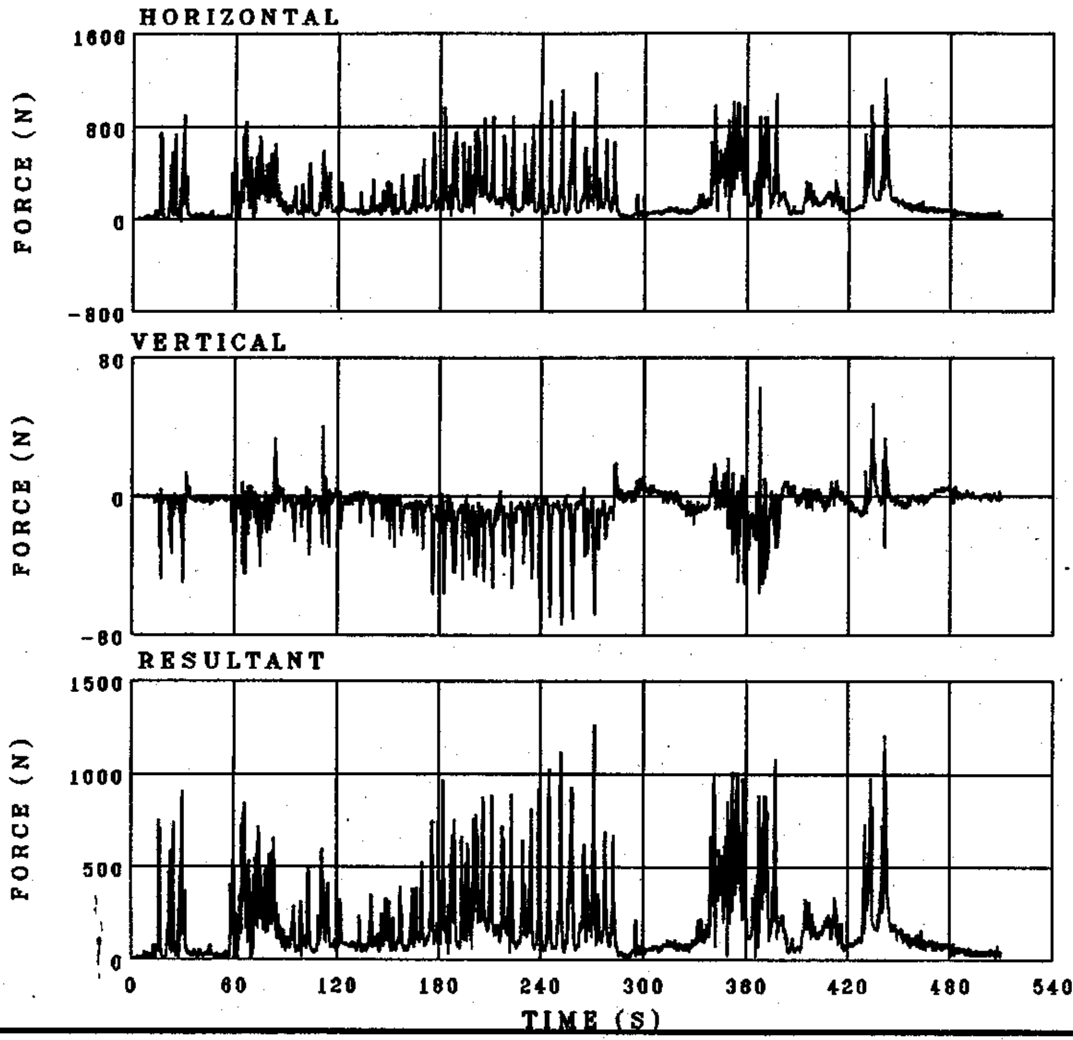
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←006

TOTAL

HORIZONTAL

MEAN FORCE = -5.595 N
MAX FORCE = 63.03 N
MIN FORCE = -74.07 N

VERTICAL

MEAN FORCE = -5.595 N
MAX FORCE = 63.03 N
MIN FORCE = -74.07 N

RESULTANT

MEAN FORCE = -5.595 N
MAX FORCE = 63.03 N
MIN FORCE = -74.07 N
AVERAGE ANGLE = -5.595 D

TEST CONDITIONS

BOARD ANGLE = 0.0 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 64.00 kPa
ICE THICKNESS = 3.200 cm
ICE DENSITY = 0.9300 g/cc

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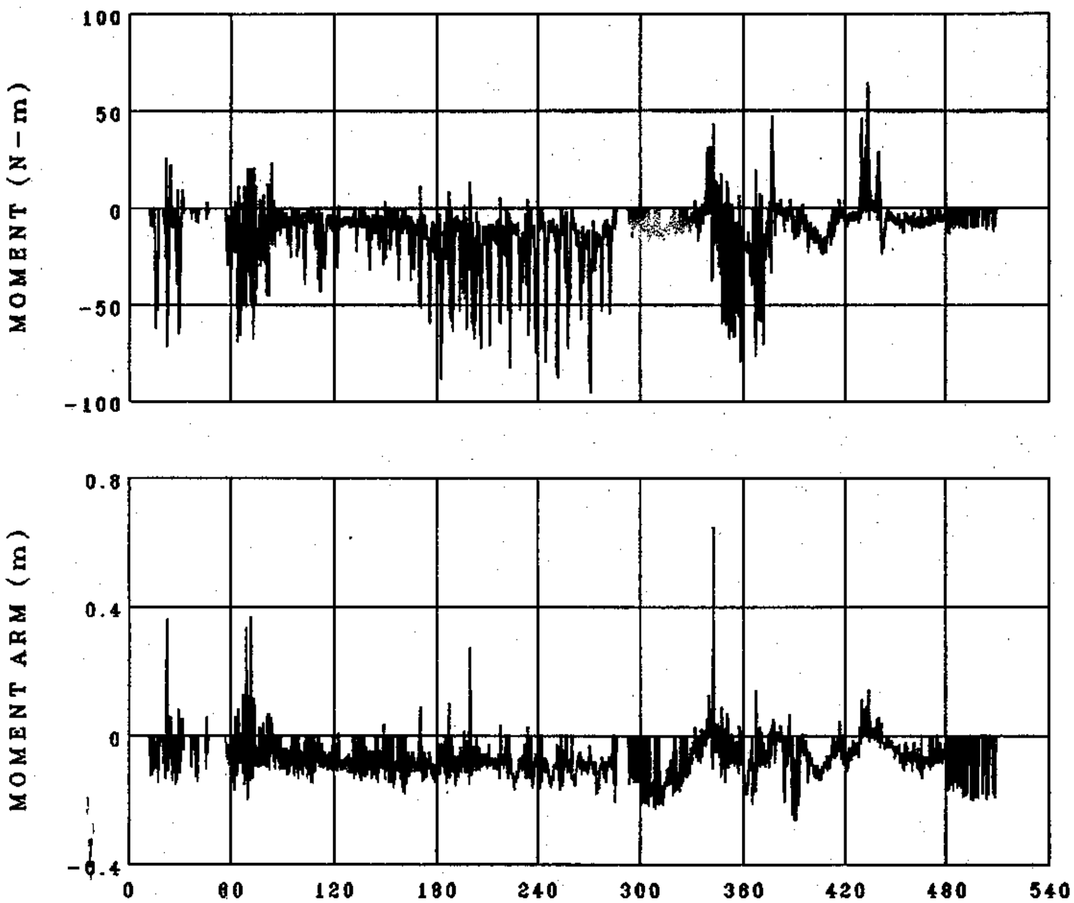
ICE PILEUP STUDY
for CANADIAN COAST GUARD

FILE TN←006

MOMENT



MOMENT

MEAN MOMENT = -11.23 N-m
MAX MOMENT = 64.40 N-m
MIN MOMENT = -96.00 N-m

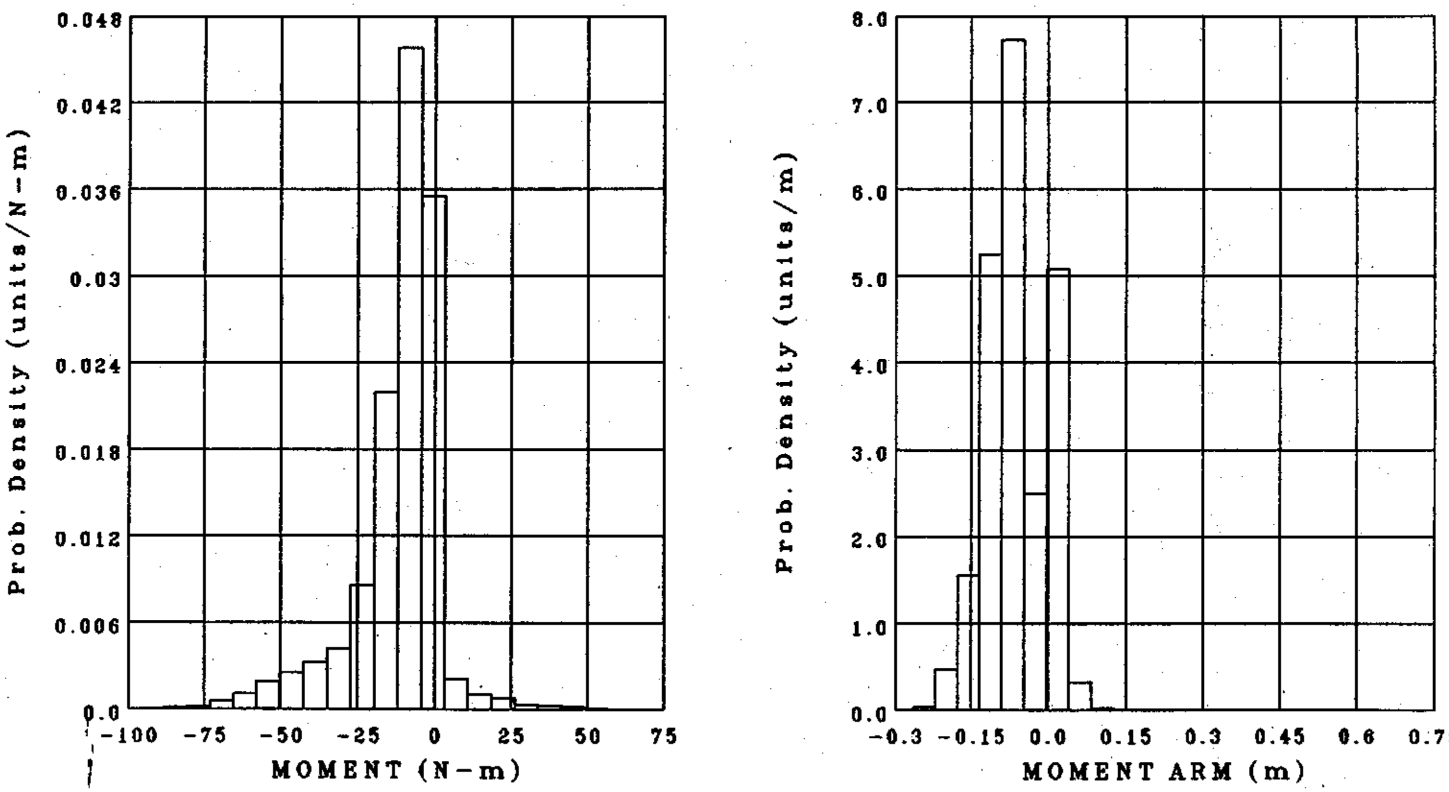
MOMENT ARM

MEAN ARM = -0.06452 m
MAX ARM = 0.6487 m
MIN ARM = -0.2638 m

TEST CONDITIONS

BOARD ANGLE = 0.0 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 64.00 kPa
ICE THICKNESS = 3.200 cm
ICE DENSITY = 0.9300 g/cc

TN←006



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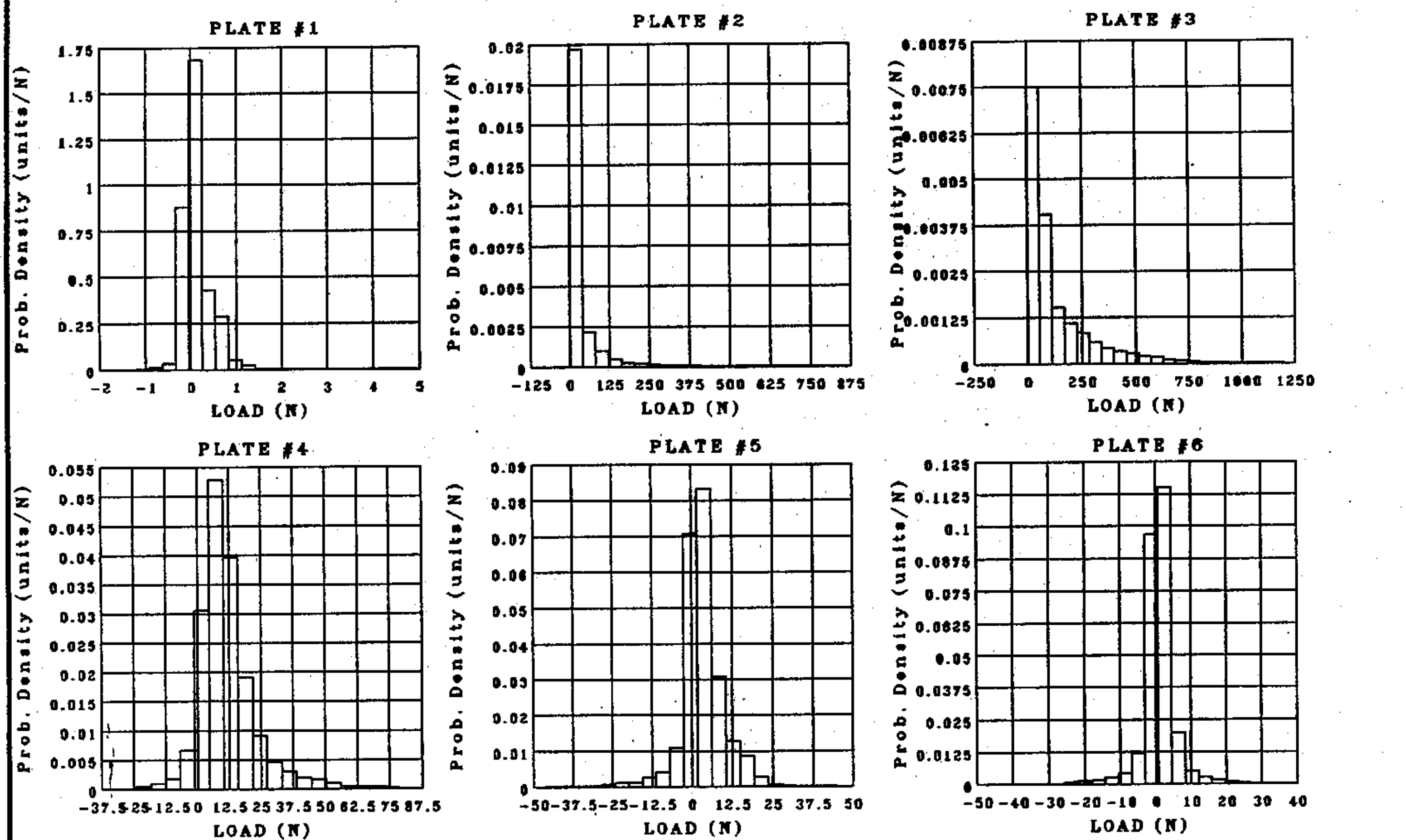
TN←006

NORMAL LOAD



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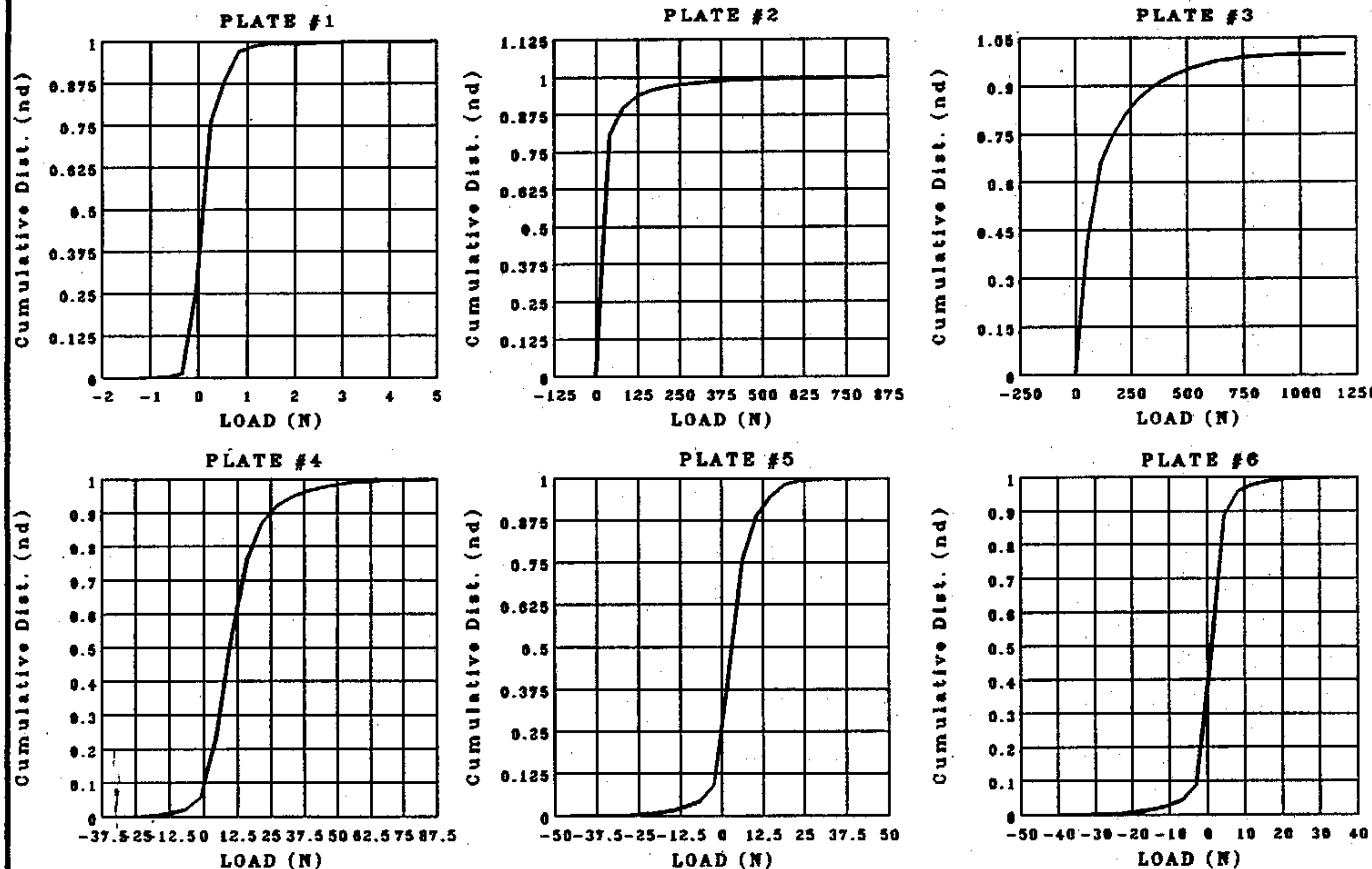
ICE PILEUP STUDY for CANADIAN COAST GUARD

TN←006
NORMAL LOAD



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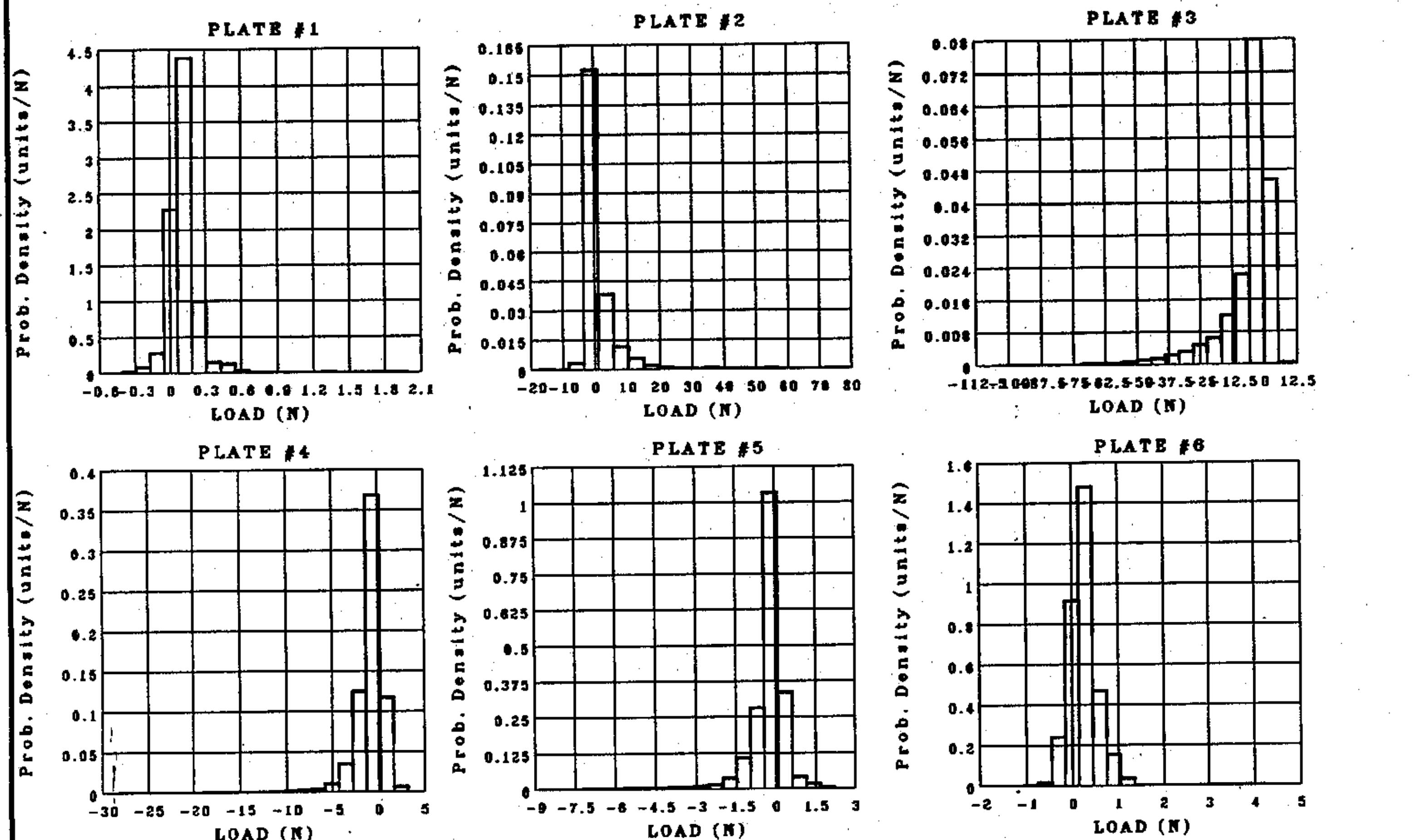
TN←006
TANGENTIAL LOAD



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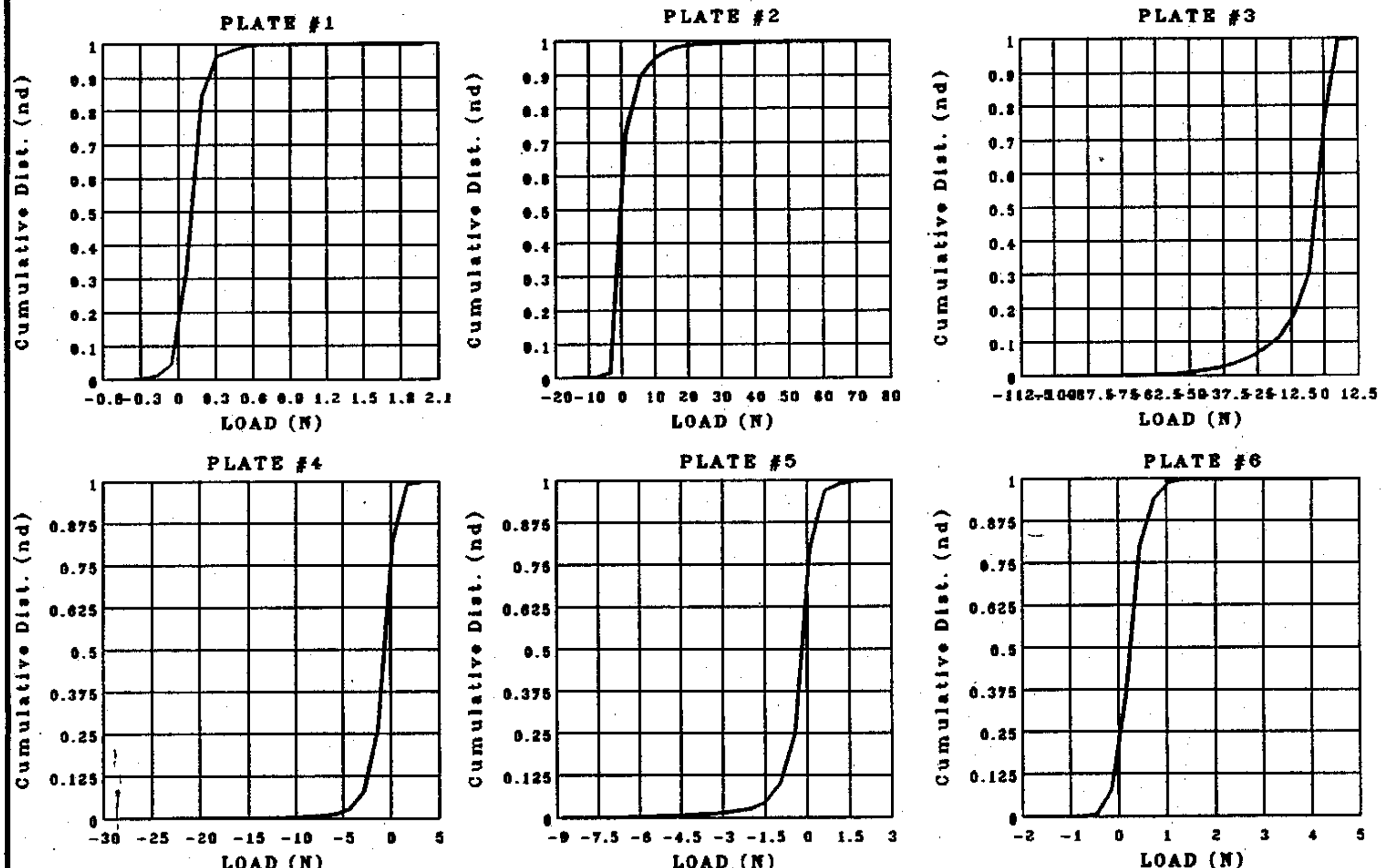
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←006
TANGENTIAL LOAD



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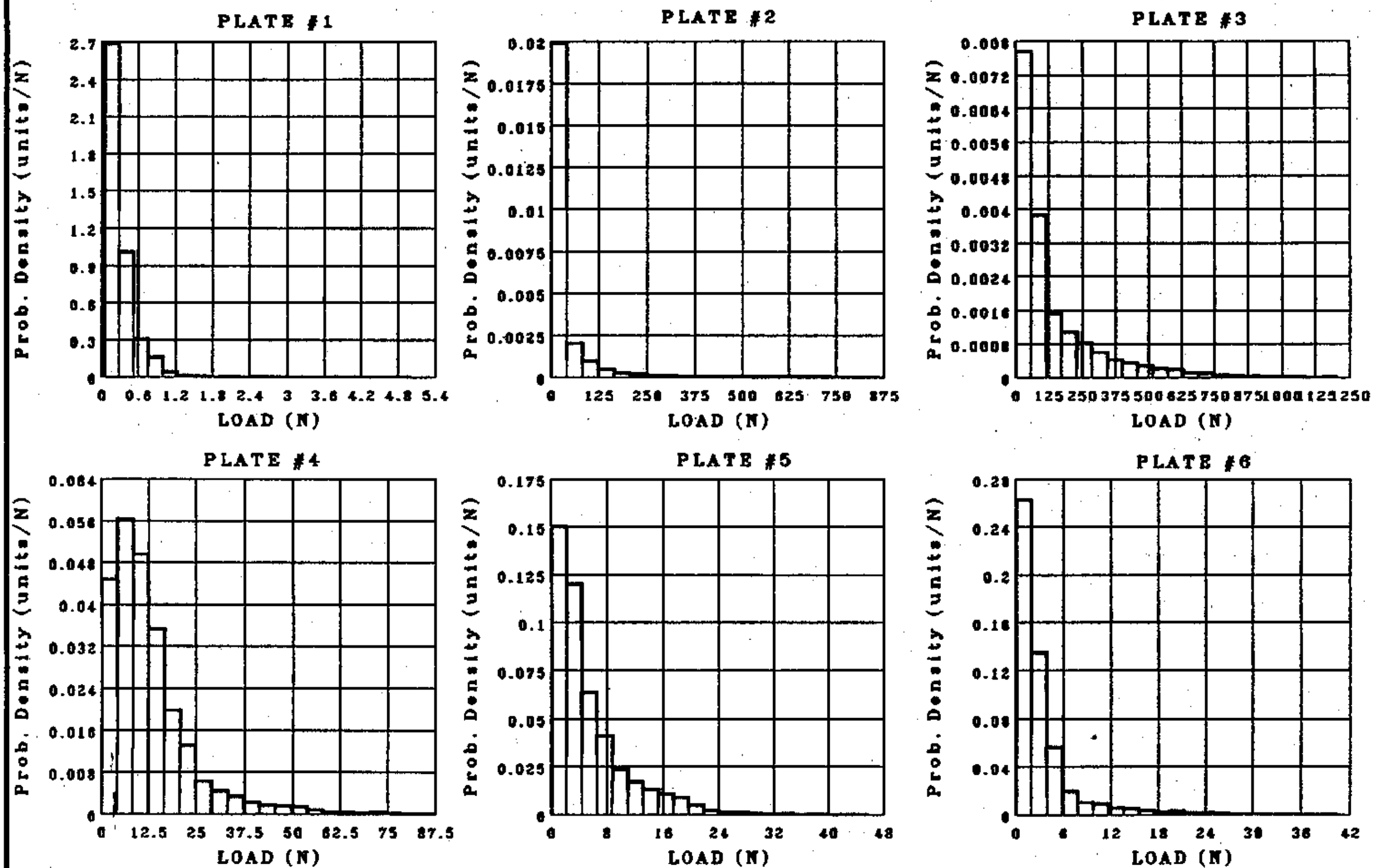
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←006
RESULTANT



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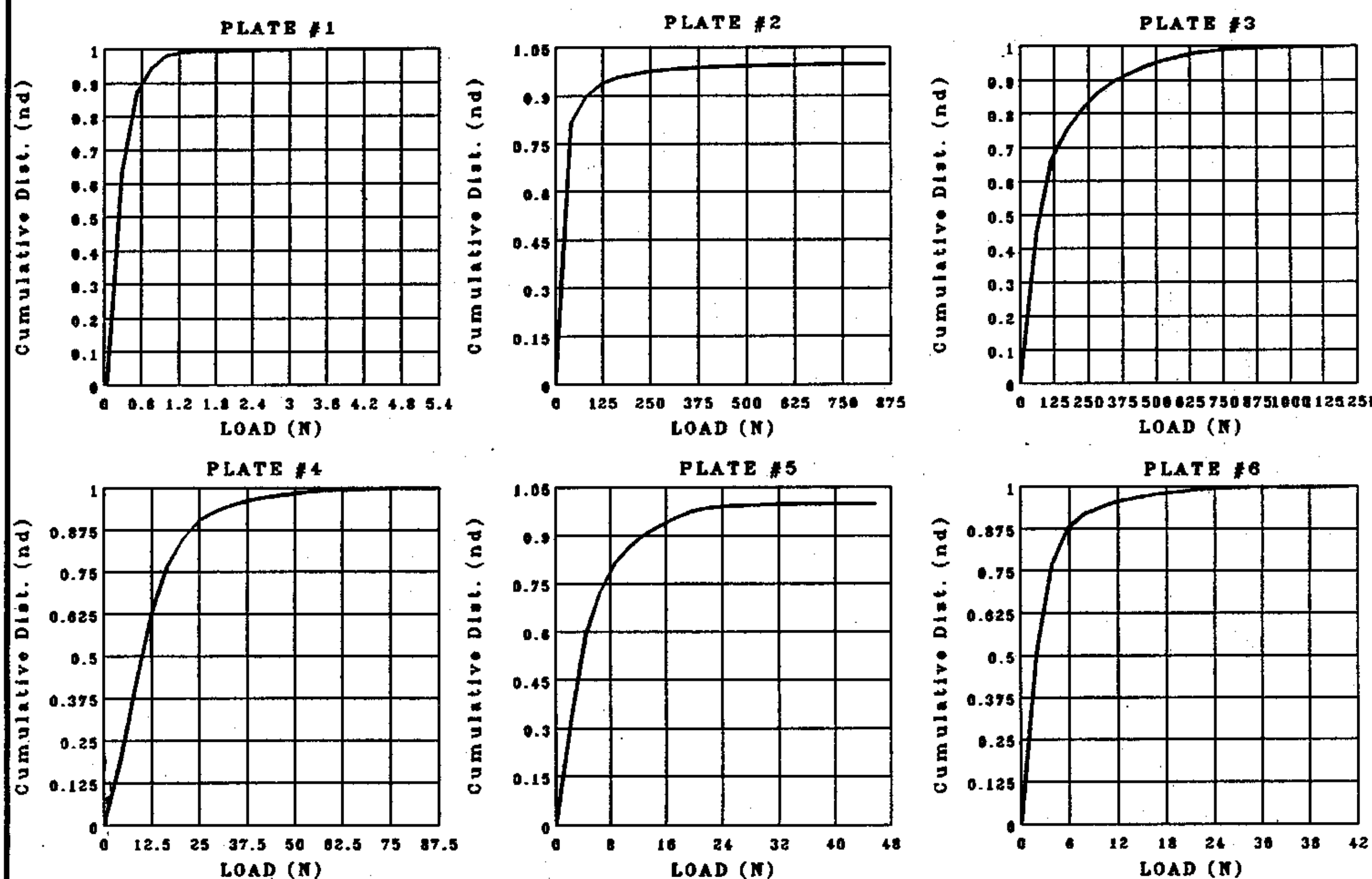
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←006
RESULTANT



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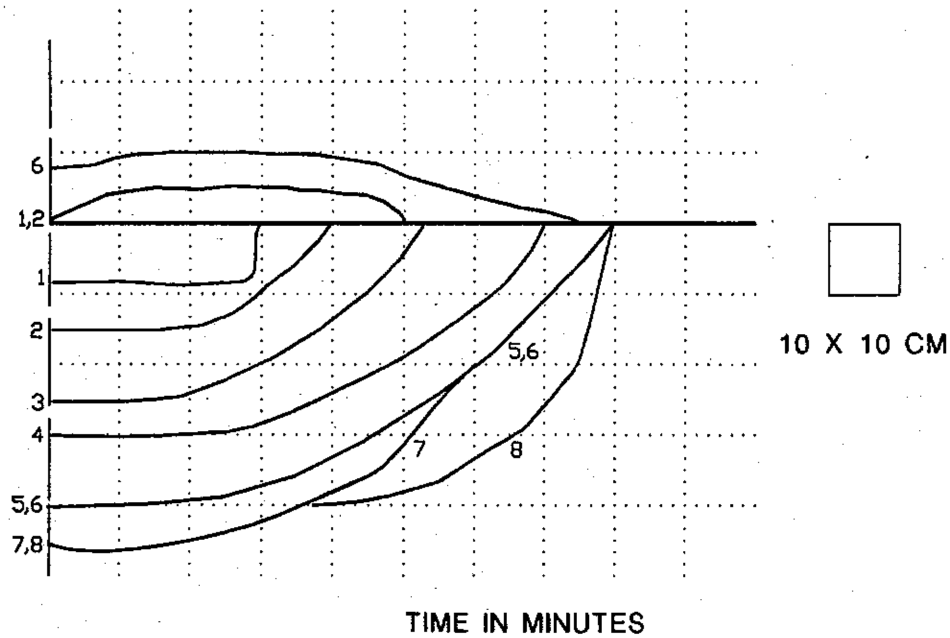
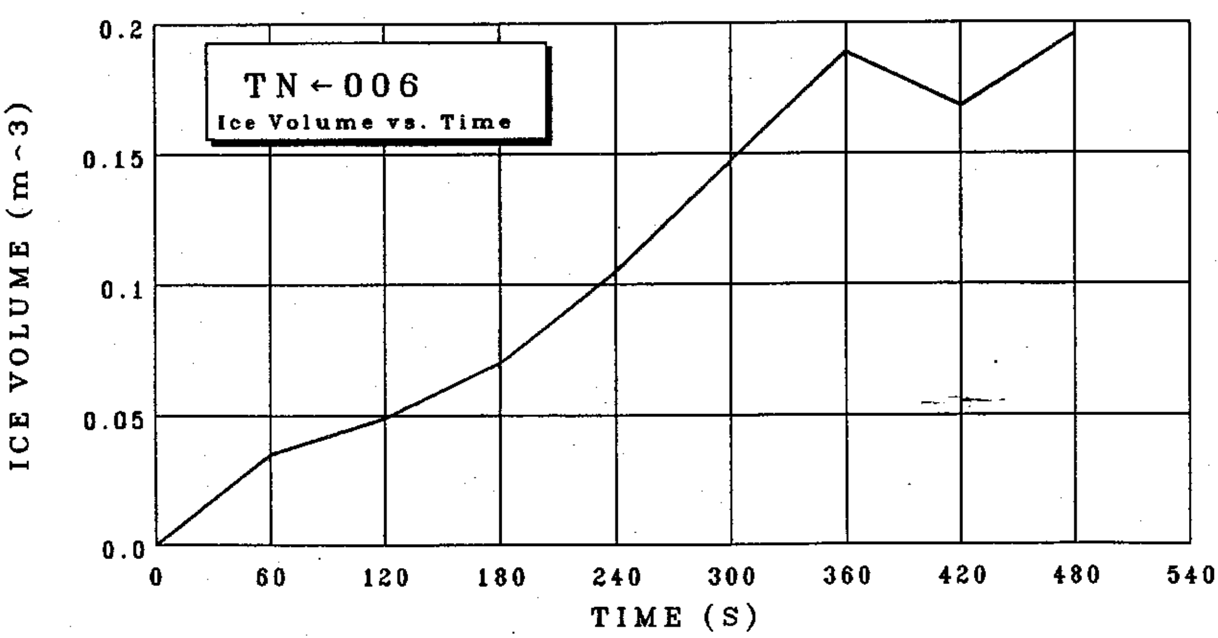
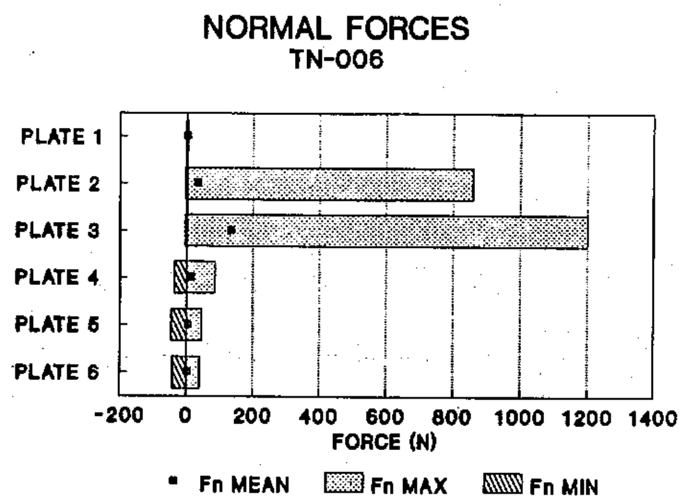
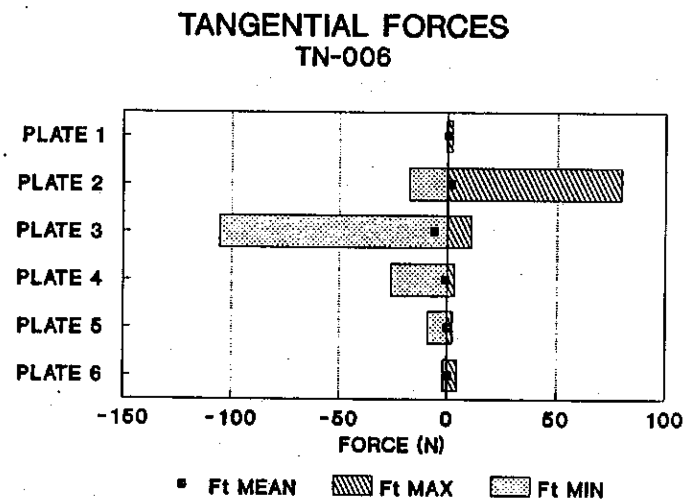
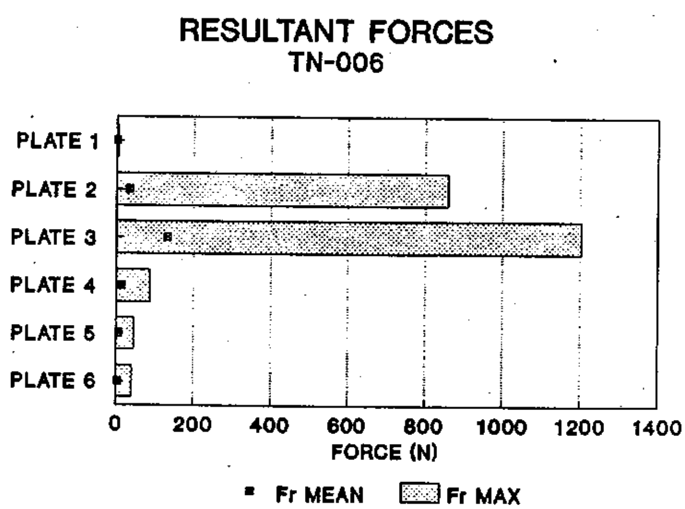
ICE PILEUP STUDY
for CANADIAN COAST GUARD

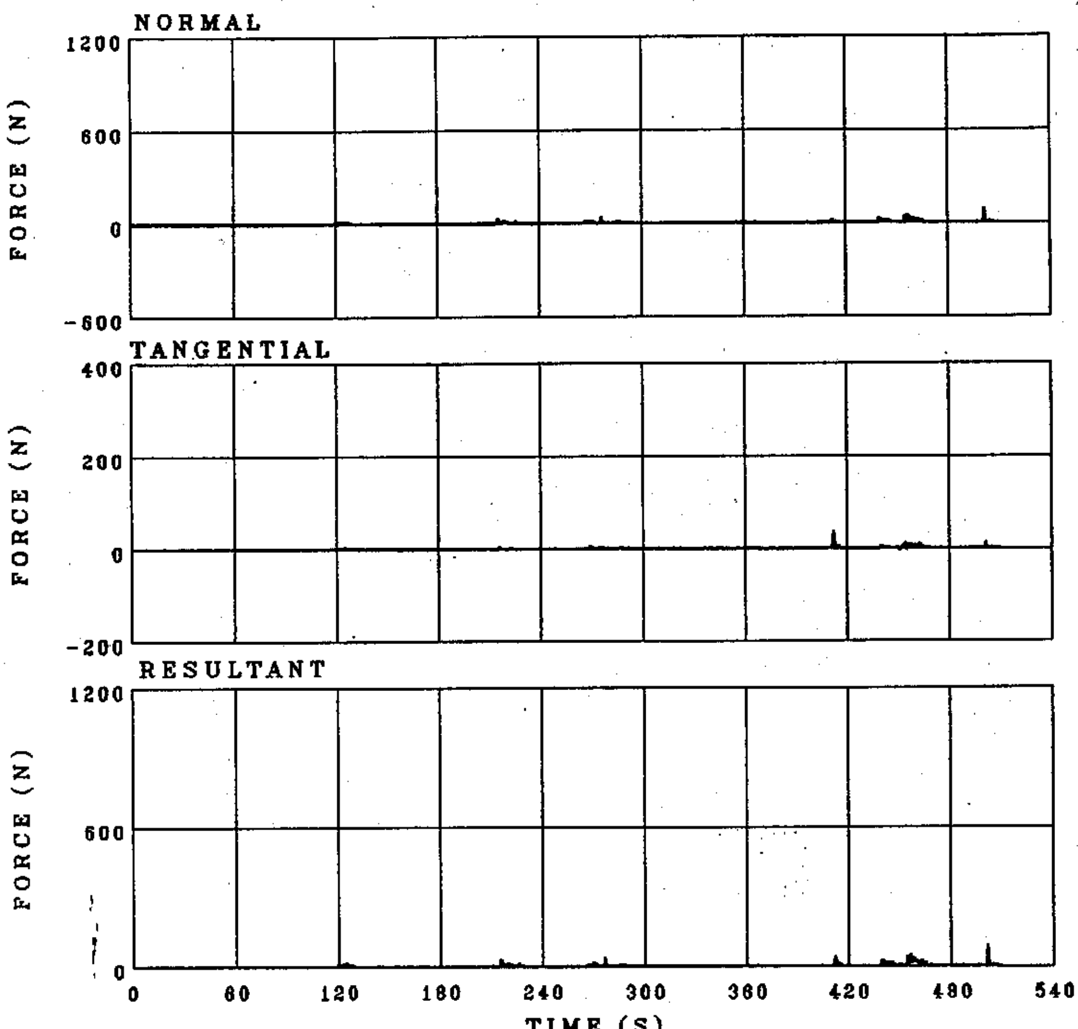

6
1,2
1
2
3
4
5,6
7,8
5,6
7
8
10 X 10 CM
TIME IN MINUTES


TN←006
Ice Volume vs. Time
ICE VOLUME (m^3)
0.2
0.15
0.1
0.05
0.0
0
60
120
180
240
300
360
420
480
540
TIME (S)


NORMAL FORCES
TN-006
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-200 0 200 400 600 800 1000 1200 1400
FORCE (N)
Fn MEAN
Fn MAX
Fn MIN


TANGENTIAL FORCES
TN-006
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-150 -100 -50 0 50 100
FORCE (N)
Ft MEAN
Ft MAX
Ft MIN


RESULTANT FORCES
TN-006
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
0 200 400 600 800 1000 1200 1400
FORCE (N)
Fr MEAN
Fr MAX



FILE TN←007

PLATE #1

NORMAL

MEAN FORCE = 1.559 N
MAX FORCE = 48.96 N
MIN FORCE = -3.123 N

TANGENTIAL

MEAN FORCE = 0.5572 N
MAX FORCE = 23.16 N
MIN FORCE = -3.751 N

RESULTANT

MEAN FORCE = 1.884 N
MAX FORCE = 49.82 N
MIN FORCE = 0.04429 N
AVERAGE ANGLE = -6.365 O

TEST CONDITIONS

BOARD ANGLE = 8.000 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 101.0 kPa
ICE THICKNESS = 3.500 cm
ICE DENSITY = 0.9300 g/cc

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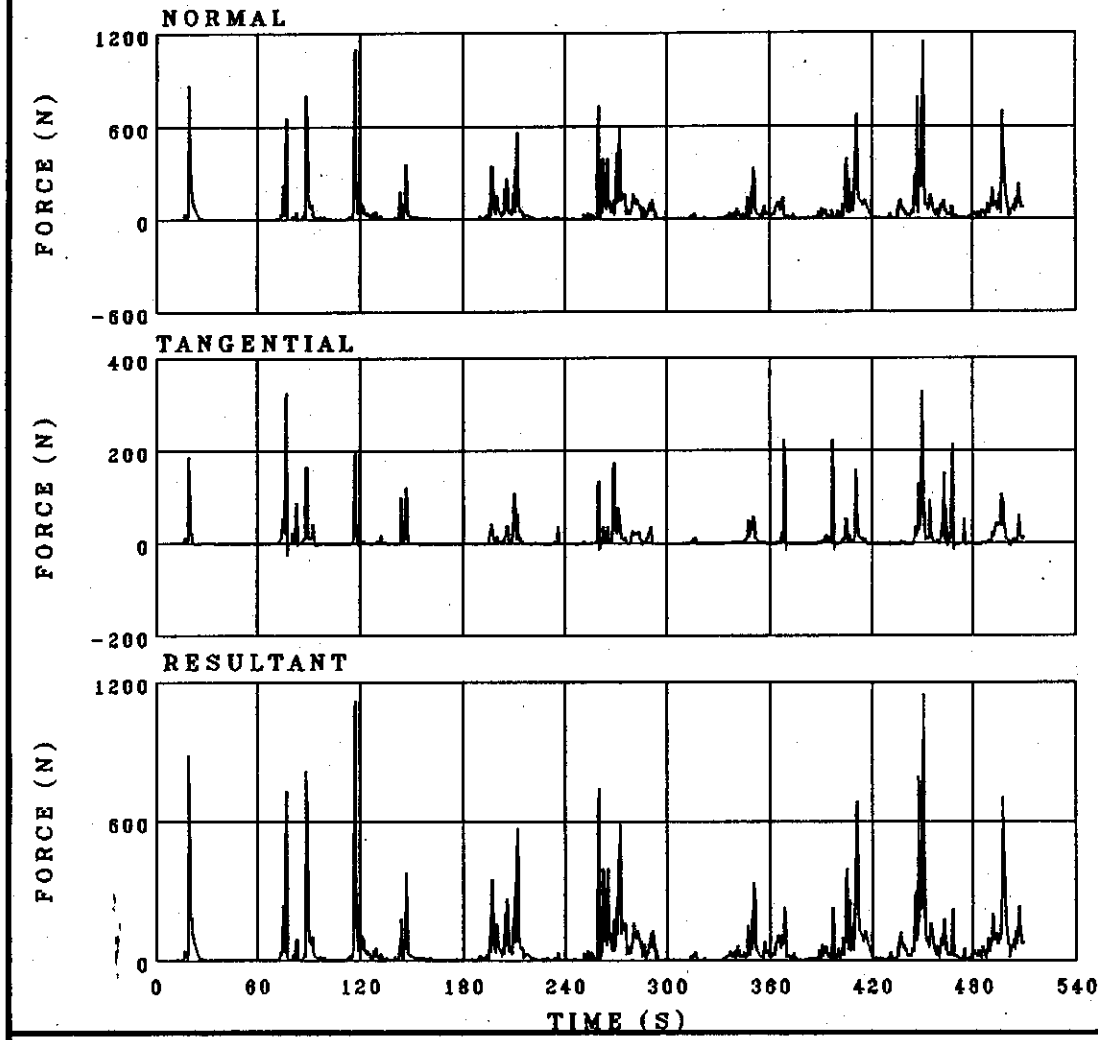
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←007

PLATE #2

NORMAL

MEAN FORCE = 44.84 N
MAX FORCE = 1147.0 N
MIN FORCE = -1.526 N

TANGENTIAL

MEAN FORCE = 7.486 N
MAX FORCE = 328.4 N
MIN FORCE = -27.67 N

RESULTANT

MEAN FORCE = 47.28 N
MAX FORCE = 1150.0 N
MIN FORCE = 0.08121 N
AVERAGE ANGLE = -15.20 O

TEST CONDITIONS

BOARD ANGLE = 8.000 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 101.0 kPa
ICE THICKNESS = 3.500 cm
ICE DENSITY = 0.9300 g/cc

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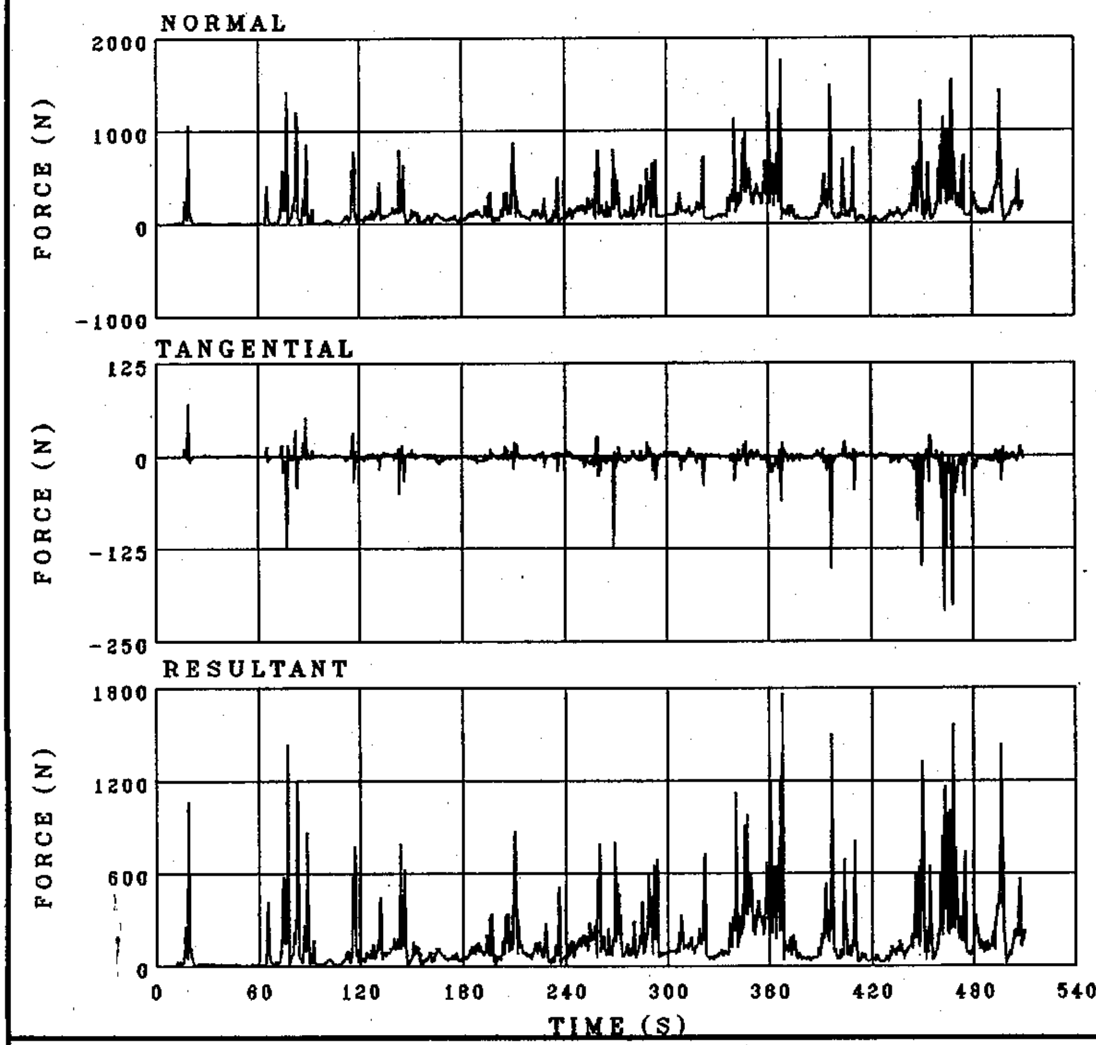
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←007

PLATE #3

NORMAL

MEAN FORCE = 153.3 N
MAX FORCE = 1766.0 N
MIN FORCE = -11.33 N

TANGENTIAL

MEAN FORCE = -2.819 N
MAX FORCE = 70.86 N
MIN FORCE = -209.6 N

RESULTANT

MEAN FORCE = 153.5 N
MAX FORCE = 1767.0 N
MIN FORCE = 0.05322 N
AVERAGE ANGLE = -0.7270 D

TEST CONDITIONS

BOARD ANGLE = 8.000 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 101.0 kPa
ICE THICKNESS = 3.500 cm
ICE DENSITY = 0.9300 g/cc

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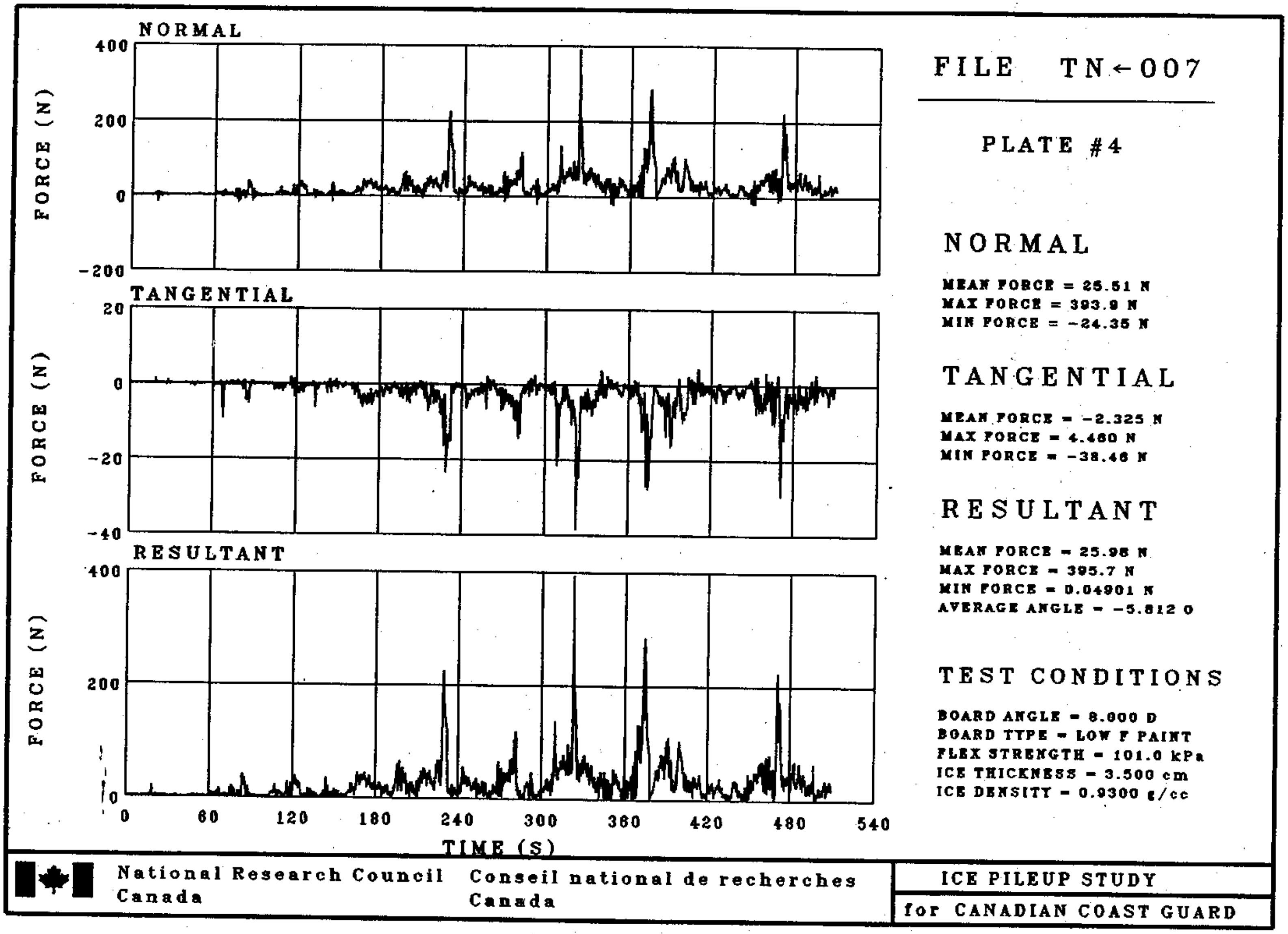
ICE PILEUP STUDY
for CANADIAN COAST GUARD



NORMAL
TANGENTIAL
RESULTANT
FORCE (N)
TIME (S)
FILE TN-007
PLATE #4
NORMAL
MEAN FORCE = 25.51 N
MAX FORCE = 393.9 N
MIN FORCE = -24.35 N
TANGENTIAL
MEAN FORCE = -2.325 N
MAX FORCE = 4.460 N
MIN FORCE = -38.46 N
RESULTANT
MEAN FORCE = 25.98 N
MAX FORCE = 395.7 N
MIN FORCE = 0.04901 N
AVERAGE ANGLE = -5.812 0
TEST CONDITIONS
BOARD ANGLE = 8.000 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 101.0 kPa
ICE THICKNESS = 3.500 cm
ICE DENSITY = 0.9300 g/cc
National Research Council Canada
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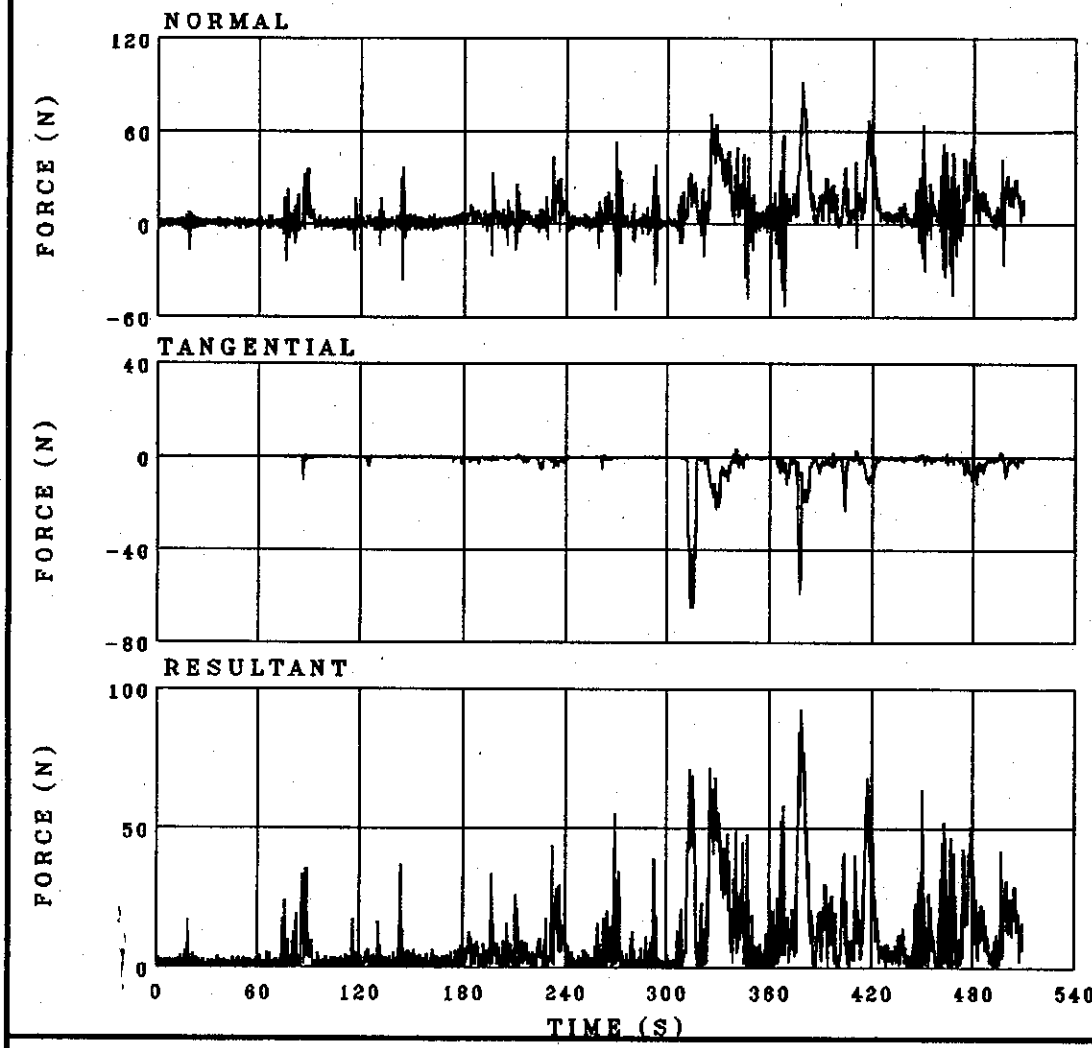
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←007

PLATE #5

NORMAL

MEAN FORCE = 6.745 N
MAX FORCE = 92.00 N
MIN FORCE = -55.31 N

TANGENTIAL

MEAN FORCE = -1.825 N
MAX FORCE = 3.895 N
MIN FORCE = -65.17 N

RESULTANT

MEAN FORCE = 8.560 N
MAX FORCE = 92.90 N
MIN FORCE = 0.02519 N
AVERAGE ANGLE = -4.206 O

TEST CONDITIONS

BOARD ANGLE = 8.000 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 101.0 kPa
ICE THICKNESS = 3.500 cm
ICE DENSITY = 0.9300 g/cc

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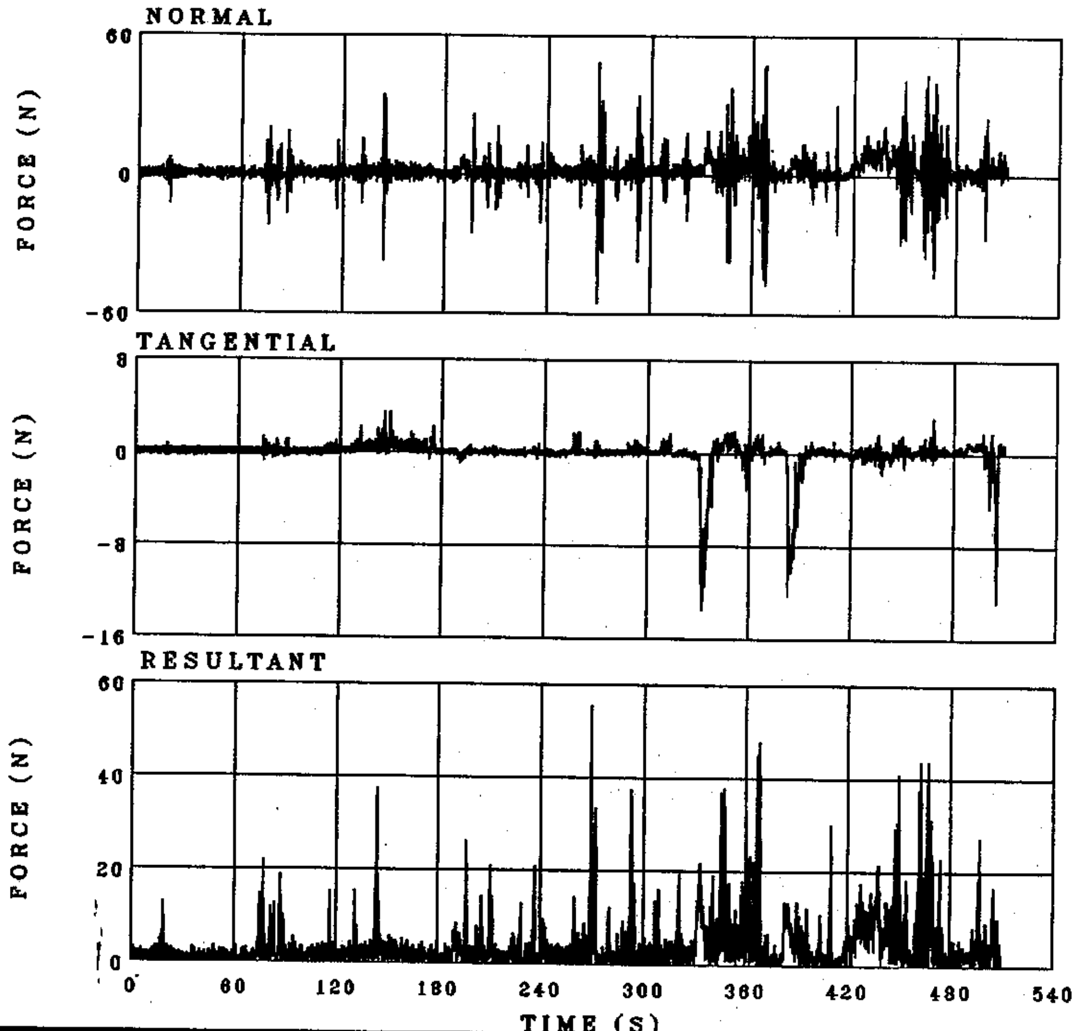
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN-007

PLATE #6

NORMAL

MEAN FORCE = 1.425 N
MAX FORCE = 48.60 N
MIN FORCE = -55.51 N

TANGENTIAL

MEAN FORCE = -0.04073 N
MAX FORCE = 3.587 N
MIN FORCE = -13.55 N

RESULTANT

MEAN FORCE = 3.101 N
MAX FORCE = 55.51 N
MIN FORCE = 0.01126 N
AVERAGE ANGLE = 26.47 O

TEST CONDITIONS

BOARD ANGLE = 8.000 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 101.0 kPa
ICE THICKNESS = 3.500 cm
ICE DENSITY = 0.9300 g/cc

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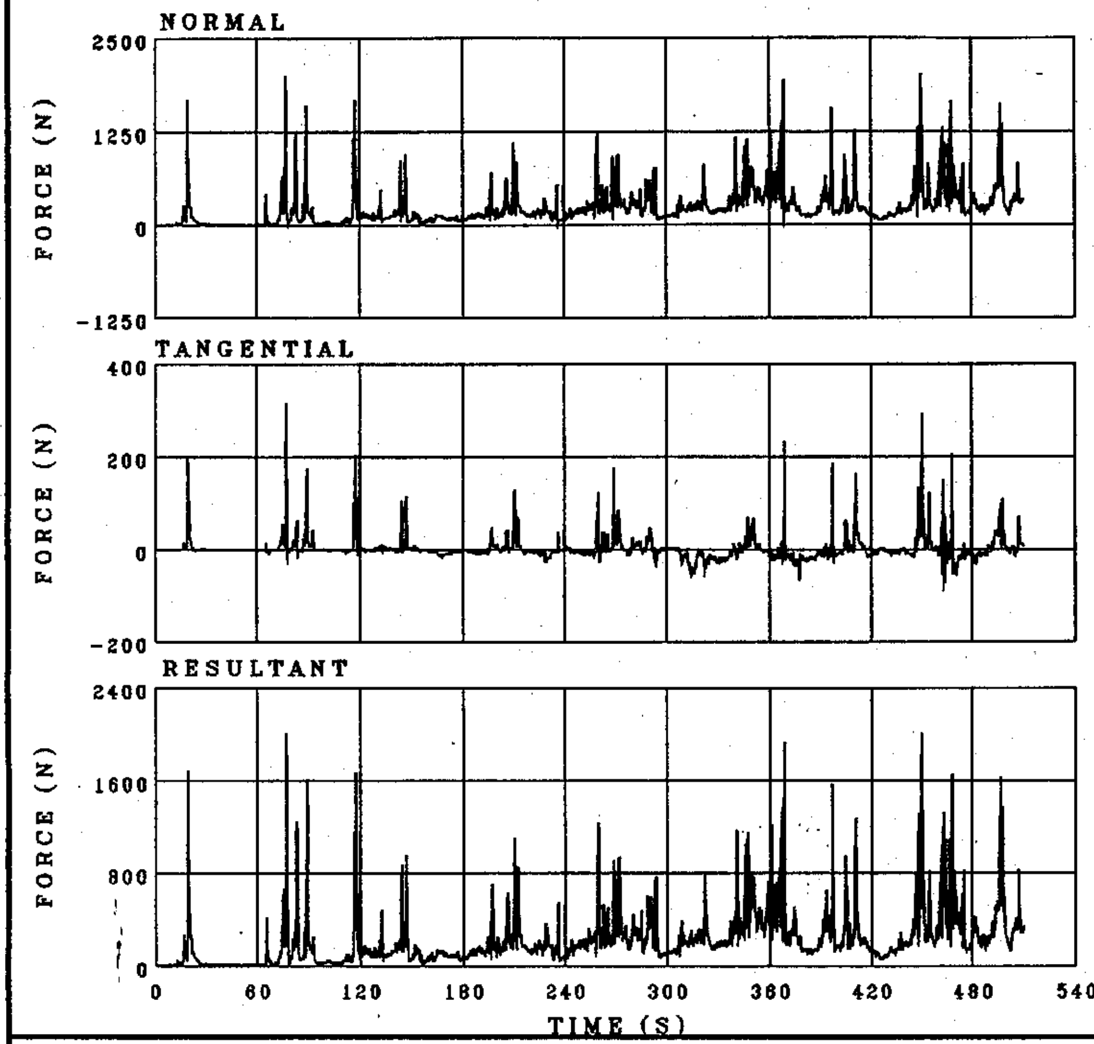
ICE PILEUP STUDY for CANADIAN COAST GUARD



FILE TN←007

TOTAL

NORMAL

MEAN FORCE = 233.4 N
MAX FORCE = 2010.0 N
MIN FORCE = -51.04 N

TANGENTIAL

MEAN FORCE = 1.034 N
MAX FORCE = 314.3 N
MIN FORCE = -90.90 N

RESULTANT

MEAN FORCE = 234.2 N
MAX FORCE = 2015.0 N
MIN FORCE = 0.1860 N
AVERAGE ANGLE = -1.347 O

TEST CONDITIONS

BOARD ANGLE = 8.000 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 101.0 kPa
ICE THICKNESS = 3.500 cm
ICE DENSITY = 0.9300 g/cc

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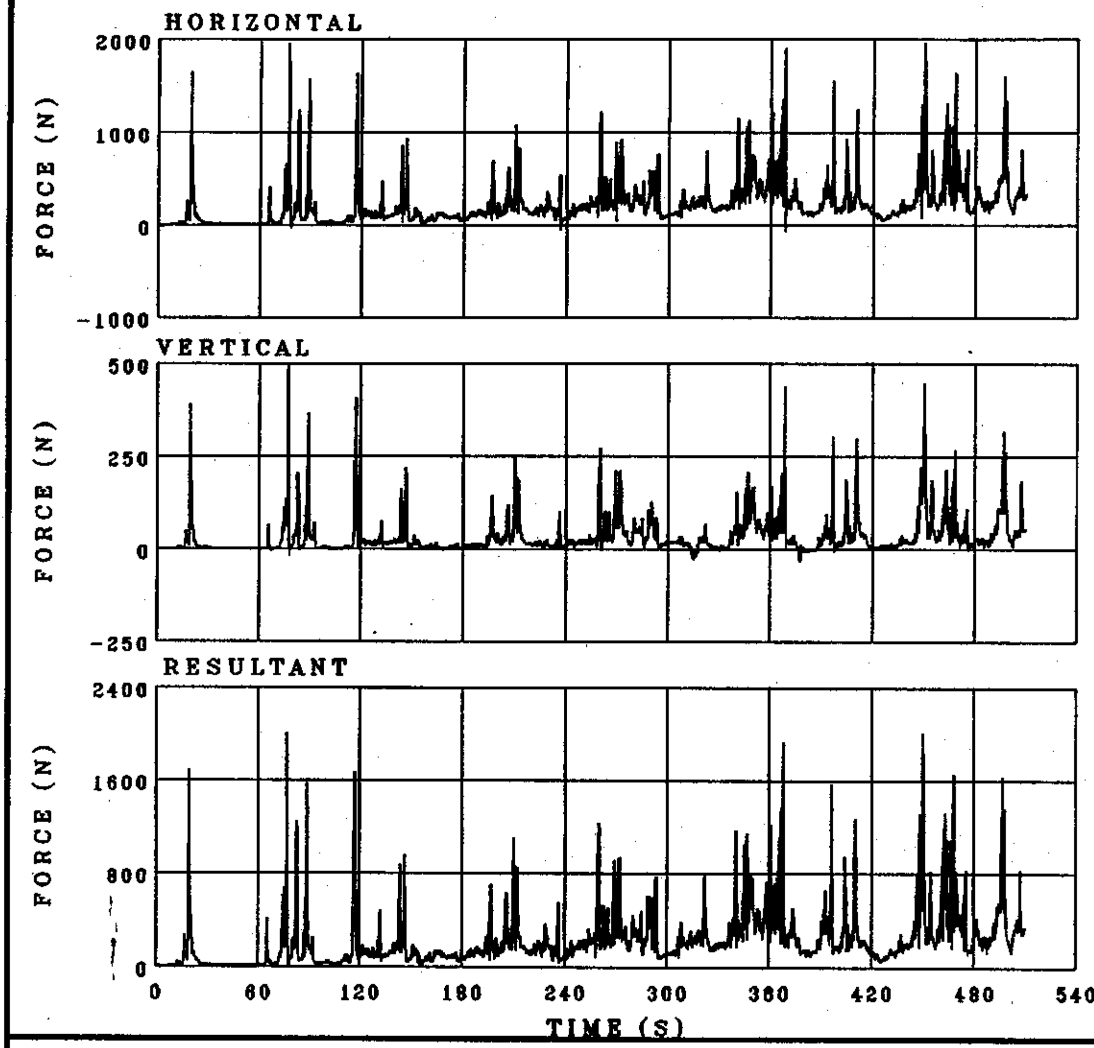
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←007

TOTAL

HORIZONTAL

MEAN FORCE = 1.034 N
MAX FORCE = 314.3 N
MIN FORCE = -90.90 N

VERTICAL

MEAN FORCE = 1.034 N
MAX FORCE = 314.3 N
MIN FORCE = -90.90 N

RESULTANT

MEAN FORCE = 1.034 N
MAX FORCE = 314.3 N
MIN FORCE = -90.90 N
AVERAGE ANGLE = 1.034 O

TEST CONDITIONS

BOARD ANGLE = 8.000 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 101.0 kPa
ICE THICKNESS = 3.500 cm
ICE DENSITY = 0.9300 g/cc

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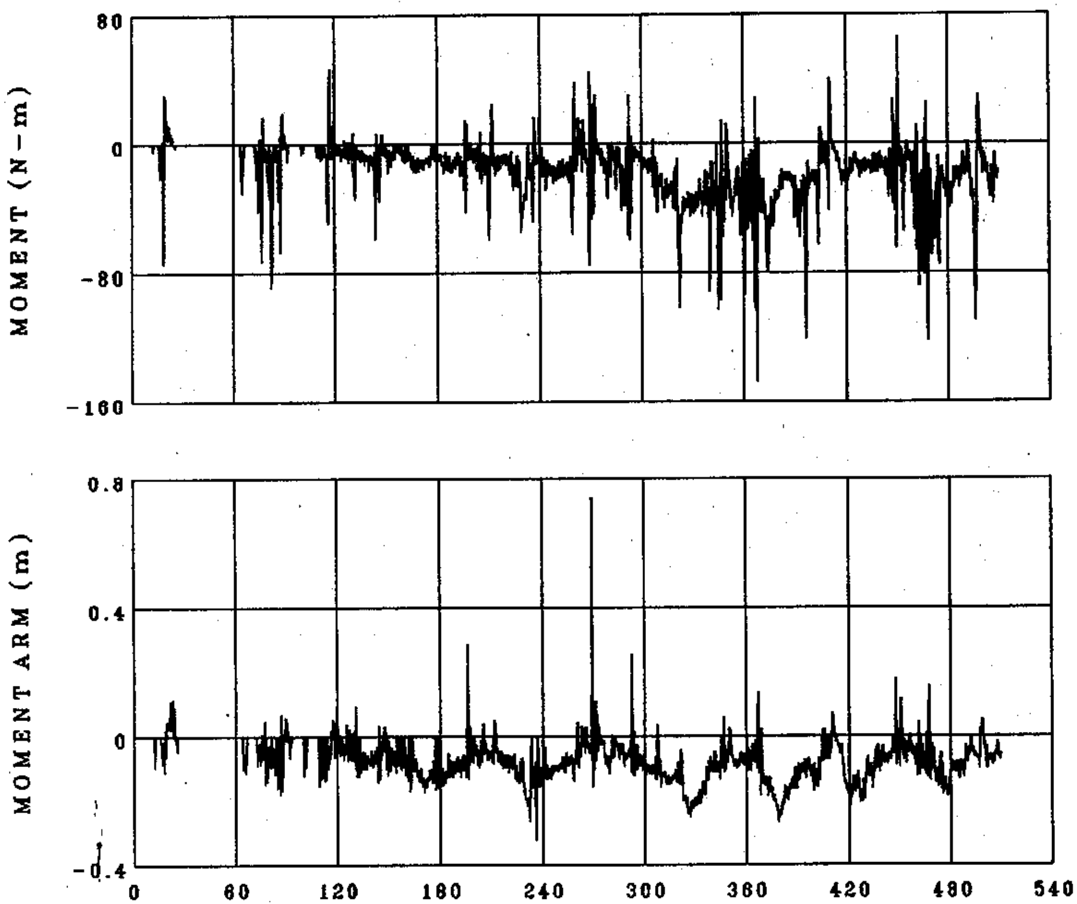
ICE PILEUP STUDY
for CANADIAN COAST GUARD

FILE TN←007

MOMENT



MOMENT

MEAN MOMENT = -16.56 N-m
MAX MOMENT = 66.18 N-m
MIN MOMENT = -147.5 N-m

MOMENT ARM

MEAN ARM = -0.07159 m
MAX ARM = 0.7431 m
MIN ARM = -0.3235 m

TEST CONDITIONS

BOARD ANGLE = 8.000 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 101.0 kPa
ICE THICKNESS = 3.500 cm
ICE DENSITY = 0.9300 g/cc

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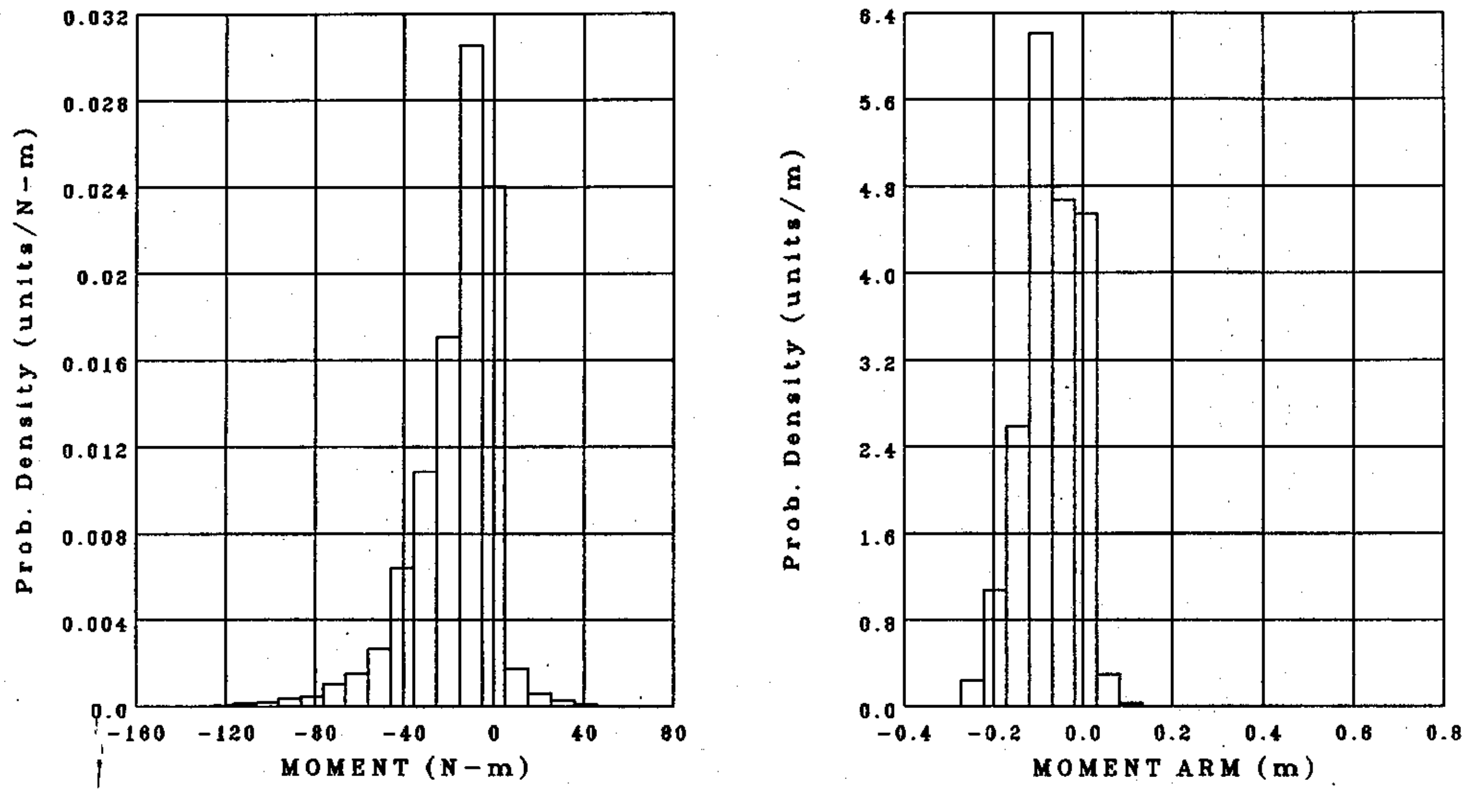
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←007



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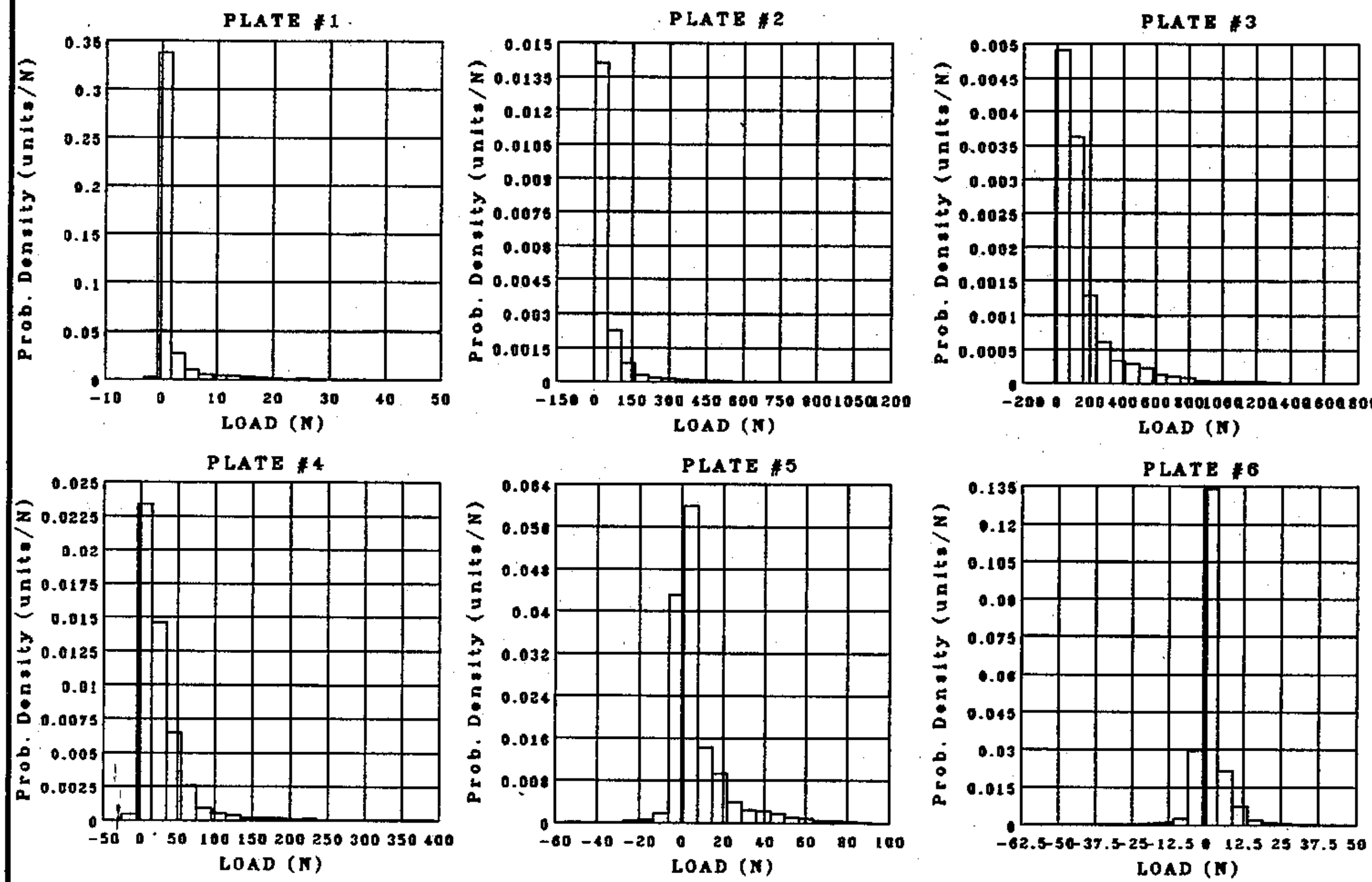
TN←007
NORMAL LOAD



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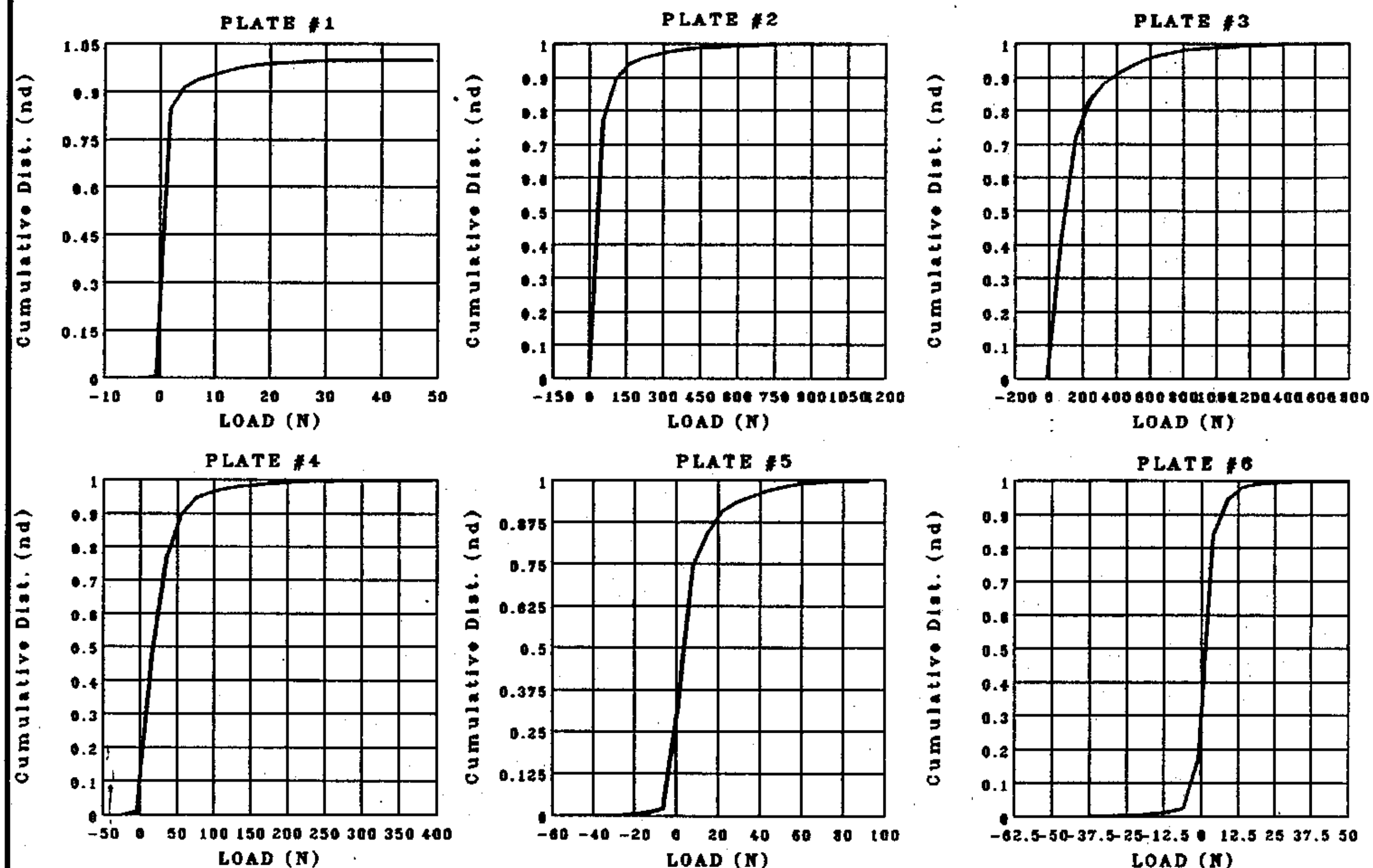
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←007
NORMAL LOAD



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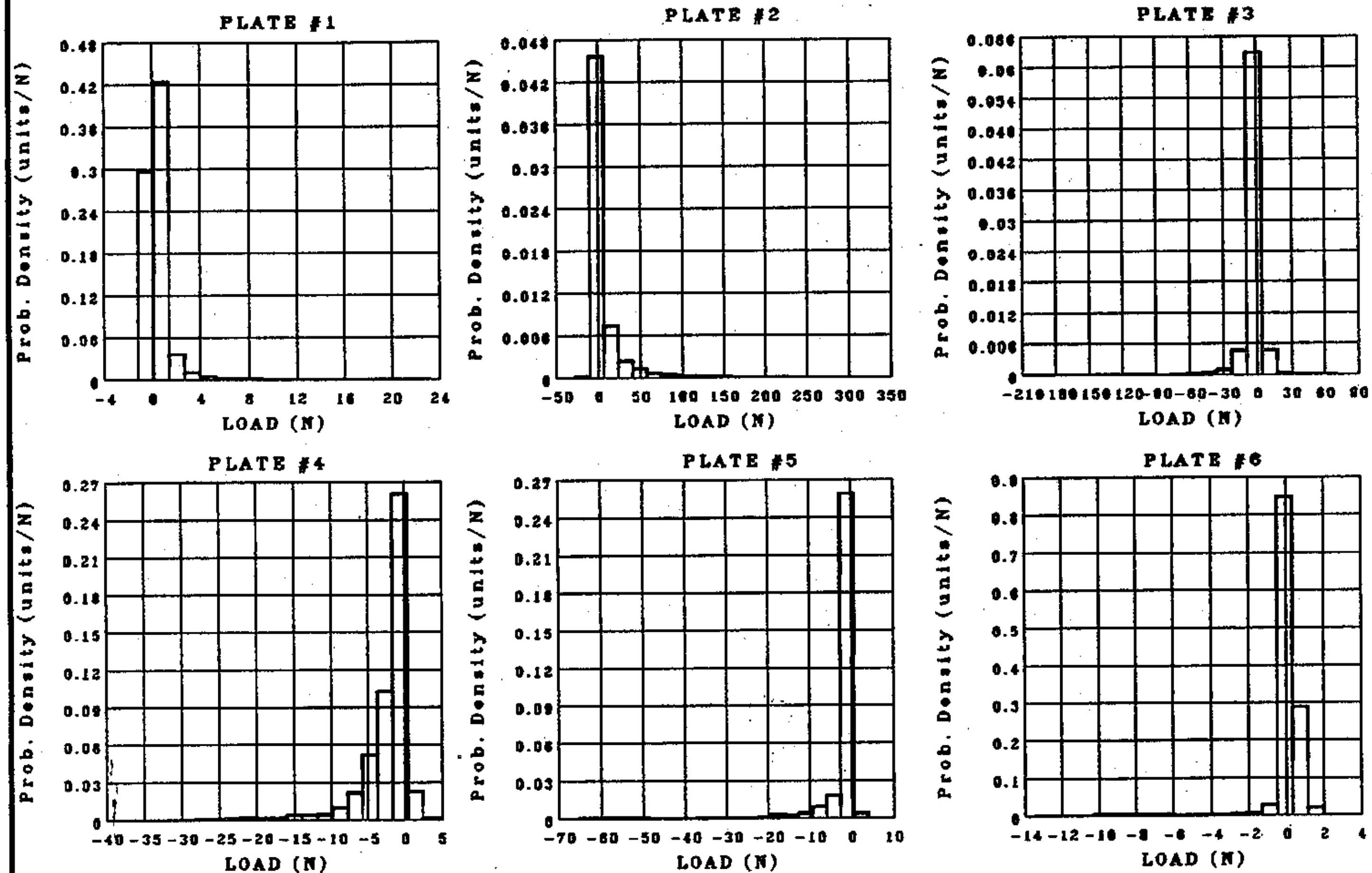
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←007
TANGENTIAL LOAD



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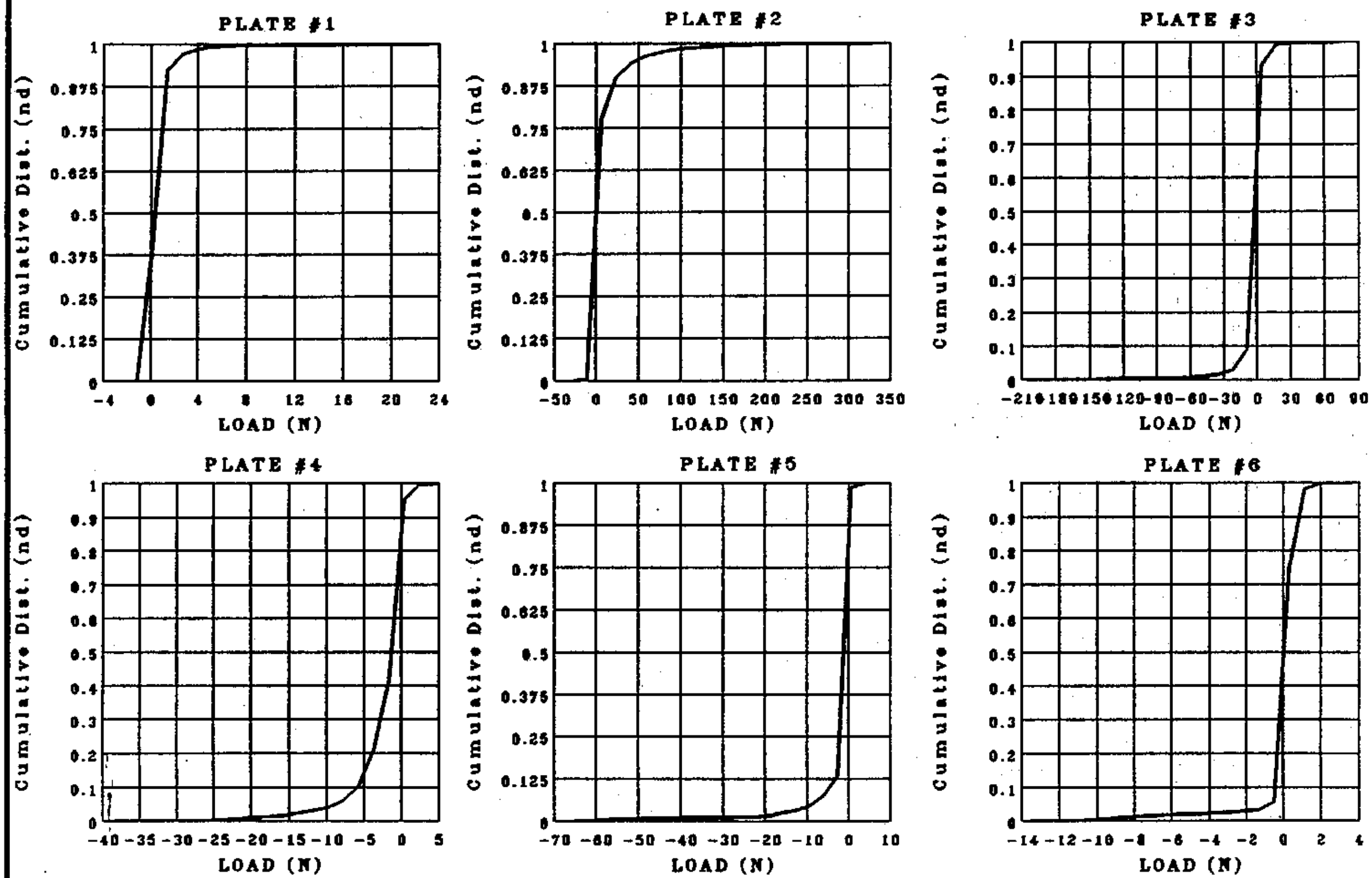
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←007
TANGENTIAL LOAD



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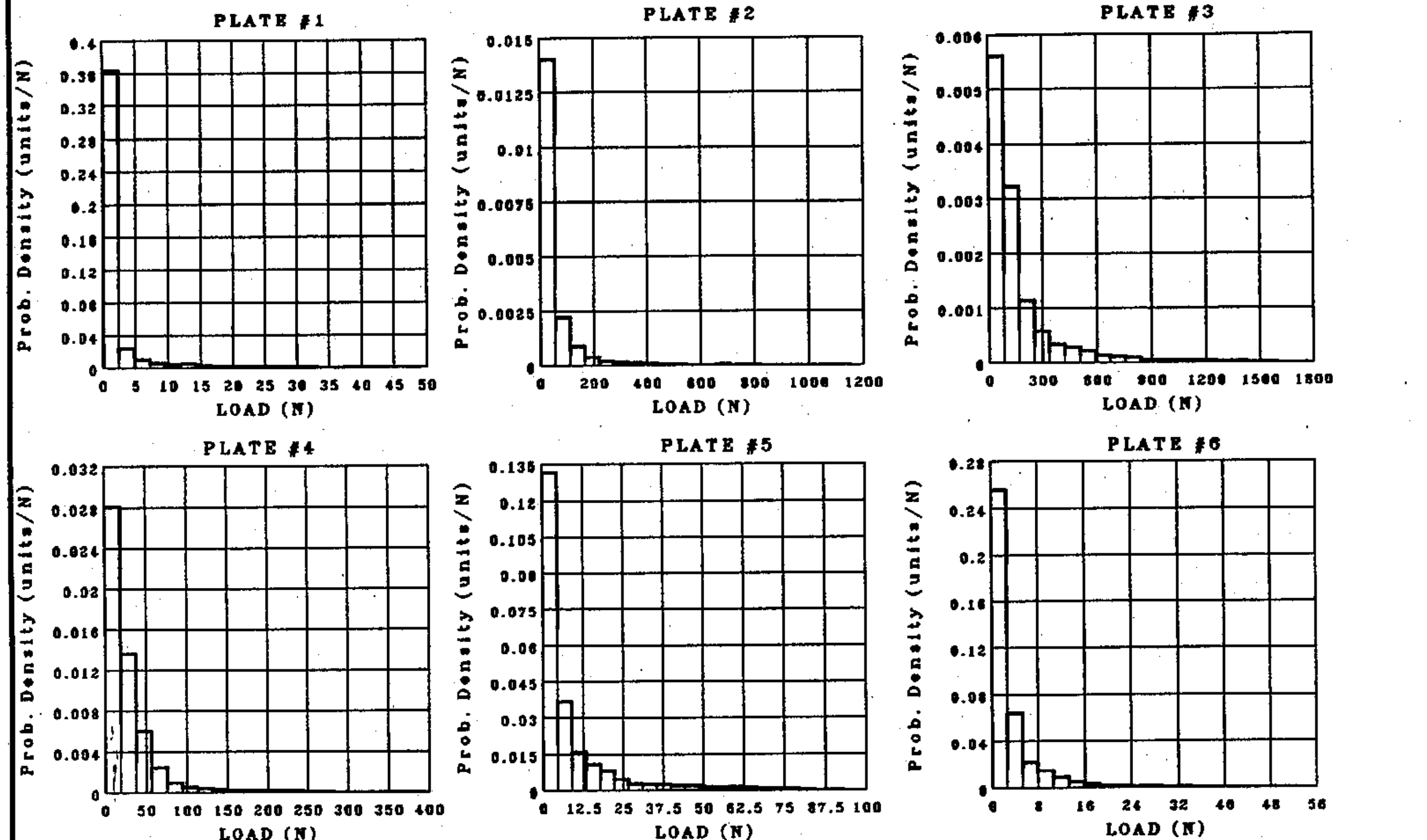
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←007
RESULTANT



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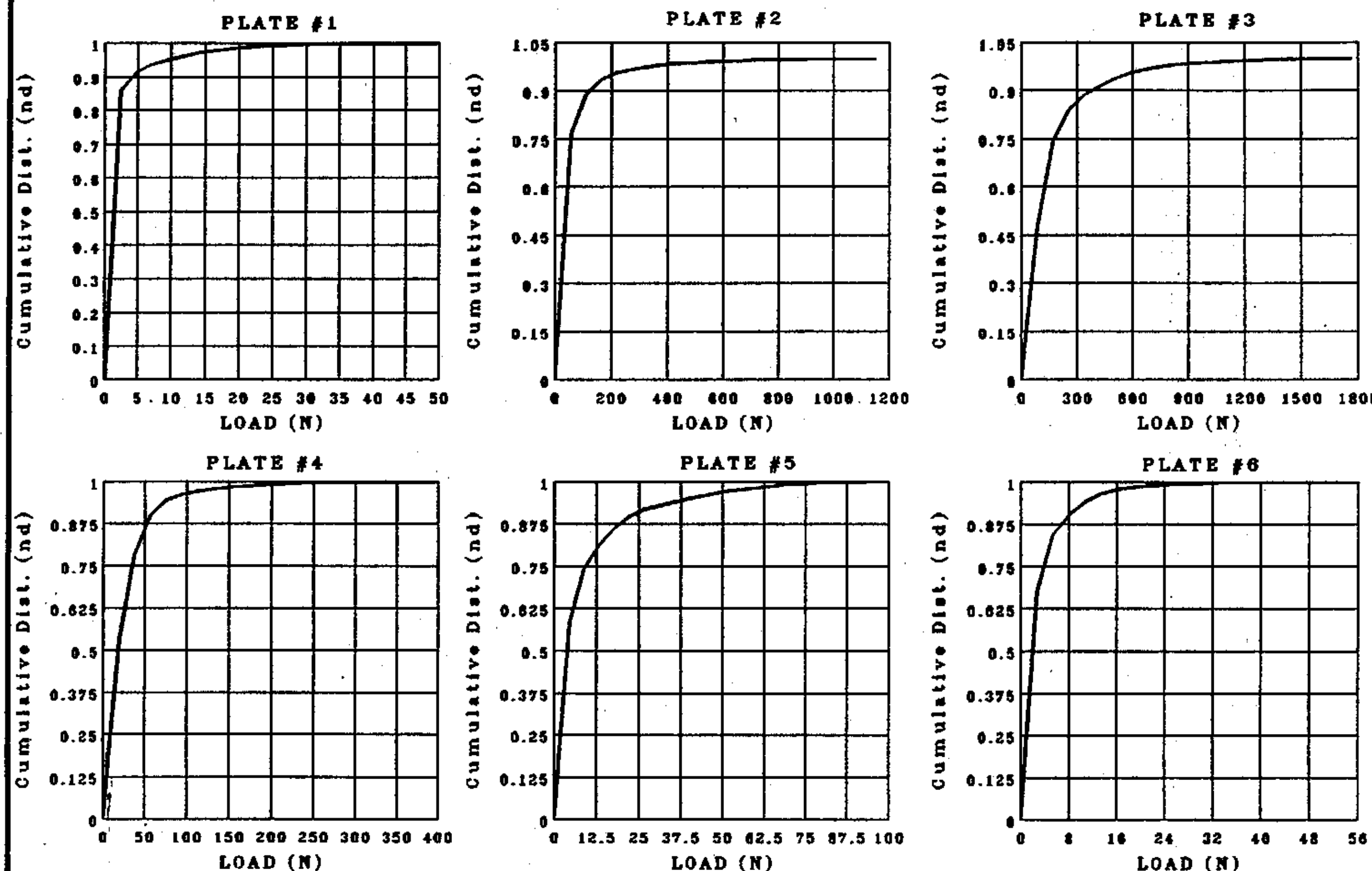
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←007
RESULTANT



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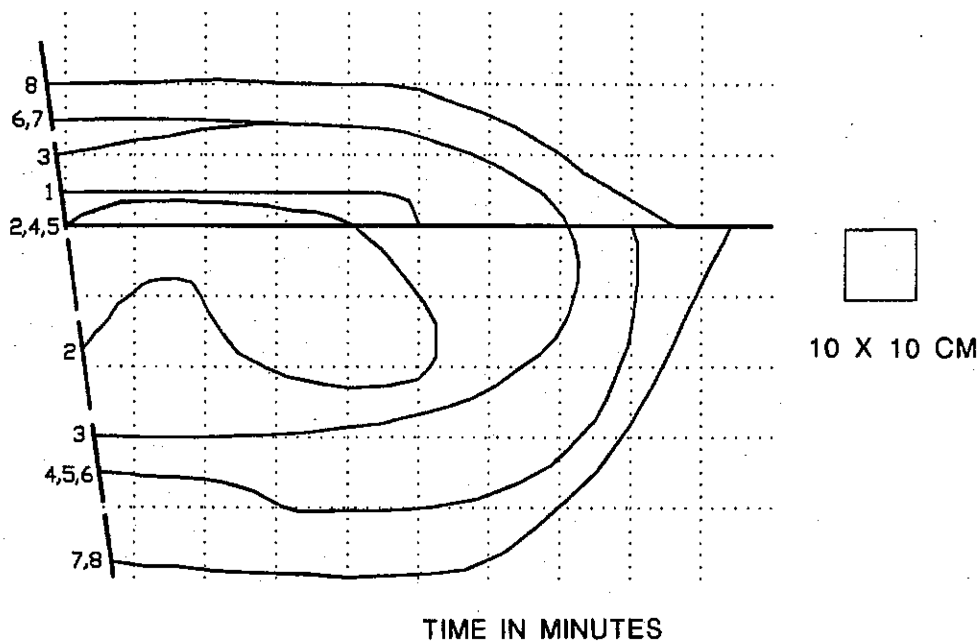
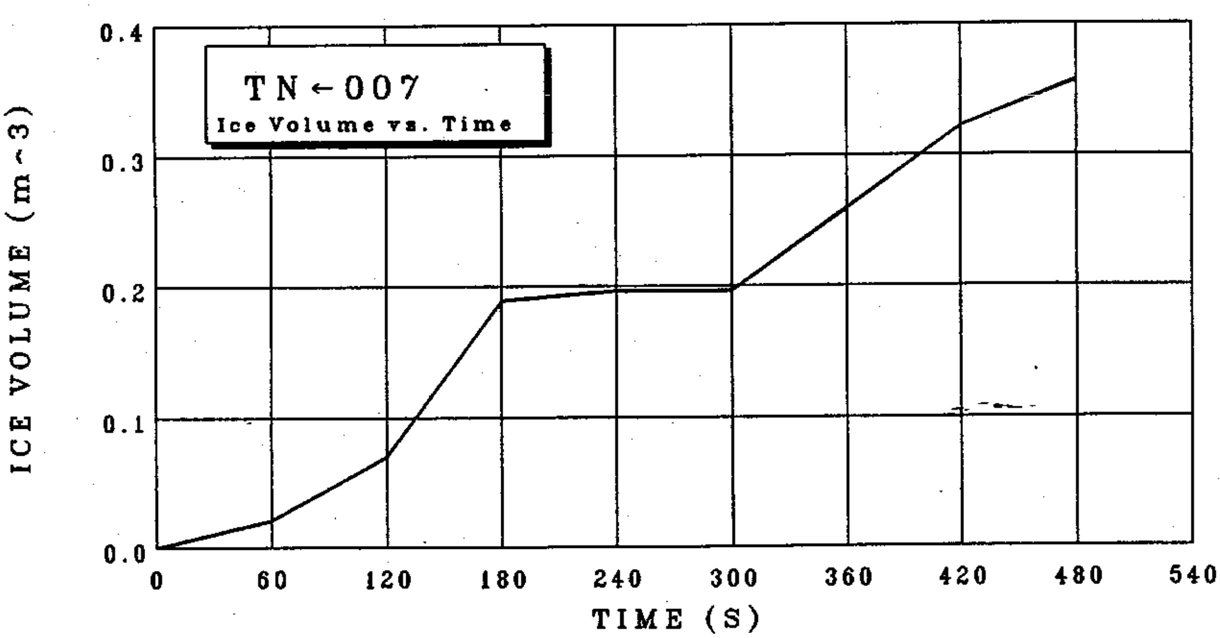
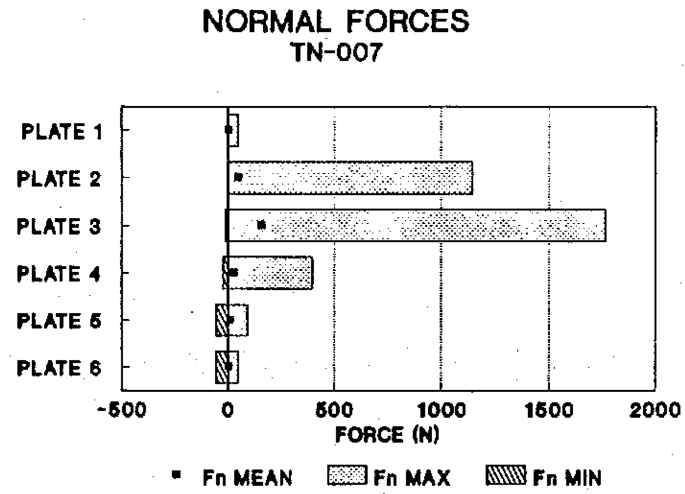
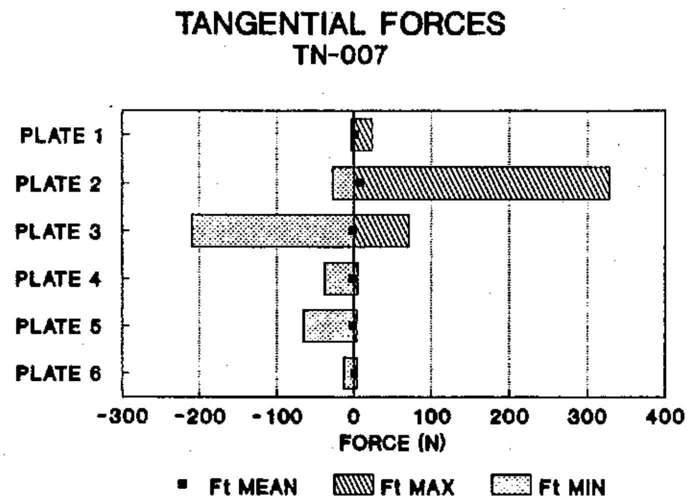
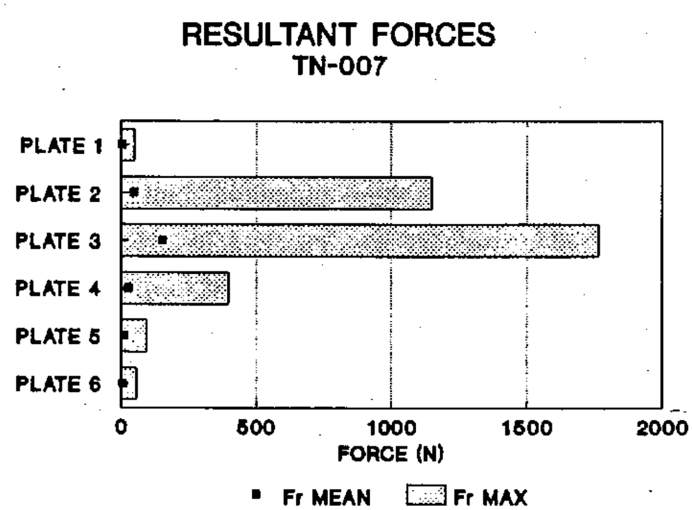
ICE PILEUP STUDY
for CANADIAN COAST GUARD

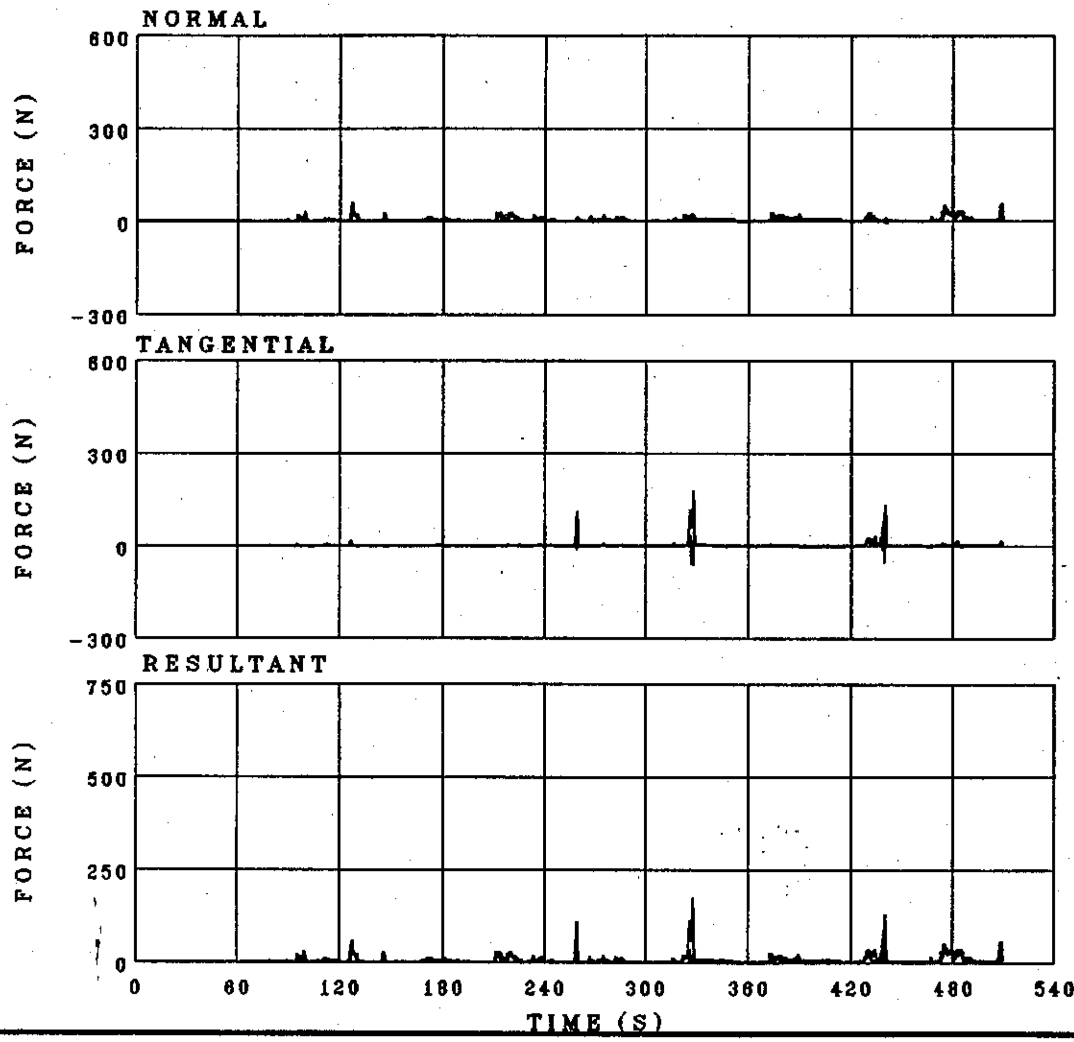

8
6,7
3
1
2,4,5
2
3
4,5,6
7,8
10 X 10 CM
TIME IN MINUTES


TN←007
Ice Volume vs. Time
ICE VOLUME (m^3)
0.0
0.1
0.2
0.3
0.4
0
60
120
180
240
300
360
420
480
540
TIME (S)


NORMAL FORCES
TN-007
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-500
0
500
1000
1500
2000
FORCE (N)
Fn MEAN
Fn MAX
Fn MIN


TANGENTIAL FORCES
TN-007
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-300
-200
-100
0
100
200
300
400
FORCE (N)
Ft MEAN
Ft MAX
Ft MIN


RESULTANT FORCES
TN-007
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
0
500
1000
1500
2000
FORCE (N)
Fr MEAN
Fr MAX



FILE TN←008

PLATE #1

NORMAL

MEAN FORCE = 3.603 N
MAX FORCE = 53.49 N
MIN FORCE = -3.711 N

TANGENTIAL

MEAN FORCE = 1.625 N
MAX FORCE = 98.15 N
MIN FORCE = -4.469 N

RESULTANT

MEAN FORCE = 4.430 N
MAX FORCE = 98.97 N
MIN FORCE = 0.08191 N
AVERAGE ANGLE = 31.77 O

TEST CONDITIONS

BOARD ANGLE = 15.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 85.00 kPa
ICE THICKNESS = 3.500 cm
ICE DENSITY = 0.9300 g/cc

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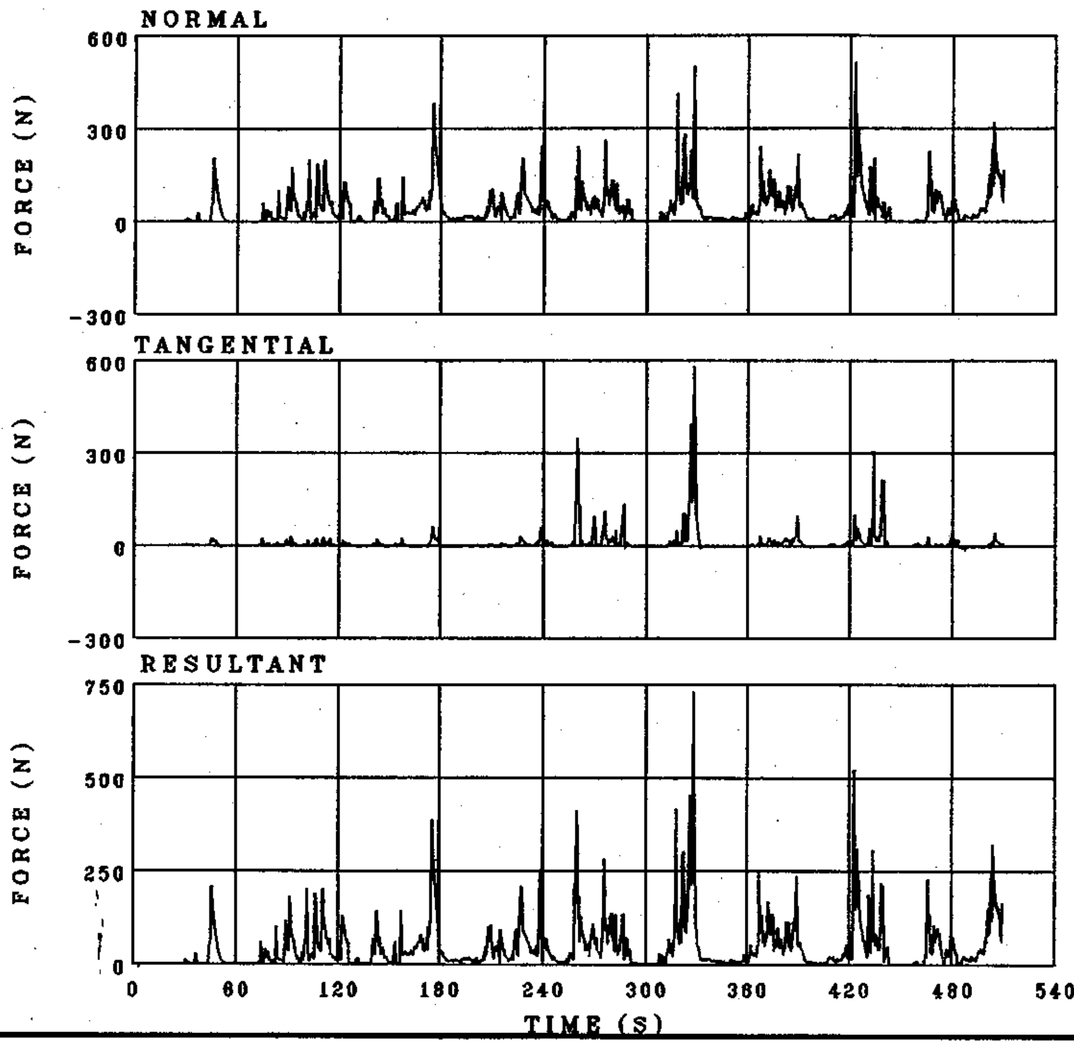
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←008

PLATE #2

NORMAL

MEAN FORCE = 39.74 N
MAX FORCE = 512.2 N
MIN FORCE = -6.491 N

TANGENTIAL

MEAN FORCE = 9.421 N
MAX FORCE = 584.3 N
MIN FORCE = -16.47 N

RESULTANT

MEAN FORCE = 43.79 N
MAX FORCE = 730.8 N
MIN FORCE = 0.01901 N
AVERAGE ANGLE = -8.560 O

TEST CONDITIONS

BOARD ANGLE = 15.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 85.00 kPa
ICE THICKNESS = 3.500 cm
ICE DENSITY = 0.9300 g/cc

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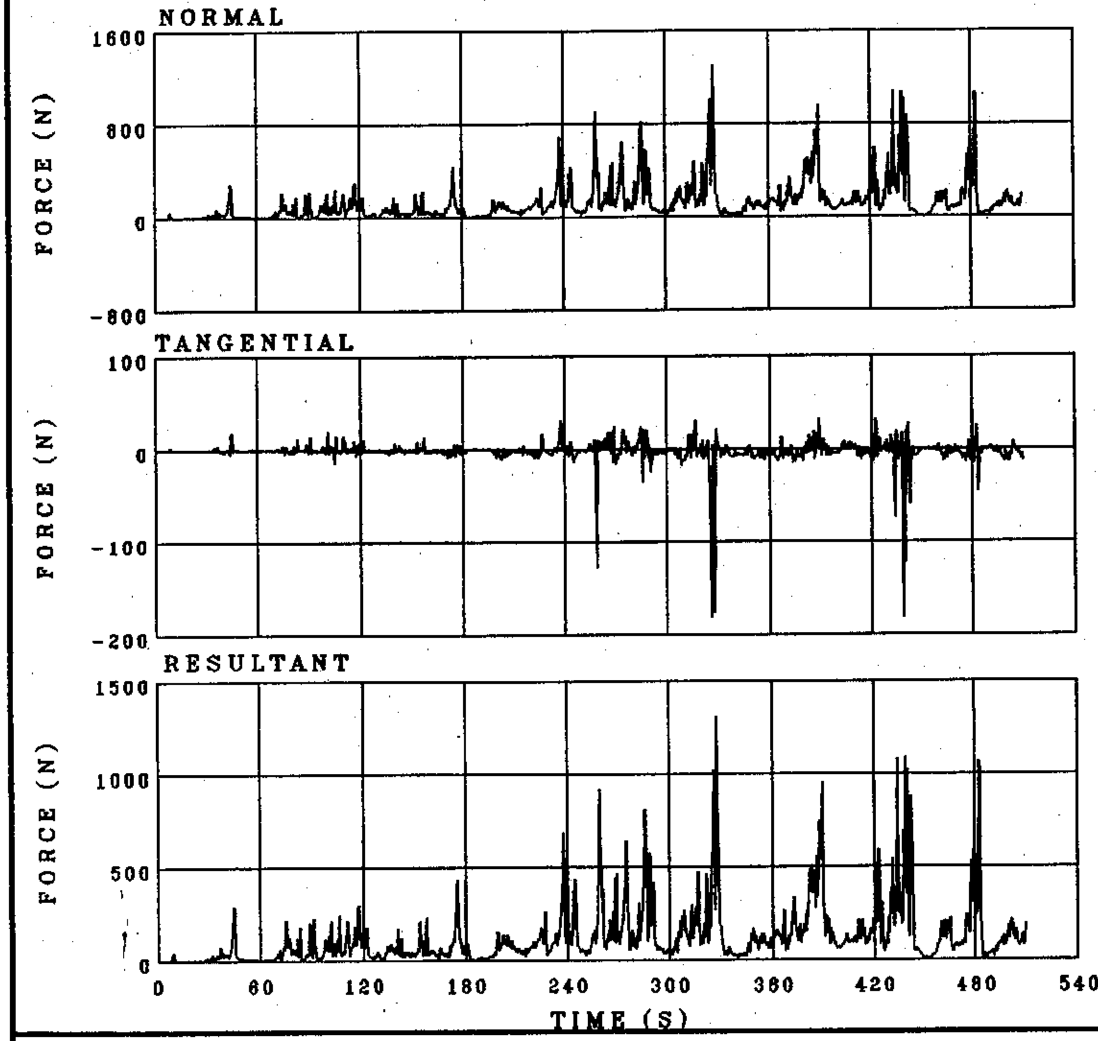
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←008

PLATE #3

NORMAL

MEAN FORCE = 122.2 N
MAX FORCE = 1289.0 N
MIN FORCE = -7.027 N

TANGENTIAL

MEAN FORCE = -2.250 N
MAX FORCE = 32.65 N
MIN FORCE = -182.3 N

RESULTANT

MEAN FORCE = 122.4 N
MAX FORCE = 1311.0 N
MIN FORCE = 0.1180 N
AVERAGE ANGLE = -1.818 O

TEST CONDITIONS

BOARD ANGLE = 15.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 85.00 kPa
ICE THICKNESS = 3.500 cm
ICE DENSITY = 0.9300 g/cc

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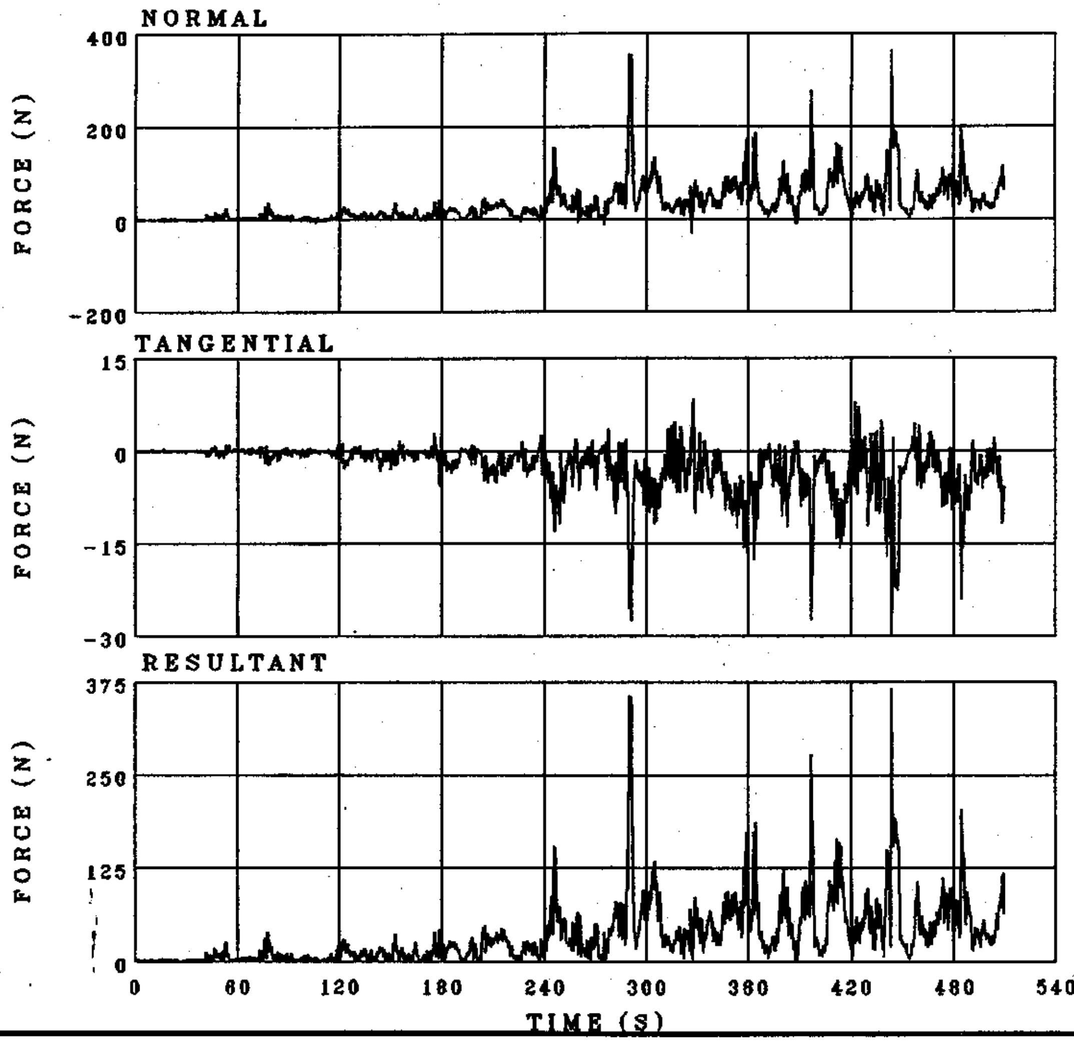
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←008

PLATE #4

NORMAL

MEAN FORCE = 34.17 N
MAX FORCE = 365.5 N
MIN FORCE = -30.00 N

TANGENTIAL

MEAN FORCE = -2.690 N
MAX FORCE = 8.334 N
MIN FORCE = -29.92 N

RESULTANT

MEAN FORCE = 34.45 N
MAX FORCE = 366.7 N
MIN FORCE = 0.05376 N
AVERAGE ANGLE = -2.260 D

TEST CONDITIONS

BOARD ANGLE = 15.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 85.00 kPa
ICE THICKNESS = 3.500 cm
ICE DENSITY = 0.9300 g/cc

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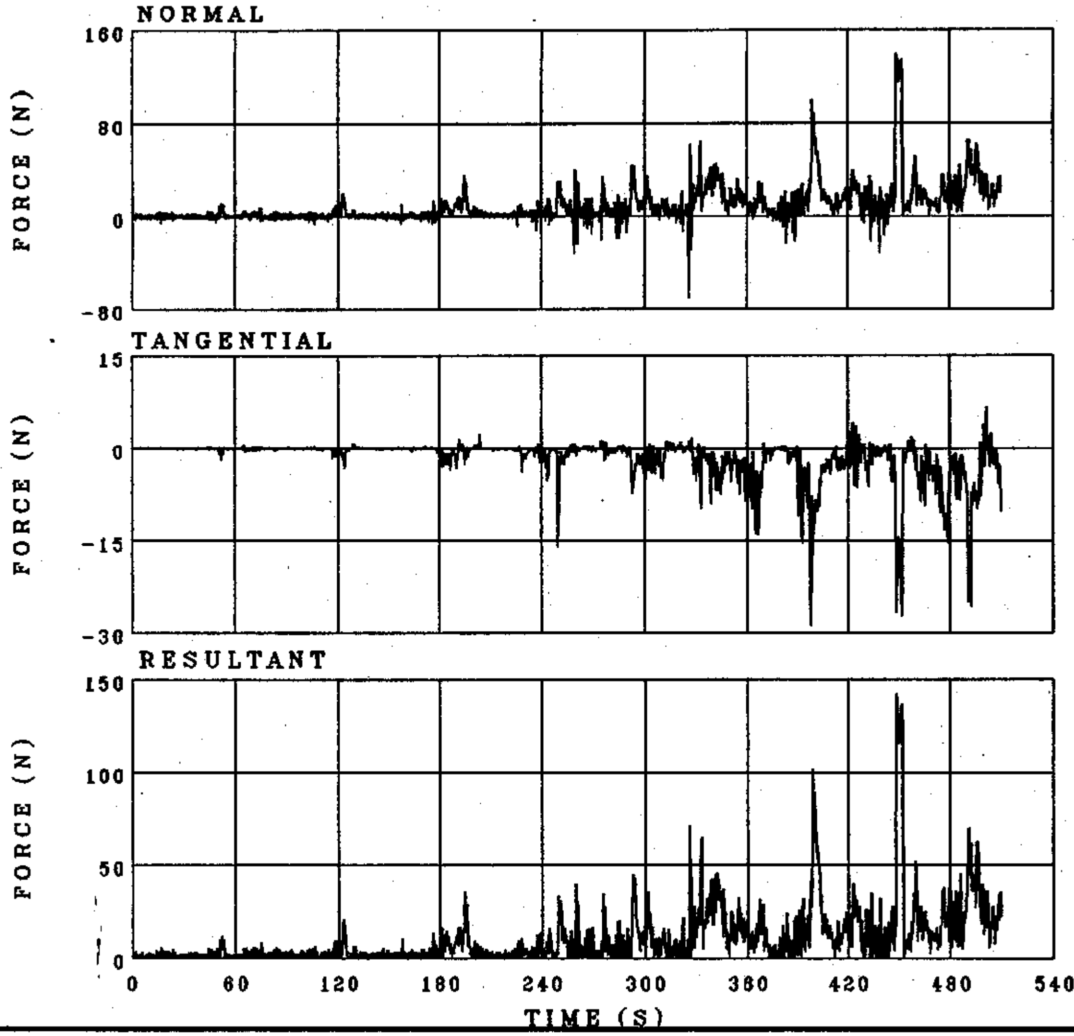
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←008

PLATE #5

NORMAL

MEAN FORCE = 8.759 N
MAX FORCE = 139.8 N
MIN FORCE = -71.19 N

TANGENTIAL

MEAN FORCE = -1.551 N
MAX FORCE = 6.658 N
MIN FORCE = -28.85 N

RESULTANT

MEAN FORCE = 9.712 N
MAX FORCE = 142.3 N
MIN FORCE = 0.01269 N
AVERAGE ANGLE = 0.8197 O

TEST CONDITIONS

BOARD ANGLE = 15.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 85.00 kPa
ICE THICKNESS = 3.500 cm
ICE DENSITY = 0.9300 g/cc

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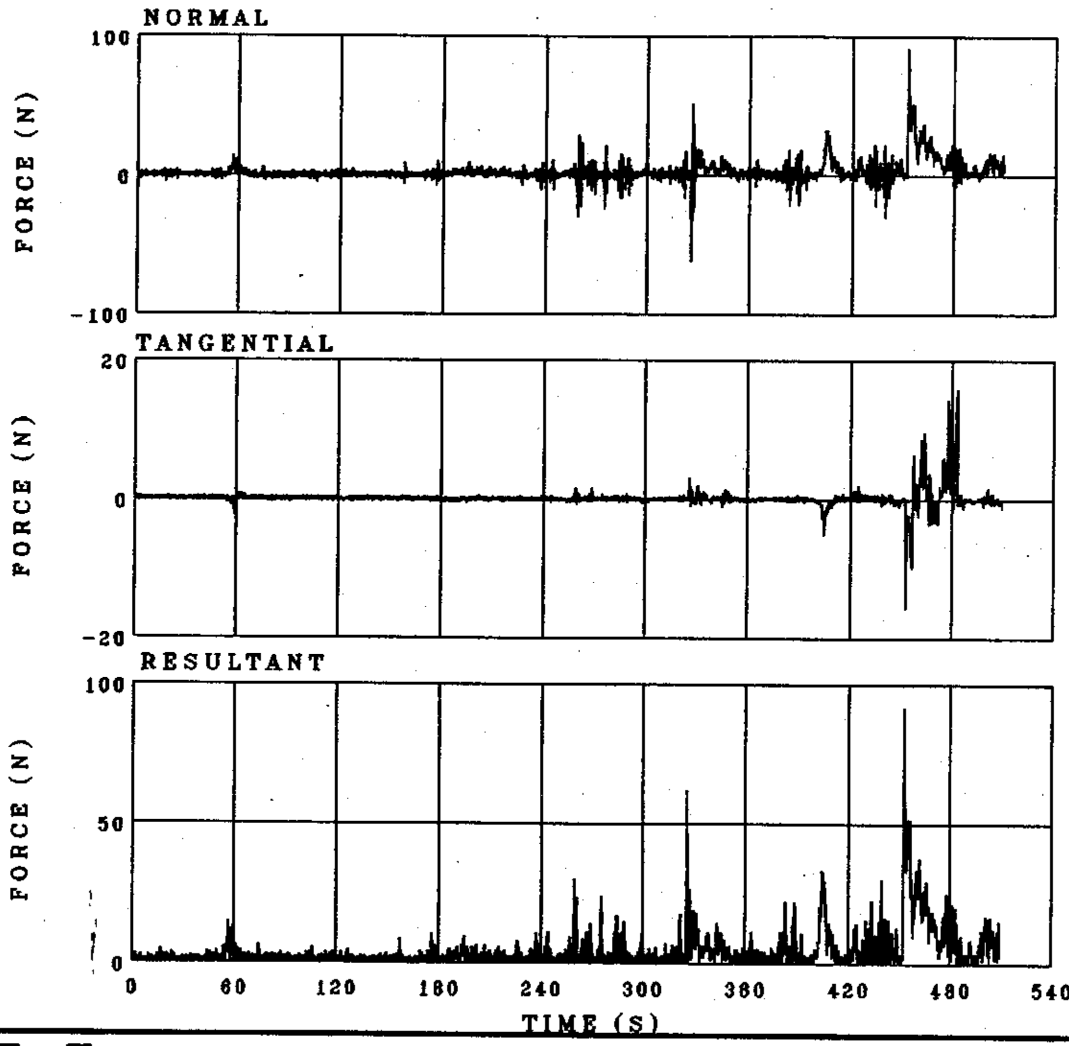
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←008

PLATE #6

NORMAL

MEAN FORCE = 2.622 N
MAX FORCE = 91.62 N
MIN FORCE = −61.94 N

TANGENTIAL

MEAN FORCE = 0.1143 N
MAX FORCE = 15.86 N
MIN FORCE = −15.79 N

RESULTANT

MEAN FORCE = 3.725 N
MAX FORCE = 91.75 N
MIN FORCE = 0.02836 N
AVERAGE ANGLE = 0.3875 O

TEST CONDITIONS

BOARD ANGLE = 15.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 85.00 kPa
ICE THICKNESS = 3.500 cm
ICE DENSITY = 0.9300 g/cc

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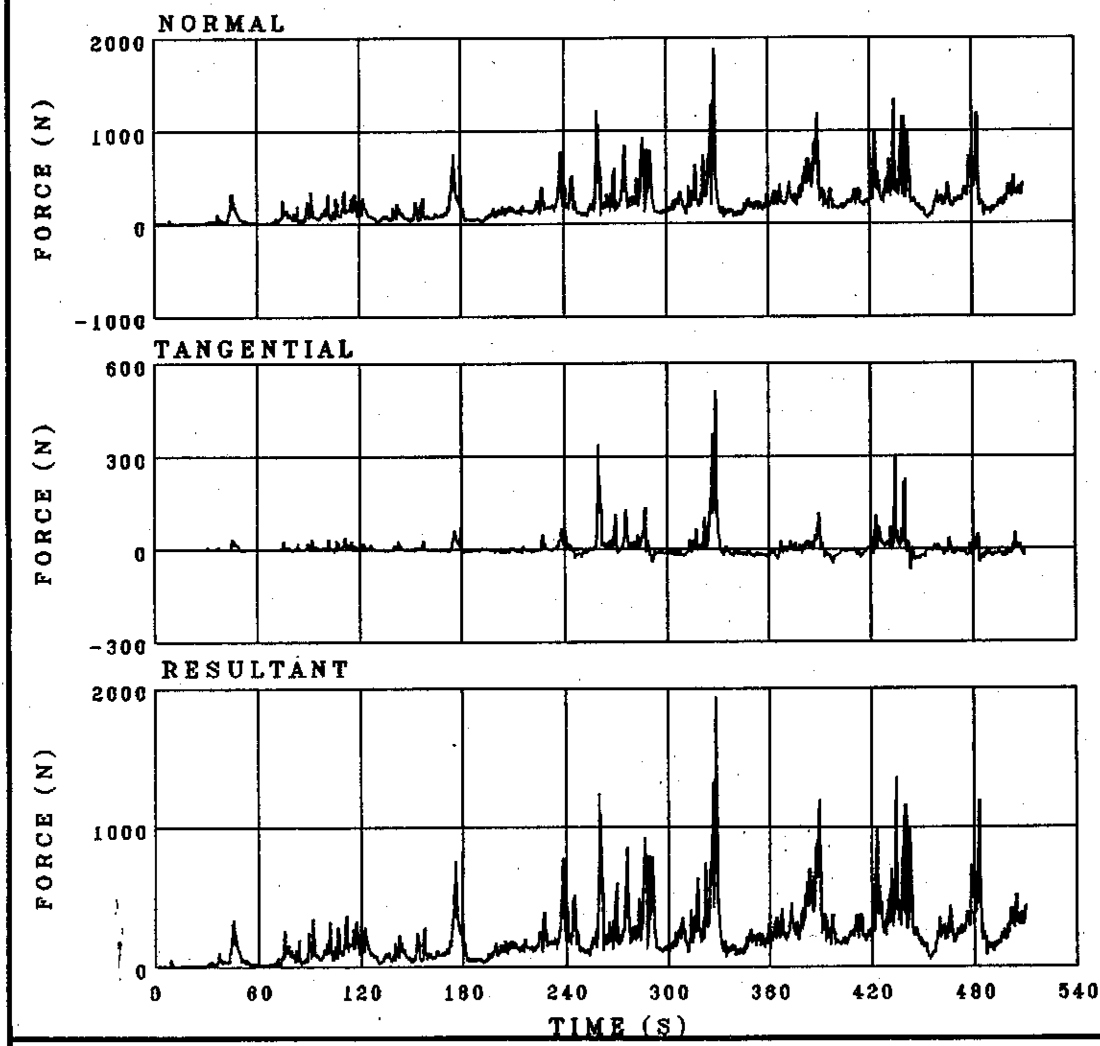
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←008

TOTAL

NORMAL

MEAN FORCE = 211.1 N
MAX FORCE = 1889.0 N
MIN FORCE = −17.76 N

TANGENTIAL

MEAN FORCE = 4.669 N
MAX FORCE = 508.8 N
MIN FORCE = −68.55 N

RESULTANT

MEAN FORCE = 212.2 N
MAX FORCE = 1941.0 N
MIN FORCE = 0.08163 N
AVERAGE ANGLE = 0.06750 O

TEST CONDITIONS

BOARD ANGLE = 15.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 85.00 kPa
ICE THICKNESS = 3.500 cm
ICE DENSITY = 0.9300 g/cc

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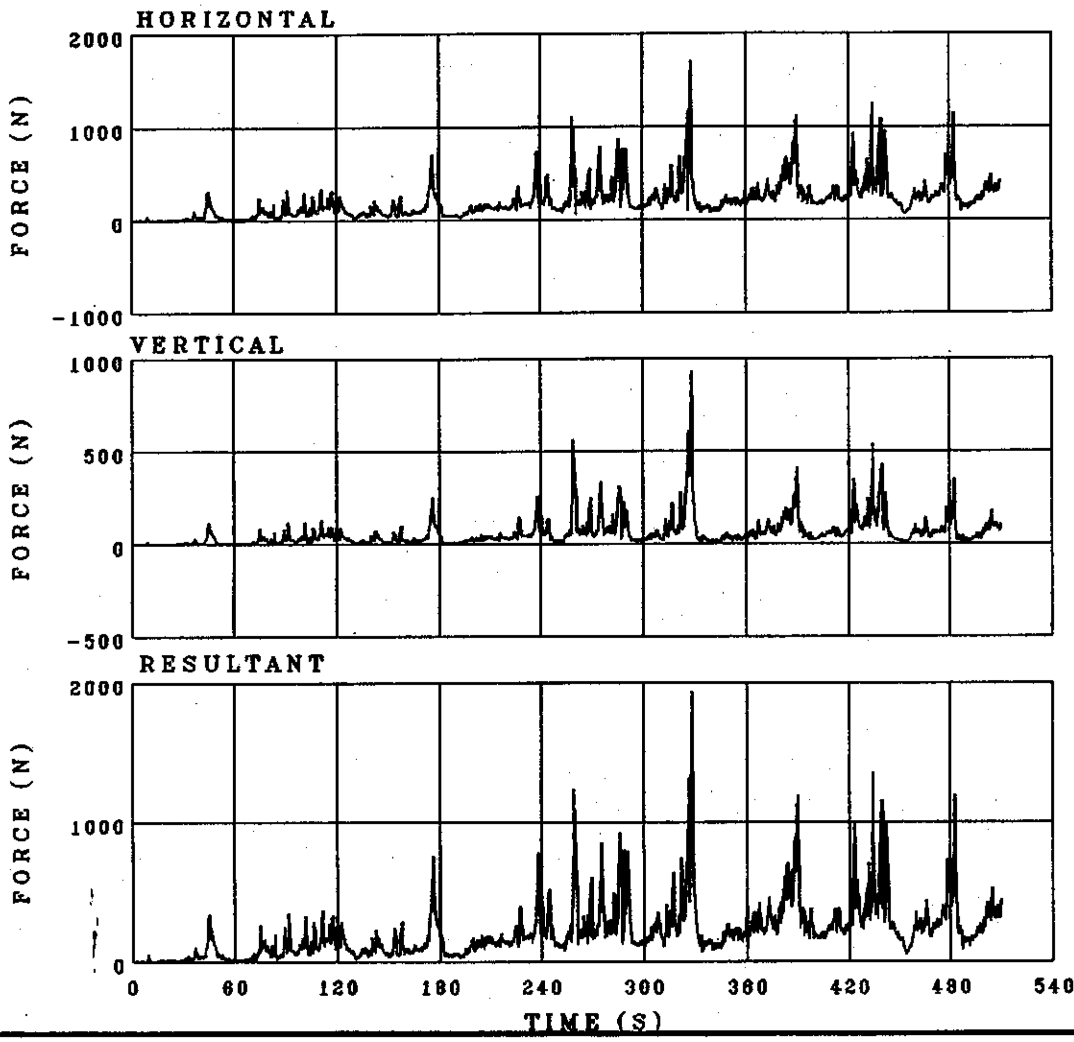
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←008

TOTAL

HORIZONTAL

MEAN FORCE = 4.669 N
MAX FORCE = 508.8 N
MIN FORCE = -68.56 N

VERTICAL

MEAN FORCE = 4.669 N
MAX FORCE = 508.8 N
MIN FORCE = -68.55 N

RESULTANT

MEAN FORCE = 4.669 N
MAX FORCE = 508.8 N
MIN FORCE = -68.55 N
AVERAGE ANGLE = 4.669 O

TEST CONDITIONS

BOARD ANGLE = 15.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 85.00 kPa
ICE THICKNESS = 3.500 cm
ICE DENSITY = 0.9300 g/cc

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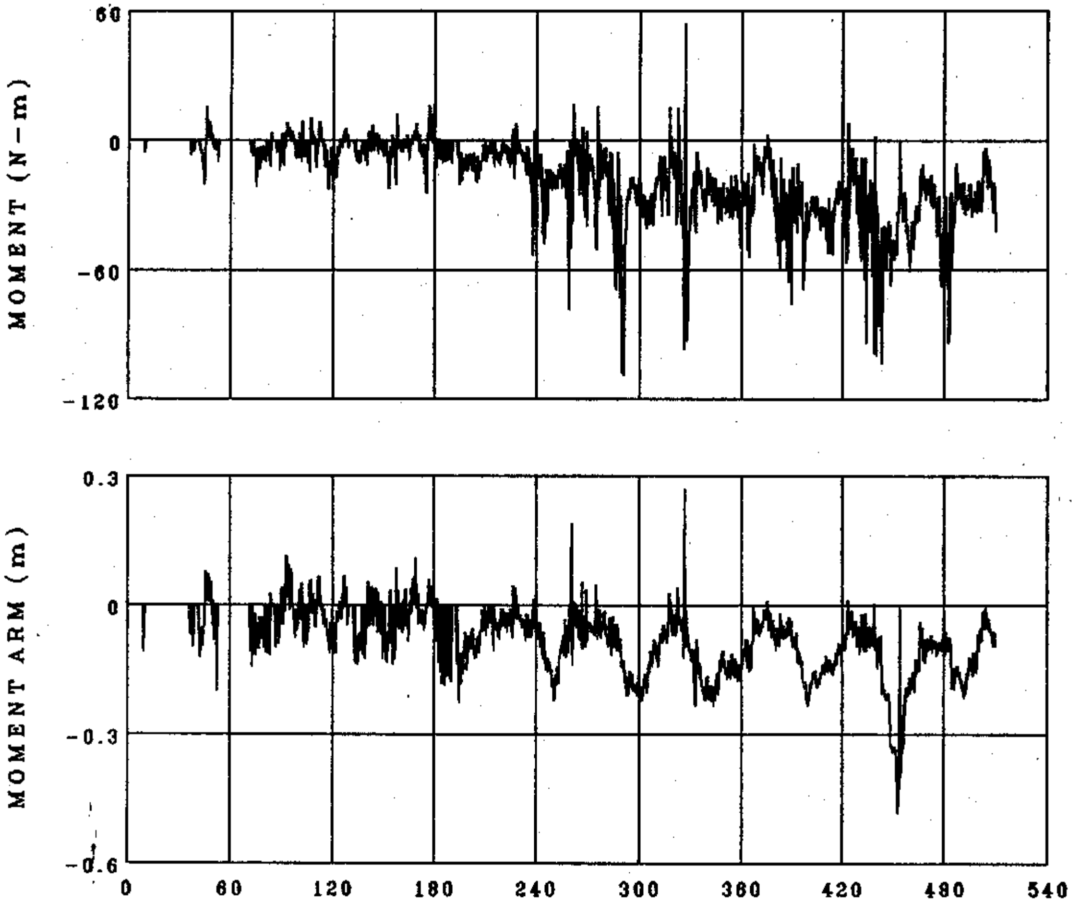
ICE PILEUP STUDY
for CANADIAN COAST GUARD

FILE TN←008

MOMENT



MOMENT

MEAN MOMENT = -17.39 N-m
MAX MOMENT = 53.95 N-m
MIN MOMENT = -109.3 N-m

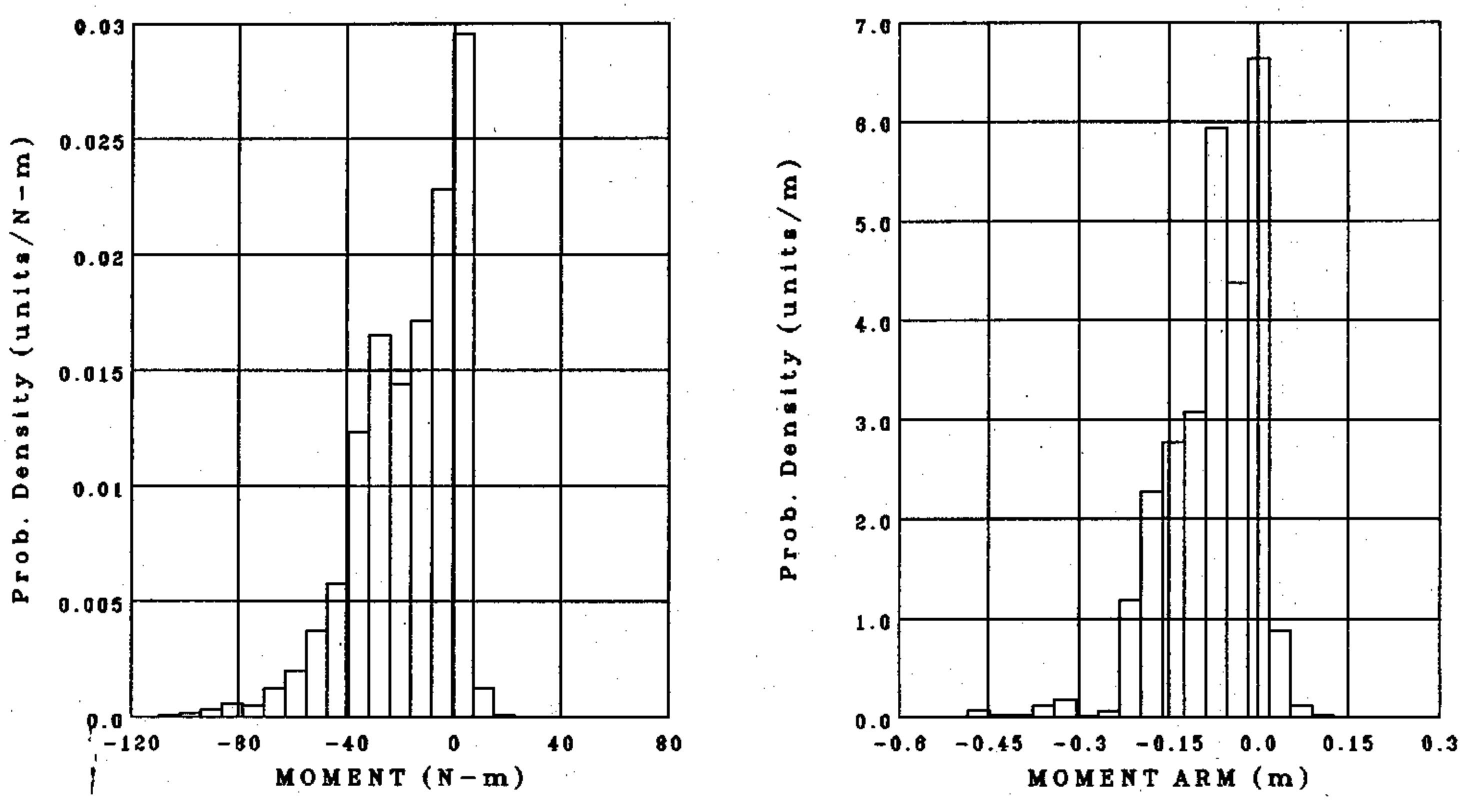
MOMENT ARM

MEAN ARM = -0.07493 m
MAX ARM = 0.2712 m
MIN ARM = -0.4843 m

TEST CONDITIONS

BOARD ANGLE = 15.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 85.00 kPa
ICE THICKNESS = 3.500 cm
ICE DENSITY = 0.9300 g/cc

TN←008



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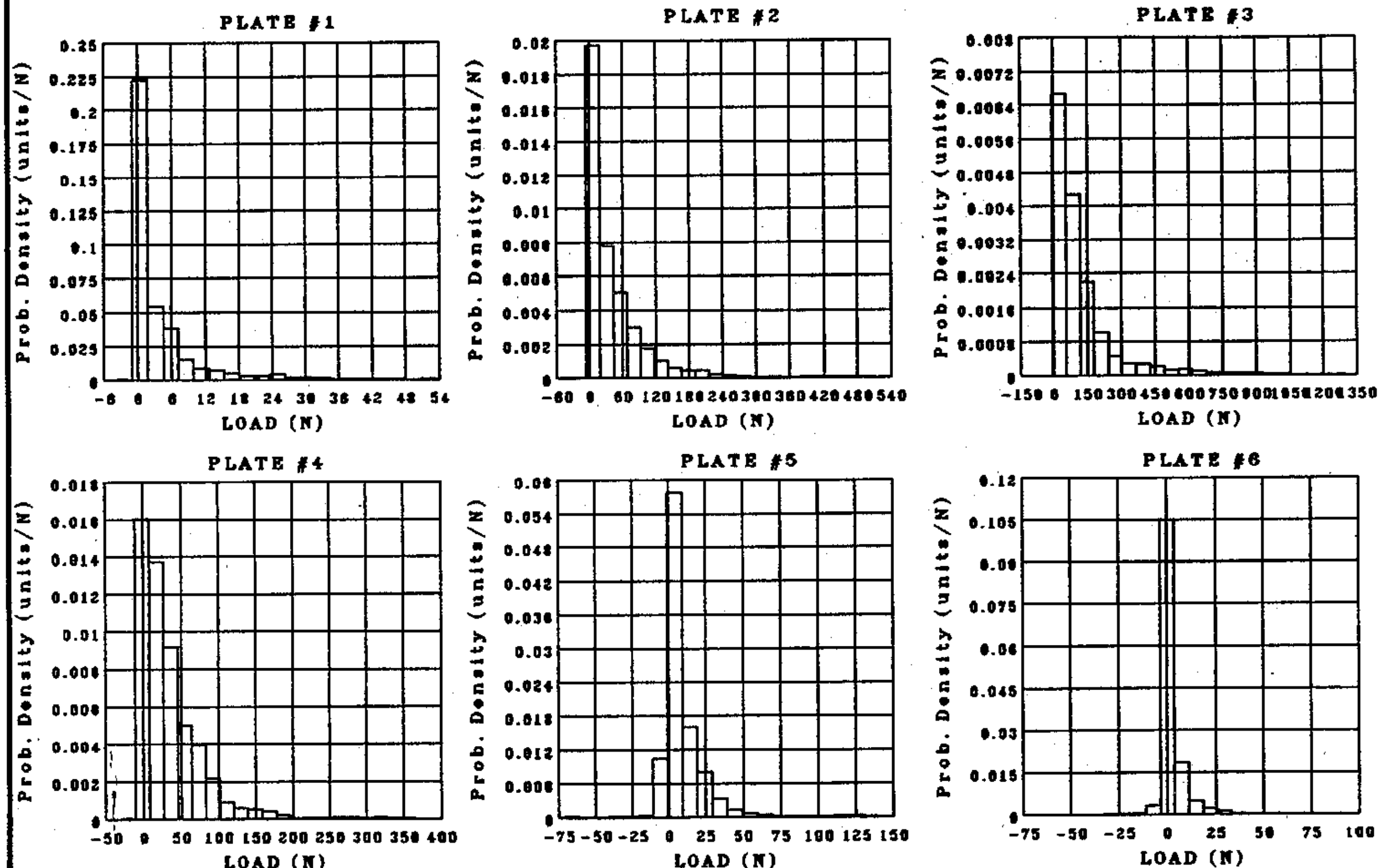
TN←008
NORMAL LOAD



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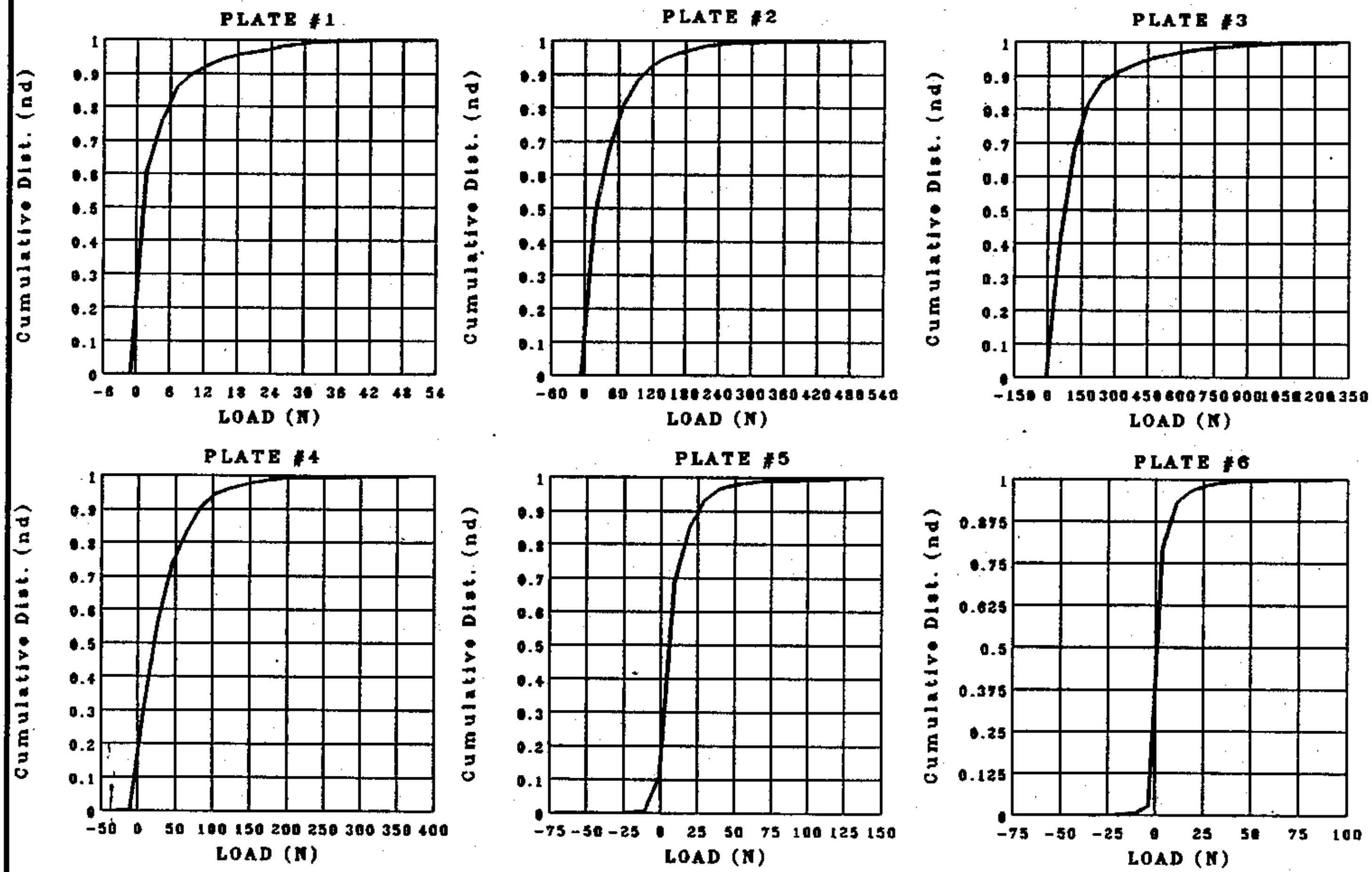
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←008
NORMAL LOAD



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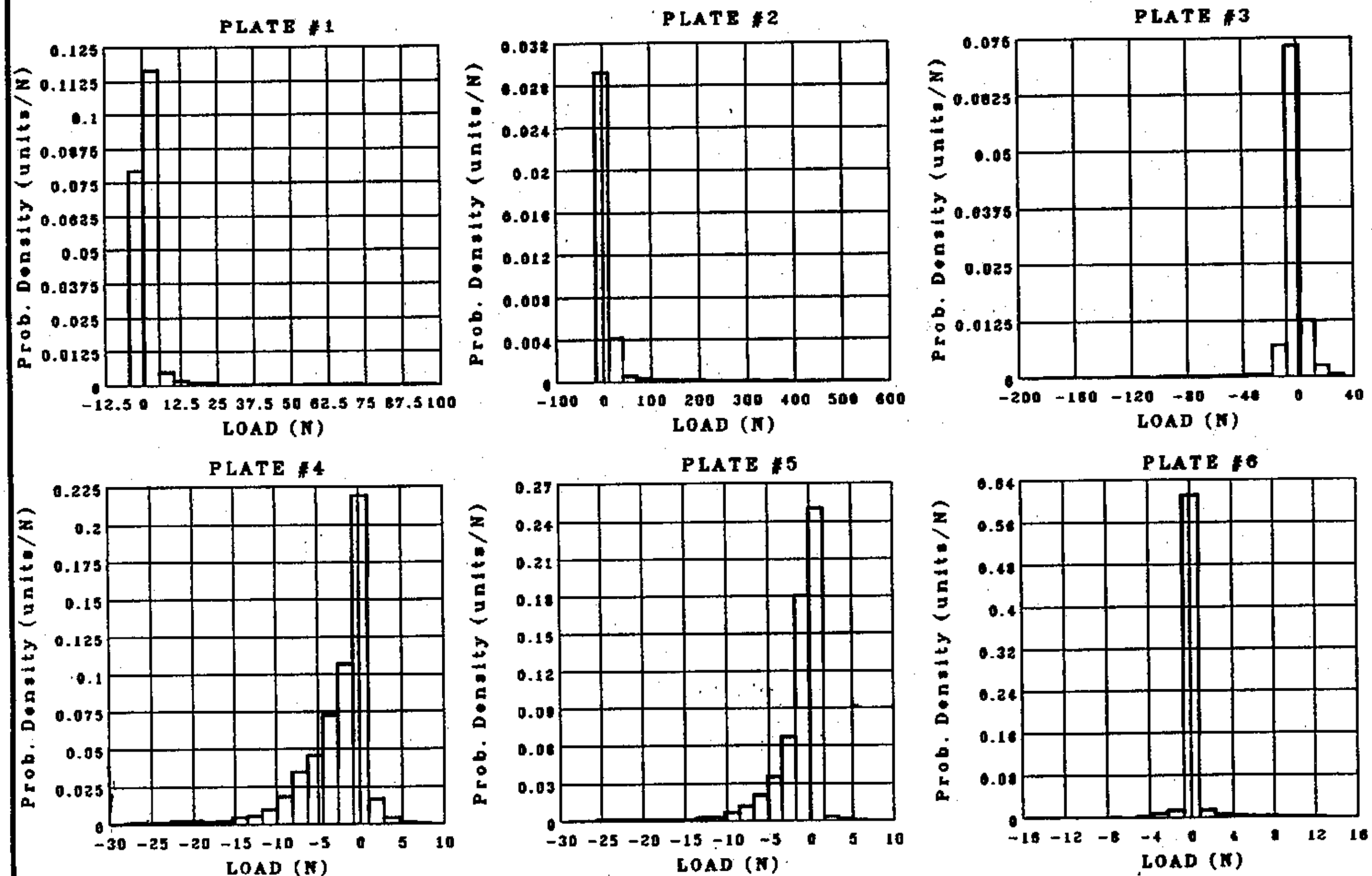
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←008
TANGENTIAL LOAD



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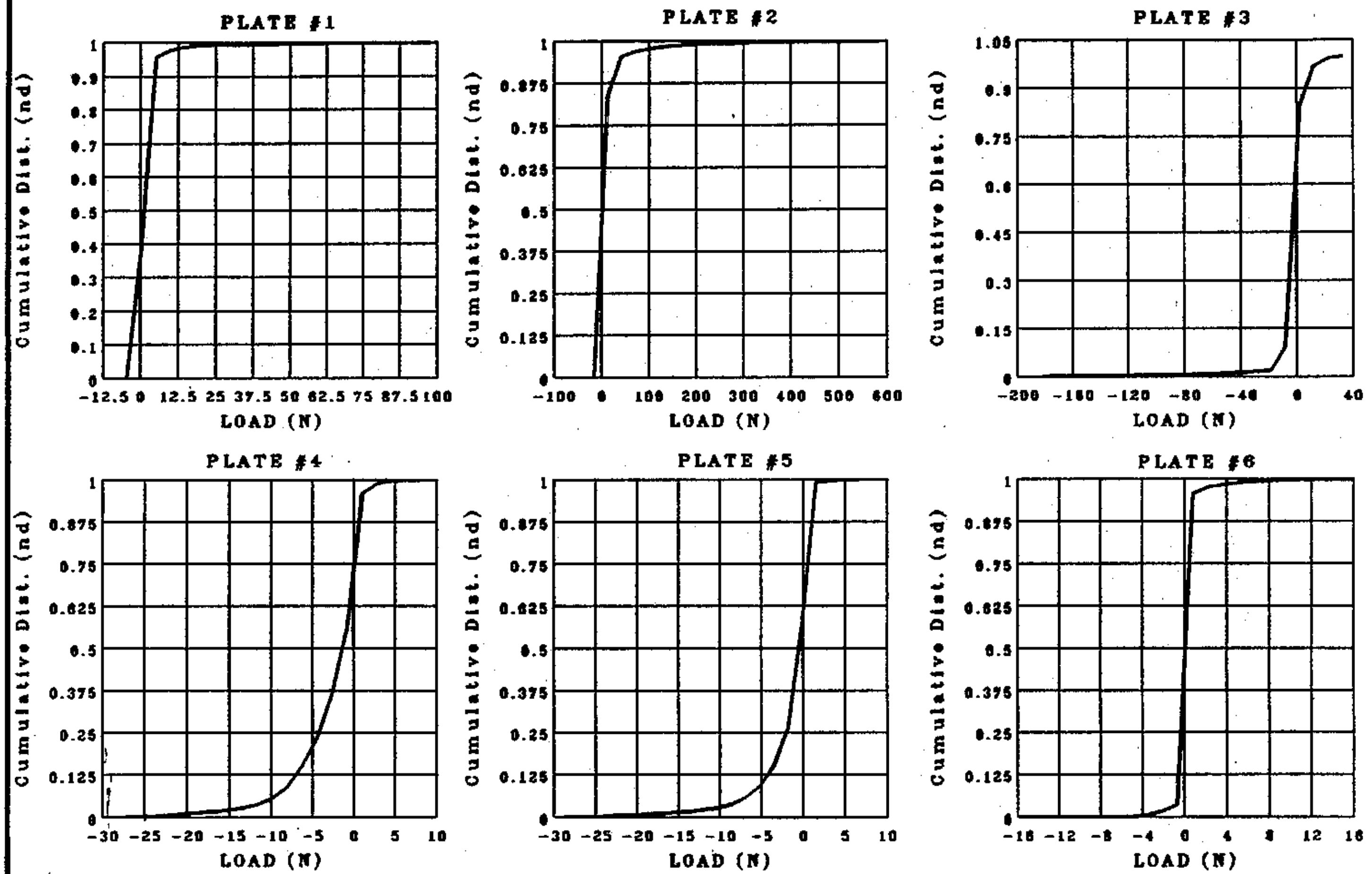
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←008

TANGENTIAL LOAD



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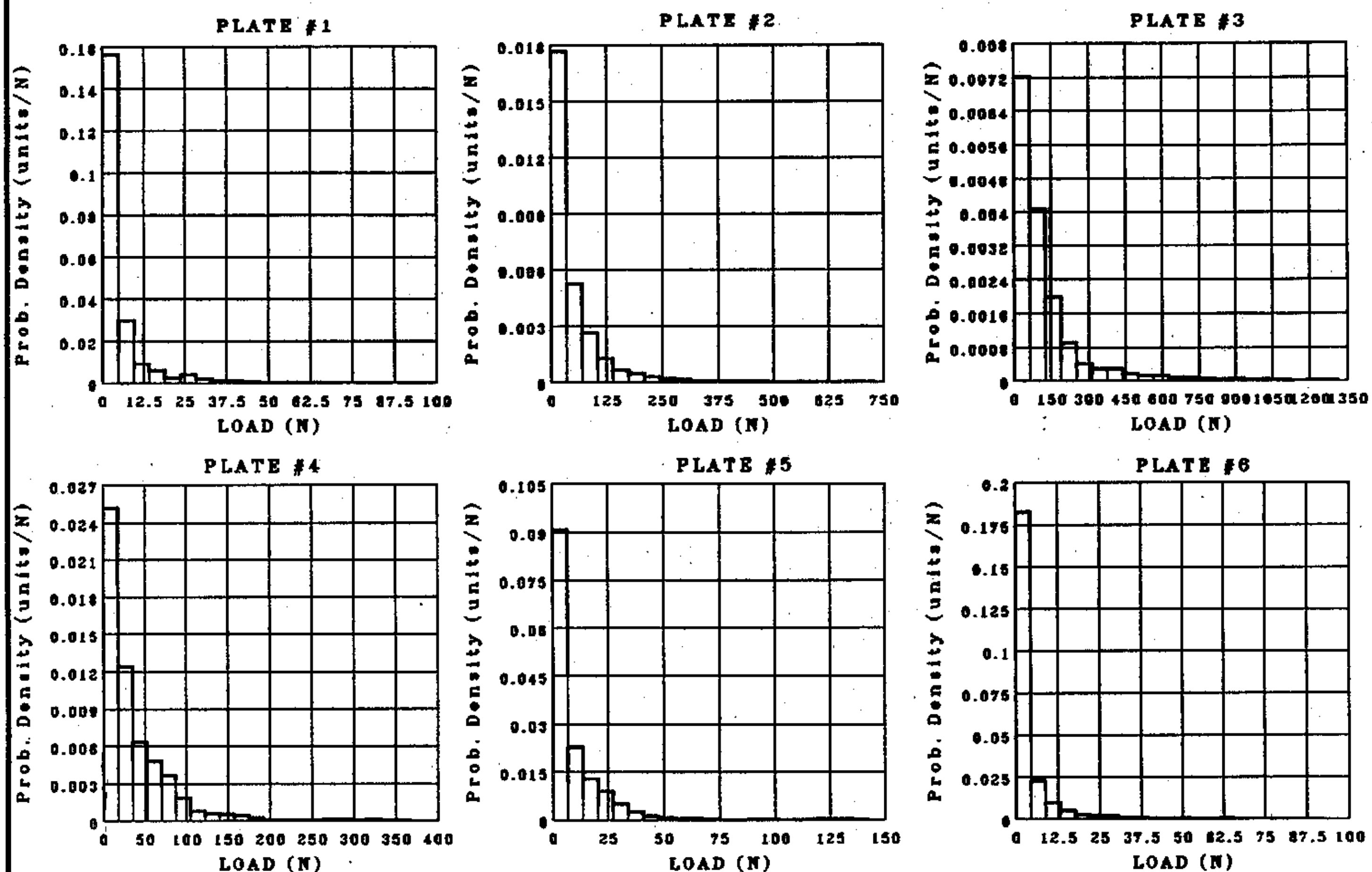
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←008
RESULTANT



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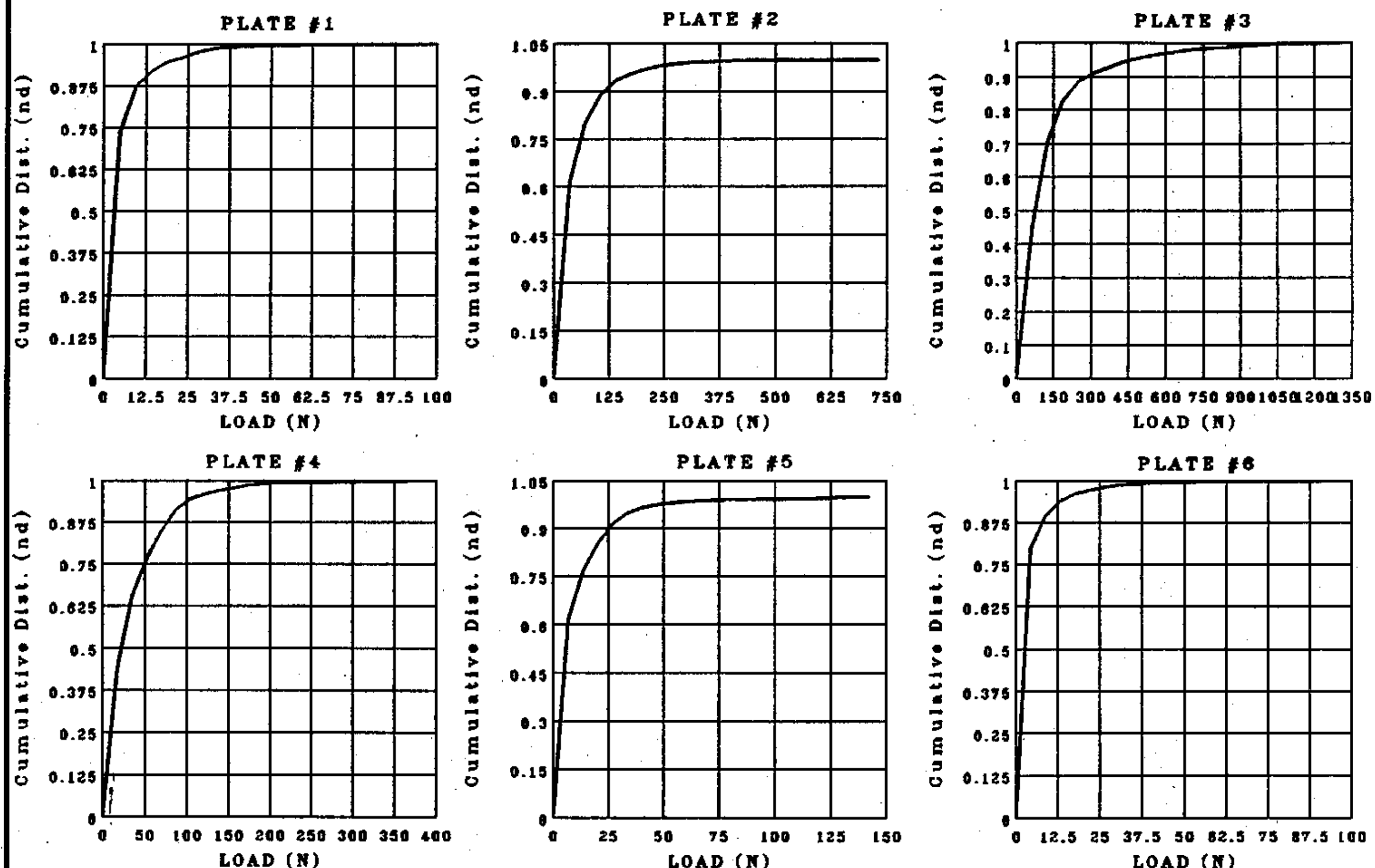
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←008
RESULTANT



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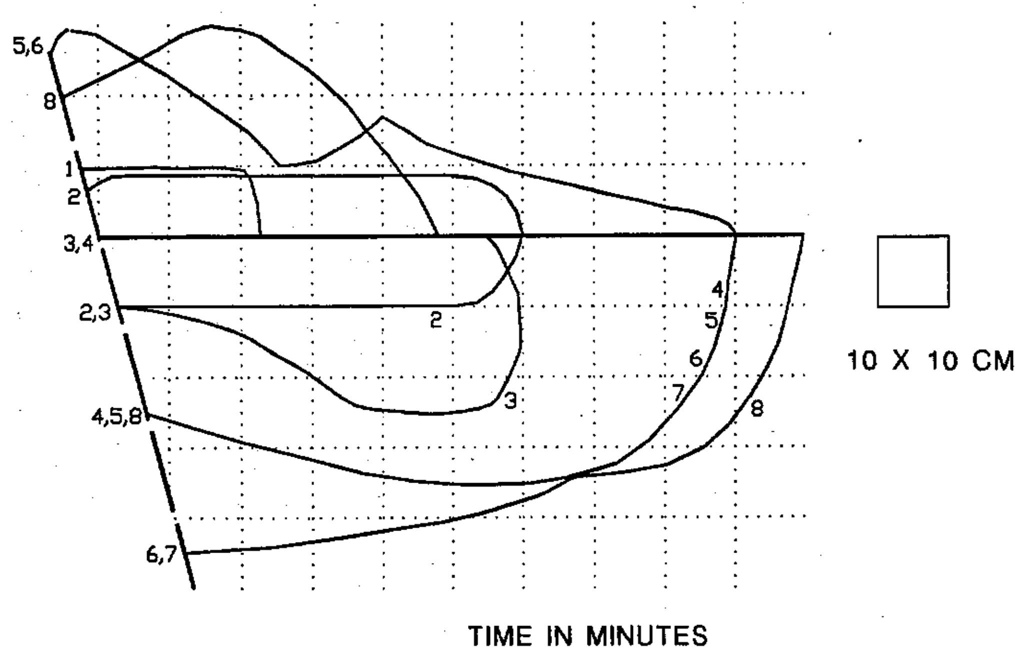
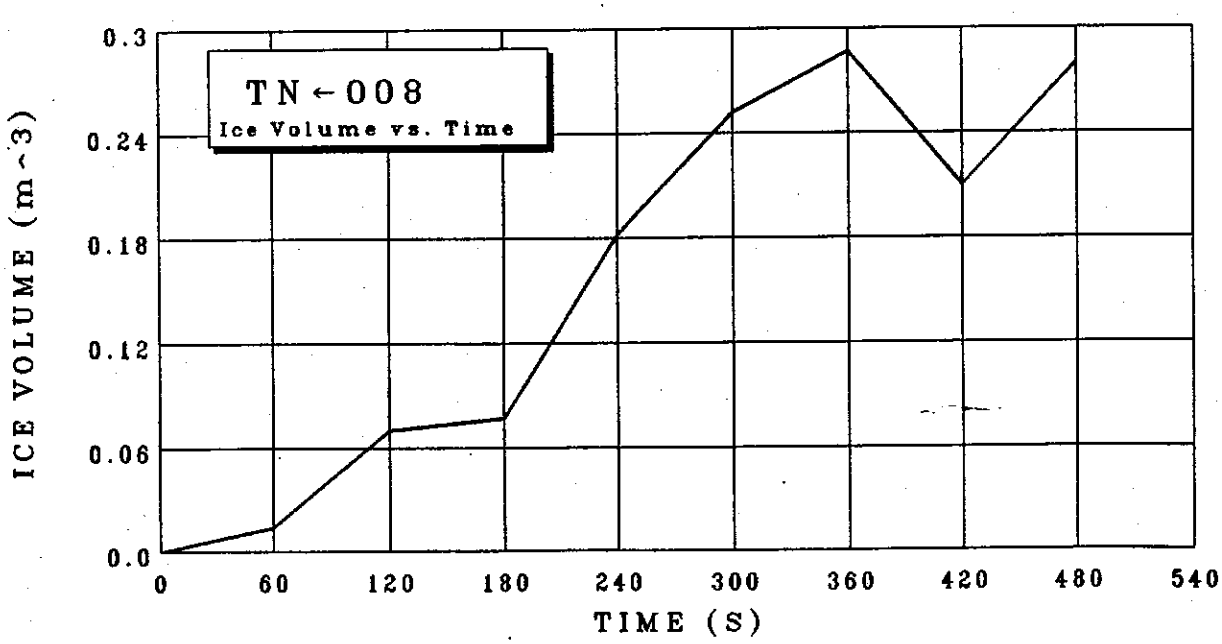
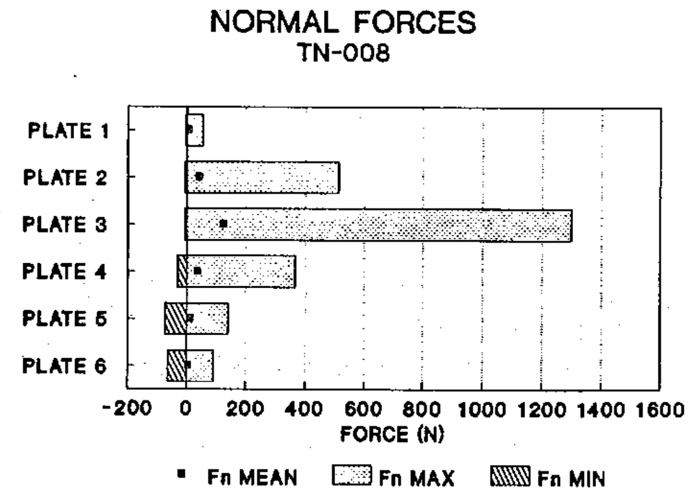
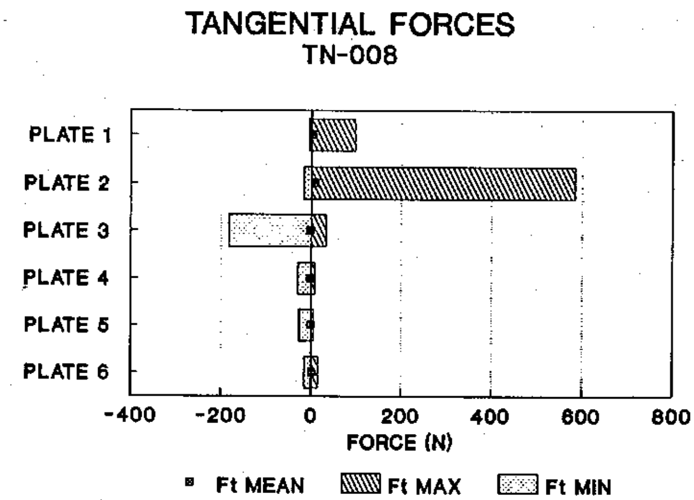
ICE PILEUP STUDY for CANADIAN COAST GUARD


5,6
8
1
2
3,4
2,3
4,5,8
6,7
2
3
4
5
6
7
8
10 X 10 CM
TIME IN MINUTES

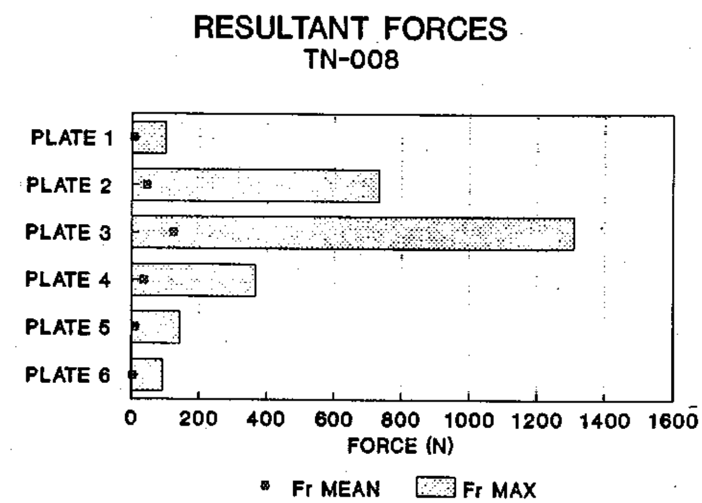

TN←008
Ice Volume vs. Time
ICE VOLUME (m^3)
0.3
0.24
0.18
0.12
0.06
0.0
0
60
120
180
240
300
360
420
480
540
TIME (S)



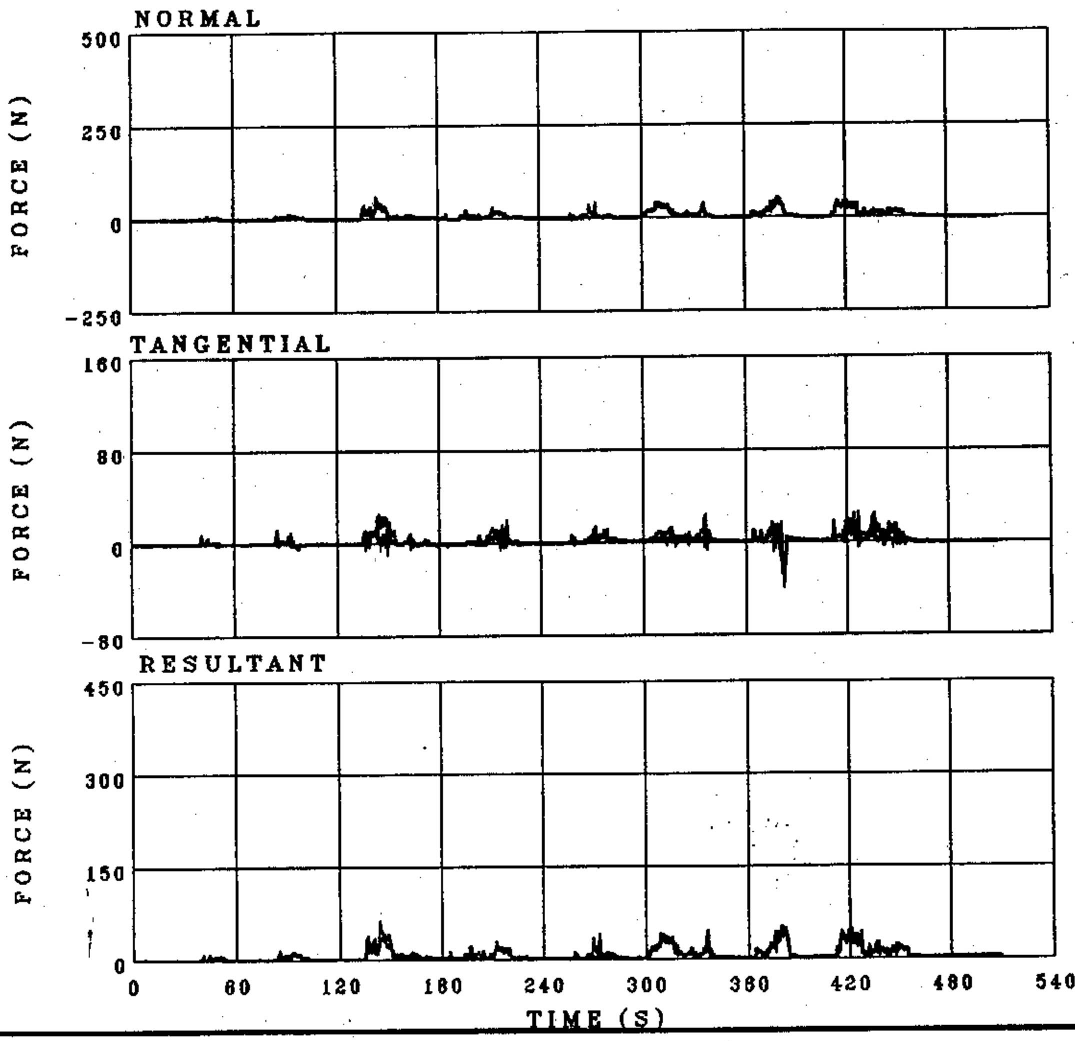
NORMAL FORCES
TN-008
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-200 0 200 400 600 800 1000 1200 1400 1600
FORCE (N)
Fn MEAN
Fn MAX
Fn MIN



TANGENTIAL FORCES
TN-008
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-400 -200 0 200 400 600 800
FORCE (N)
Ft MEAN
Ft MAX
Ft MIN



RESULTANT FORCES
TN-008
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
0 200 400 600 800 1000 1200 1400 1600
FORCE (N)
Fr MEAN
Fr MAX



FILE TN←009

PLATE #1

NORMAL

MEAN FORCE = 4.705 N
MAX FORCE = 51.19 N
MIN FORCE = -3.907 N

TANGENTIAL

MEAN FORCE = 1.642 N
MAX FORCE = 22.41 N
MIN FORCE = -32.97 N

RESULTANT

MEAN FORCE = 6.460 N
MAX FORCE = 52.91 N
MIN FORCE = 0.07582 N
AVERAGE ANGLE = -11.18 O

TEST CONDITIONS

BOARD ANGLE = 24.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 62.00 kPa
ICE THICKNESS = 3.600 cm
ICE DENSITY = 0.9300 g/cc

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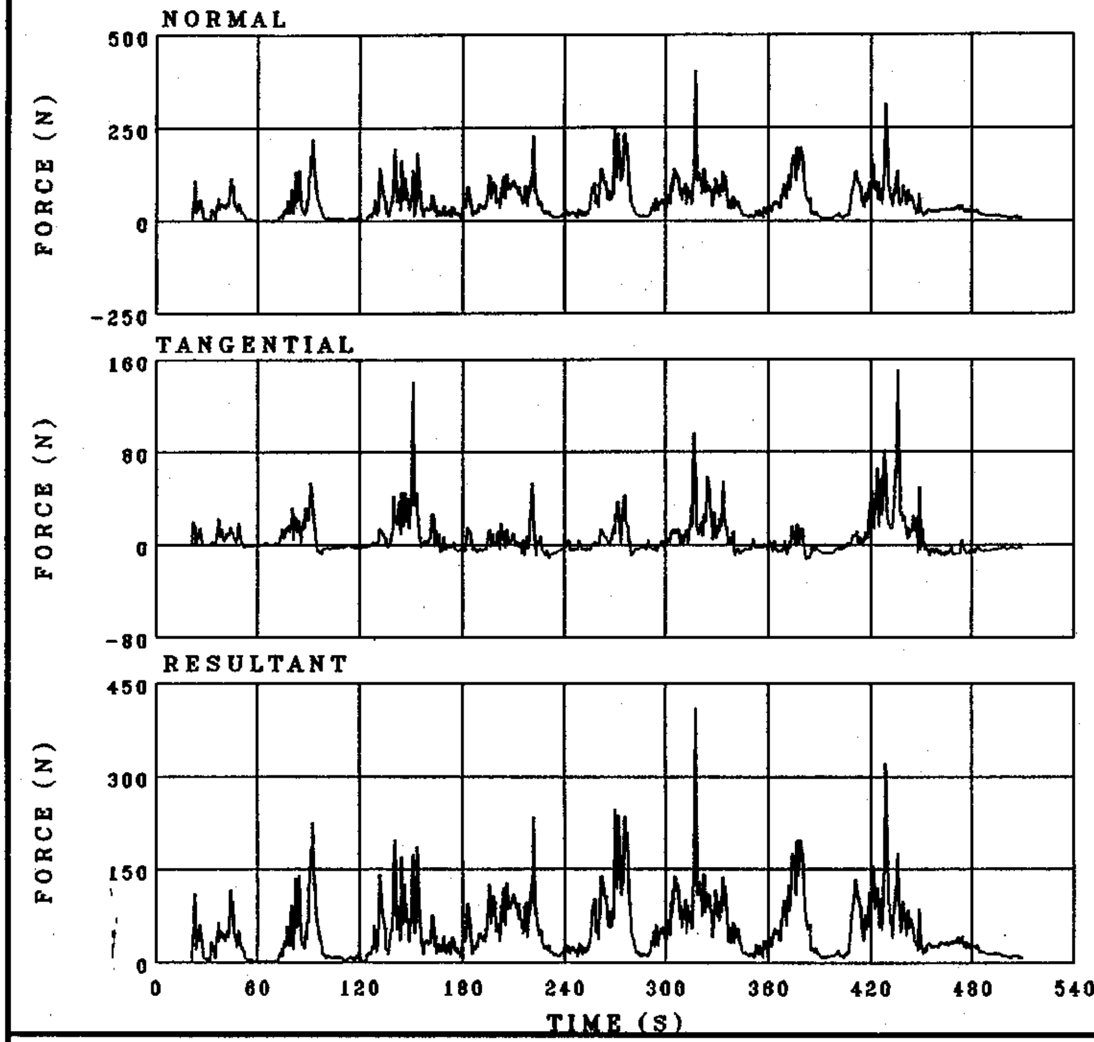
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN-009

PLATE #2

NORMAL

MEAN FORCE = 47.13 N
MAX FORCE = 405.5 N
MIN FORCE = -0.4816 N

TANGENTIAL

MEAN FORCE = 5.324 N
MAX FORCE = 150.4 N
MIN FORCE = -12.67 N

RESULTANT

MEAN FORCE = 48.77 N
MAX FORCE = 411.4 N
MIN FORCE = 0.06587 N
AVERAGE ANGLE = -1.176 D

TEST CONDITIONS

BOARD ANGLE = 24.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 62.00 kPa
ICE THICKNESS = 3.600 cm
ICE DENSITY = 0.9300 g/cc

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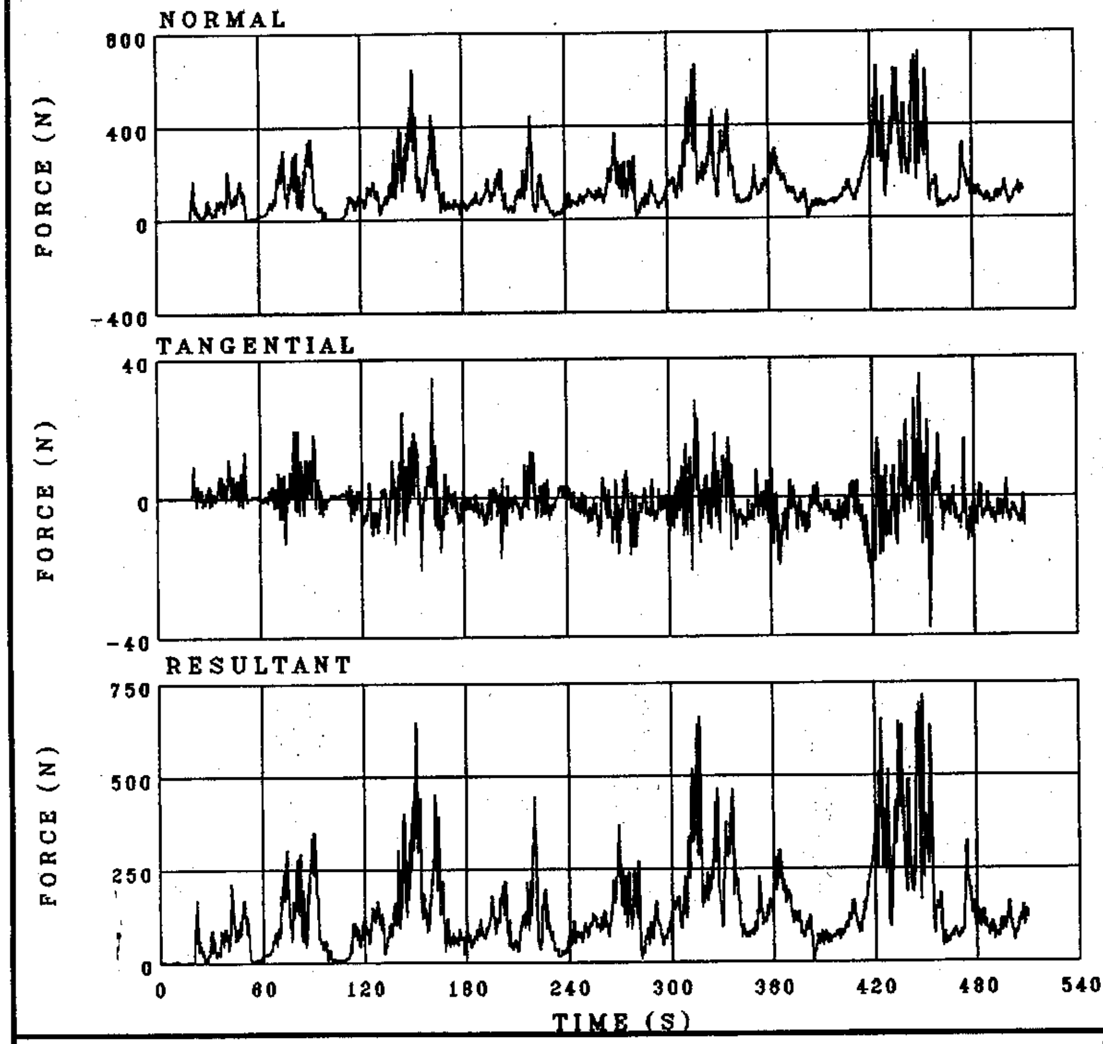
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←009

PLATE #3

NORMAL

MEAN FORCE = 136.5 N
MAX FORCE = 714.7 N
MIN FORCE = -6.142 N

TANGENTIAL

MEAN FORCE = -1.249 N
MAX FORCE = 35.34 N
MIN FORCE = -37.90 N

RESULTANT

MEAN FORCE = 136.7 N
MAX FORCE = 715.3 N
MIN FORCE = 0.07210 N
AVERAGE ANGLE = -1.464 O

TEST CONDITIONS

BOARD ANGLE = 24.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 62.00 kPa
ICE THICKNESS = 3.600 cm
ICE DENSITY = 0.9300 g/cc

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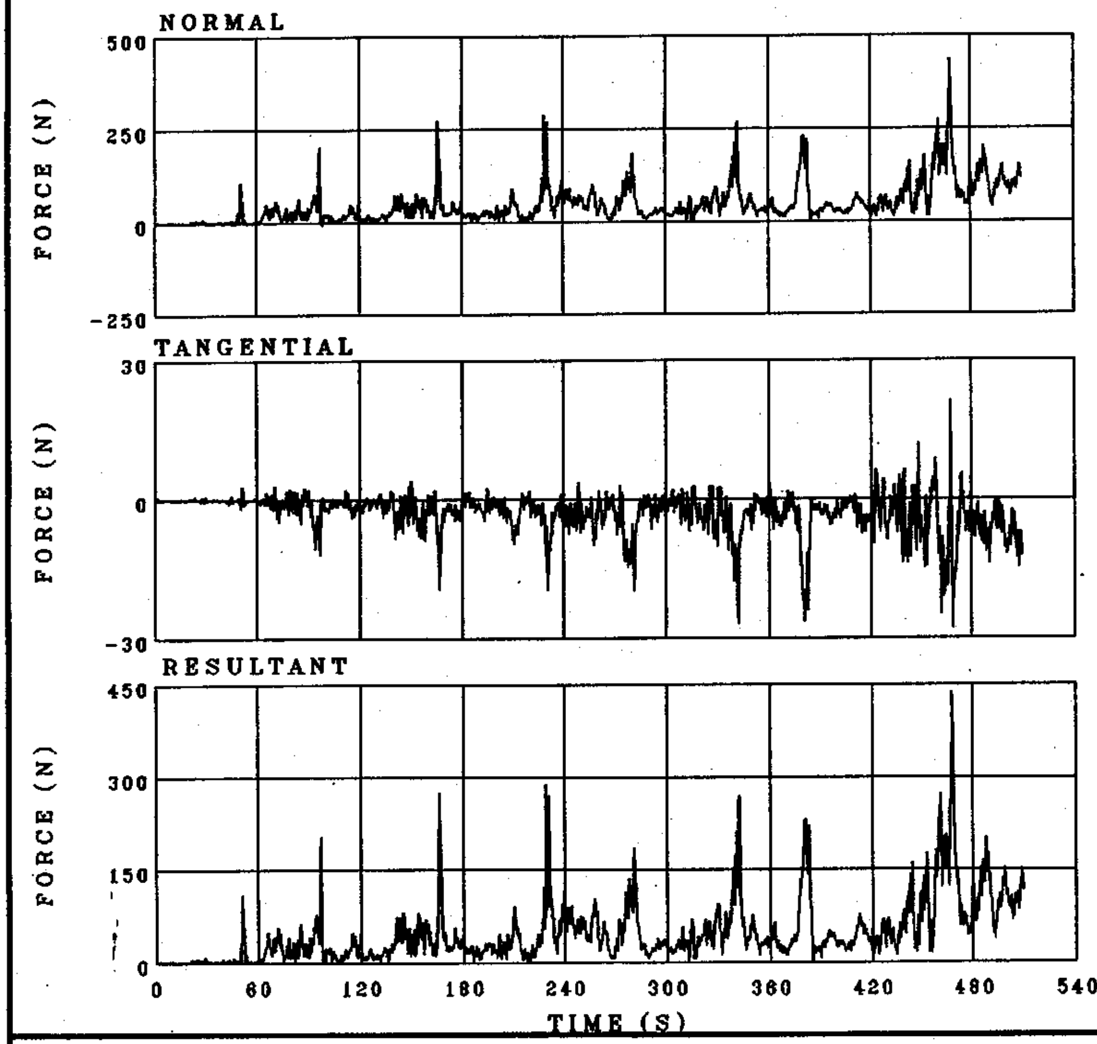
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←009

PLATE #4

NORMAL

MEAN FORCE = 47.21 N
MAX FORCE = 437.0 N
MIN FORCE = -8.400 N

TANGENTIAL

MEAN FORCE = -3.166 N
MAX FORCE = 21.52 N
MIN FORCE = -27.90 N

RESULTANT

MEAN FORCE = 47.51 N
MAX FORCE = 437.5 N
MIN FORCE = 0.009558 N
AVERAGE ANGLE = -2.106 O

TEST CONDITIONS

BOARD ANGLE = 24.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 62.00 kPa
ICE THICKNESS = 3.600 cm
ICE DENSITY = 0.9300 g/cc

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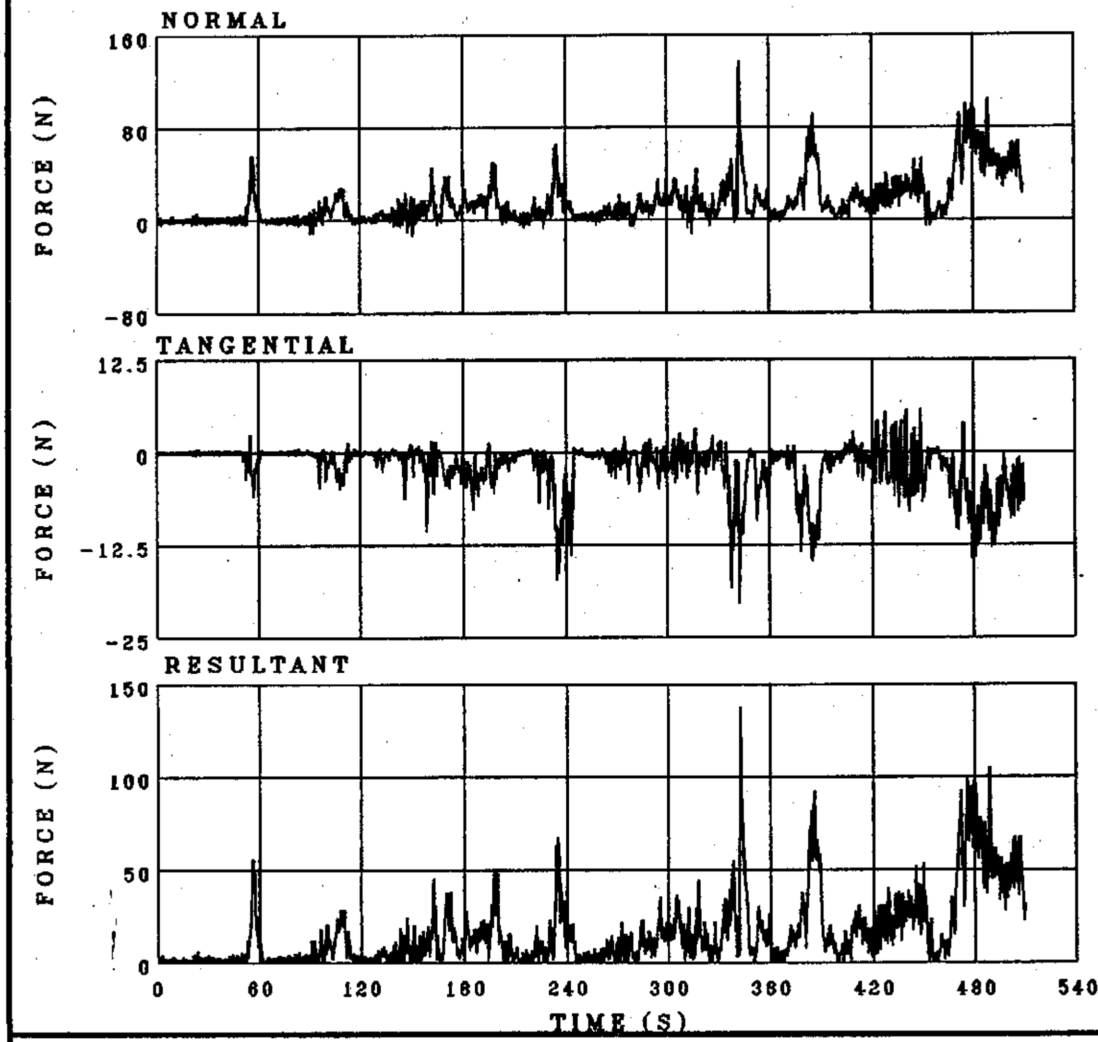
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←009

PLATE #5

NORMAL

MEAN FORCE = 14.78 N
MAX FORCE = 136.8 N
MIN FORCE = -14.69 N

TANGENTIAL

MEAN FORCE = -2.010 N
MAX FORCE = 5.898 N
MIN FORCE = -20.54 N

RESULTANT

MEAN FORCE = 15.47 N
MAX FORCE = 138.0 N
MIN FORCE = 0.04401 N
AVERAGE ANGLE = -7.191 O

TEST CONDITIONS

BOARD ANGLE = 24.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 62.00 kPa
ICE THICKNESS = 3.600 cm
ICE DENSITY = 0.9300 g/cc

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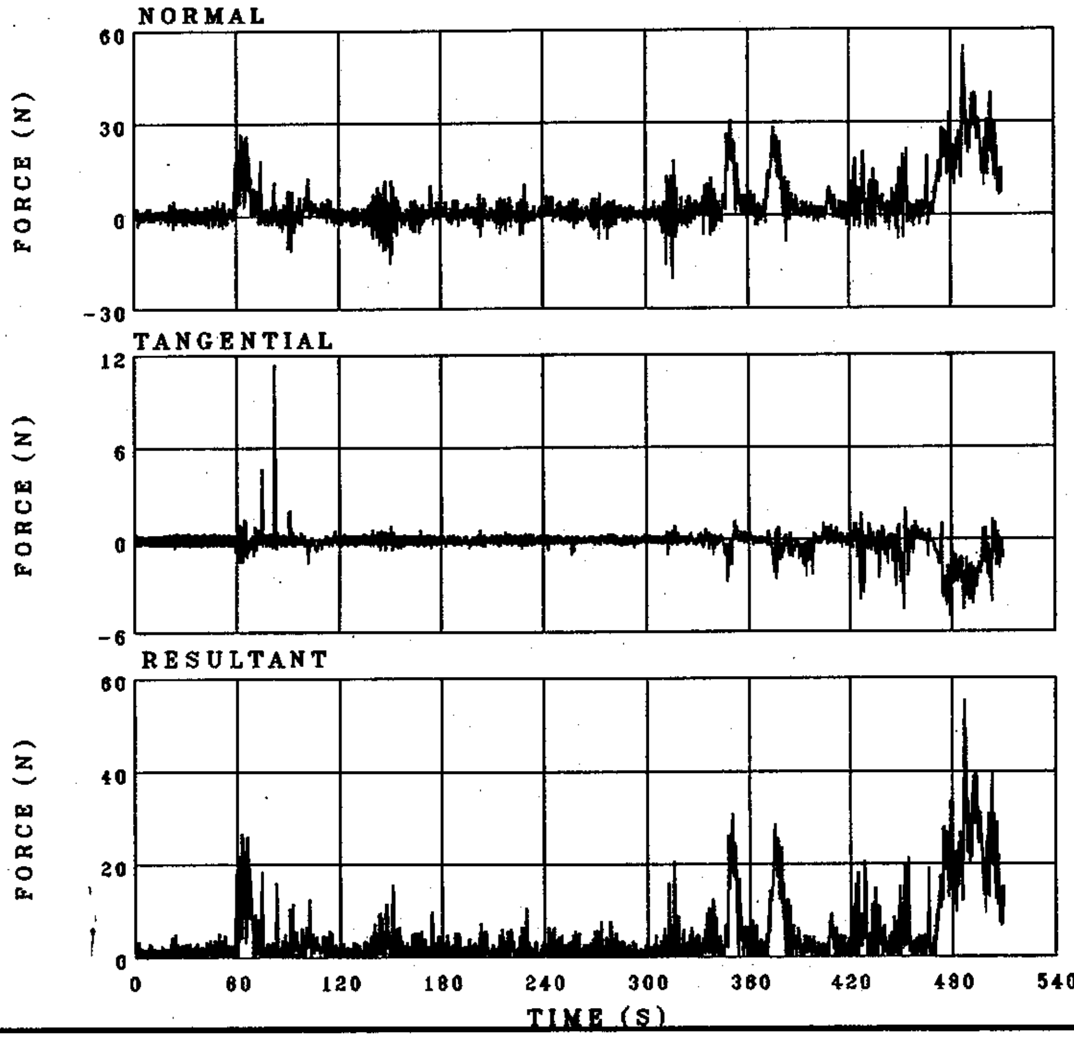
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←009

PLATE #6

NORMAL

MEAN FORCE = 3.428 N
MAX FORCE = 54.94 N
MIN FORCE = -20.71 N

TANGENTIAL

MEAN FORCE = -0.2447 N
MAX FORCE = 11.41 N
MIN FORCE = -5.030 N

RESULTANT

MEAN FORCE = 4.231 N
MAX FORCE = 55.12 N
MIN FORCE = 0.02577 N
AVERAGE ANGLE = -18.76 O

TEST CONDITIONS

BOARD ANGLE = 24.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 62.00 kPa
ICE THICKNESS = 3.600 cm
ICE DENSITY = 0.9300 g/cc

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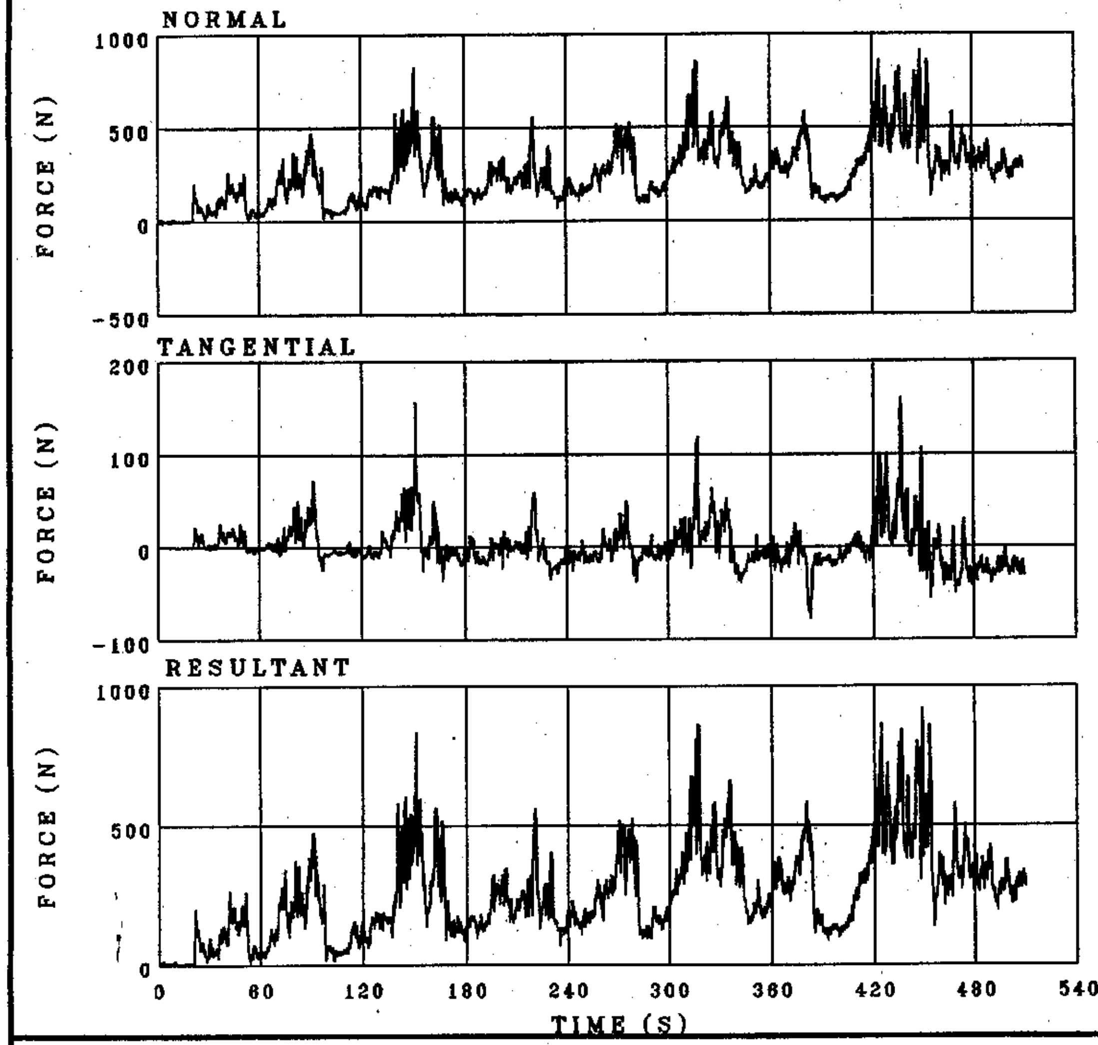
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←009

TOTAL

NORMAL

MEAN FORCE = 253.8 N
MAX FORCE = 916.0 N
MIN FORCE = −15.70 N

TANGENTIAL

MEAN FORCE = 0.2962 N
MAX FORCE = 160.6 N
MIN FORCE = −79.00 N

RESULTANT

MEAN FORCE = 254.7 N
MAX FORCE = 922.3 N
MIN FORCE = 9.1216 N
AVERAGE ANGLE = −1.318 O

TEST CONDITIONS

BOARD ANGLE = 24.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 62.00 kPa
ICE THICKNESS = 3.600 cm
ICE DENSITY = 0.9300 g/cc

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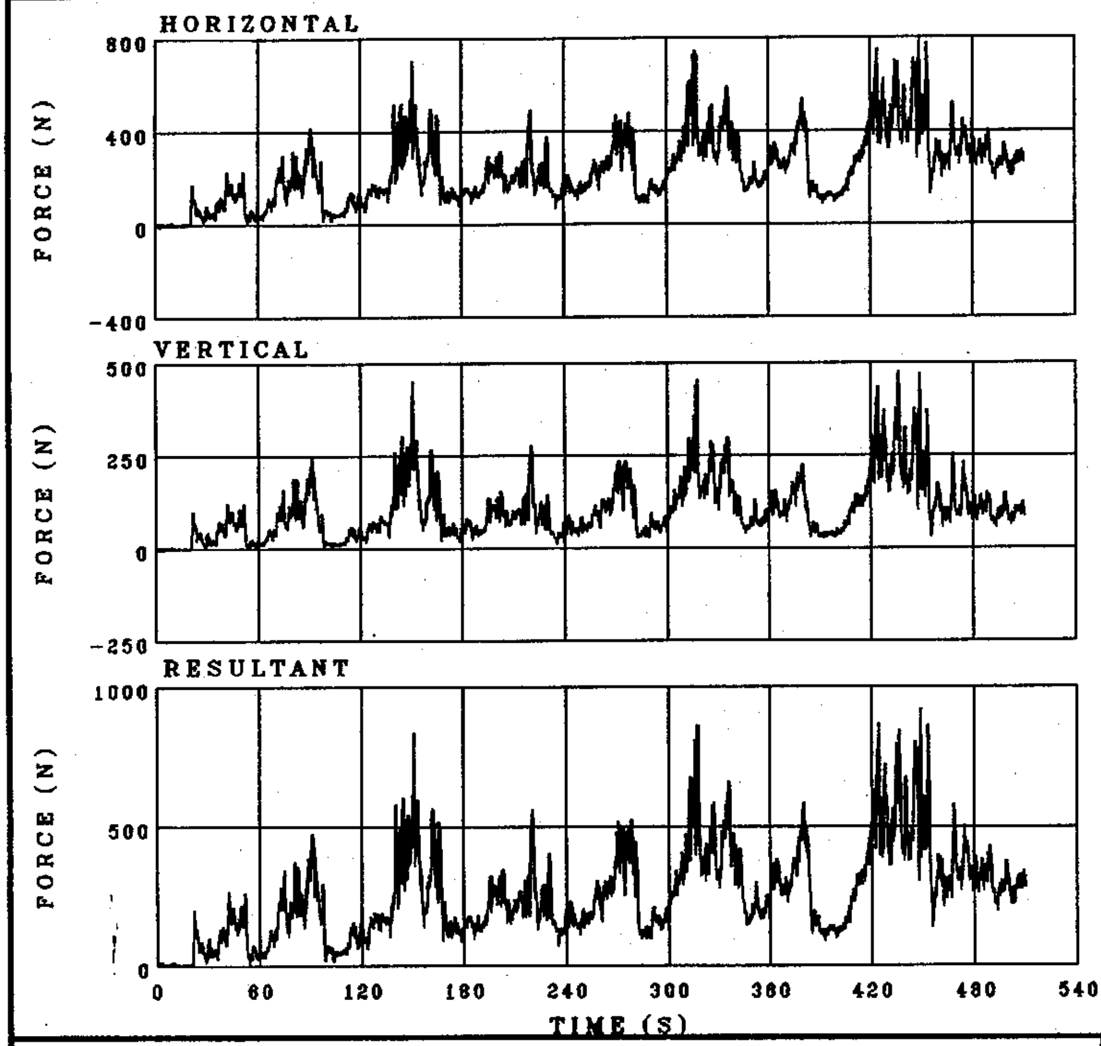
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←009

TOTAL

HORIZONTAL

MEAN FORCE = 0.2962 N
MAX FORCE = 160.6 N
MIN FORCE = -79.00 N

VERTICAL

MEAN FORCE = 0.2962 N
MAX FORCE = 160.6 N
MIN FORCE = -79.00 N

RESULTANT

MEAN FORCE = 0.2962 N
MAX FORCE = 160.6 N
MIN FORCE = -79.00 N
AVERAGE ANGLE = 0.2962 D

TEST CONDITIONS

BOARD ANGLE = 24.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 62.00 kPa
ICE THICKNESS = 3.600 cm
ICE DENSITY = 0.9300 g/cc

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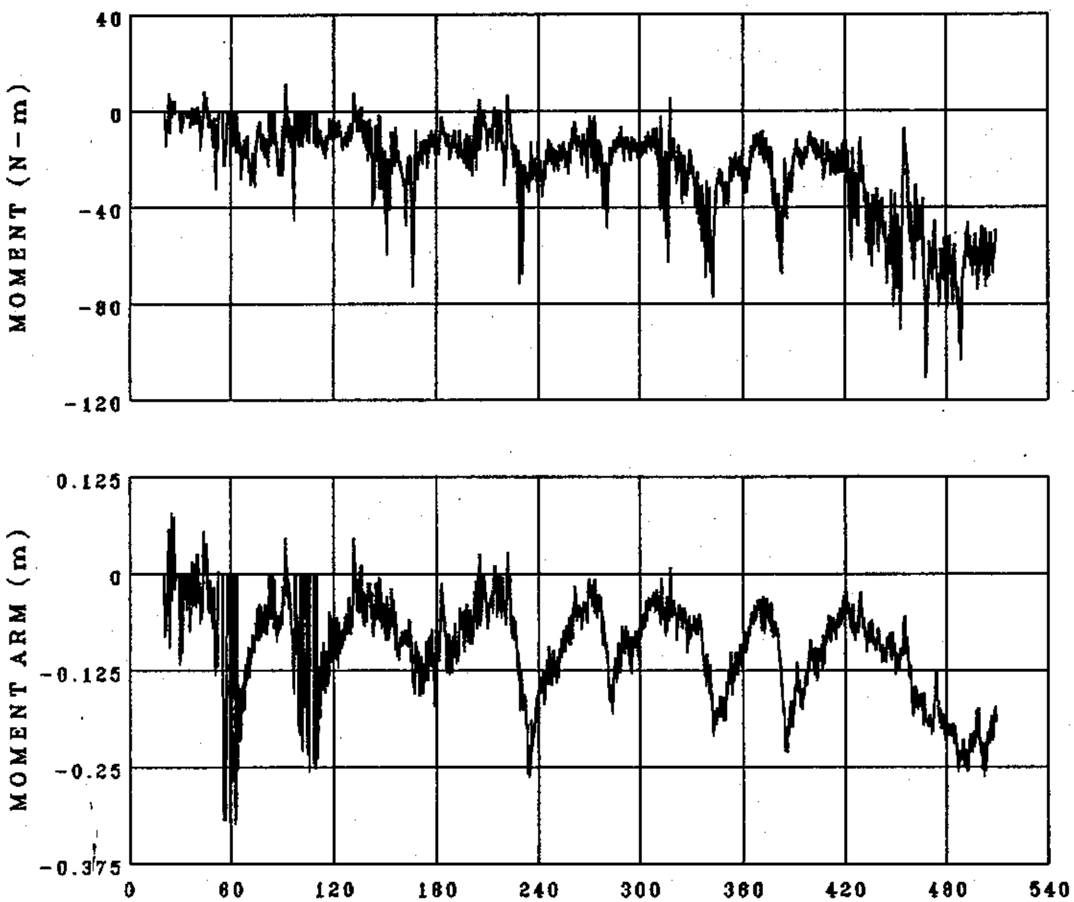
ICE PILEUP STUDY
for CANADIAN COAST GUARD

FILE TN←009



MOMENT

MOMENT

MEAN MOMENT = -23.32 N-m
MAX MOMENT = 11.34 N-m
MIN MOMENT = -111.1 N-m

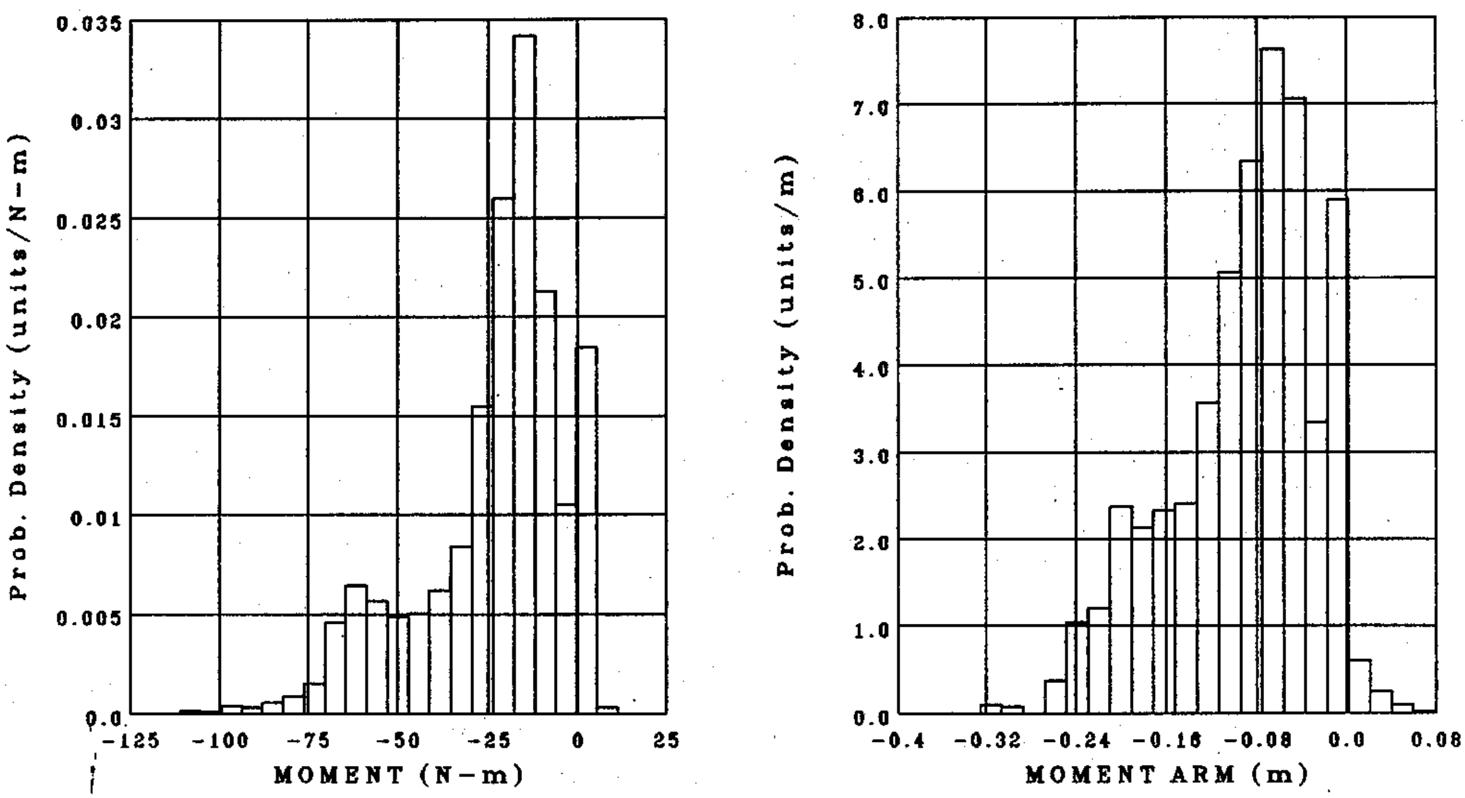
MOMENT ARM

MEAN ARM = -0.08959 m
MAX ARM = 0.07902 m
MIN ARM = -0.3254 m

TEST CONDITIONS

BOARD ANGLE = 24.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 62.00 kPa
ICE THICKNESS = 3.600 cm
ICE DENSITY = 0.9300 g/cc

TN←009



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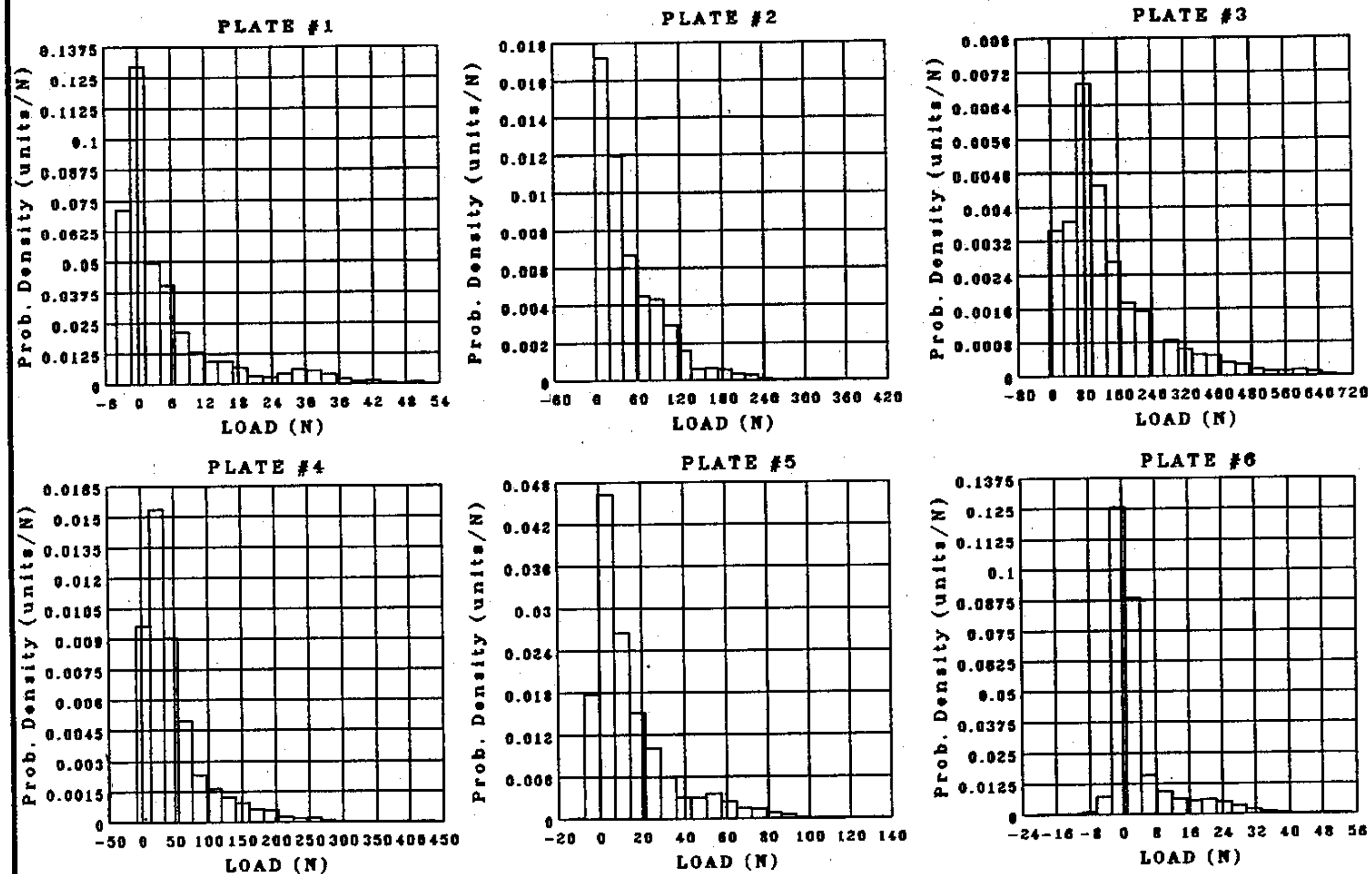
ICE PILEUP STUDY for CANADIAN COAST GUARD

TN←009
NORMAL LOAD



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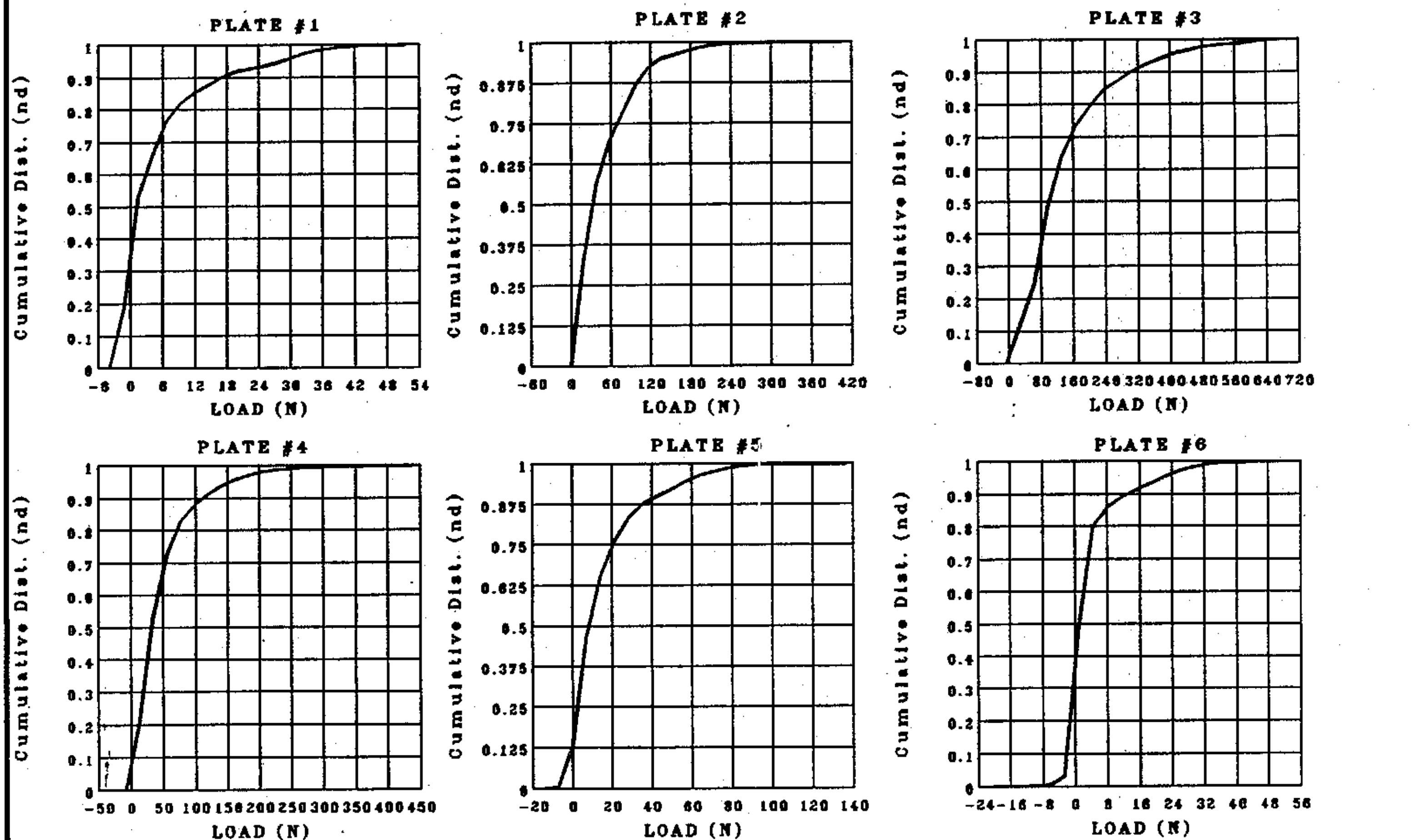
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←009
NORMAL LOAD



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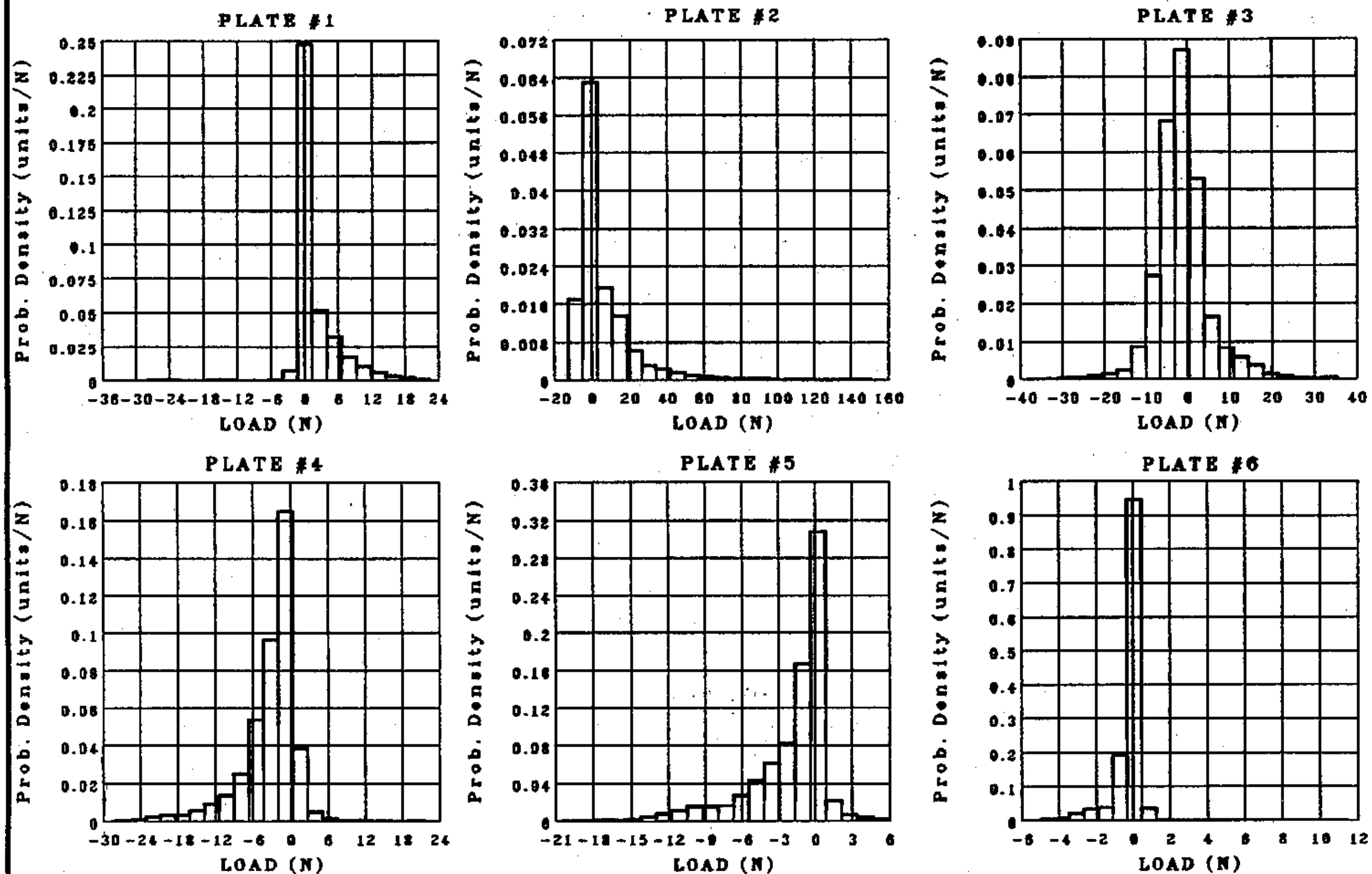
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←009

TANGENTIAL LOAD



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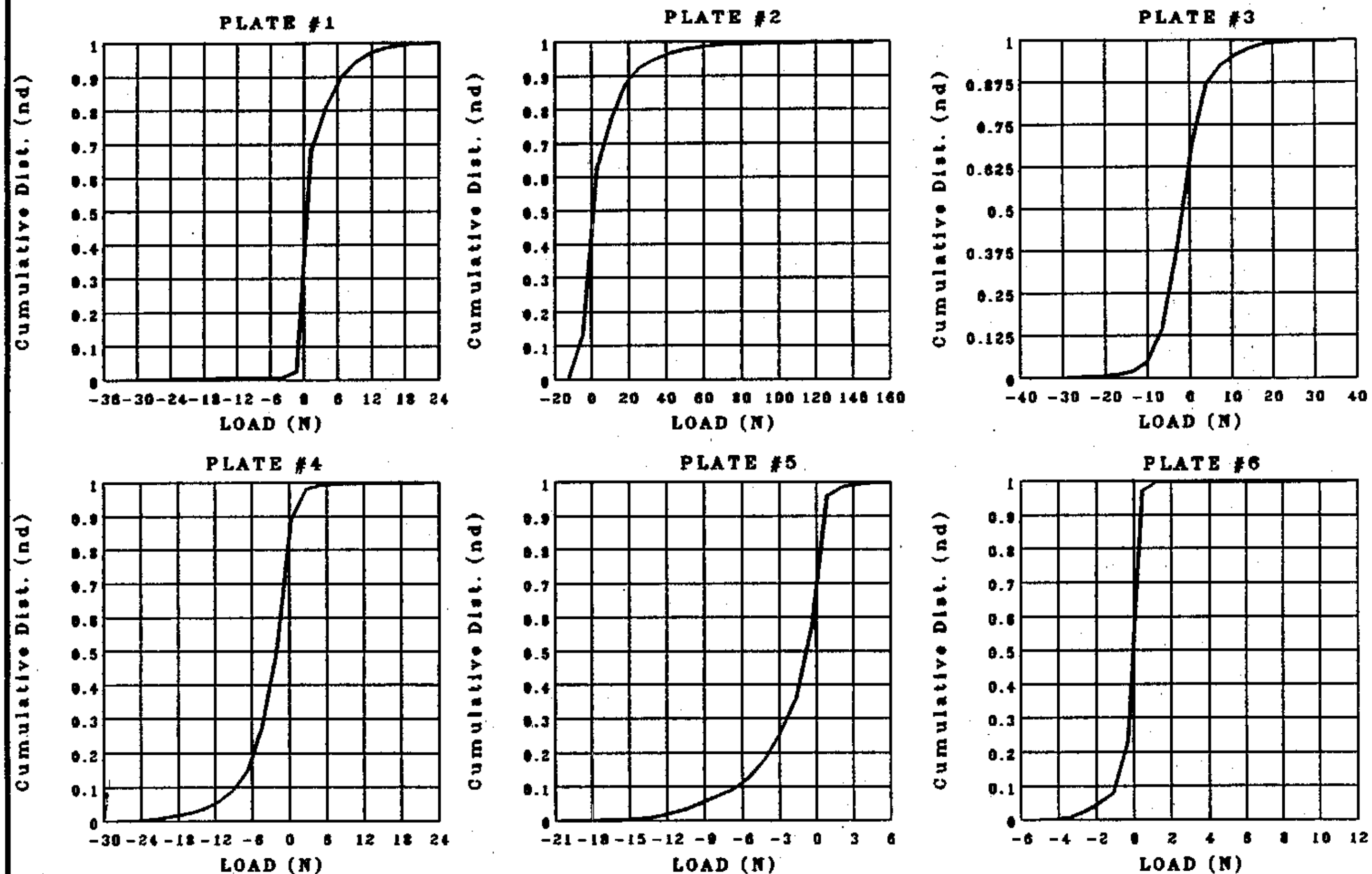
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←009
TANGENTIAL LOAD



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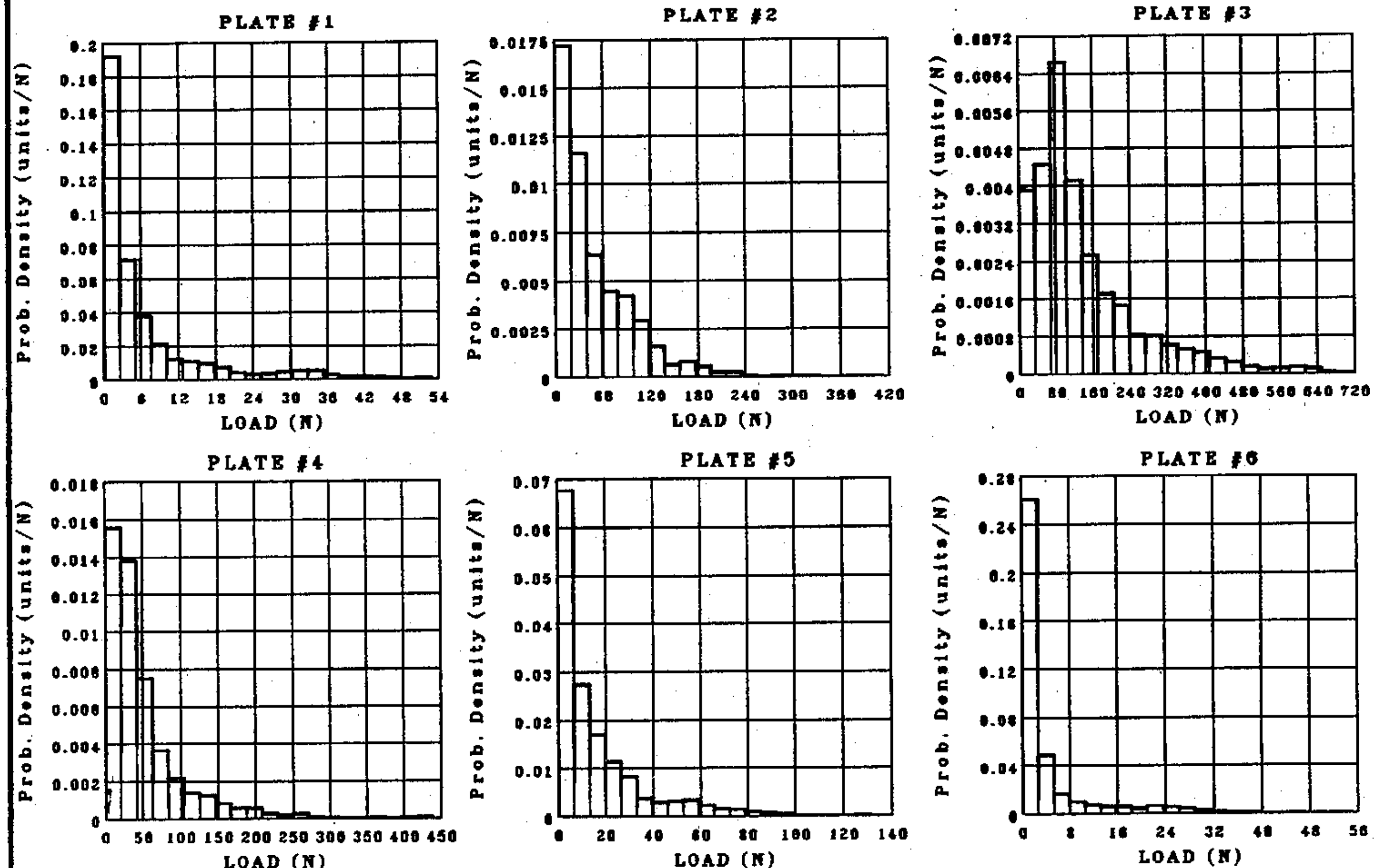
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←009
RESULTANT



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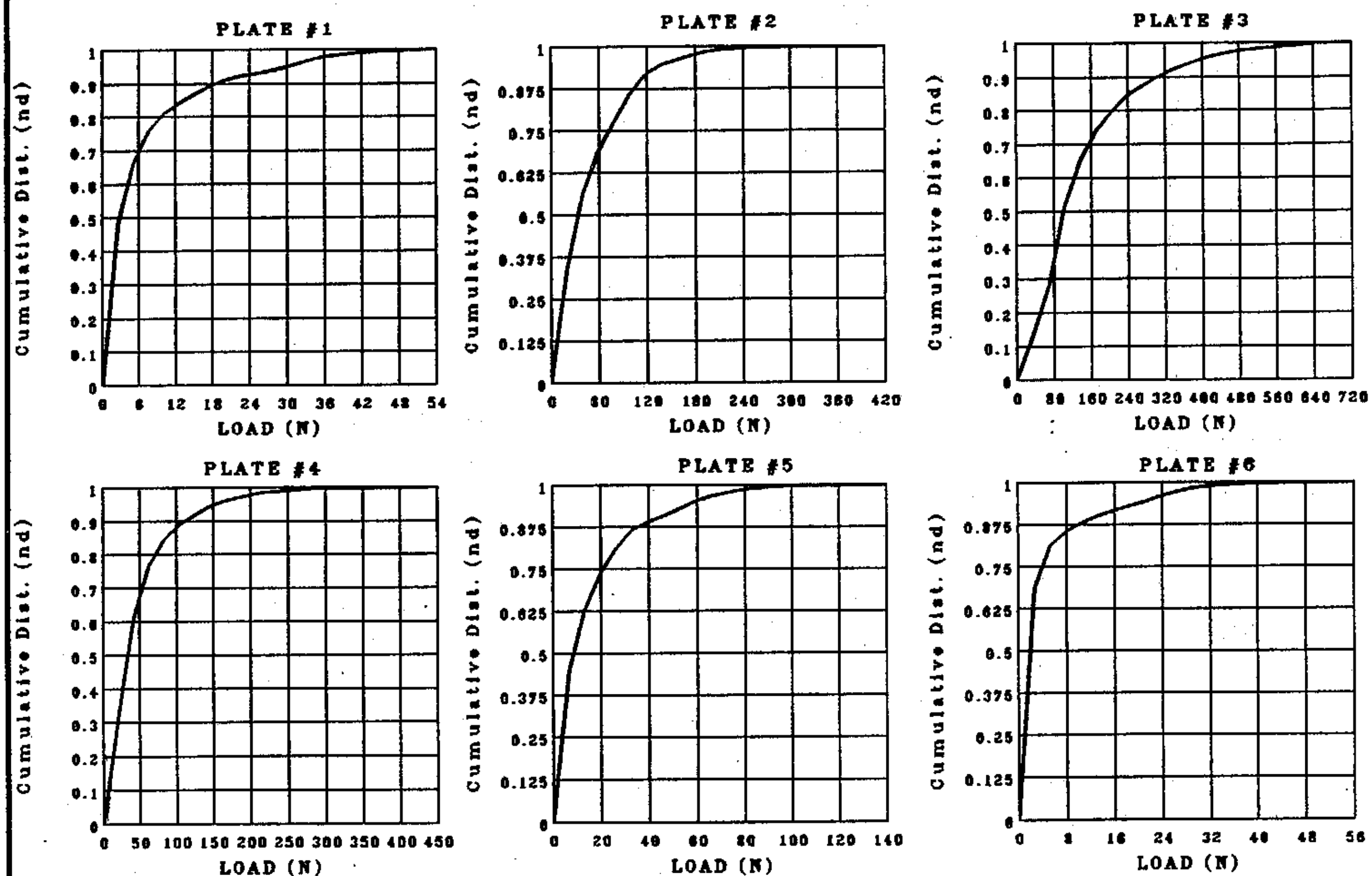
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←009
RESULTANT



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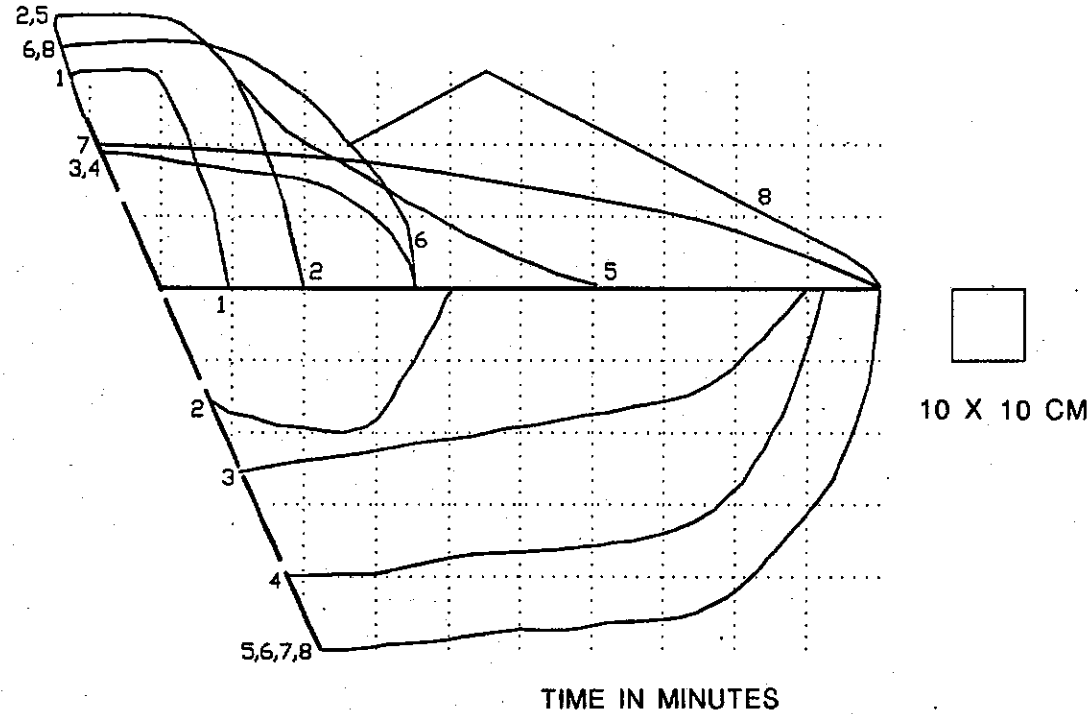
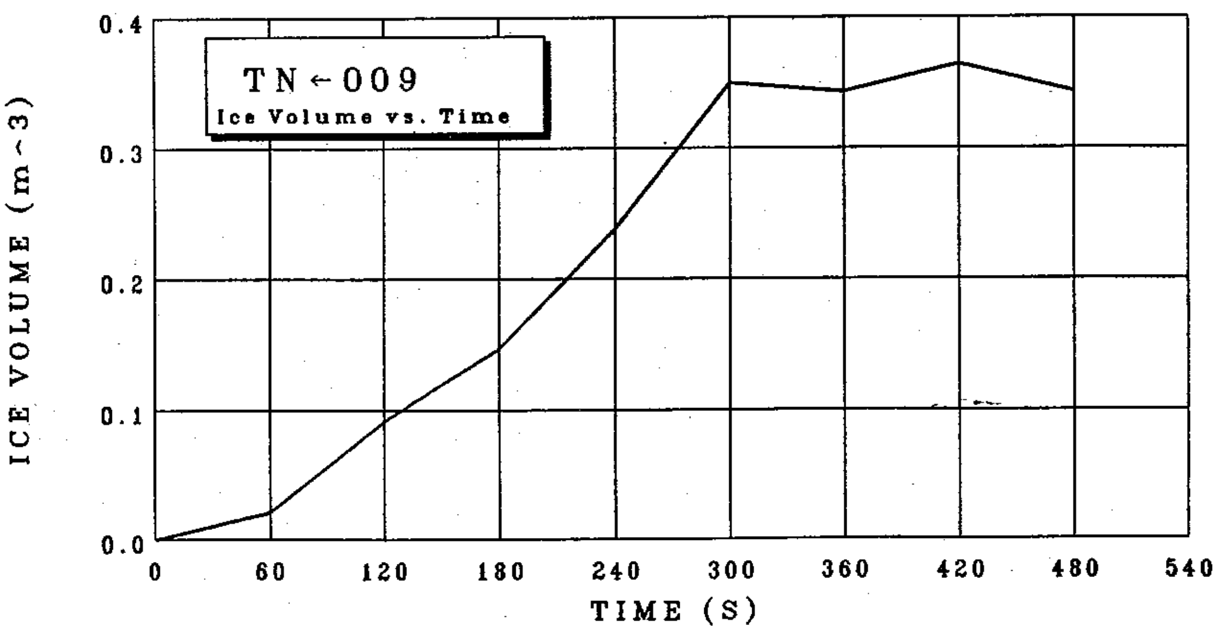
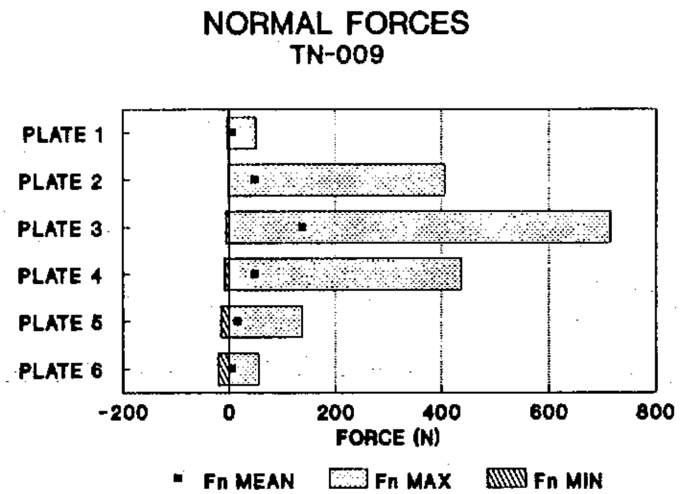
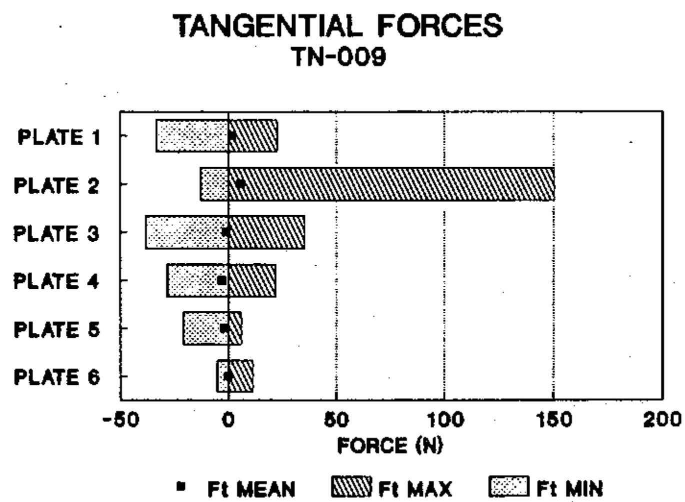
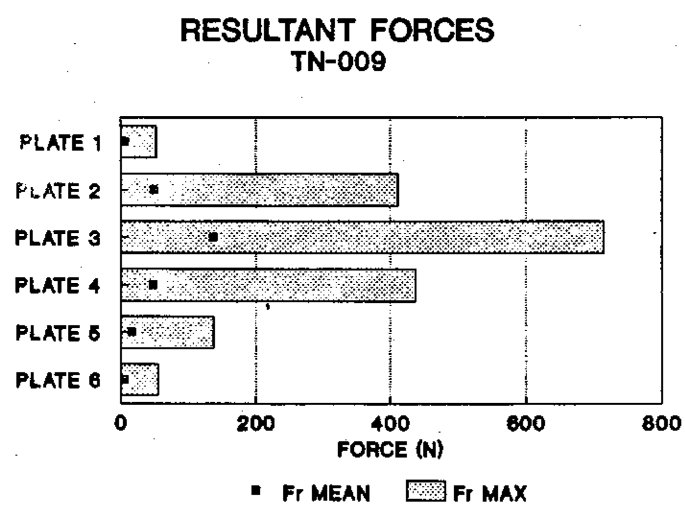
ICE PILEUP STUDY
for CANADIAN COAST GUARD

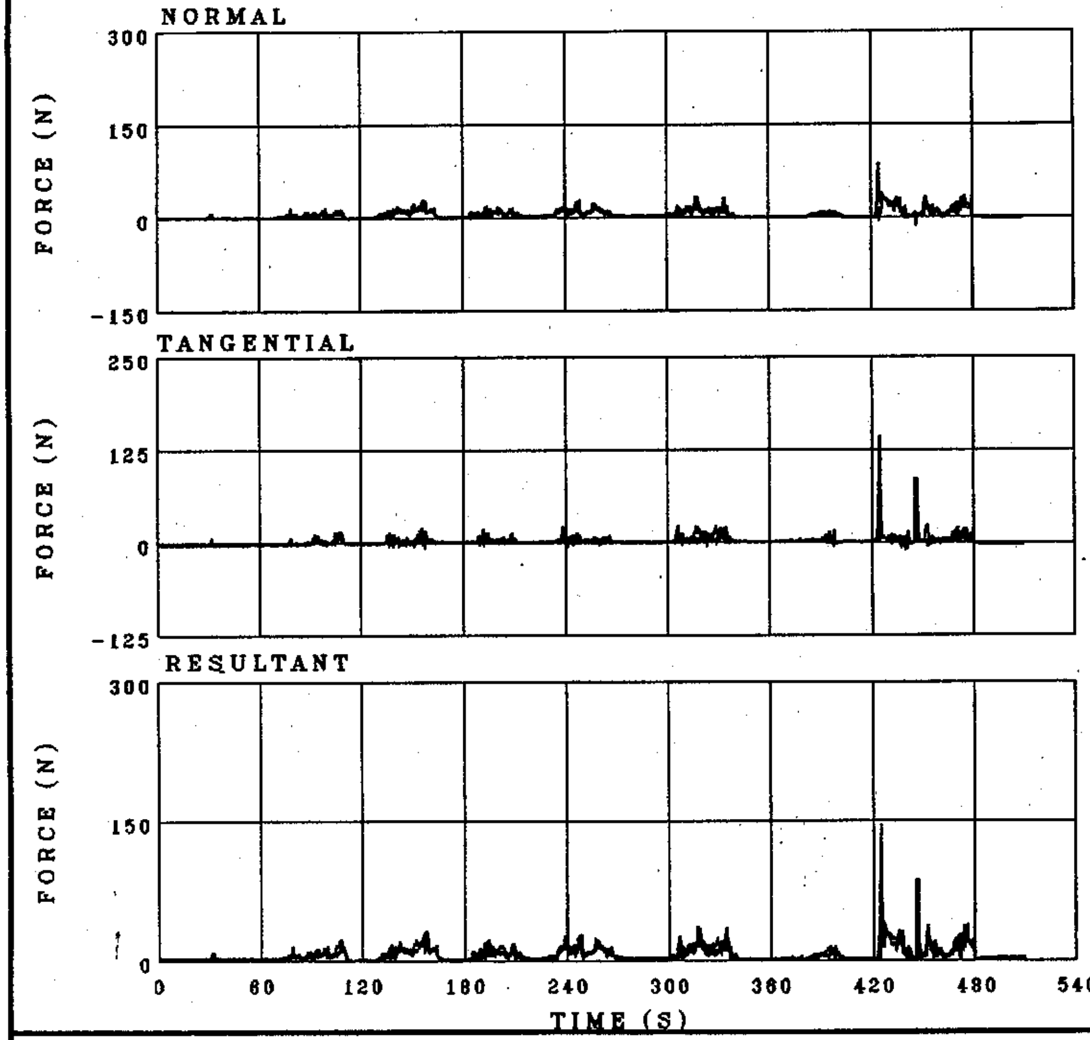

2,5
6,8
1
7
3,4
8
6
2
5
1
2
3
4
5,6,7,8
10 X 10 CM
TIME IN MINUTES


TN←009
Ice Volume vs. Time
ICE VOLUME (m^3)
0.4
0.3
0.2
0.1
0.0
0
60
120
180
240
300
360
420
480
540
TIME (S)


NORMAL FORCES
TN-009
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-200
0
200
400
600
800
FORCE (N)
Fn MEAN
Fn MAX
Fn MIN


TANGENTIAL FORCES
TN-009
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-50
0
50
100
150
200
FORCE (N)
Ft MEAN
Ft MAX
Ft MIN


RESULTANT FORCES
TN-009
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
0
200
400
600
800
FORCE (N)
Fr MEAN
Fr MAX



FILE TN←010

PLATE #1

NORMAL

MEAN FORCE = 4.971 N
MAX FORCE = 50.40 N
MIN FORCE = -7.721 N

TANGENTIAL

MEAN FORCE = 1.923 N
MAX FORCE = 99.54 N
MIN FORCE = -5.590 N

RESULTANT

MEAN FORCE = 6.343 N
MAX FORCE = 111.6 N
MIN FORCE = 0.1026 N
AVERAGE ANGLE = 8.308 O

TEST CONDITIONS

BOARD ANGLE = 24.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 60.00 kPa
ICE THICKNESS = 3.100 cm
ICE DENSITY = 0.8700 g/cc

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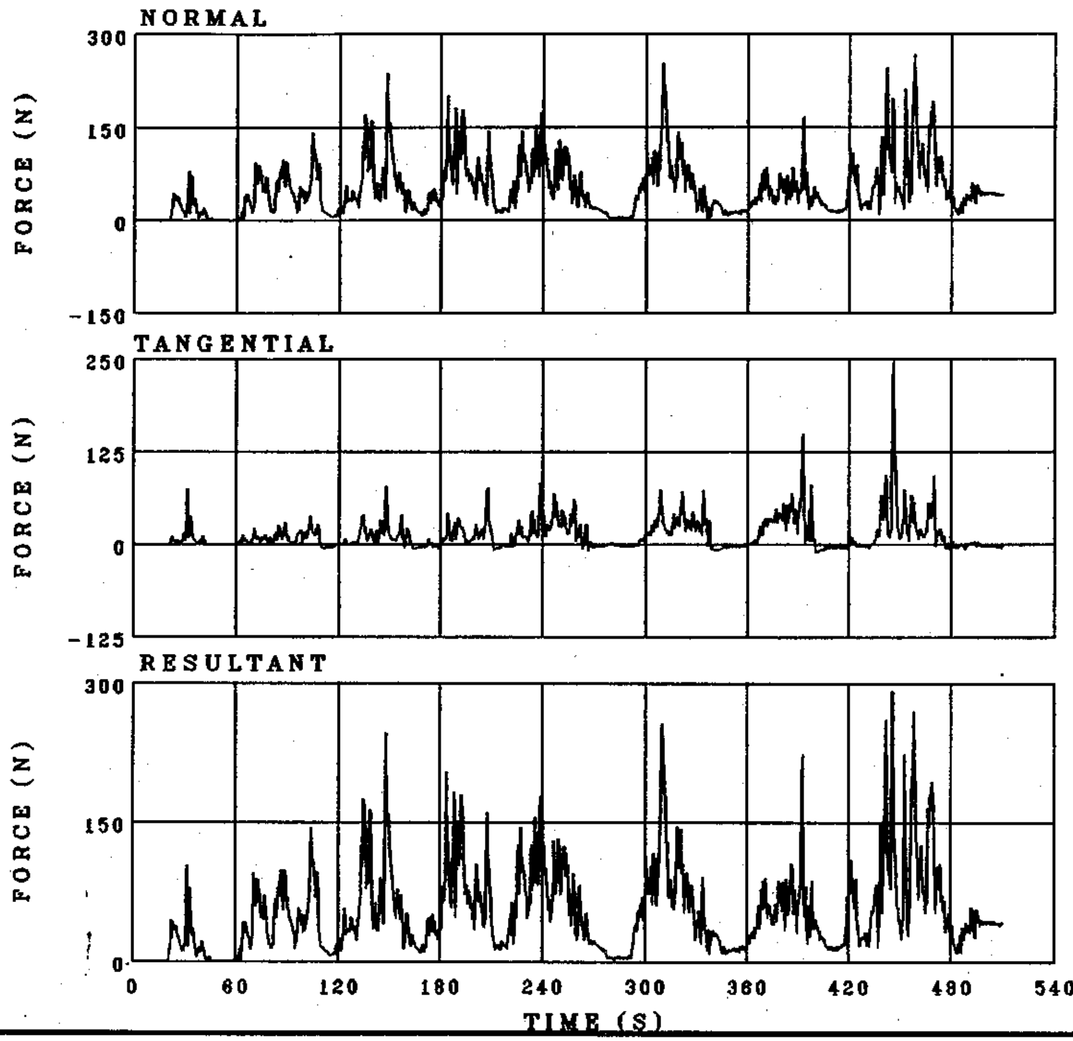
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←010

PLATE #2

NORMAL

MEAN FORCE = 48.81 N
MAX FORCE = 266.9 N
MIN FORCE = -0.7076 N

TANGENTIAL

MEAN FORCE = 12.15 N
MAX FORCE = 247.8 N
MIN FORCE = -10.97 N

RESULTANT

MEAN FORCE = 52.27 N
MAX FORCE = 292.0 N
MIN FORCE = 0.005310 N
AVERAGE ANGLE = 2.270 D

TEST CONDITIONS

BOARD ANGLE = 24.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 60.00 kPa
ICE THICKNESS = 3.100 cm
ICE DENSITY = 0.8700 g/cc

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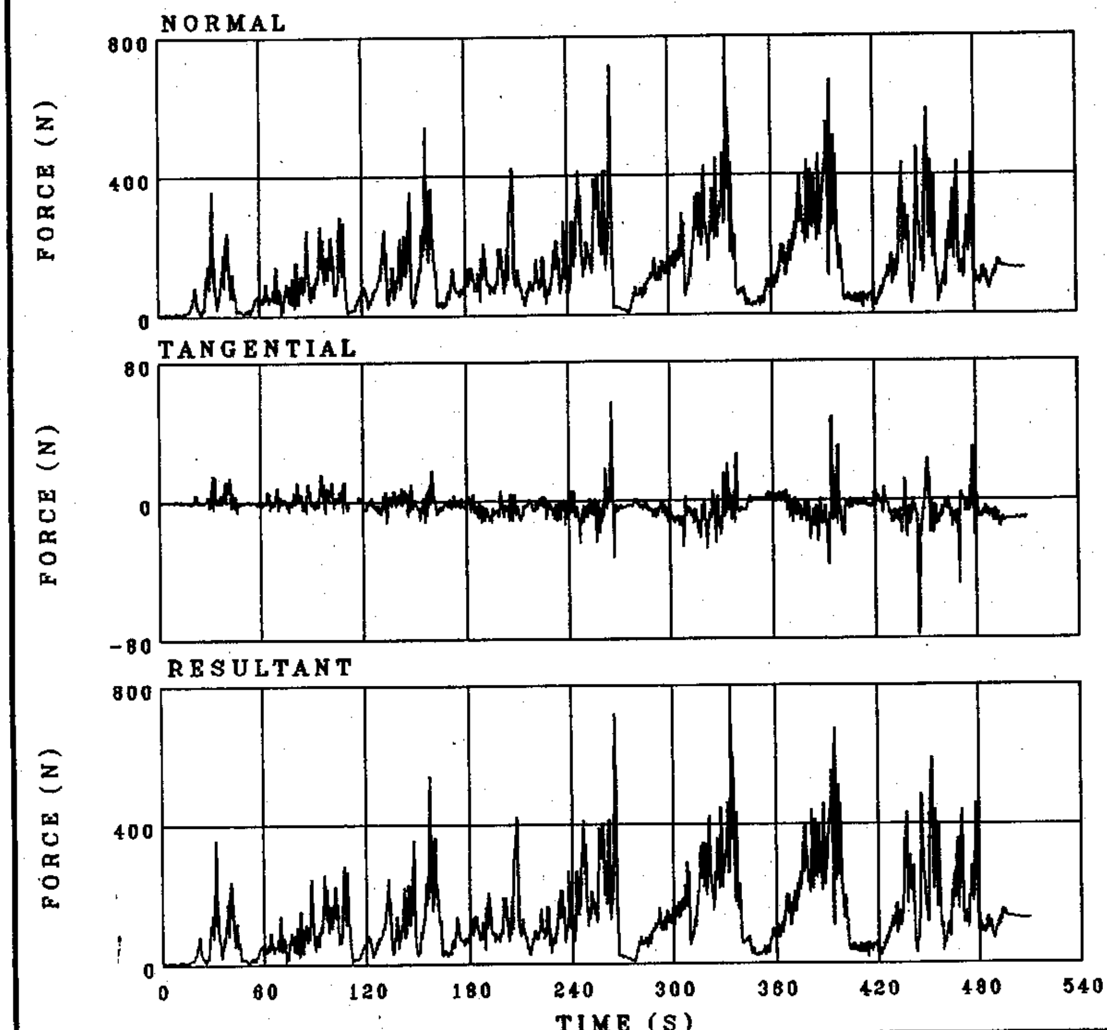
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←010

PLATE #3

NORMAL

MEAN FORCE = 133.8 N
MAX FORCE = 795.1 N
MIN FORCE = 1.363 N

TANGENTIAL

MEAN FORCE = -3.491 N
MAX FORCE = 56.61 N
MIN FORCE = -78.56 N

RESULTANT

MEAN FORCE = 133.9 N
MAX FORCE = 795.2 N
MIN FORCE = 1.420 N
AVERAGE ANGLE = -2.077 D

TEST CONDITIONS

BOARD ANGLE = 24.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 60.00 kPa
ICE THICKNESS = 3.100 cm
ICE DENSITY = 0.8700 g/cc

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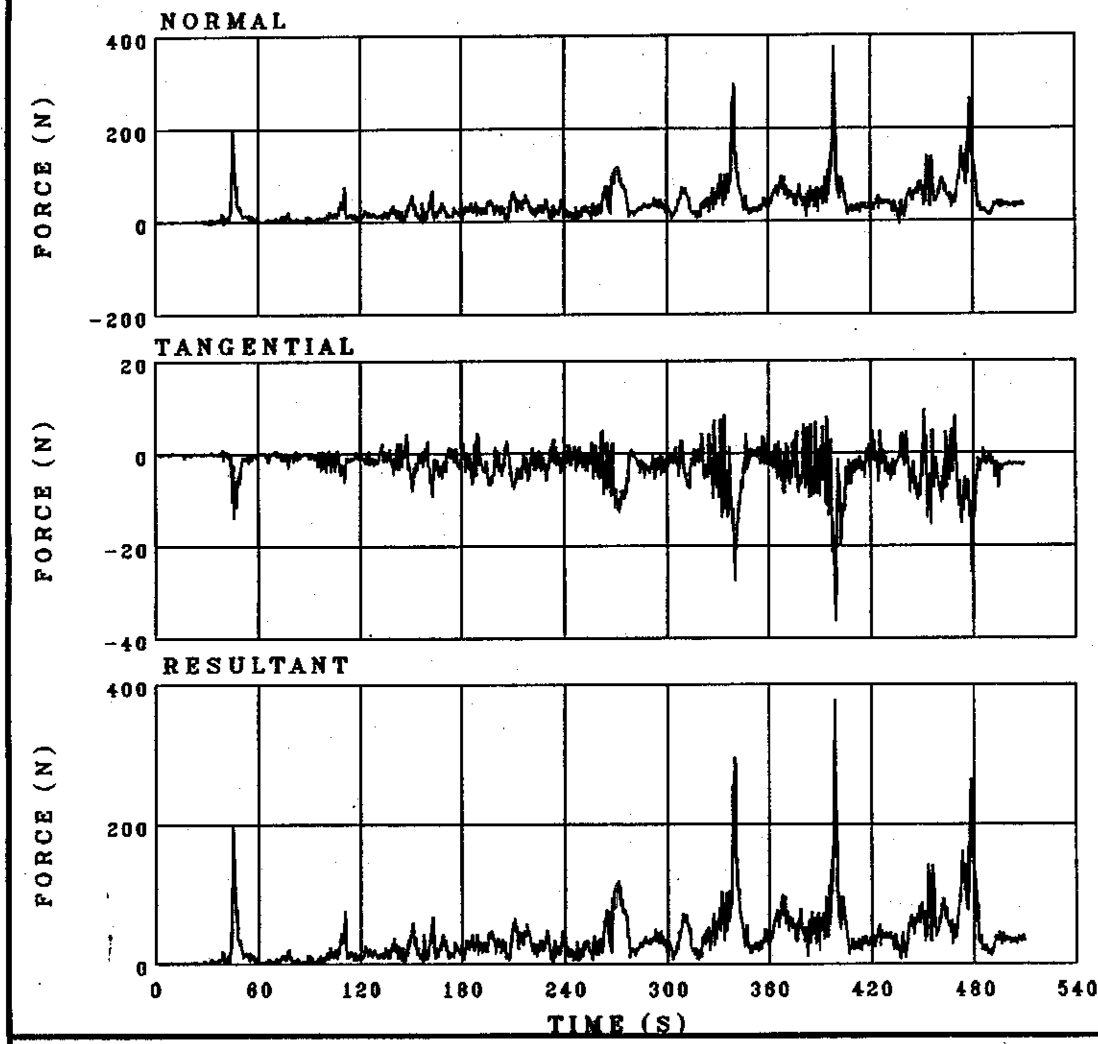
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←010

PLATE #4

NORMAL

MEAN FORCE = 34.99 N
MAX FORCE = 377.3 N
MIN FORCE = -8.865 N

TANGENTIAL

MEAN FORCE = -2.684 N
MAX FORCE = 9.478 N
MIN FORCE = -36.35 N

RESULTANT

MEAN FORCE = 35.23 N
MAX FORCE = 378.0 N
MIN FORCE = 0.04080 N
AVERAGE ANGLE = -4.022 O

TEST CONDITIONS

BOARD ANGLE = 24.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 60.00 kPa
ICE THICKNESS = 3.100 cm
ICE DENSITY = 0.8700 g/cc

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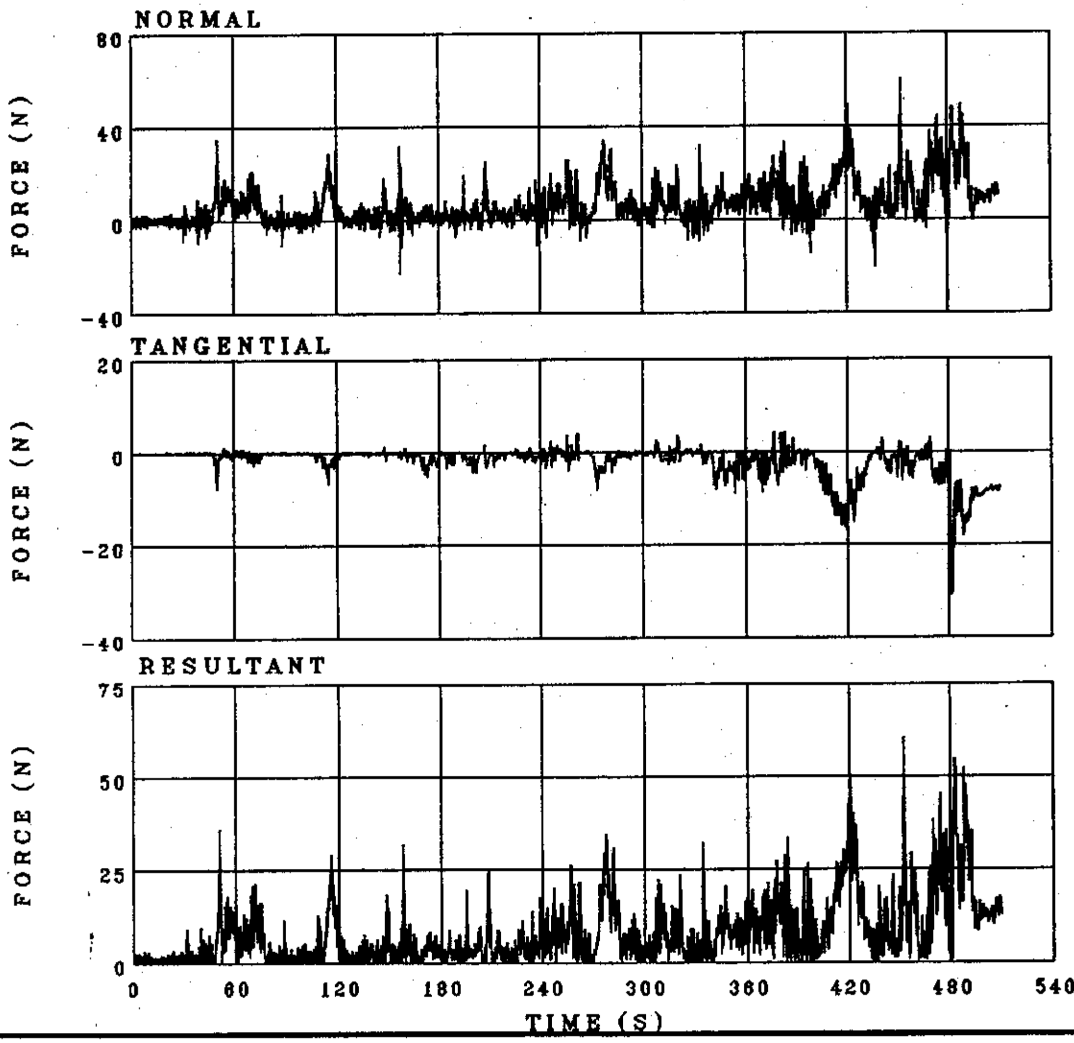
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←010

PLATE #5

NORMAL

MEAN FORCE = 6.460 N
MAX FORCE = 60.73 N
MIN FORCE = -22.91 N

TANGENTIAL

MEAN FORCE = -1.961 N
MAX FORCE = 4.521 N
MIN FORCE = -30.93 N

RESULTANT

MEAN FORCE = 7.588 N
MAX FORCE = 60.76 N
MIN FORCE = 0.03825 N
AVERAGE ANGLE = -17.56 O

TEST CONDITIONS

BOARD ANGLE = 24.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 60.00 kPa
ICE THICKNESS = 3.100 cm
ICE DENSITY = 0.8700 g/cc

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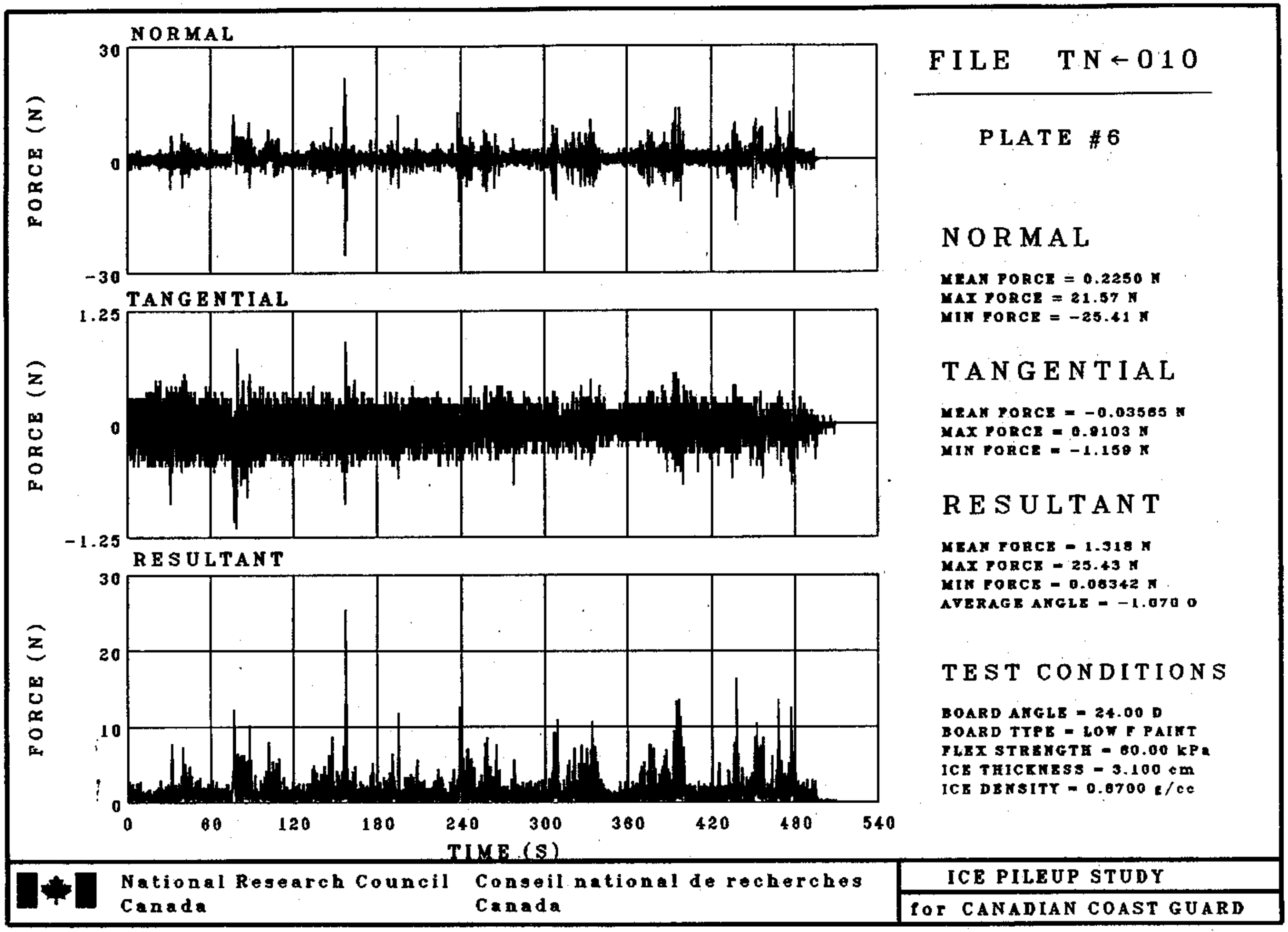
ICE PILEUP STUDY
for CANADIAN COAST GUARD


NORMAL
FORCE (N)
30
0
-30
TANGENTIAL
1.25
0
-1.25
RESULTANT
30
20
10
0
0
60
120
180
240
300
360
420
480
540
TIME (S)
FILE TN←010
PLATE #6
NORMAL
MEAN FORCE = 0.2250 N
MAX FORCE = 21.57 N
MIN FORCE = -25.41 N
TANGENTIAL
MEAN FORCE = -0.03565 N
MAX FORCE = 0.9103 N
MIN FORCE = -1.159 N
RESULTANT
MEAN FORCE = 1.318 N
MAX FORCE = 25.43 N
MIN FORCE = 0.06342 N
AVERAGE ANGLE = -1.070 D
TEST CONDITIONS
BOARD ANGLE = 24.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 60.00 kPa
ICE THICKNESS = 3.100 cm
ICE DENSITY = 0.8700 g/cc
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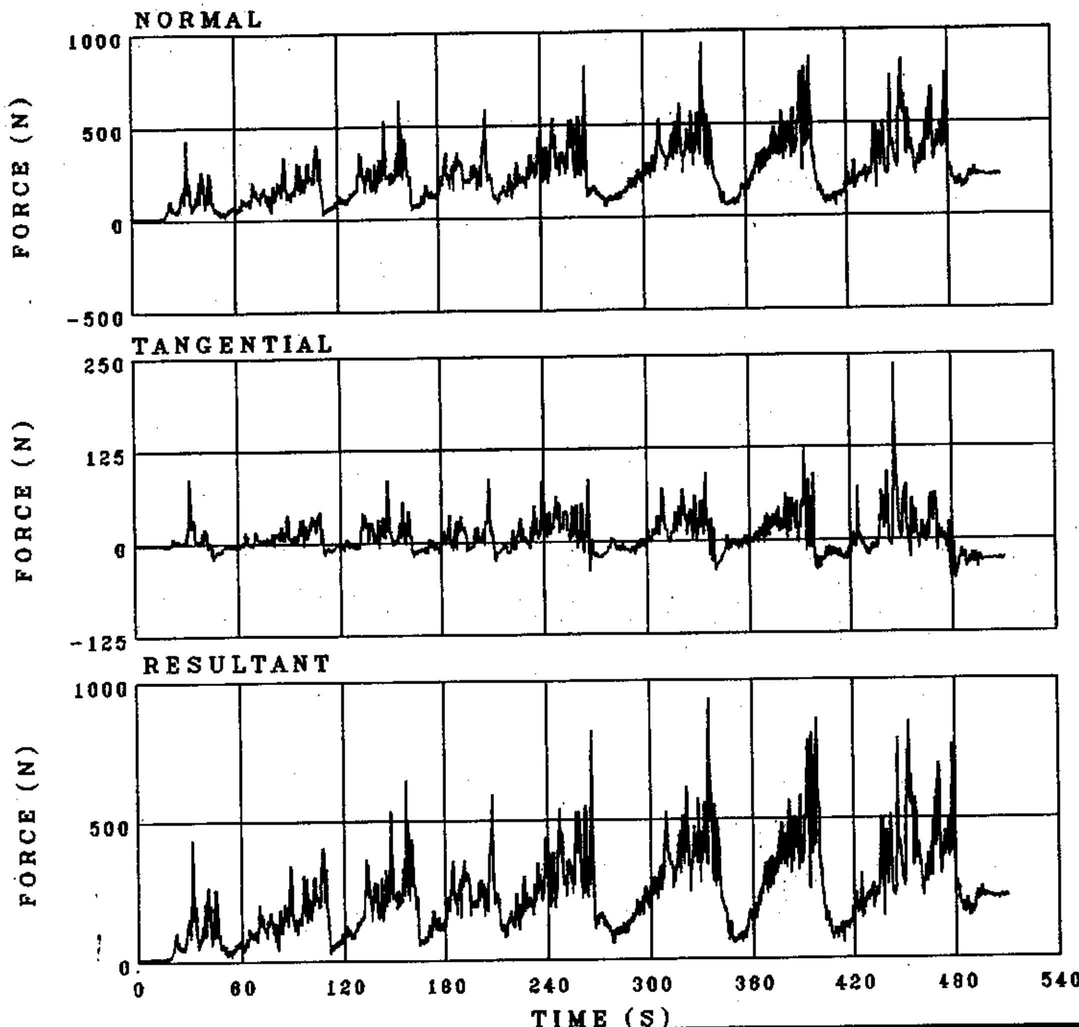
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←010

TOTAL

NORMAL

MEAN FORCE = 229.2 N
MAX FORCE = 931.7 N
MIN FORCE = -5.466 N

TANGENTIAL

MEAN FORCE = 5.905 N
MAX FORCE = 237.1 N
MIN FORCE = -53.75 N

RESULTANT

MEAN FORCE = 230.2 N
MAX FORCE = 935.4 N
MIN FORCE = 1.769 N
AVERAGE ANGLE = -1.253 O

TEST CONDITIONS

BOARD ANGLE = 24.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 60.00 kPa
ICE THICKNESS = 3.100 cm
ICE DENSITY = 0.8700 g/cc

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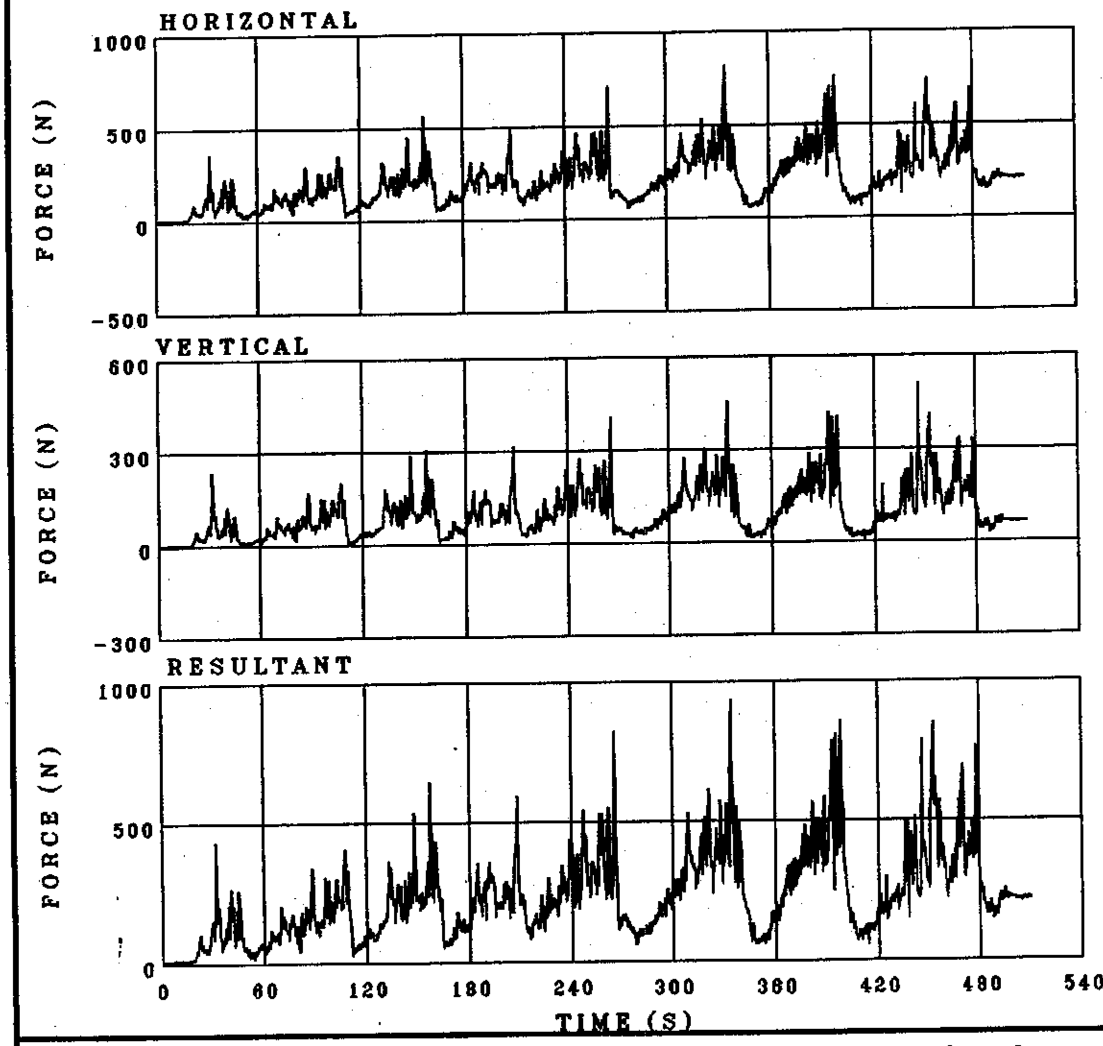
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←010

TOTAL

HORIZONTAL

MEAN FORCE = 5.905 N
MAX FORCE = 237.1 N
MIN FORCE = -53.75 N

VERTICAL

MEAN FORCE = 5.905 N
MAX FORCE = 237.1 N
MIN FORCE = -53.75 N

RESULTANT

MEAN FORCE = 5.905 N
MAX FORCE = 237.1 N
MIN FORCE = -53.75 N
AVERAGE ANGLE = 5.905 O

TEST CONDITIONS

BOARD ANGLE = 24.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 60.00 kPa
ICE THICKNESS = 3.100 cm
ICE DENSITY = 0.8700 g/cc

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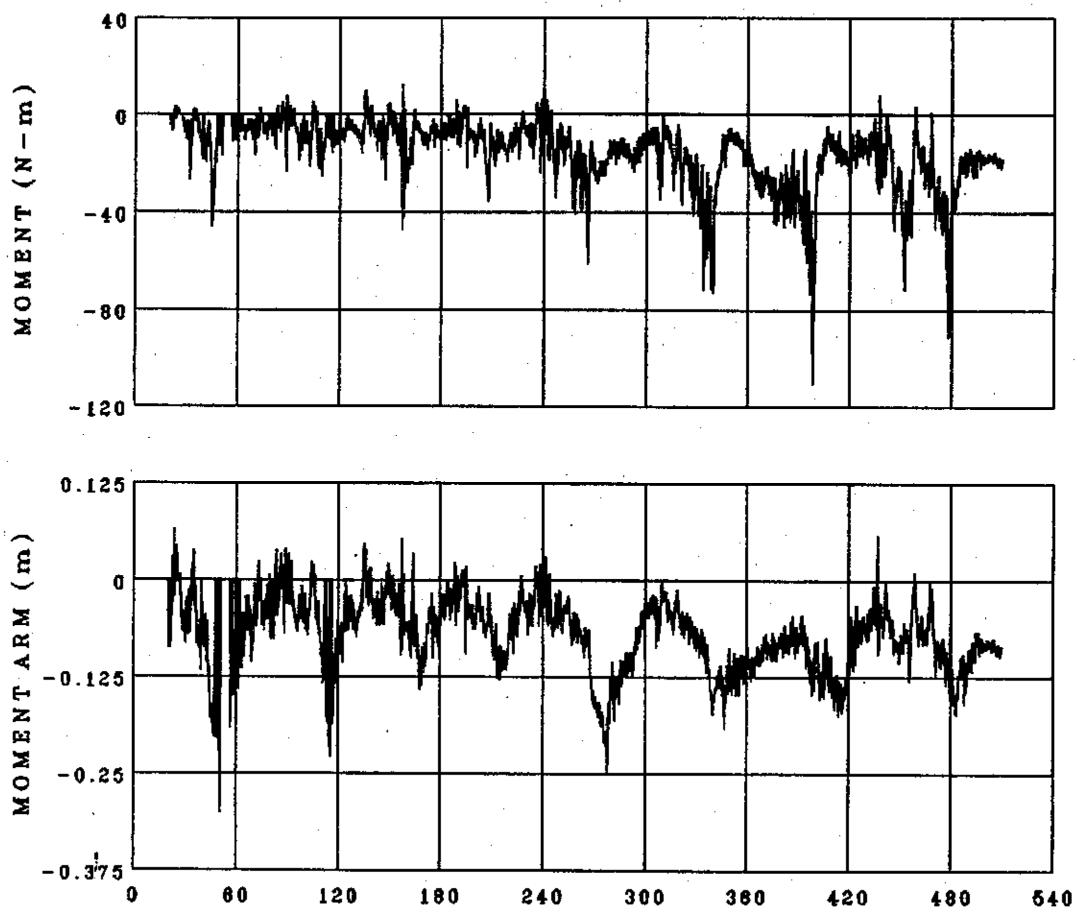
ICE PILEUP STUDY
for CANADIAN COAST GUARD

FILE TN←010

MOMENT



MOMENT

MEAN MOMENT = -15.50 N-m
MAX MOMENT = 12.50 N-m
MIN MOMENT = -110.6 N-m

MOMENT ARM

MEAN ARM = -0.06784 m
MAX ARM = 0.06603 m
MIN ARM = -0.3014 m

TEST CONDITIONS

BOARD ANGLE = 24.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 60.00 kPa
ICE THICKNESS = 3.100 cm
ICE DENSITY = 0.8700 g/cc

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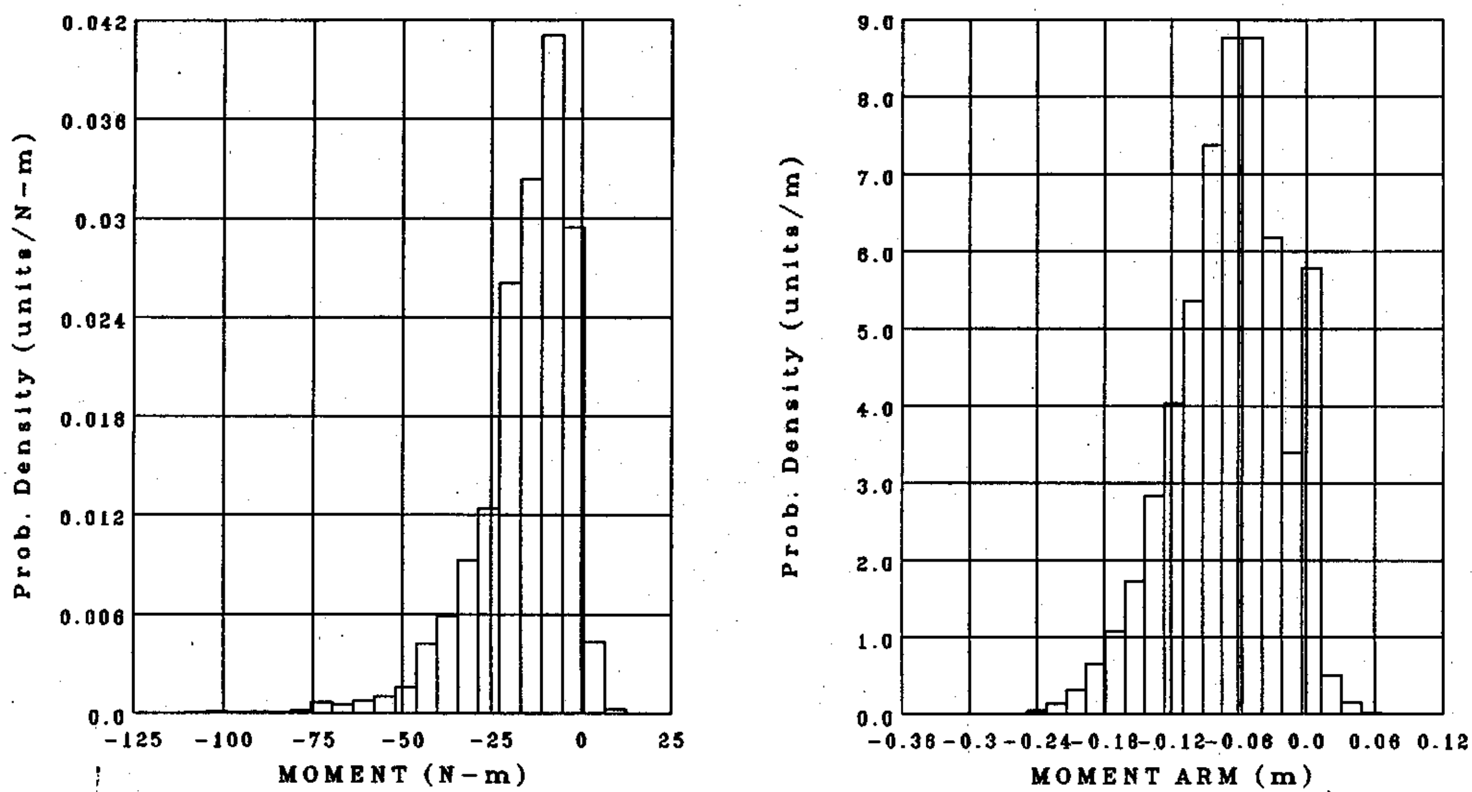
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←010



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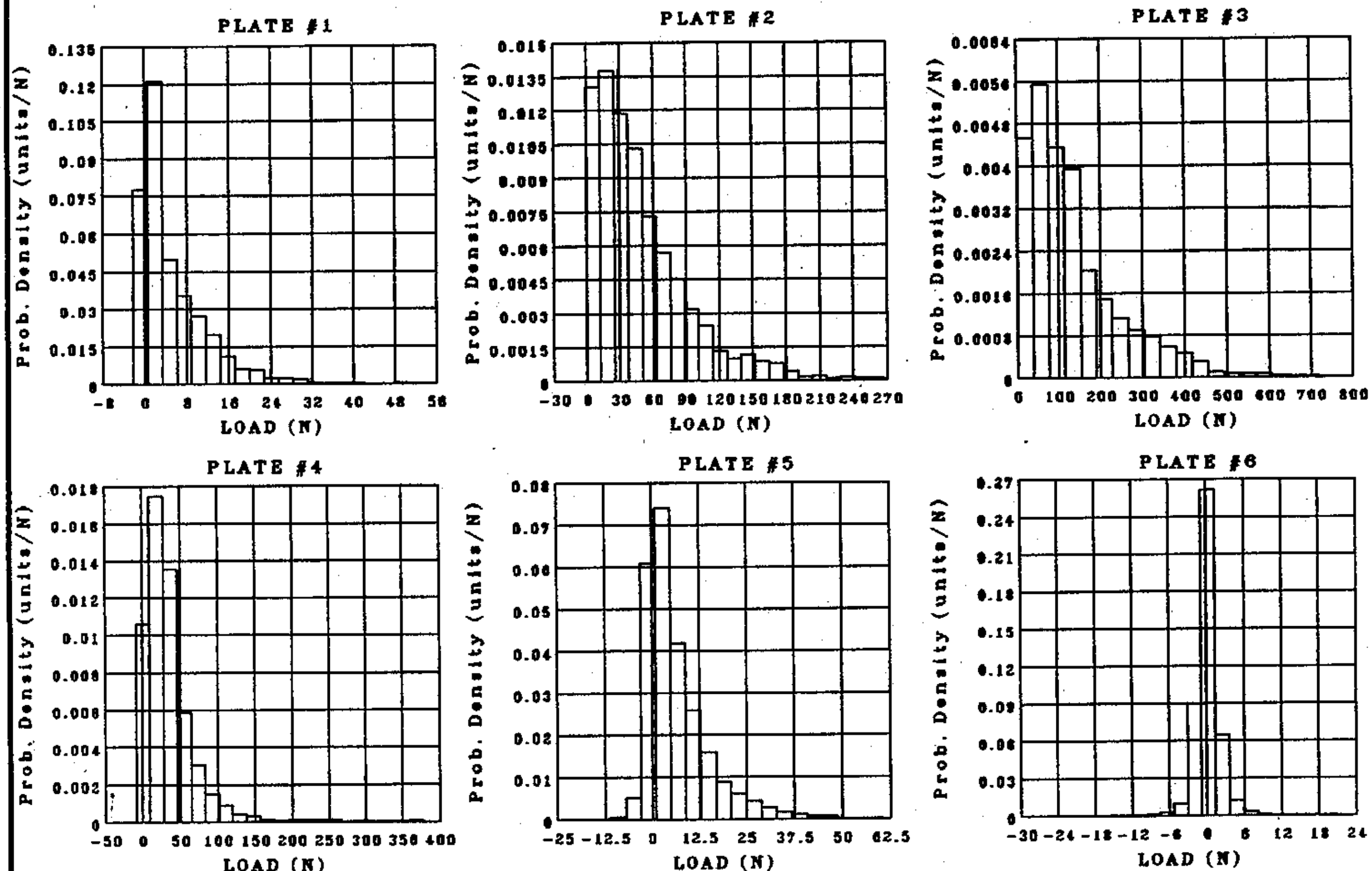
TN←010
NORMAL LOAD



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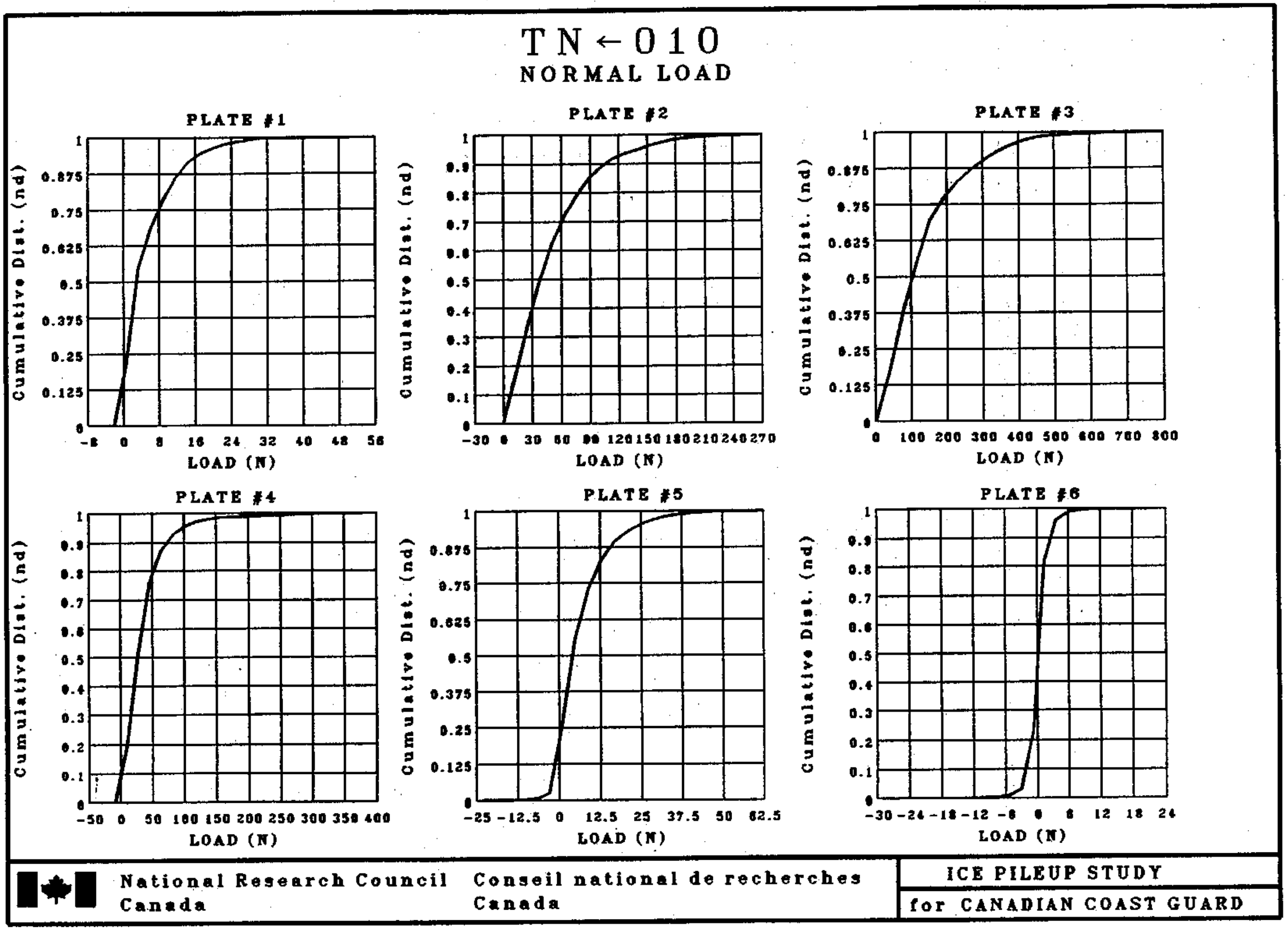
TN ← 010
NORMAL LOAD
PLATE #1
PLATE #2
PLATE #3
PLATE #4
PLATE #5
PLATE #6
Cumulative Dist. (nd)
LOAD (N)
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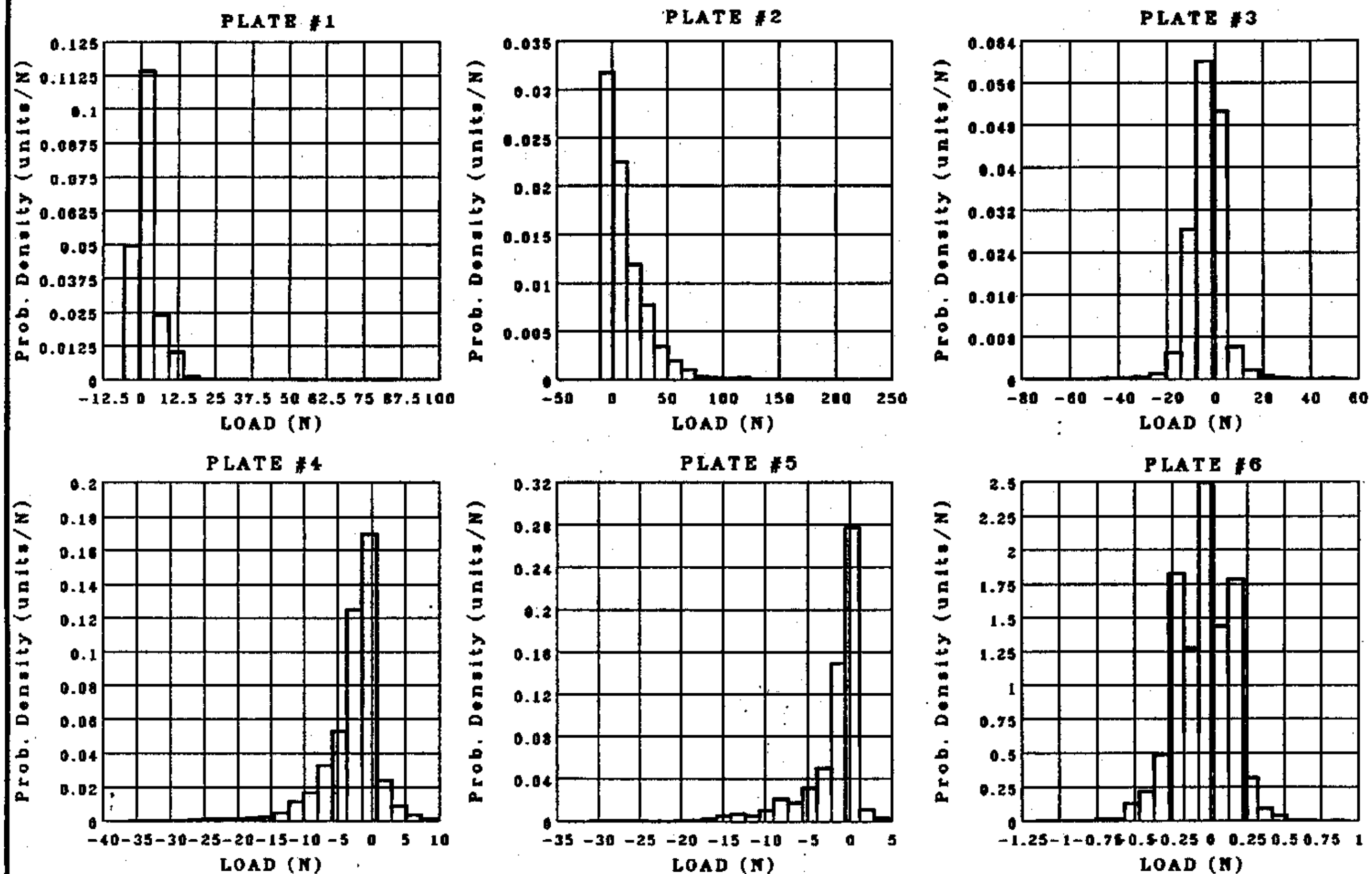
TN←010
TANGENTIAL LOAD



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ICE PILEUP STUDY
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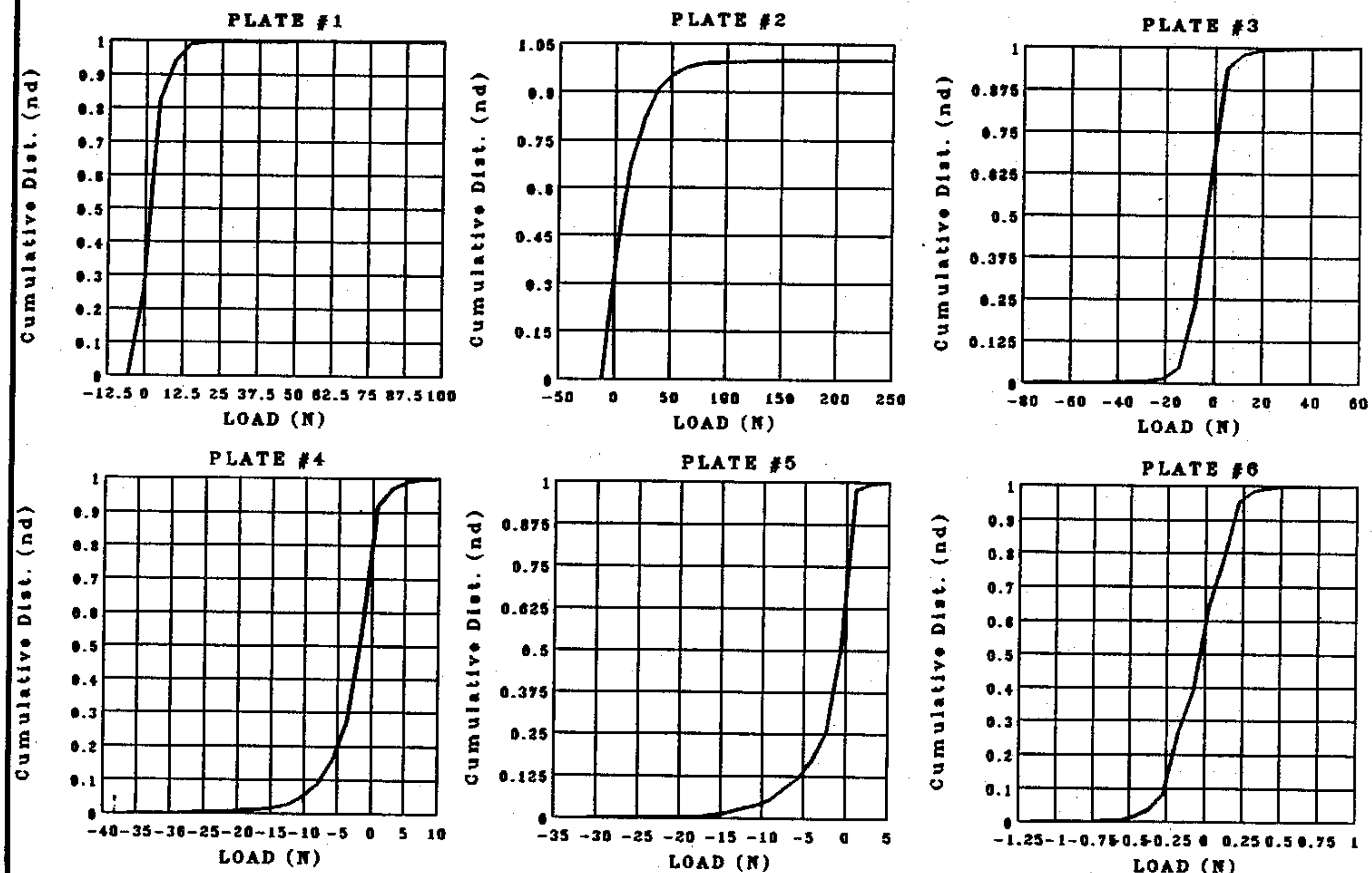
TN←010
TANGENTIAL LOAD



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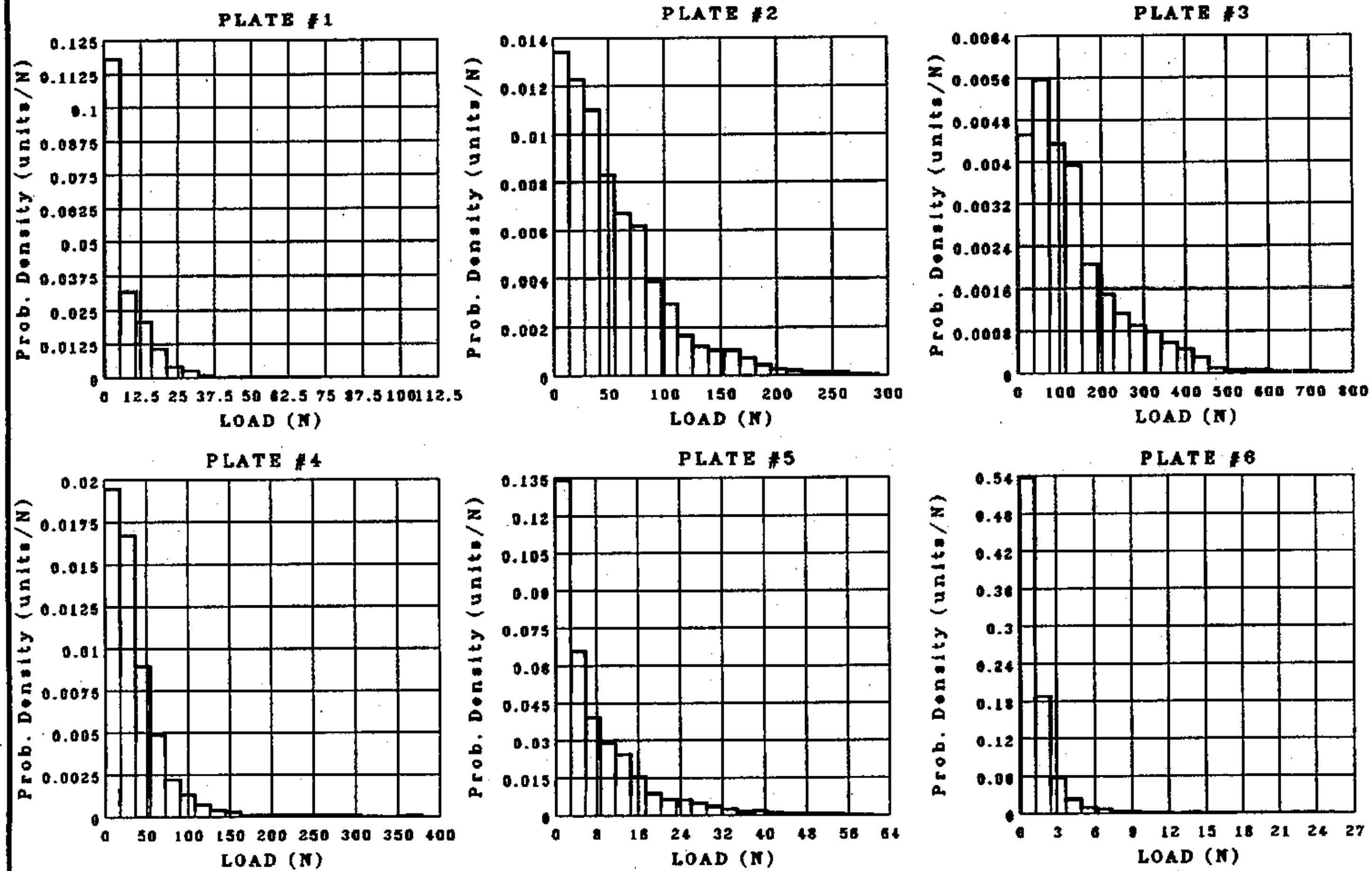
ICE PILEUP STUDY for CANADIAN COAST GUARD

TN←010
RESULTANT



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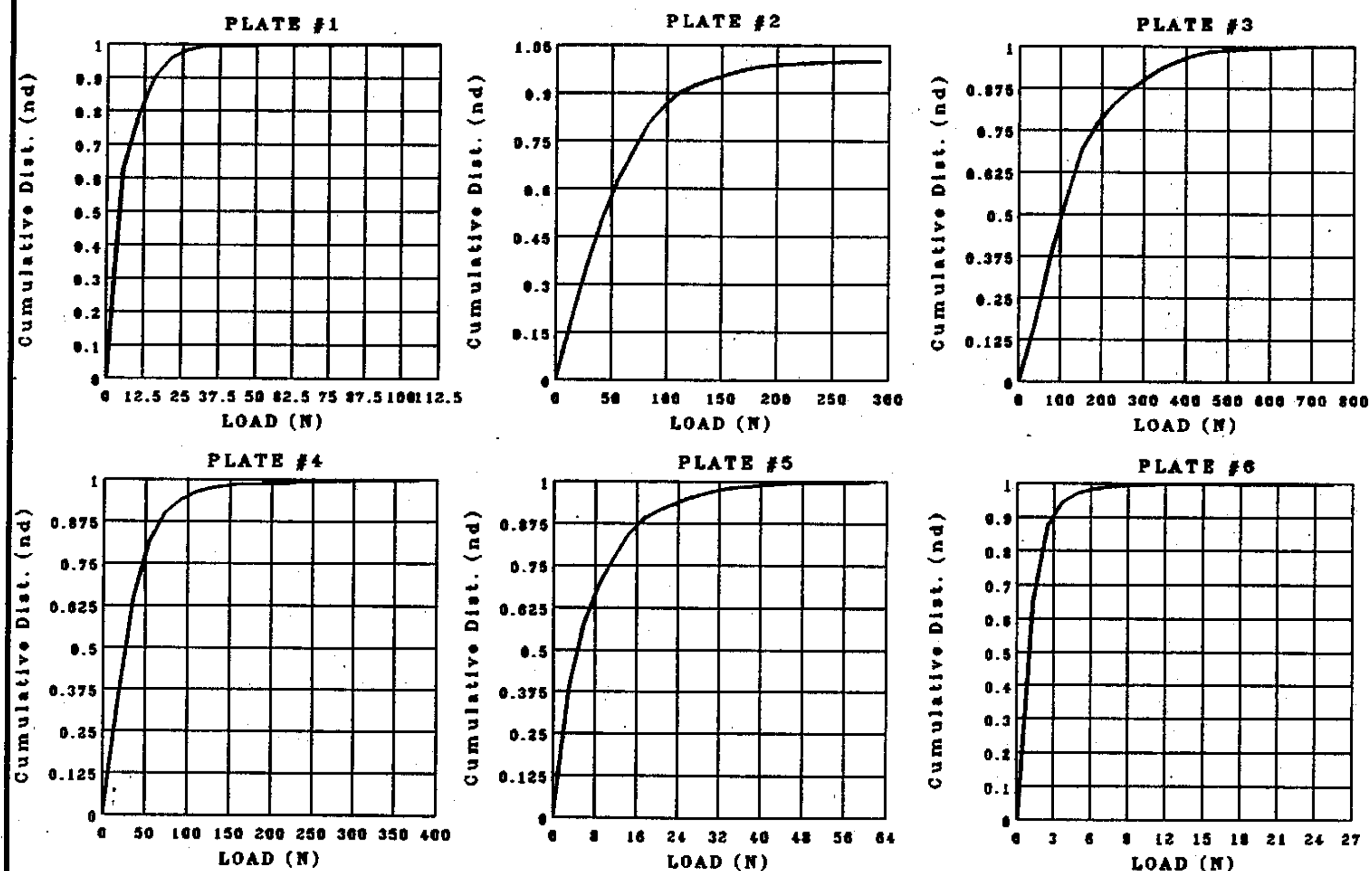
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN ← 010
RESULTANT



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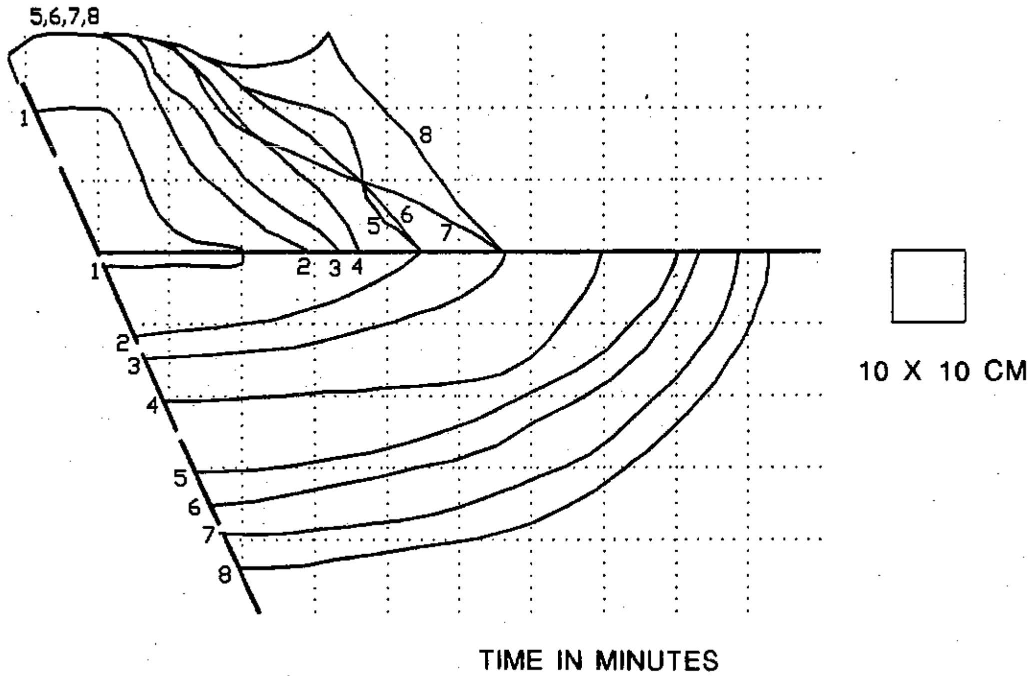
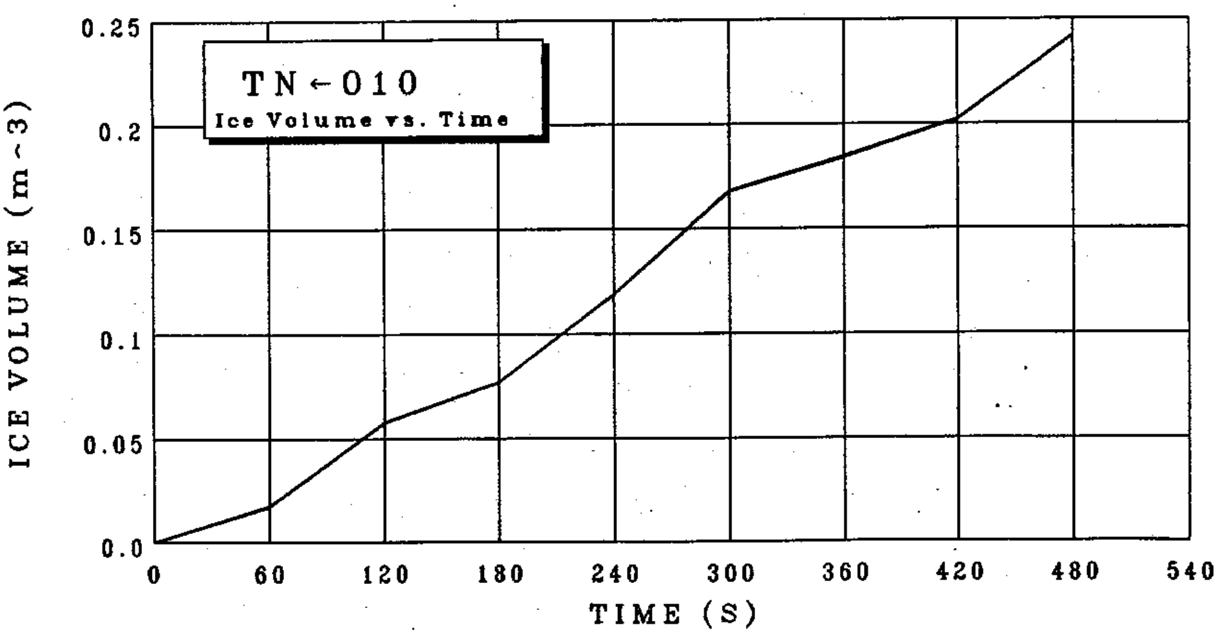
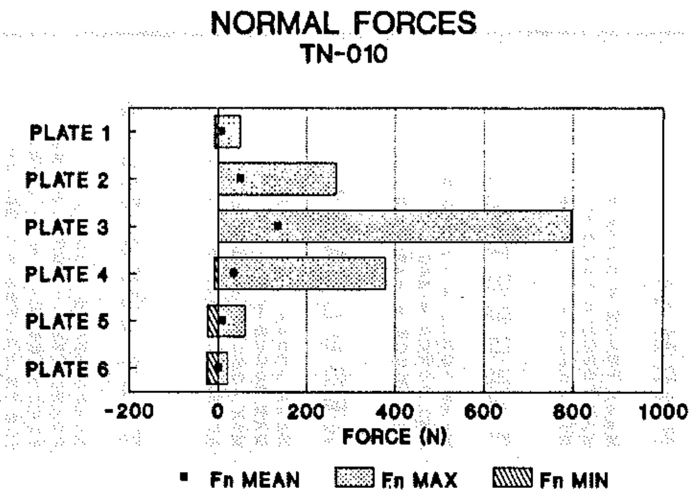
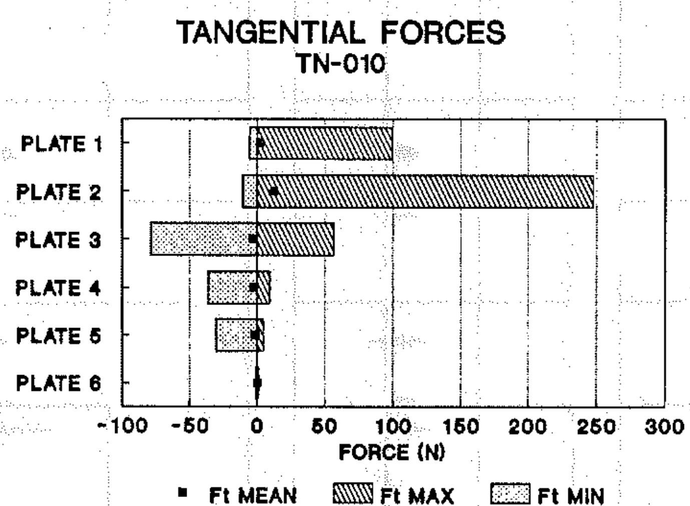
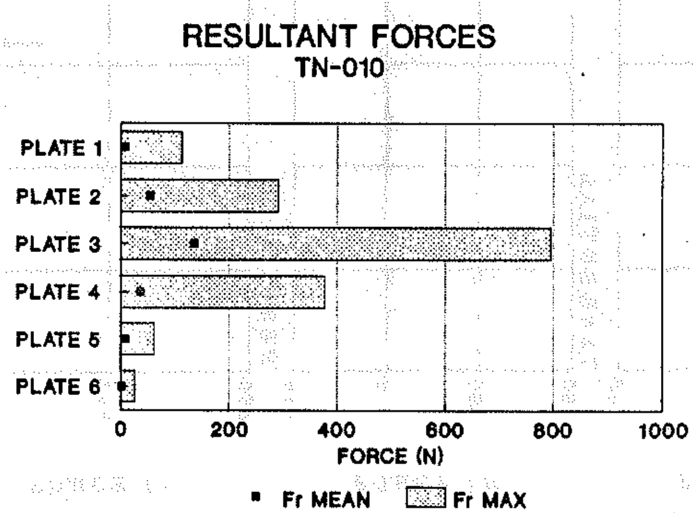
ICE PILEUP STUDY
for CANADIAN COAST GUARD

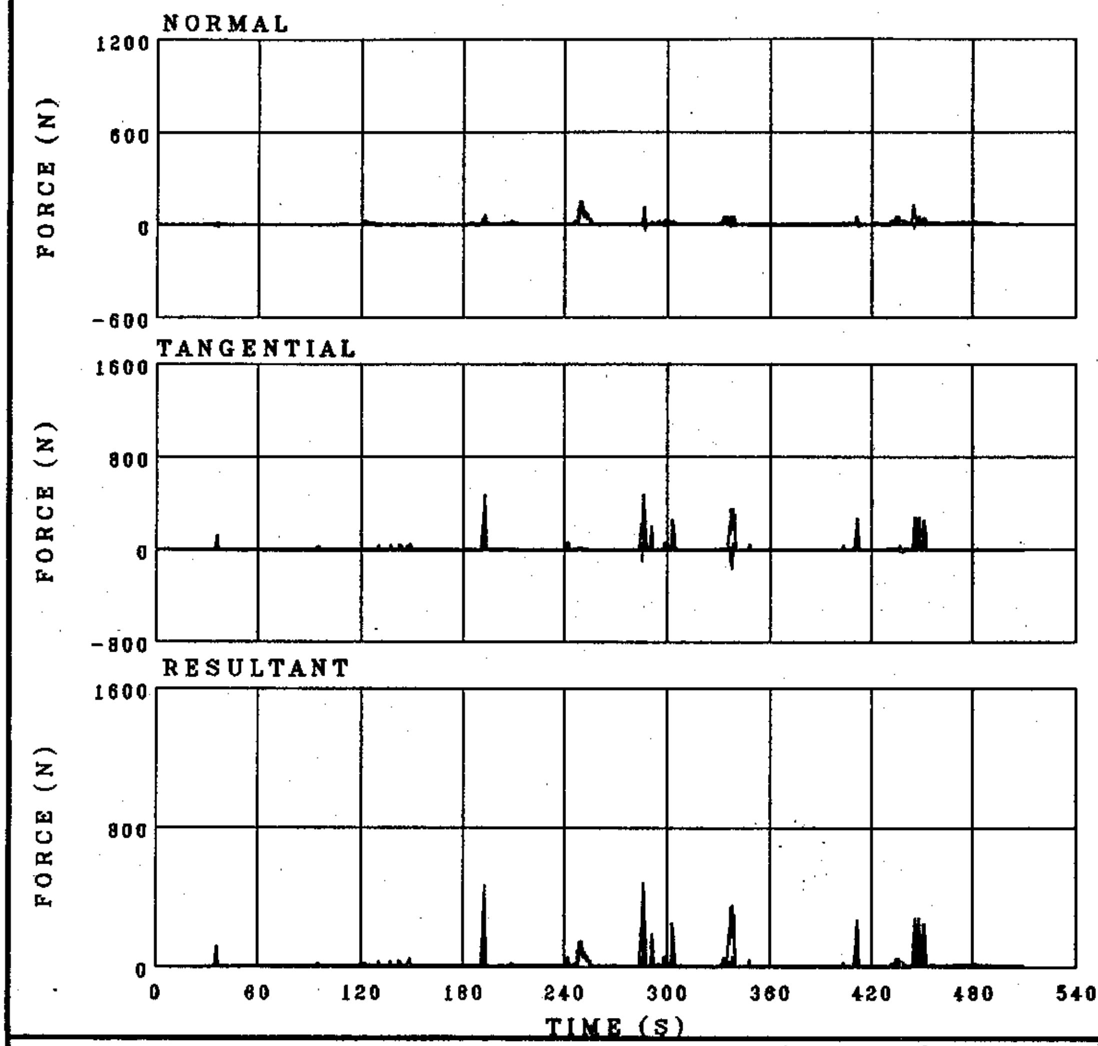

5,6,7,8
1
2
3
4
5
6
7
8
10 X 10 CM
TIME IN MINUTES


TN←010
Ice Volume vs. Time
0.25
0.2
0.15
0.1
0.05
0.0
0
60
120
180
240
300
360
420
480
540
TIME (S)
ICE VOLUME (m^3)


NORMAL FORCES
TN-010
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-200
0
200
400
600
800
1000
FORCE (N)
Fn MEAN
Fn MAX
Fn MIN


TANGENTIAL FORCES
TN-010
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-100
-50
0
50
100
150
200
250
300
FORCE (N)
Ft MEAN
Ft MAX
Ft MIN


RESULTANT FORCES
TN-010
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
0
200
400
600
800
1000
FORCE (N)
Fr MEAN
Fr MAX



FILE TN←011

PLATE #1

NORMAL

MEAN FORCE = 3.102 N
MAX FORCE = 141.7 N
MIN FORCE = -17.72 N

TANGENTIAL

MEAN FORCE = -1.375 N
MAX FORCE = 343.5 N
MIN FORCE = -18.42 N

RESULTANT

MEAN FORCE = 11.07 N
MAX FORCE = 346.1 N
MIN FORCE = 0.3165 N
AVERAGE ANGLE = -70.55 O

TEST CONDITIONS

BOARD ANGLE = 13.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 94.00 kPa
ICE THICKNESS = 3.300 cm
ICE DENSITY = 0.8900 g/cc

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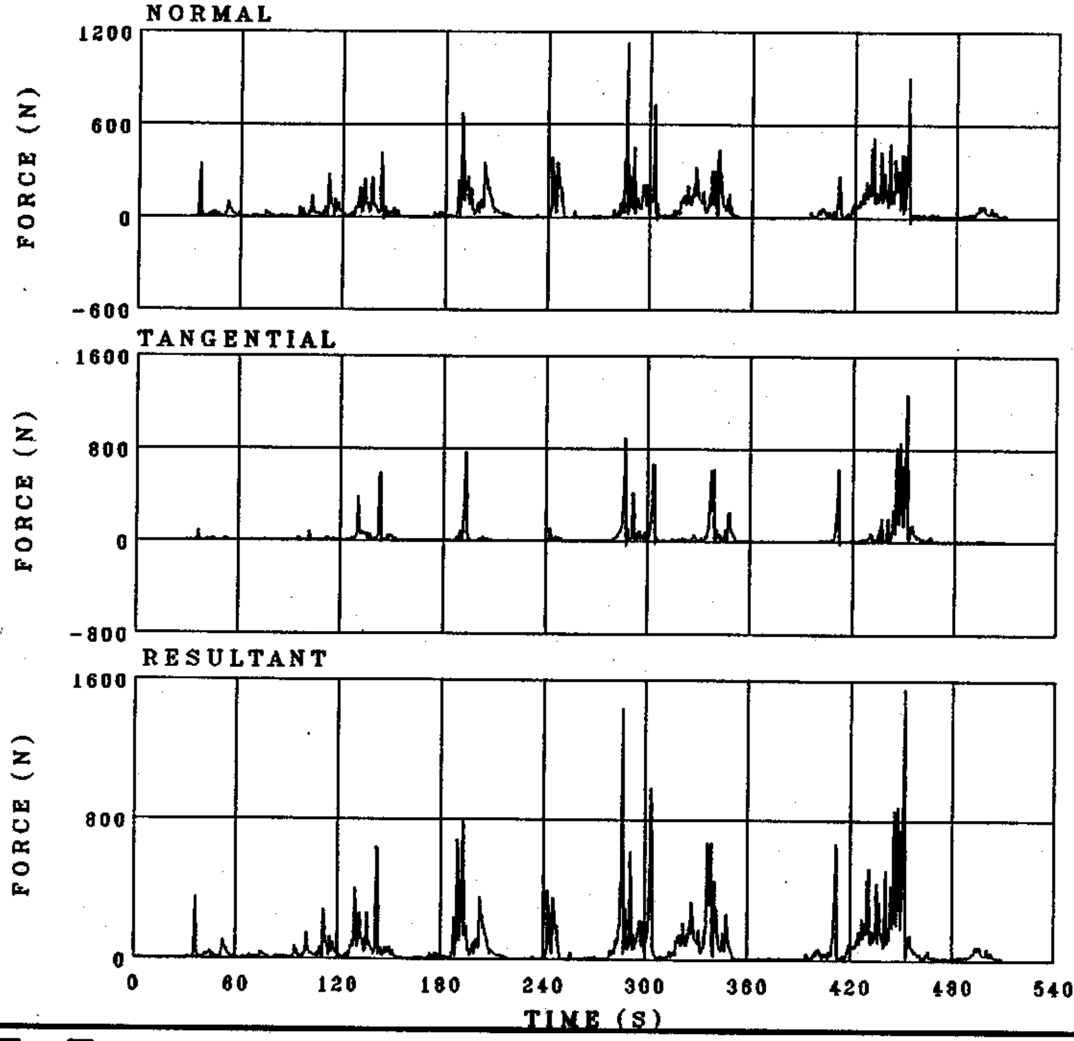
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←011

PLATE #2

NORMAL

MEAN FORCE = 50.34 N
MAX FORCE = 1129.0 N
MIN FORCE = -31.35 N

TANGENTIAL

MEAN FORCE = 33.98 N
MAX FORCE = 1278.0 N
MIN FORCE = -40.77 N

RESULTANT

MEAN FORCE = 67.77 N
MAX FORCE = 1556.0 N
MIN FORCE = 0.6333 N
AVERAGE ANGLE = 46.05 O

TEST CONDITIONS

BOARD ANGLE = 13.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 94.00 kPa
ICE THICKNESS = 3.300 cm
ICE DENSITY = 0.8900 g/cc

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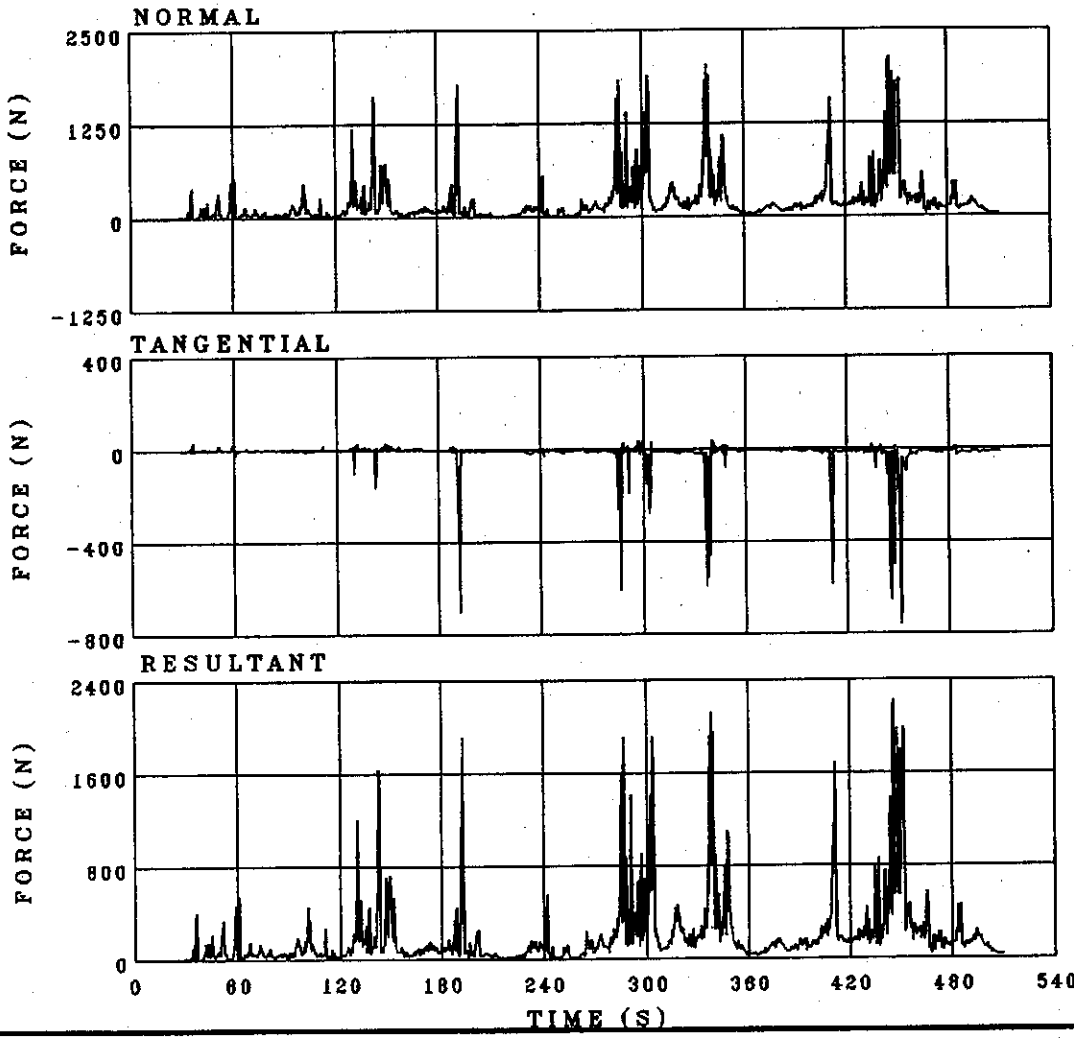
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←011

PLATE #3

NORMAL

MEAN FORCE = 185.7 N
MAX FORCE = 2127.0 N
MIN FORCE = -2.133 N

TANGENTIAL

MEAN FORCE = -15.27 N
MAX FORCE = 36.90 N
MIN FORCE = -765.3 N

RESULTANT

MEAN FORCE = 187.3 N
MAX FORCE = 2225.0 N
MIN FORCE = 0.1047 N
AVERAGE ANGLE = -4.563 O

TEST CONDITIONS

BOARD ANGLE = 13.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 94.00 kPa
ICE THICKNESS = 3.300 cm
ICE DENSITY = 0.8900 g/cc

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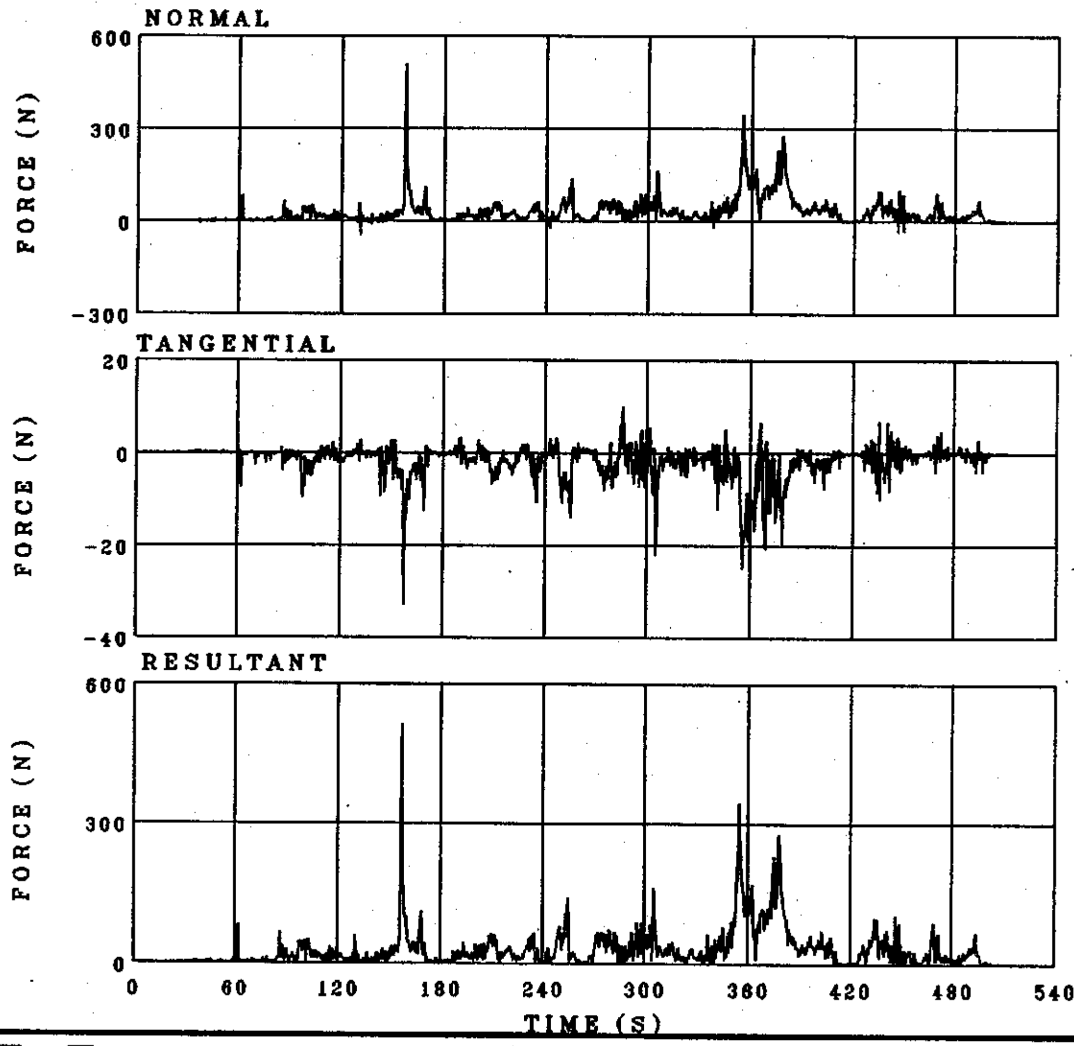
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←011

PLATE #4

NORMAL

MEAN FORCE = 27.96 N
MAX FORCE = 511.7 N
MIN FORCE = -47.29 N

TANGENTIAL

MEAN FORCE = -1.711 N
MAX FORCE = 10.17 N
MIN FORCE = -33.07 N

RESULTANT

MEAN FORCE = 28.36 N
MAX FORCE = 512.8 N
MIN FORCE = 0.05273 N
AVERAGE ANGLE = 0.1883 O

TEST CONDITIONS

BOARD ANGLE = 13.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 94.00 kPa
ICE THICKNESS = 3.300 cm
ICE DENSITY = 0.8900 g/cc

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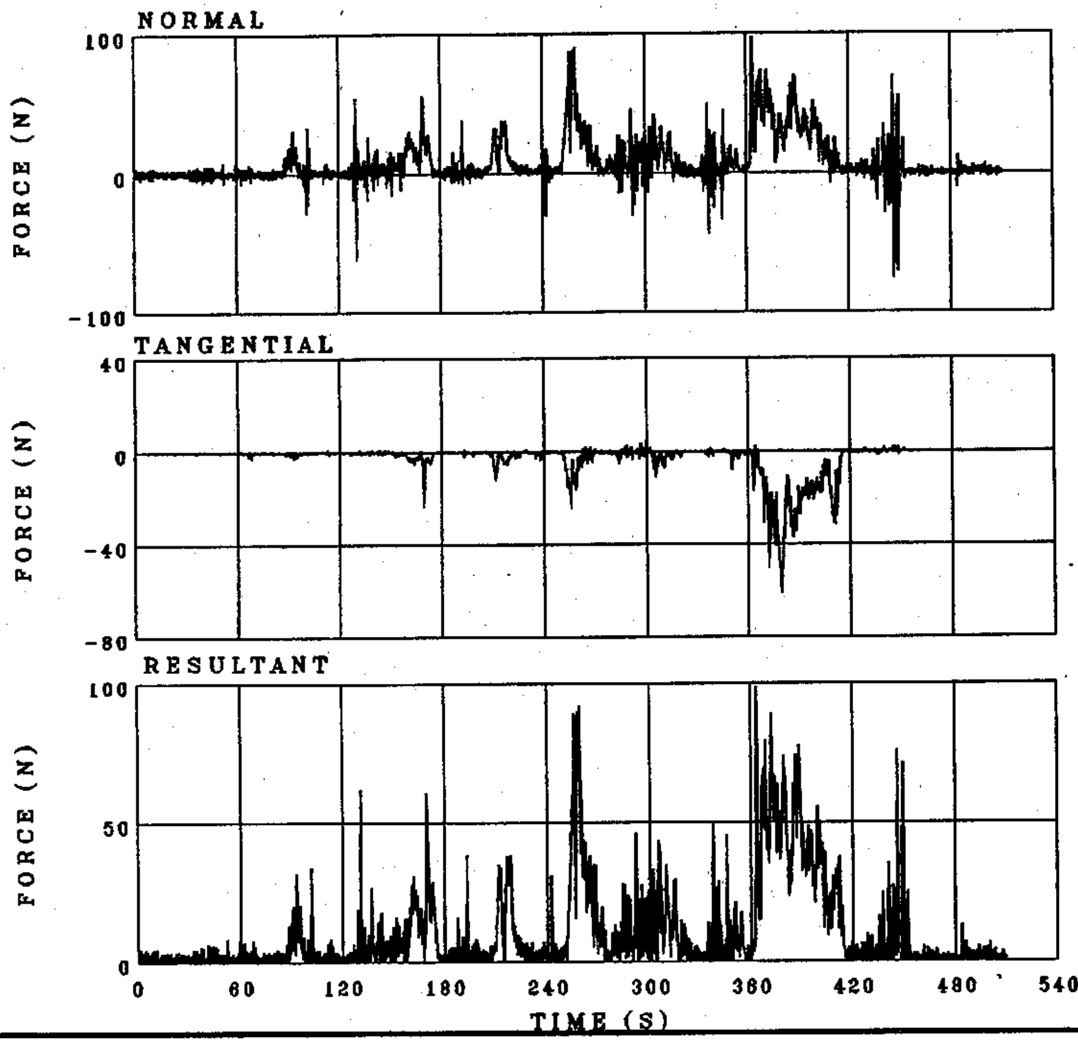
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←011

PLATE #5

NORMAL

MEAN FORCE = 8.011 N
MAX FORCE = 97.91 N
MIN FORCE = −76.02 N

TANGENTIAL

MEAN FORCE = −2.834 N
MAX FORCE = 3.738 N
MIN FORCE = −61.23 N

RESULTANT

MEAN FORCE = 9.955 N
MAX FORCE = 98.77 N
MIN FORCE = 0.02979 N
AVERAGE ANGLE = −6.091 O

TEST CONDITIONS

BOARD ANGLE = 13.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 94.00 kPa
ICE THICKNESS = 3.300 cm
ICE DENSITY = 0.8900 g/cc

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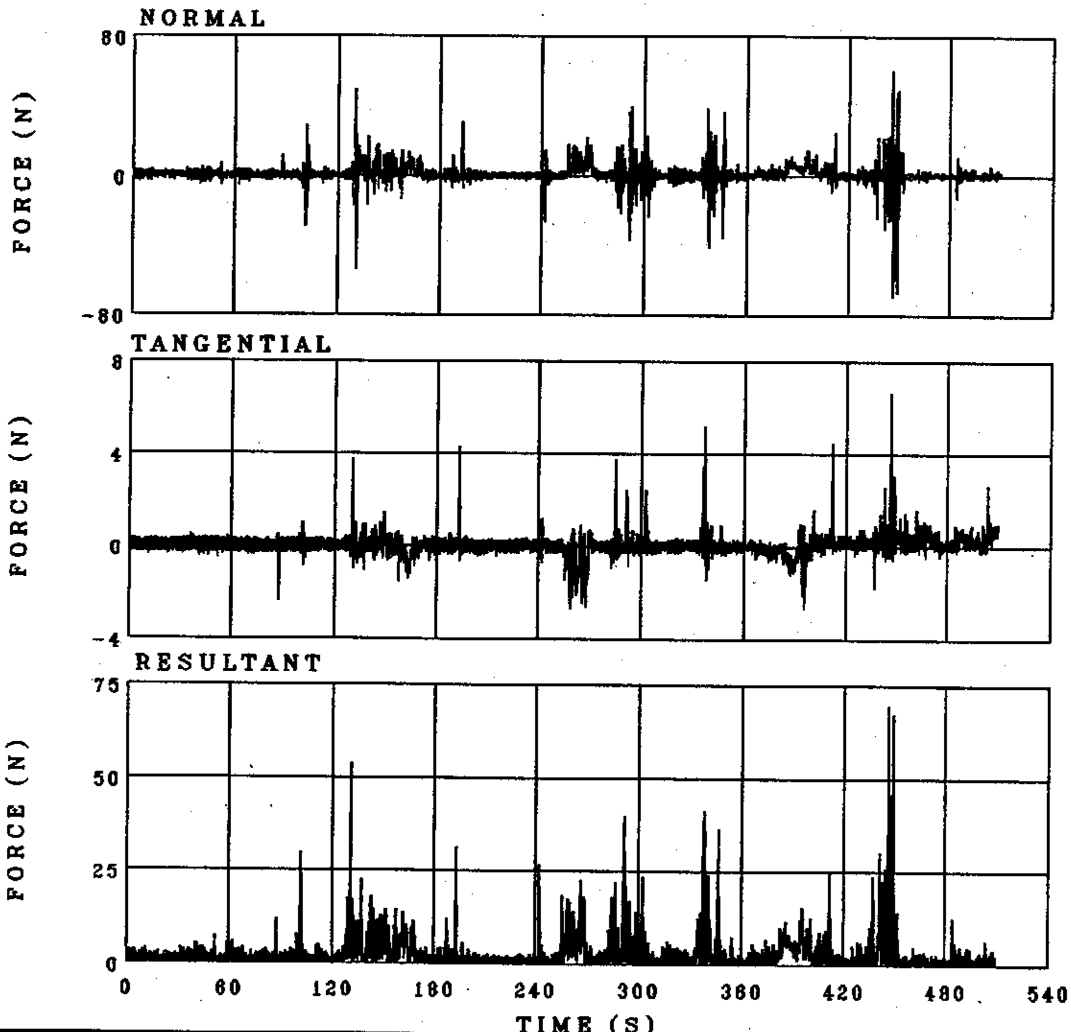
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←011

PLATE #6

NORMAL

MEAN FORCE = 1.081 N
MAX FORCE = 60.90 N
MIN FORCE = -69.65 N

TANGENTIAL

MEAN FORCE = 0.01660 N
MAX FORCE = 6.676 N
MIN FORCE = -2.724 N

RESULTANT

MEAN FORCE = 2.420 N
MAX FORCE = 69.66 N
MIN FORCE = 0.05966 N
AVERAGE ANGLE = -0.8946 O

TEST CONDITIONS

BOARD ANGLE = 13.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 94.00 kPa
ICE THICKNESS = 3.300 cm
ICE DENSITY = 0.8900 g/cc

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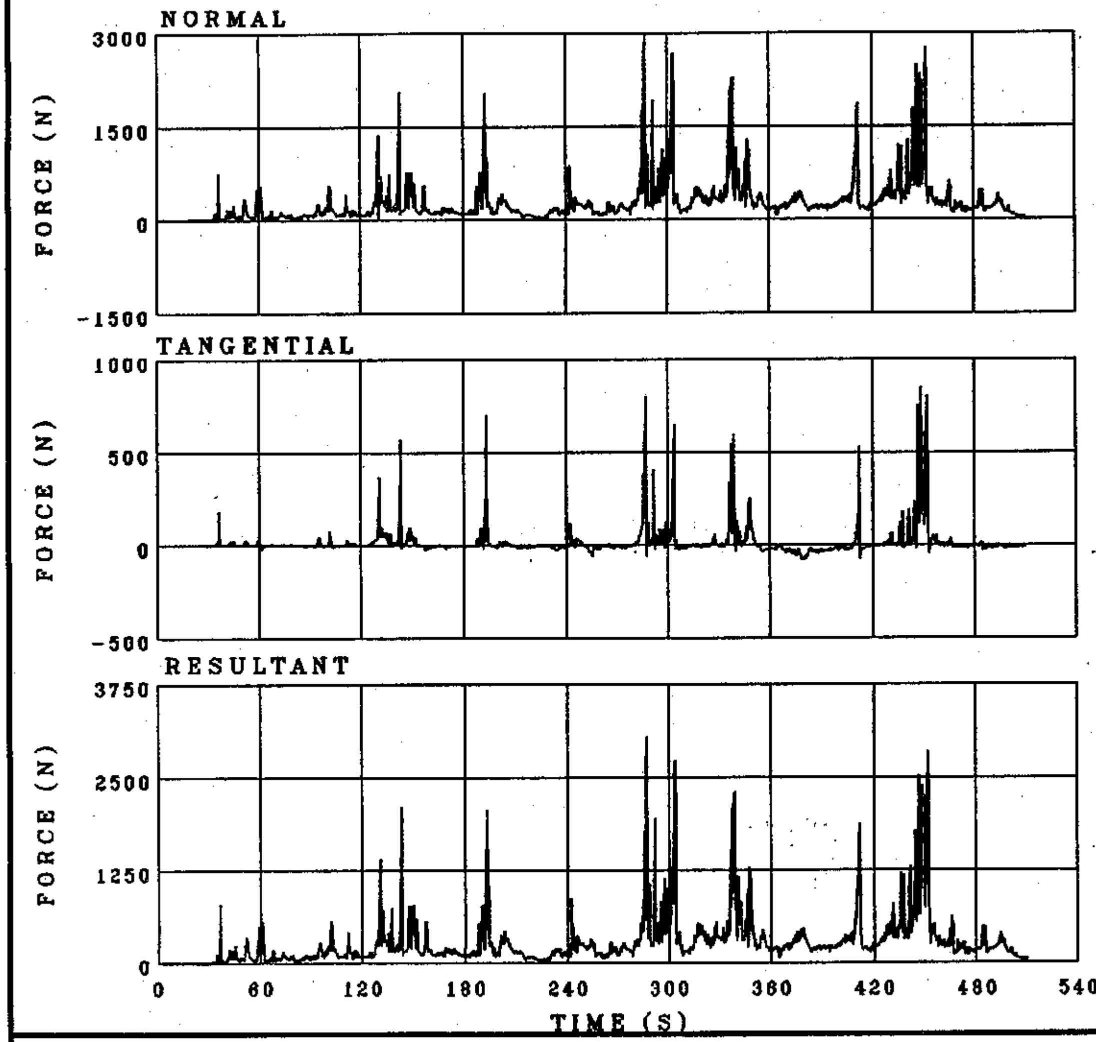
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←011

TOTAL

NORMAL

MEAN FORCE = 276.2 N
MAX FORCE = 2981.0 N
MIN FORCE = -14.12 N

TANGENTIAL

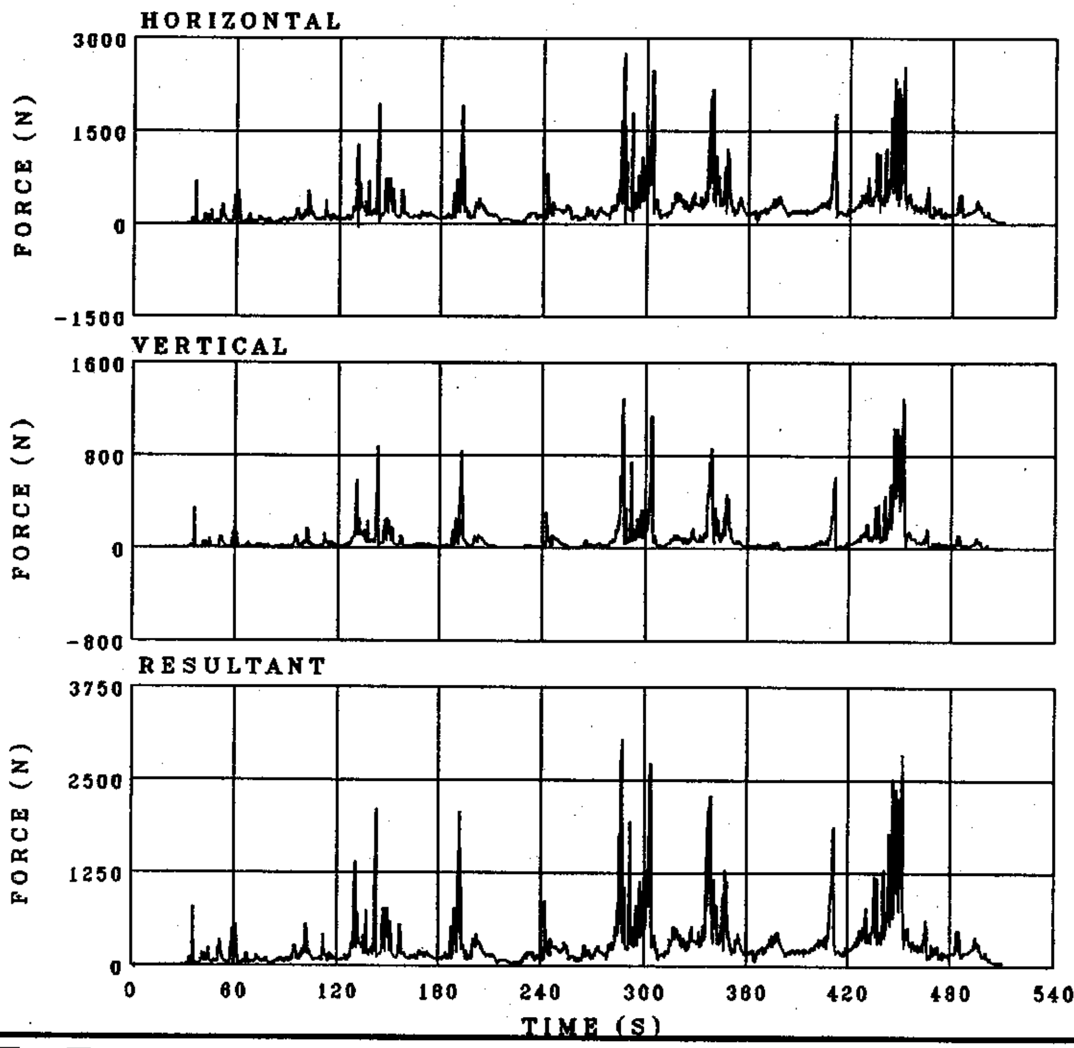
MEAN FORCE = 12.81 N
MAX FORCE = 849.1 N
MIN FORCE = -81.10 N

RESULTANT

MEAN FORCE = 279.4 N
MAX FORCE = 3047.0 N
MIN FORCE = 0.03110 N
AVERAGE ANGLE = -0.4013 O

TEST CONDITIONS

BOARD ANGLE = 13.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 94.00 kPa
ICE THICKNESS = 3.300 cm
ICE DENSITY = 0.8900 g/cc



FILE TN←011

TOTAL

HORIZONTAL

MEAN FORCE = 12.81 N
MAX FORCE = 849.1 N
MIN FORCE = -81.10 N

VERTICAL

MEAN FORCE = 12.81 N
MAX FORCE = 849.1 N
MIN FORCE = -81.10 N

RESULTANT

MEAN FORCE = 12.81 N
MAX FORCE = 849.1 N
MIN FORCE = -81.10 N
AVERAGE ANGLE = 12.81 D

TEST CONDITIONS

BOARD ANGLE = 13.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 94.00 kPa
ICE THICKNESS = 3.300 cm
ICE DENSITY = 0.8900 g/cc

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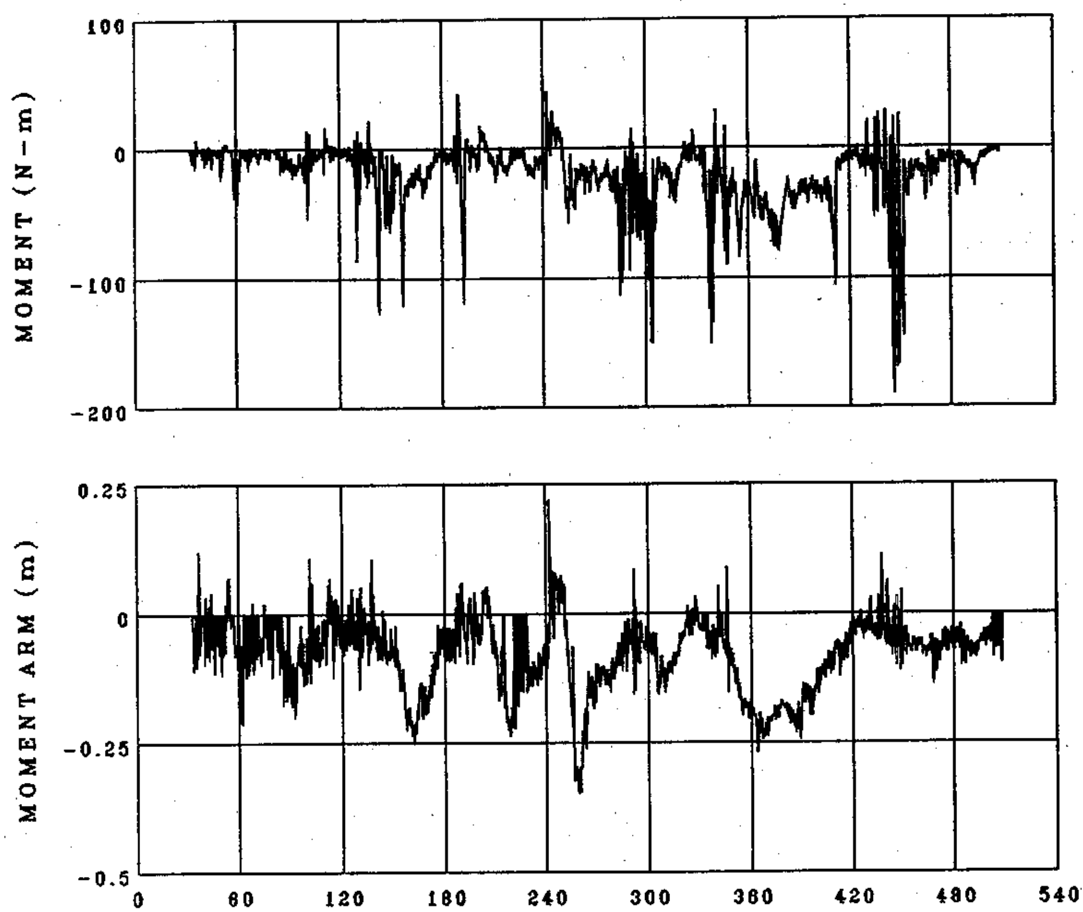
ICE PILEUP STUDY
for CANADIAN COAST GUARD

FILE TN←011

MOMENT



MOMENT

MEAN MOMENT = -19.14 N-m
MAX MOMENT = 44.31 N-m
MIN MOMENT = -190.9 N-m

MOMENT ARM

MEAN ARM = -0.07400 m
MAX ARM = 0.2205 m
MIN ARM = -0.3495 m

TEST CONDITIONS

BOARD ANGLE = 13.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 94.00 kPa
ICE THICKNESS = 3.300 cm
ICE DENSITY = 0.8900 g/cc

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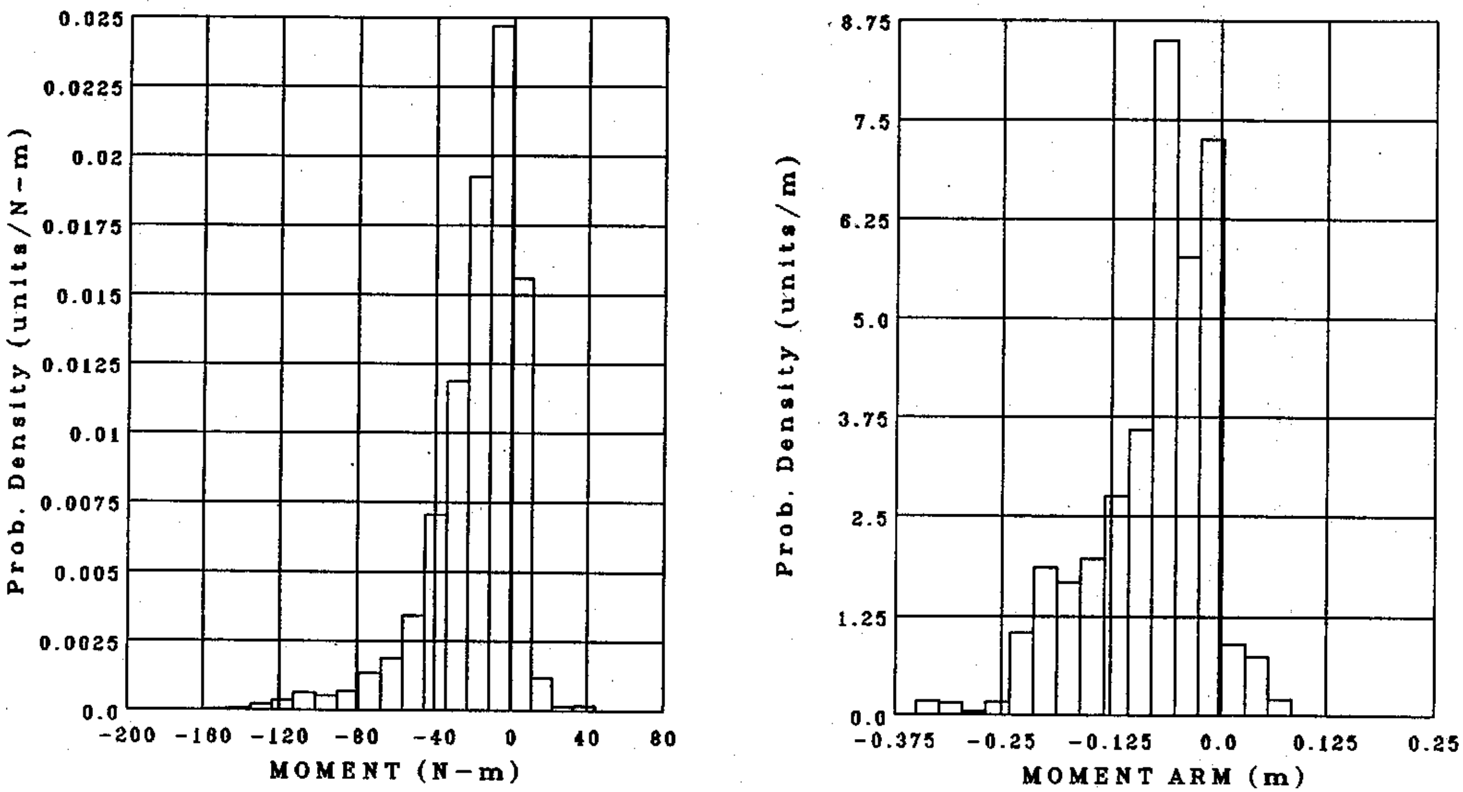
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←011



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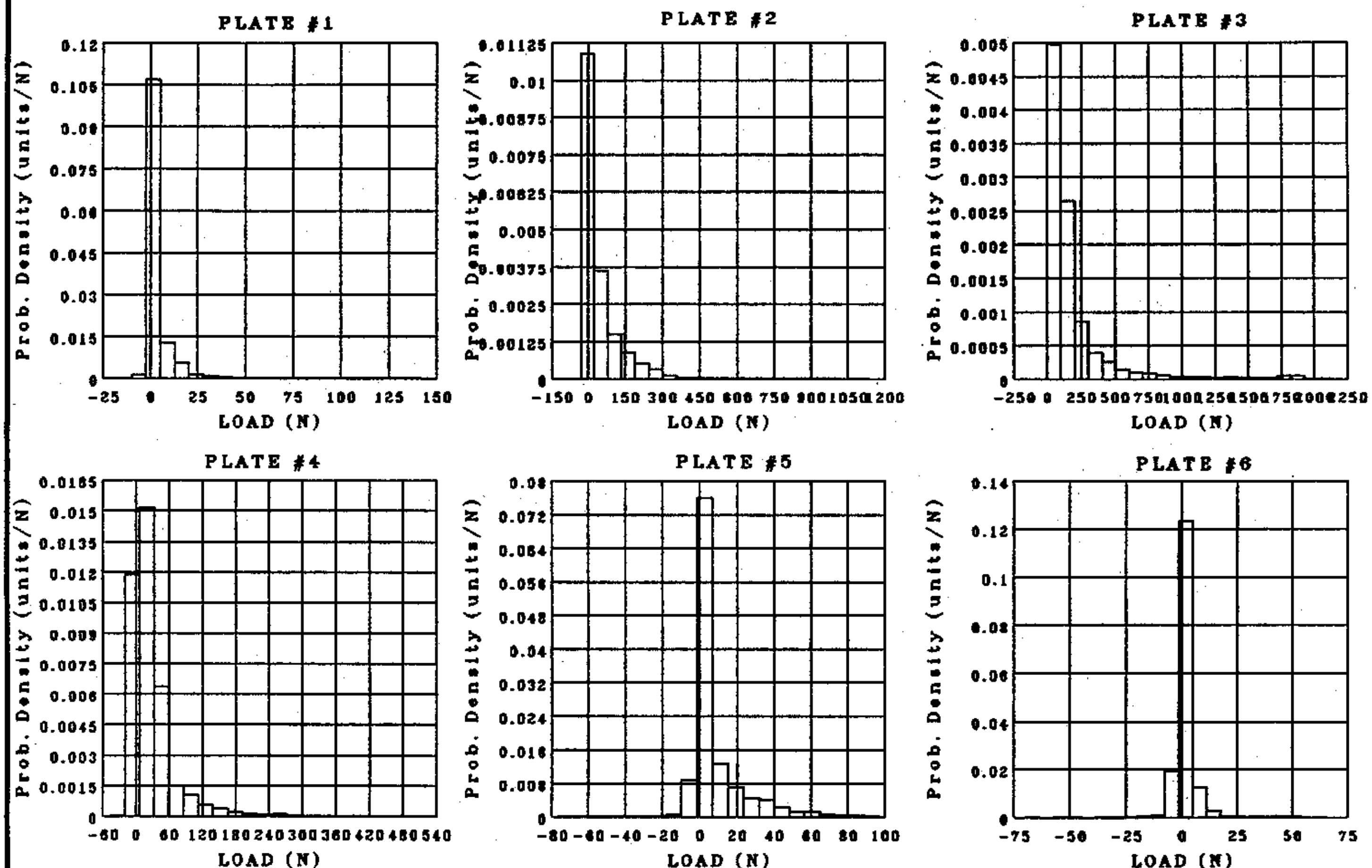
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←011
NORMAL LOAD



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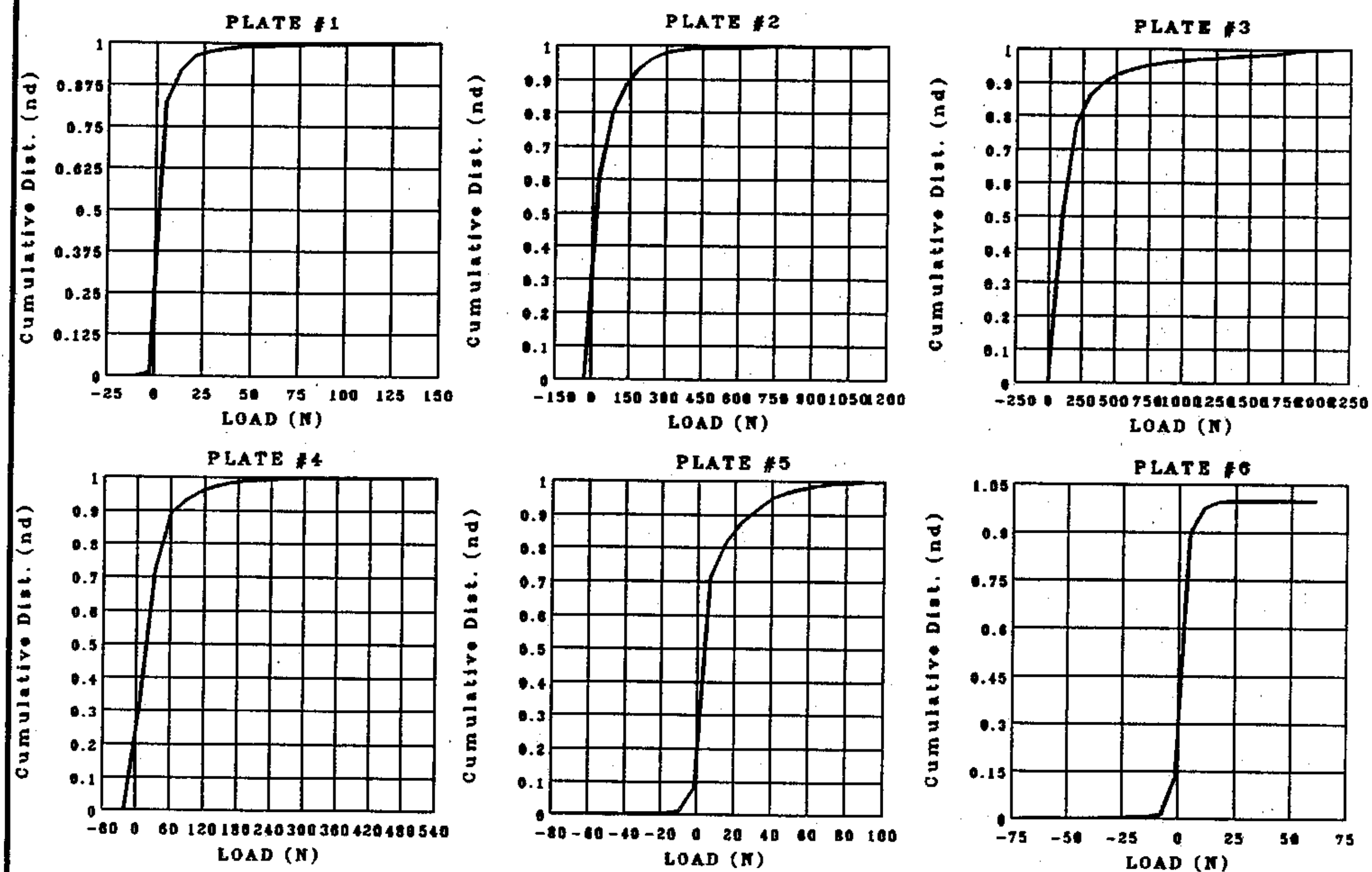
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←011
NORMAL LOAD



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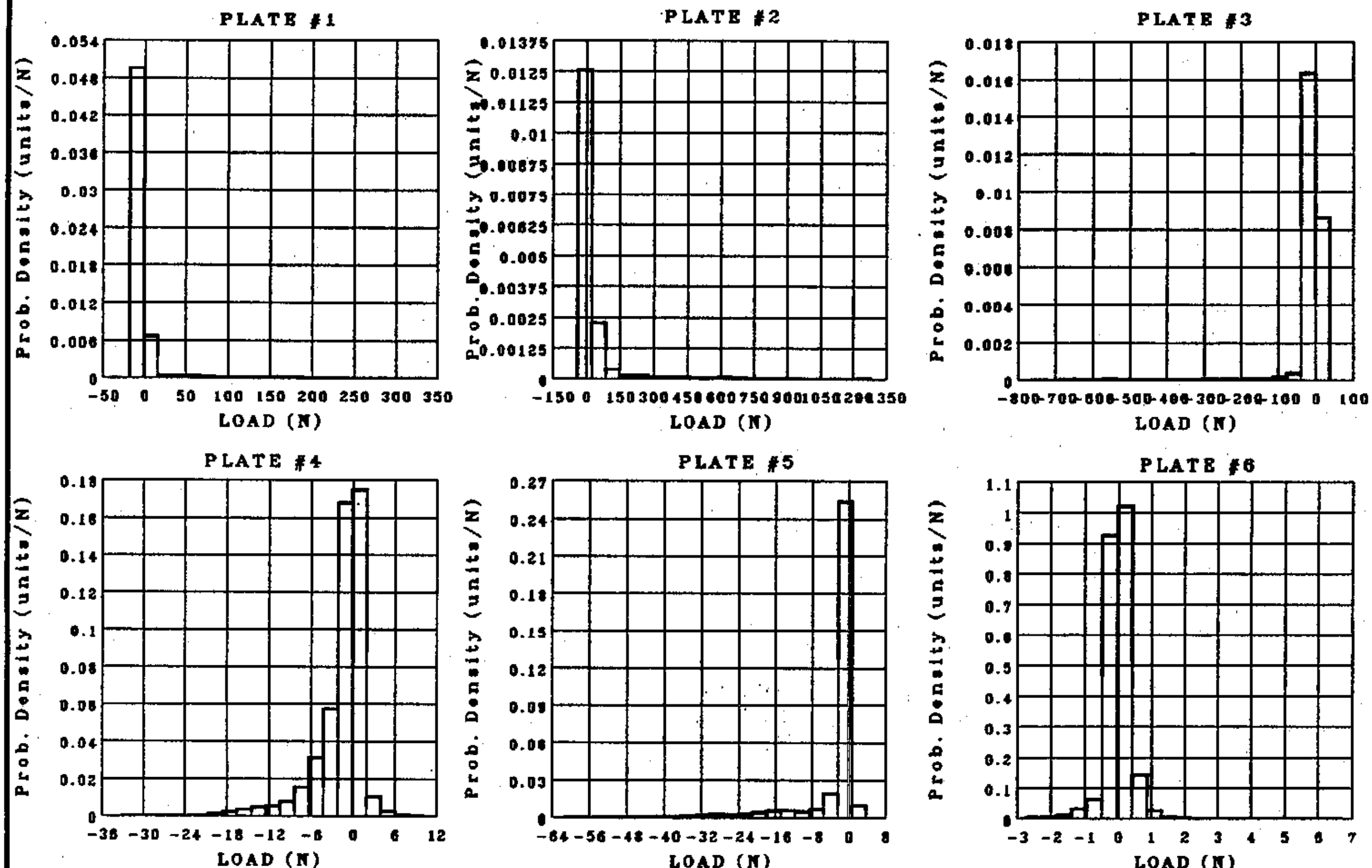
ICE PILEUP STUDY	for CANADIAN COAST GUARD

TN←011
TANGENTIAL LOAD



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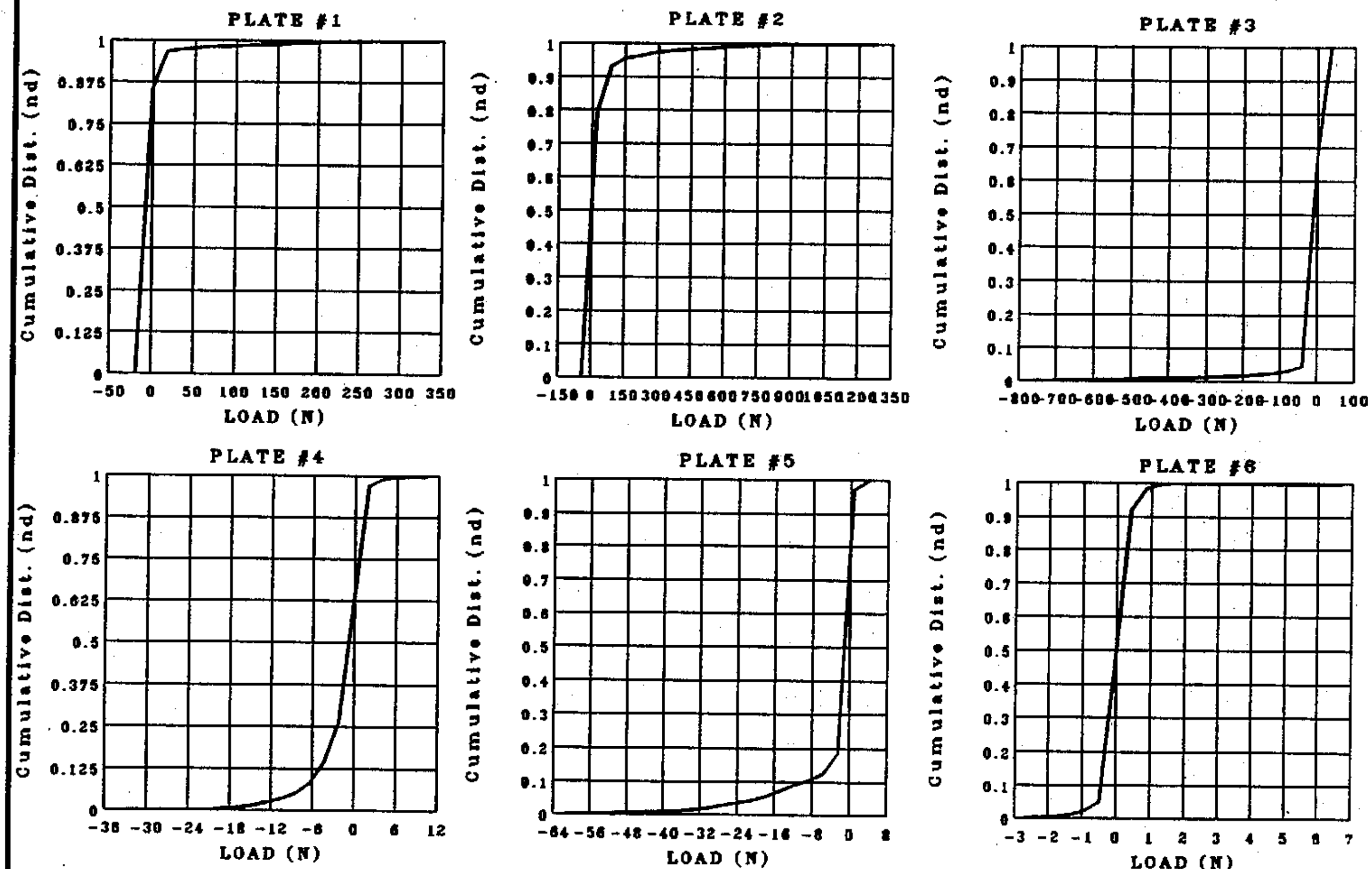
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←011
TANGENTIAL LOAD



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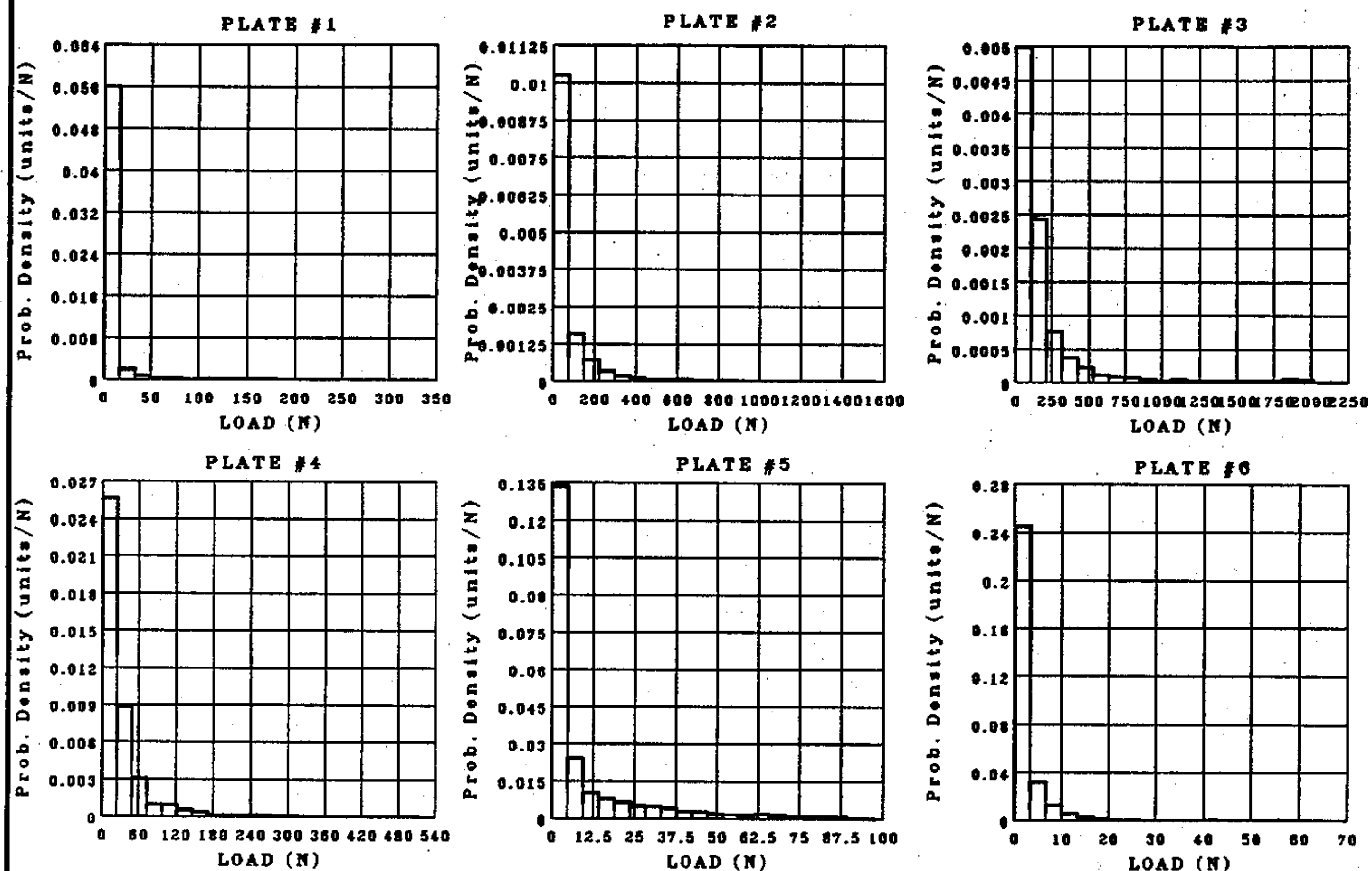
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←011
RESULTANT



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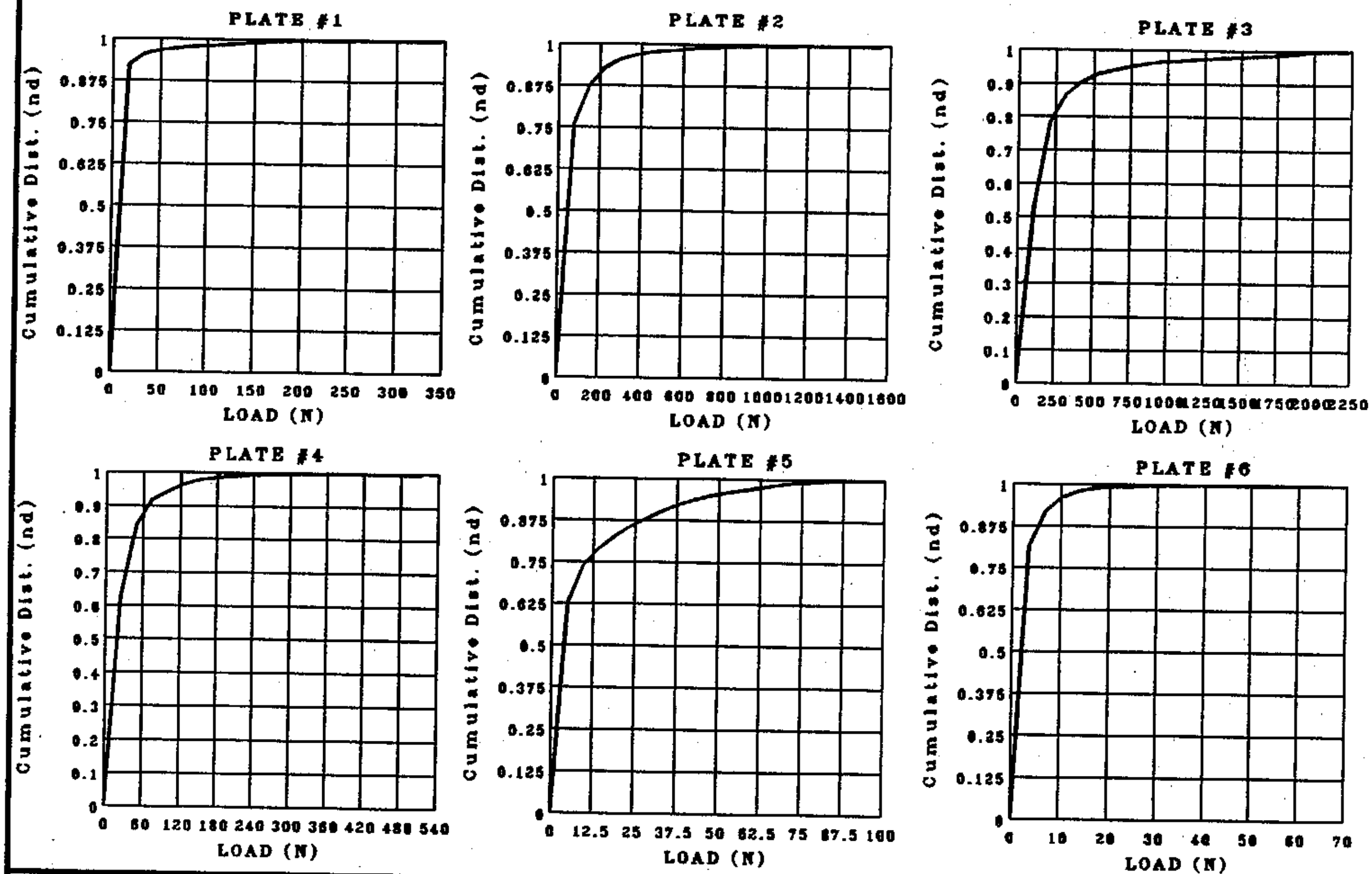
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←011
RESULTANT



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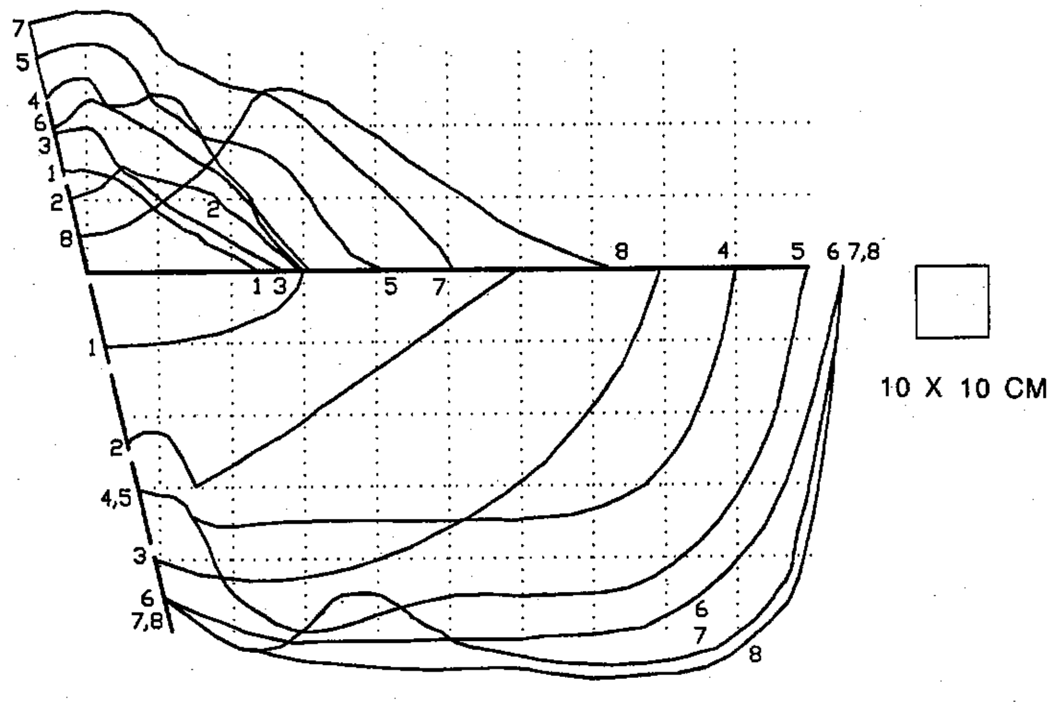
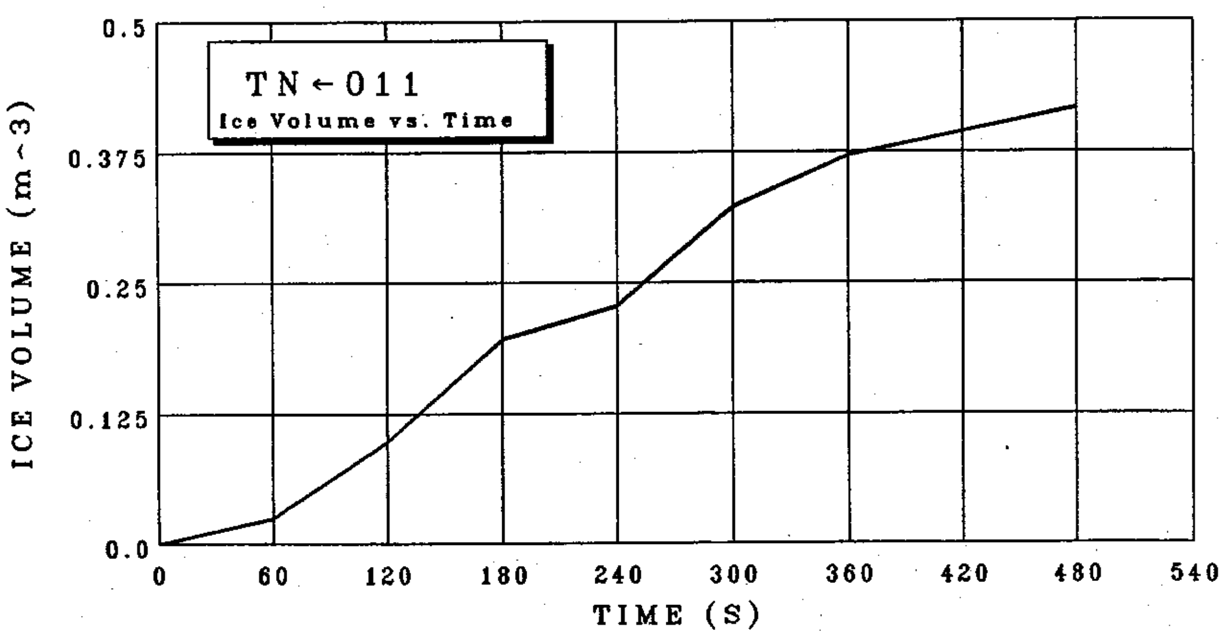
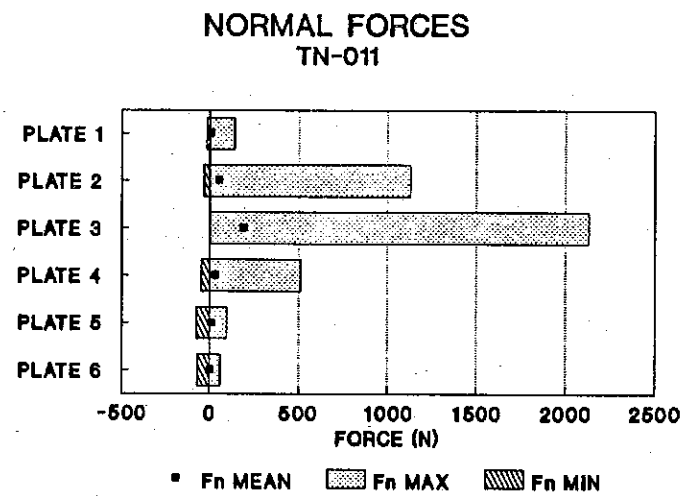
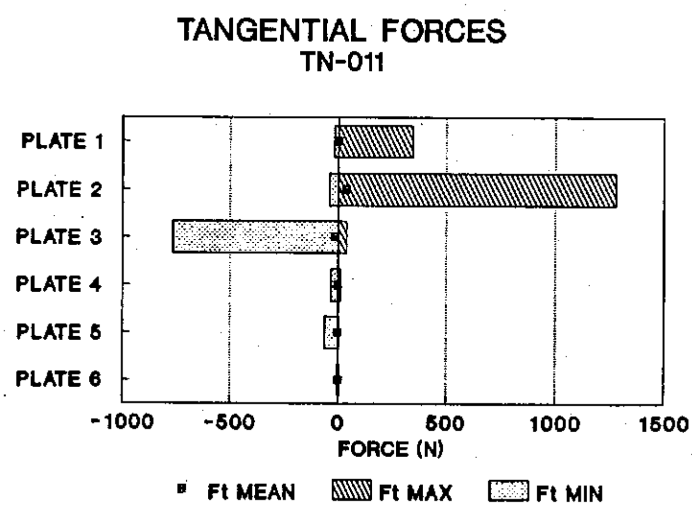
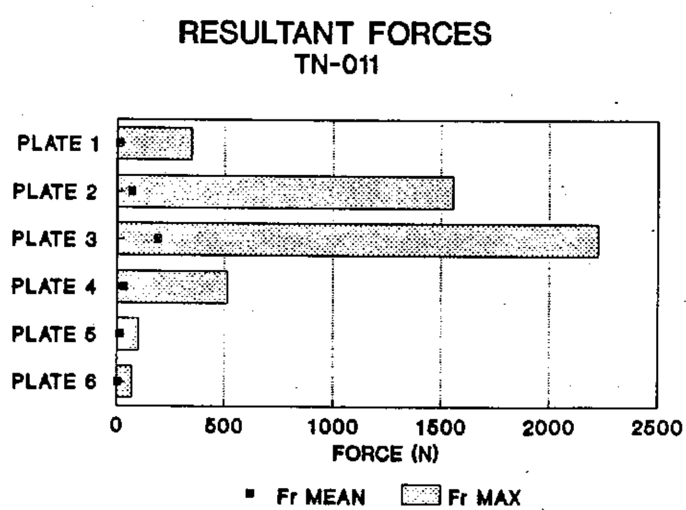
ICE PILEUP STUDY
for CANADIAN COAST GUARD

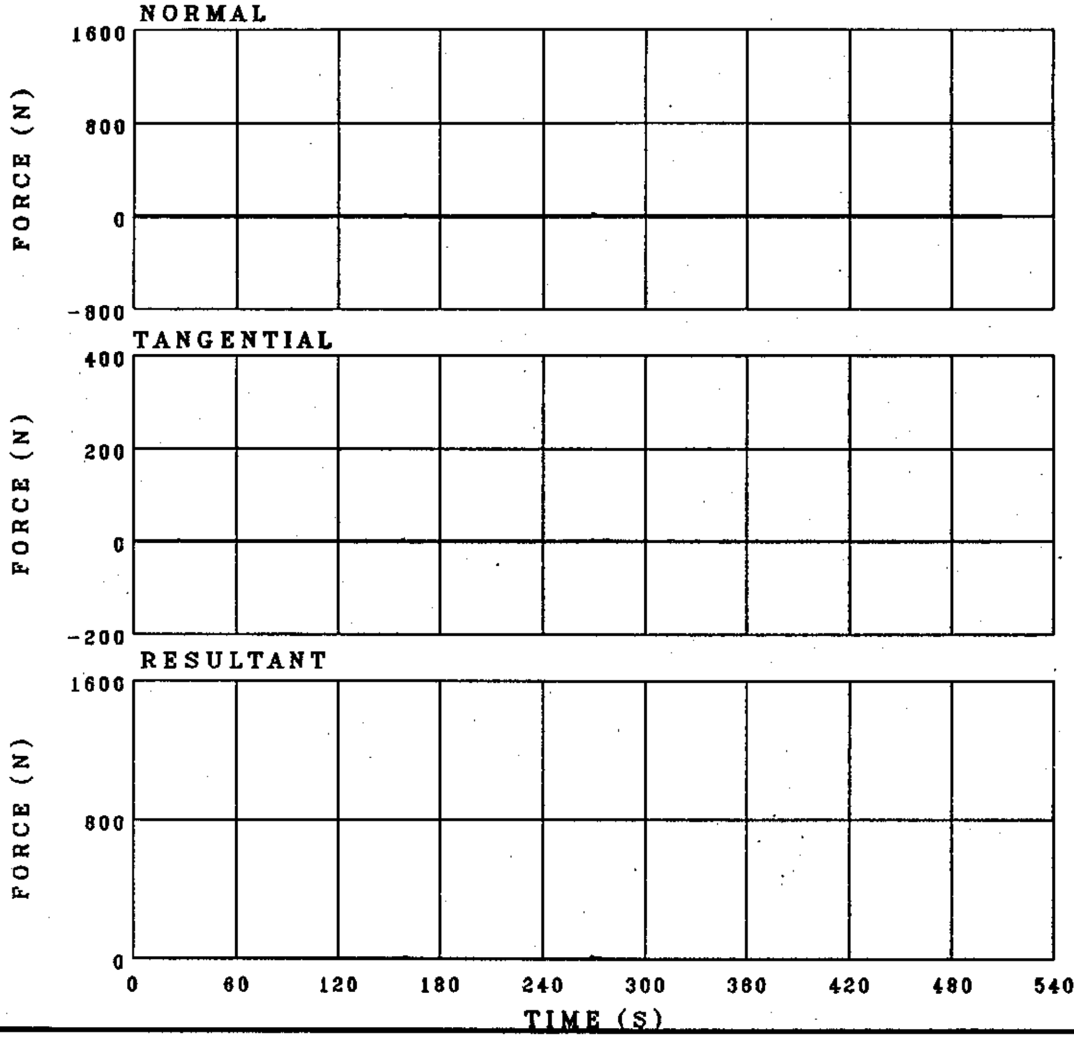

7
5
4
6
3
1
2
8
2
8
4
5
6 7,8
1 3
5
7
1
2
4,5
3
6
7,8
6
7
8
10 X 10 CM
TIME IN MINUTES


TN ← 011
Ice Volume vs. Time
ICE VOLUME (m^3)
0.5
0.375
0.25
0.125
0.0
0
60
120
180
240
300
360
420
480
540
TIME (S)


NORMAL FORCES
TN-011
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-500
0
500
1000
1500
2000
2500
FORCE (N)
Fn MEAN
Fn MAX
Fn MIN


TANGENTIAL FORCES
TN-011
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-1000
-500
0
500
1000
1500
FORCE (N)
Ft MEAN
Ft MAX
Ft MIN


RESULTANT FORCES
TN-011
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
0
500
1000
1500
2000
2500
FORCE (N)
Fr MEAN
Fr MAX



FILE TN←012

PLATE #1

NORMAL

MEAN FORCE = 0.3118 N
MAX FORCE = 14.44 N
MIN FORCE = -2.462 N

TANGENTIAL

MEAN FORCE = 0.2158 N
MAX FORCE = 3.578 N
MIN FORCE = -1.544 N

RESULTANT

MEAN FORCE = 0.6802 N
MAX FORCE = 14.62 N
MIN FORCE = 0.05714 N
AVERAGE ANGLE = 11.87 O

TEST CONDITIONS

BOARD ANGLE = 0.0 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 58.00 kPa
ICE THICKNESS = 3.200 cm
ICE DENSITY = 0.8800 g/cc

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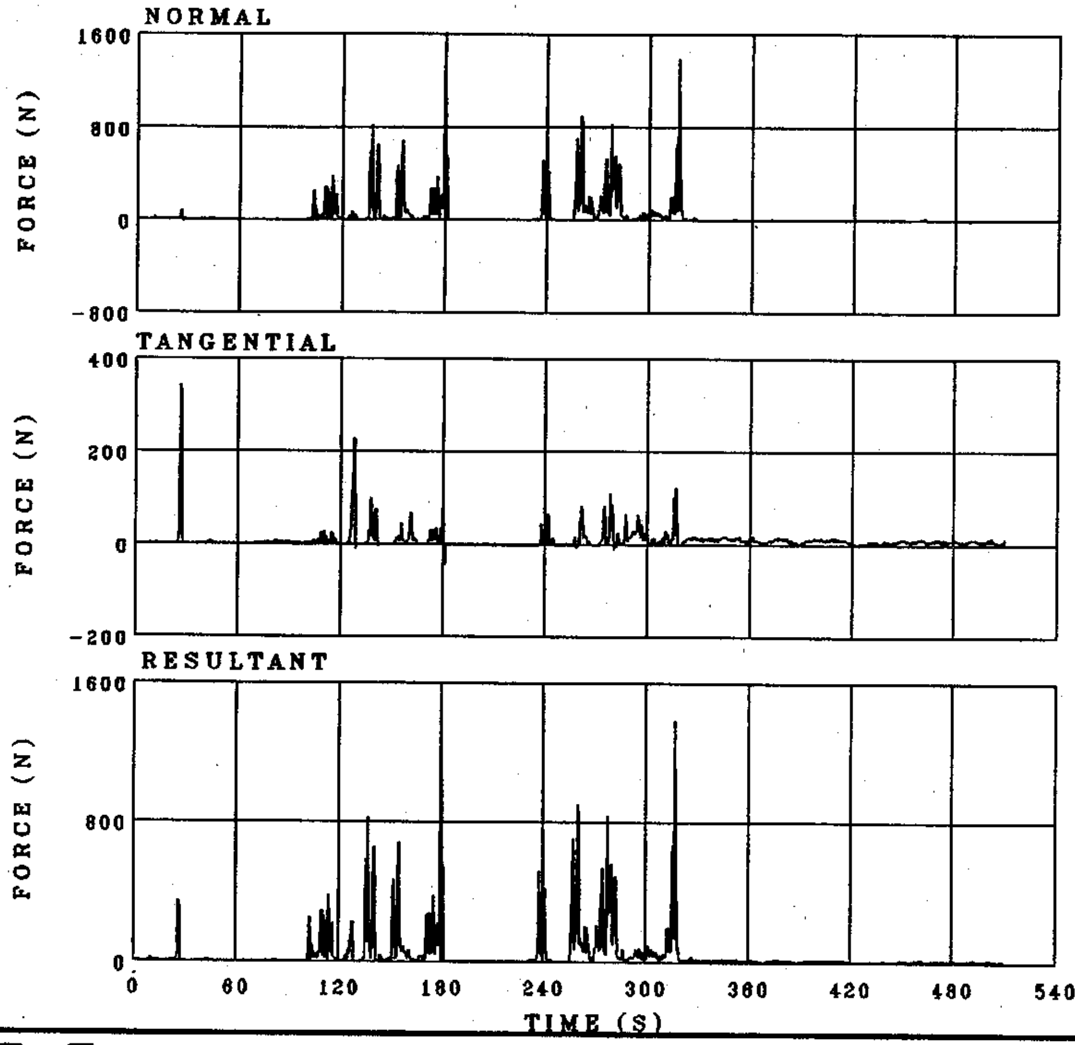
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←012

PLATE #2

NORMAL

MEAN FORCE = 33.13 N
MAX FORCE = 1547.0 N
MIN FORCE = -18.91 N

TANGENTIAL

MEAN FORCE = 8.180 N
MAX FORCE = 344.2 N
MIN FORCE = -43.61 N

RESULTANT

MEAN FORCE = 39.59 N
MAX FORCE = 1551.8 N
MIN FORCE = 0.02100 N
AVERAGE ANGLE = 34.46 O

TEST CONDITIONS

BOARD ANGLE = 0.0 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 58.00 kPa
ICE THICKNESS = 3.200 cm
ICE DENSITY = 0.8800 g/cc

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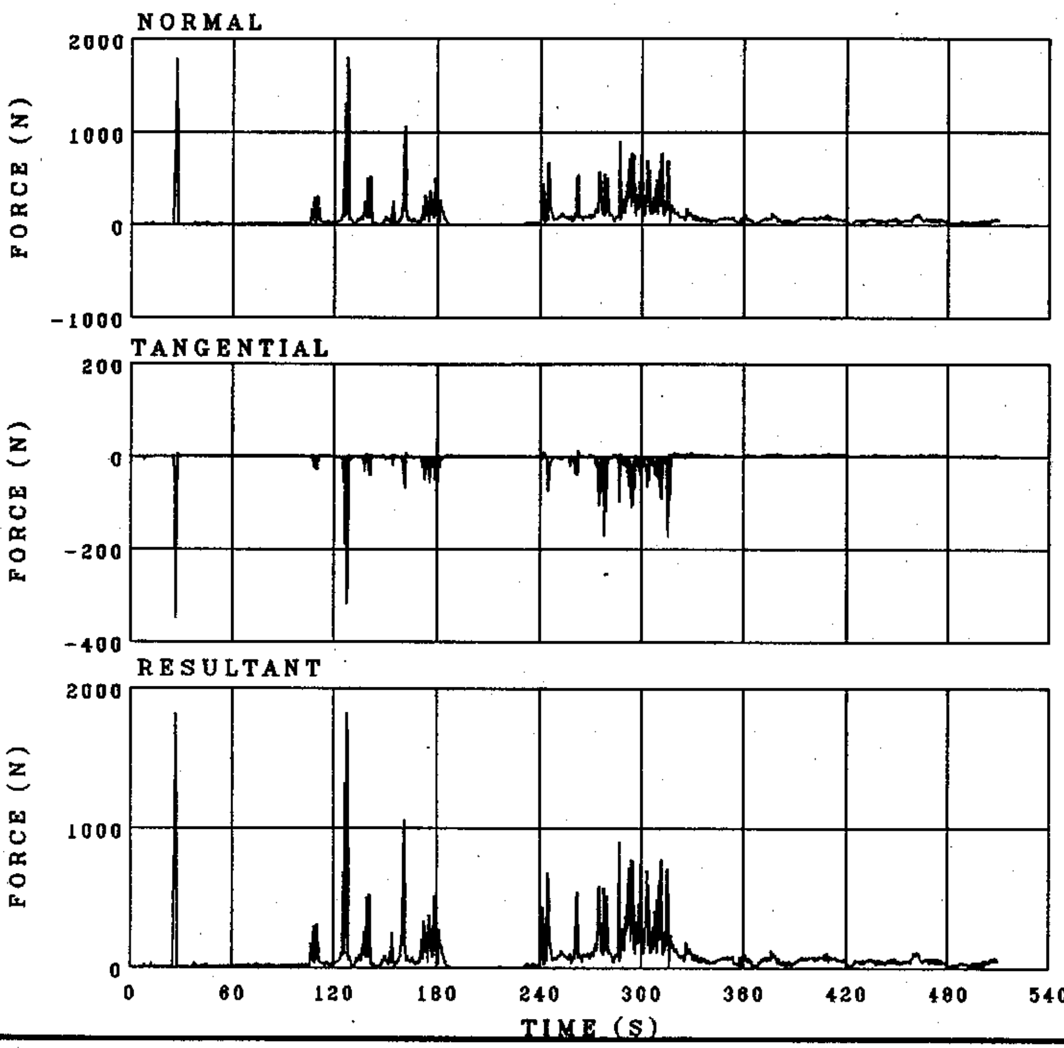
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN-012

PLATE #3

NORMAL

MEAN FORCE = 78.31 N
MAX FORCE = 1802.0 N
MIN FORCE = -4.578 N

TANGENTIAL

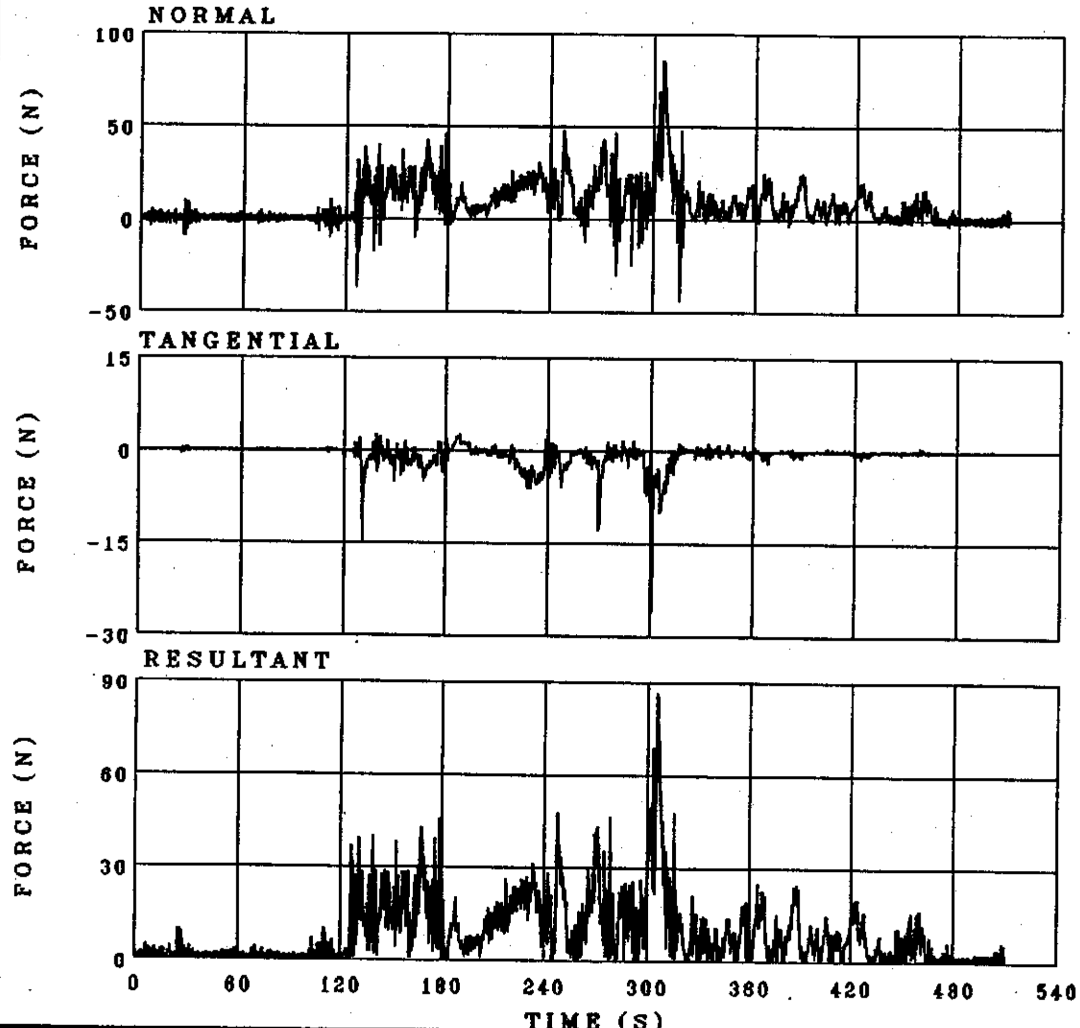
MEAN FORCE = -2.524 N
MAX FORCE = 14.94 N
MIN FORCE = -350.1 N

RESULTANT

MEAN FORCE = 78.80 N
MAX FORCE = 1827.0 N
MIN FORCE = 0.1972 N
AVERAGE ANGLE = 7.786 O

TEST CONDITIONS

BOARD ANGLE = 0.0 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 58.00 kPa
ICE THICKNESS = 3.200 cm
ICE DENSITY = 0.8800 g/cc



FILE TN←012

PLATE #4

NORMAL

MEAN FORCE = 7.960 N
MAX FORCE = 86.30 N
MIN FORCE = -44.04 N

TANGENTIAL

MEAN FORCE = -0.6519 N
MAX FORCE = 2.771 N
MIN FORCE = -26.69 N

RESULTANT

MEAN FORCE = 8.519 N
MAX FORCE = 86.86 N
MIN FORCE = 0.07732 N
AVERAGE ANGLE = 4.046 O

TEST CONDITIONS

BOARD ANGLE = 0.0 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 56.00 kPa
ICE THICKNESS = 3.200 cm
ICE DENSITY = 0.8800 g/cc

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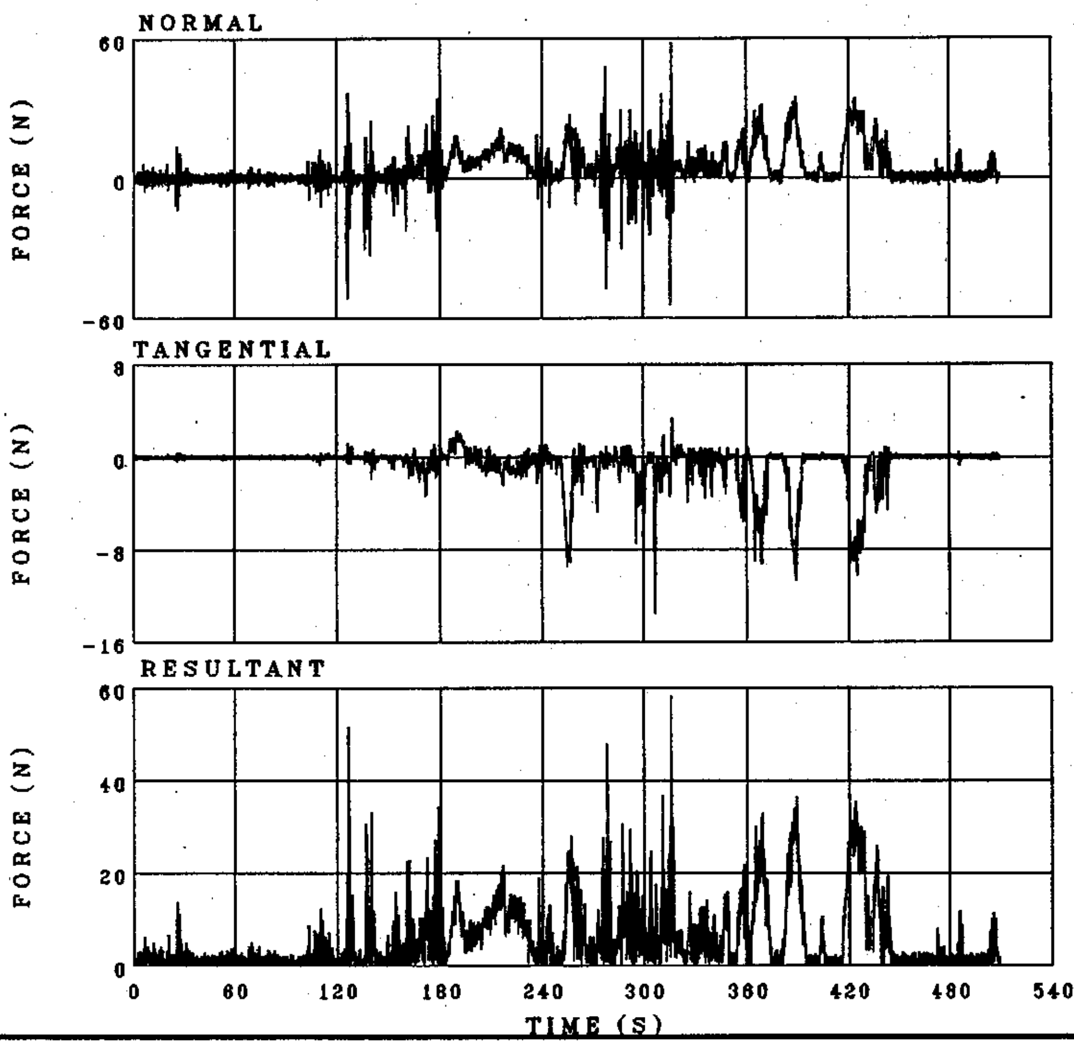
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN-012

PLATE #5

NORMAL

MEAN FORCE = 4.365 N
MAX FORCE = 58.35 N
MIN FORCE = -54.57 N

TANGENTIAL

MEAN FORCE = -0.6394 N
MAX FORCE = 3.336 N
MIN FORCE = -13.60 N

RESULTANT

MEAN FORCE = 5.362 N
MAX FORCE = 58.37 N
MIN FORCE = 0.01254 N
AVERAGE ANGLE = 1.859 D

TEST CONDITIONS

BOARD ANGLE = 0.0 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 58.00 kPa
ICE THICKNESS = 3.200 cm
ICE DENSITY = 0.8800 g/cc

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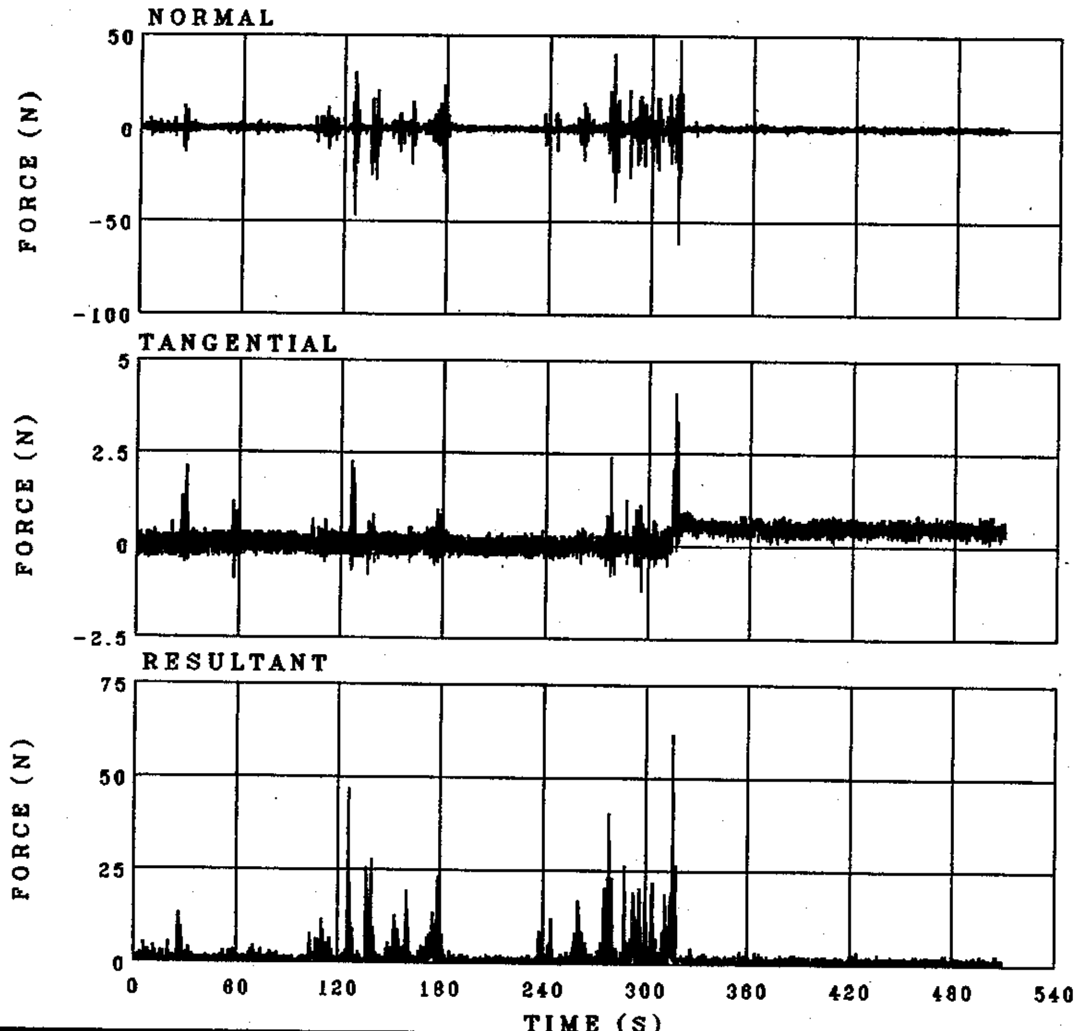
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←012

PLATE #6

NORMAL

MEAN FORCE = 0.2858 N
MAX FORCE = 48.07 N
MIN FORCE = -61.70 N

TANGENTIAL

MEAN FORCE = 0.1995 N
MAX FORCE = 4.128 N
MIN FORCE = -1.242 N

RESULTANT

MEAN FORCE = 1.480 N
MAX FORCE = 61.83 N
MIN FORCE = 0.009889 N
AVERAGE ANGLE = 29.11 D

TEST CONDITIONS

BOARD ANGLE = 0.0 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 58.00 kPa
ICE THICKNESS = 3.200 cm
ICE DENSITY = 0.8800 g/cc

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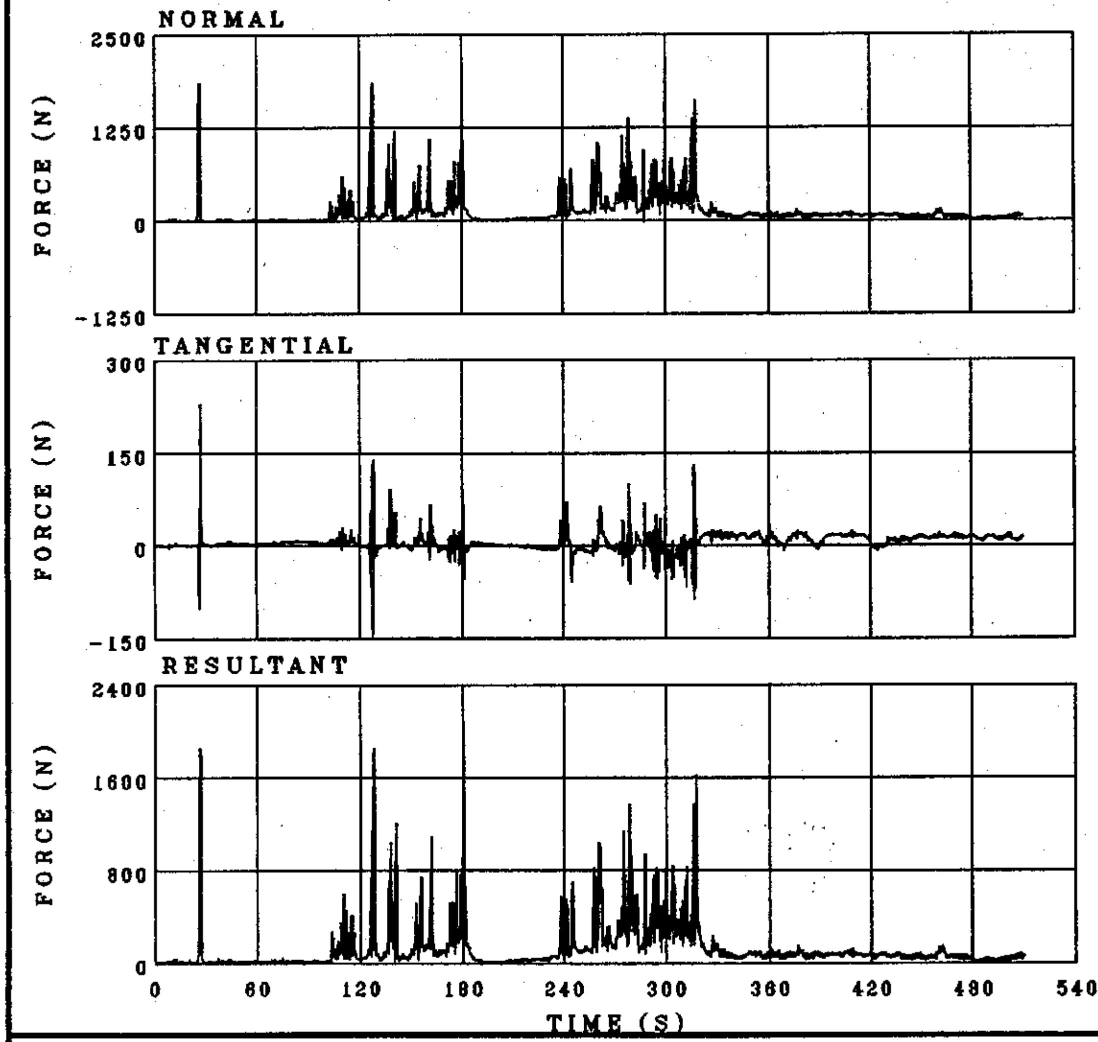
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←012

TOTAL

NORMAL

MEAN FORCE = 124.4 N
MAX FORCE = 2050.0 N
MIN FORCE = -36.02 N

TANGENTIAL

MEAN FORCE = 4.780 N
MAX FORCE = 230.8 N
MIN FORCE = -146.5 N

RESULTANT

MEAN FORCE = 125.5 N
MAX FORCE = 2050.0 N
MIN FORCE = 0.2525 N
AVERAGE ANGLE = 9.079 O

TEST CONDITIONS

BOARD ANGLE = 0.0 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 58.00 kPa
ICE THICKNESS = 3.200 cm
ICE DENSITY = 0.8800 g/cc

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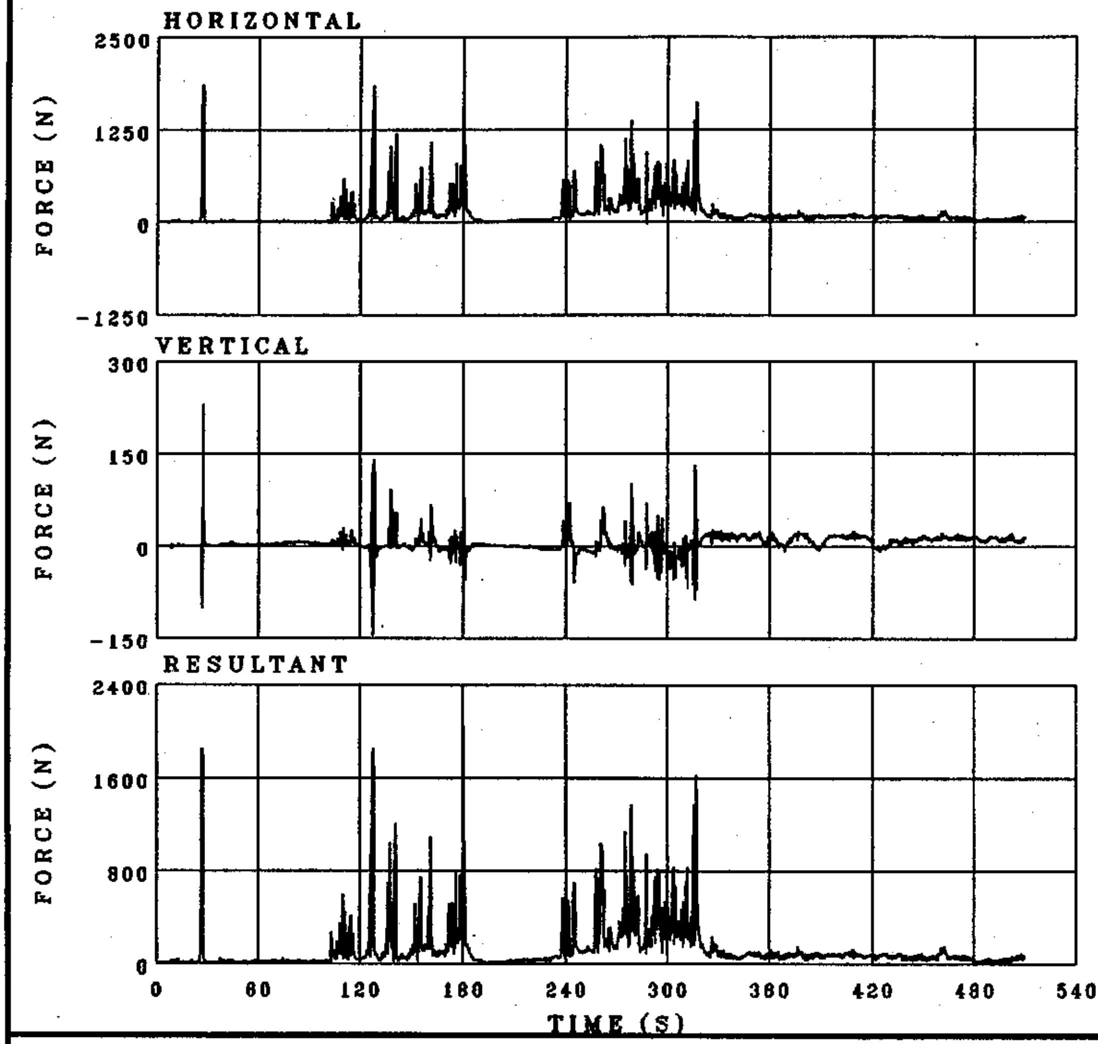
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←012

TOTAL

HORIZONTAL

MEAN FORCE = 4.780 N
MAX FORCE = 230.8 N
MIN FORCE = -146.5 N

VERTICAL

MEAN FORCE = 4.780 N
MAX FORCE = 230.8 N
MIN FORCE = -146.5 N

RESULTANT

MEAN FORCE = 4.780 N
MAX FORCE = 230.8 N
MIN FORCE = -146.5 N
AVERAGE ANGLE = 4.780 D

TEST CONDITIONS

BOARD ANGLE = 0.0 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 58.00 kPa
ICE THICKNESS = 3.200 cm
ICE DENSITY = 0.8800 g/cc

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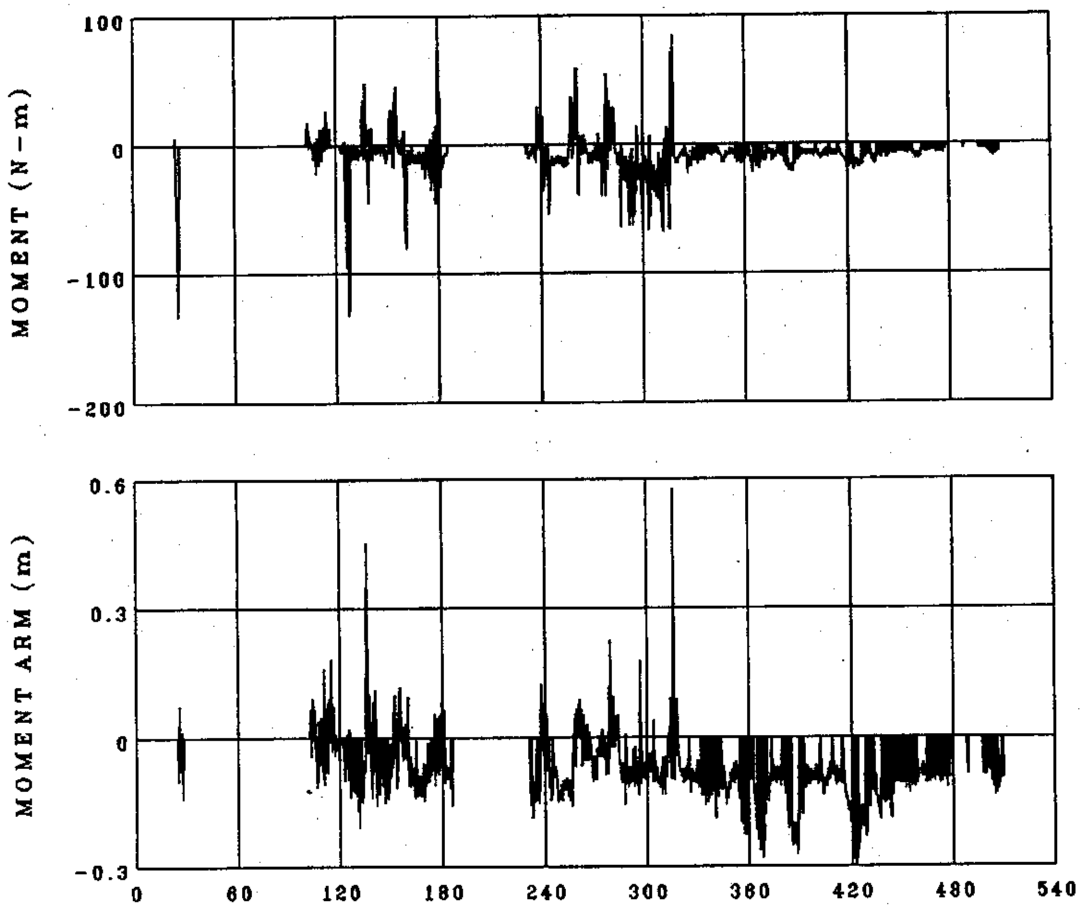
ICE PILEUP STUDY
for CANADIAN COAST GUARD

FILE TN-012



MOMENT

MOMENT

MEAN MOMENT = -5.569 N-m
MAX MOMENT = 85.09 N-m
MIN MOMENT = -133.7 N-m

MOMENT ARM

MEAN ARM = -0.04700 m
MAX ARM = 0.5787 m
MIN ARM = -0.2969 m

TEST CONDITIONS

BOARD ANGLE = 0.0 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 58.00 kPa
ICE THICKNESS = 3.200 cm
ICE DENSITY = 0.8800 g/cc

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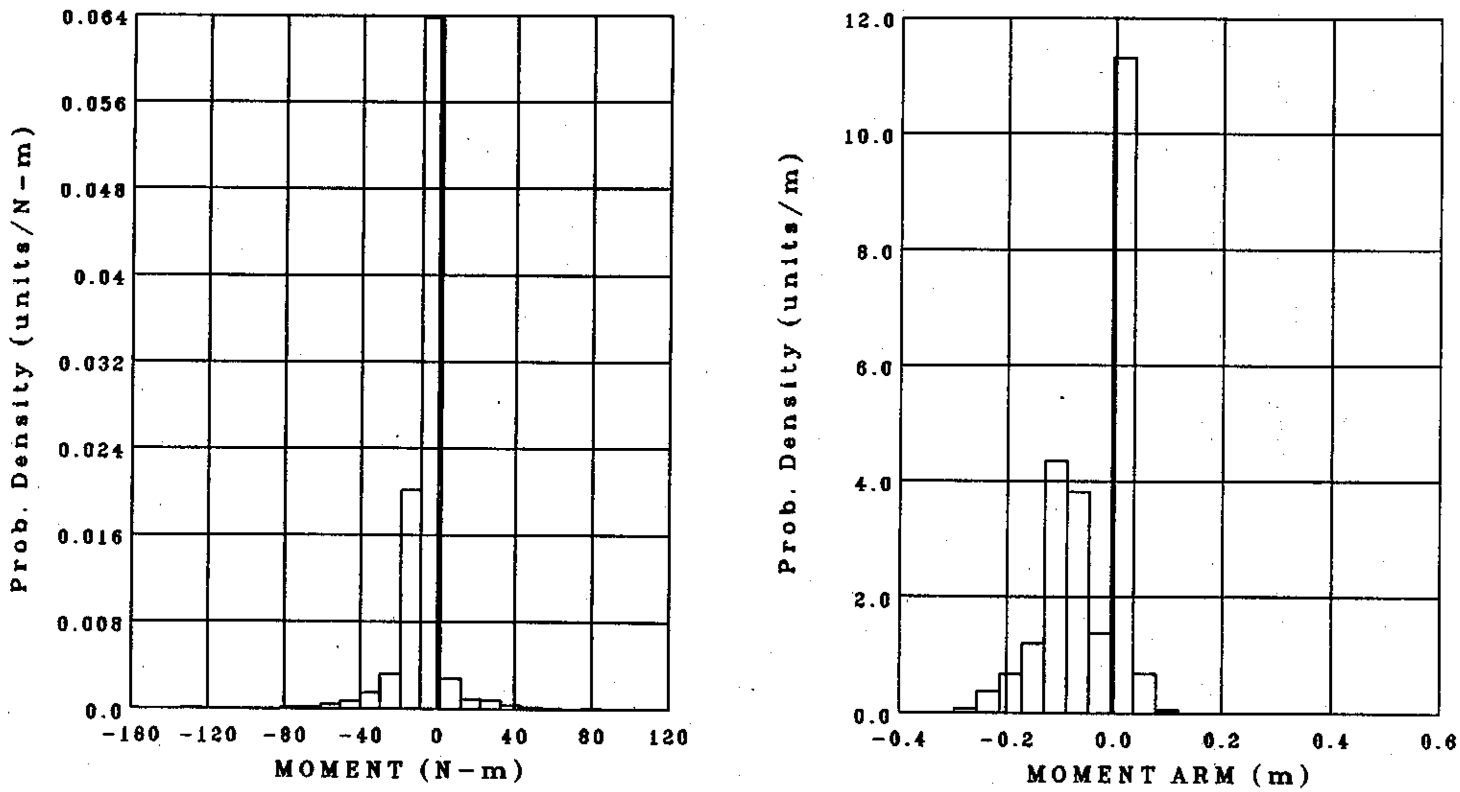
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←012



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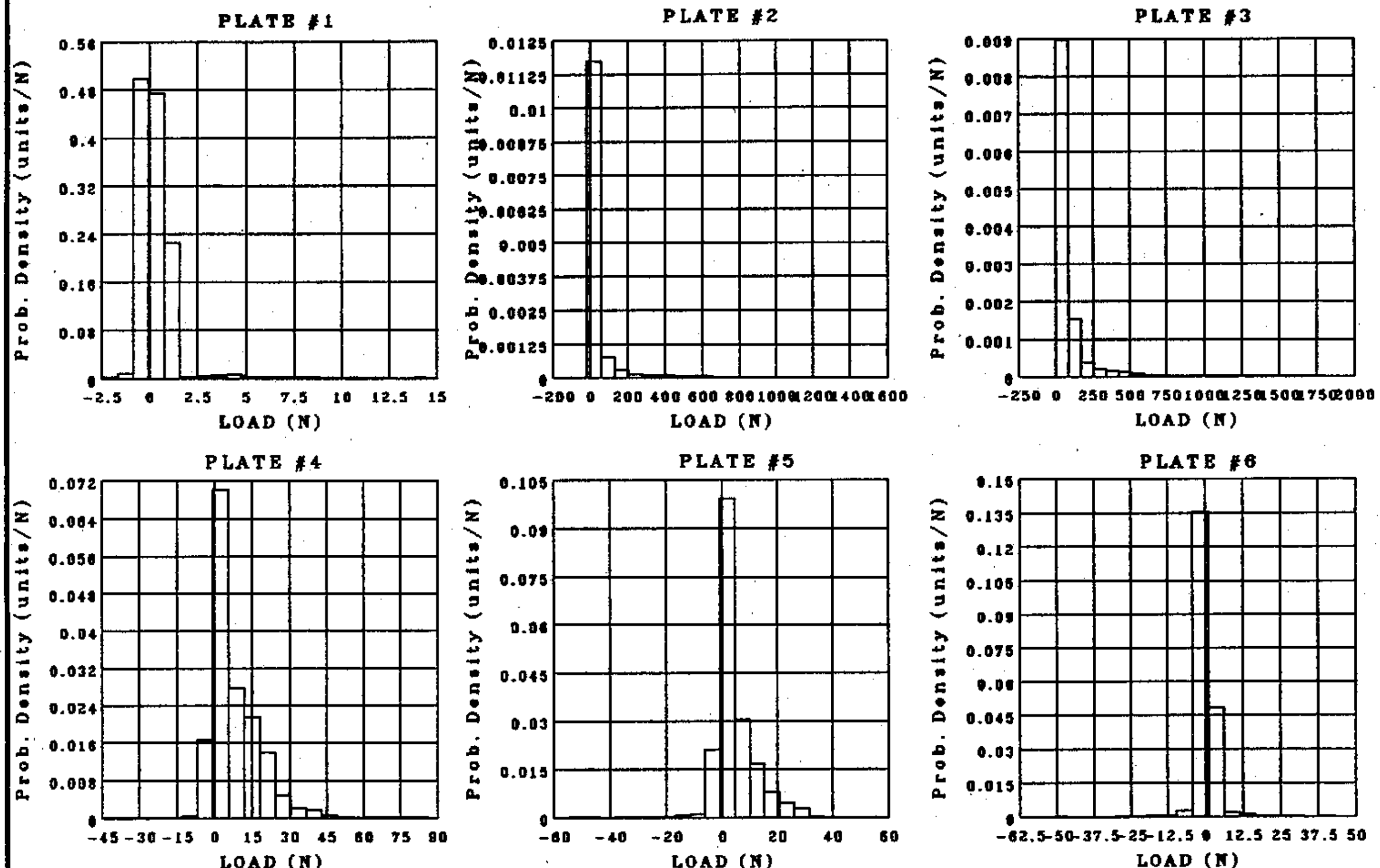
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←012
NORMAL LOAD



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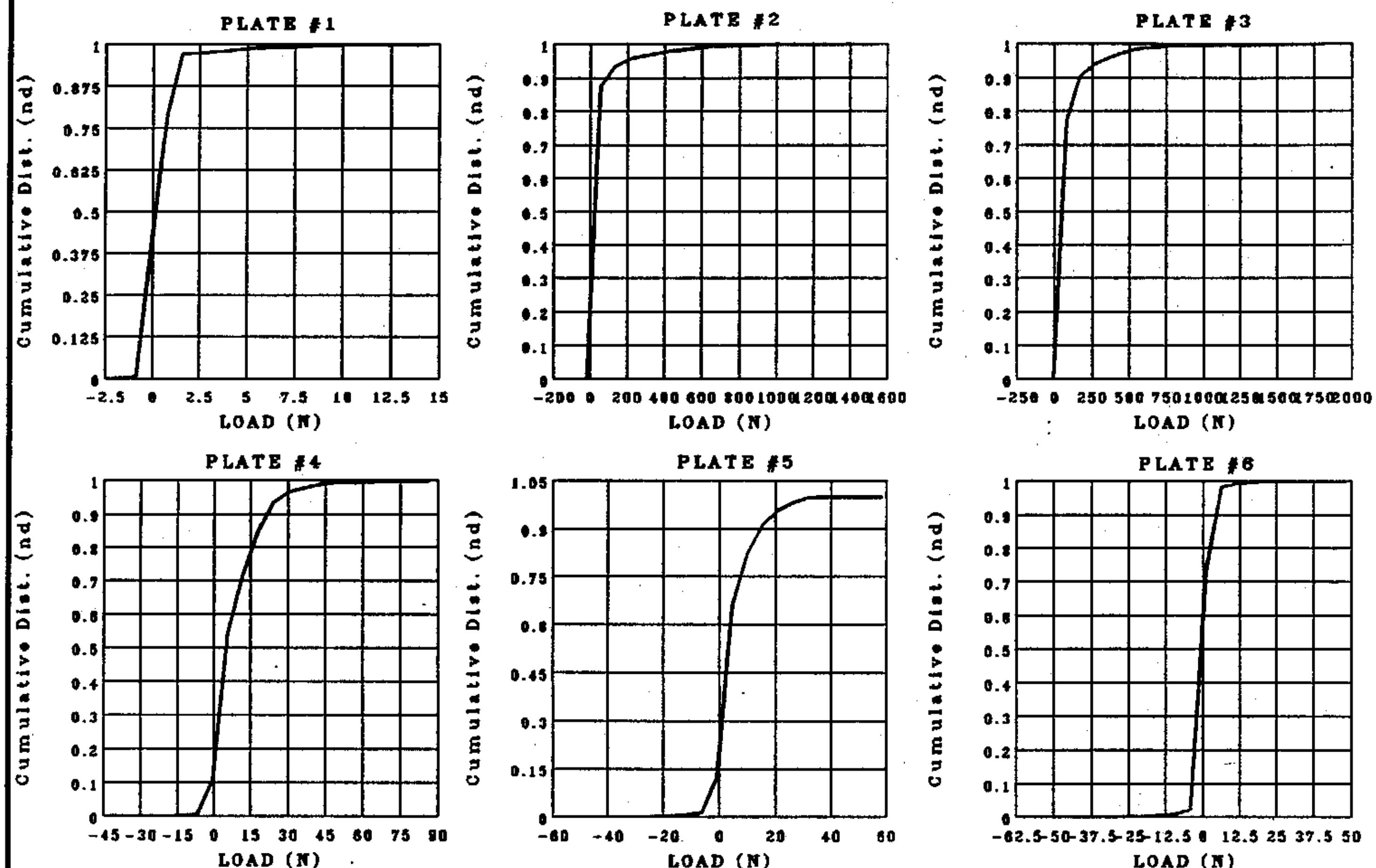
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←012
NORMAL LOAD



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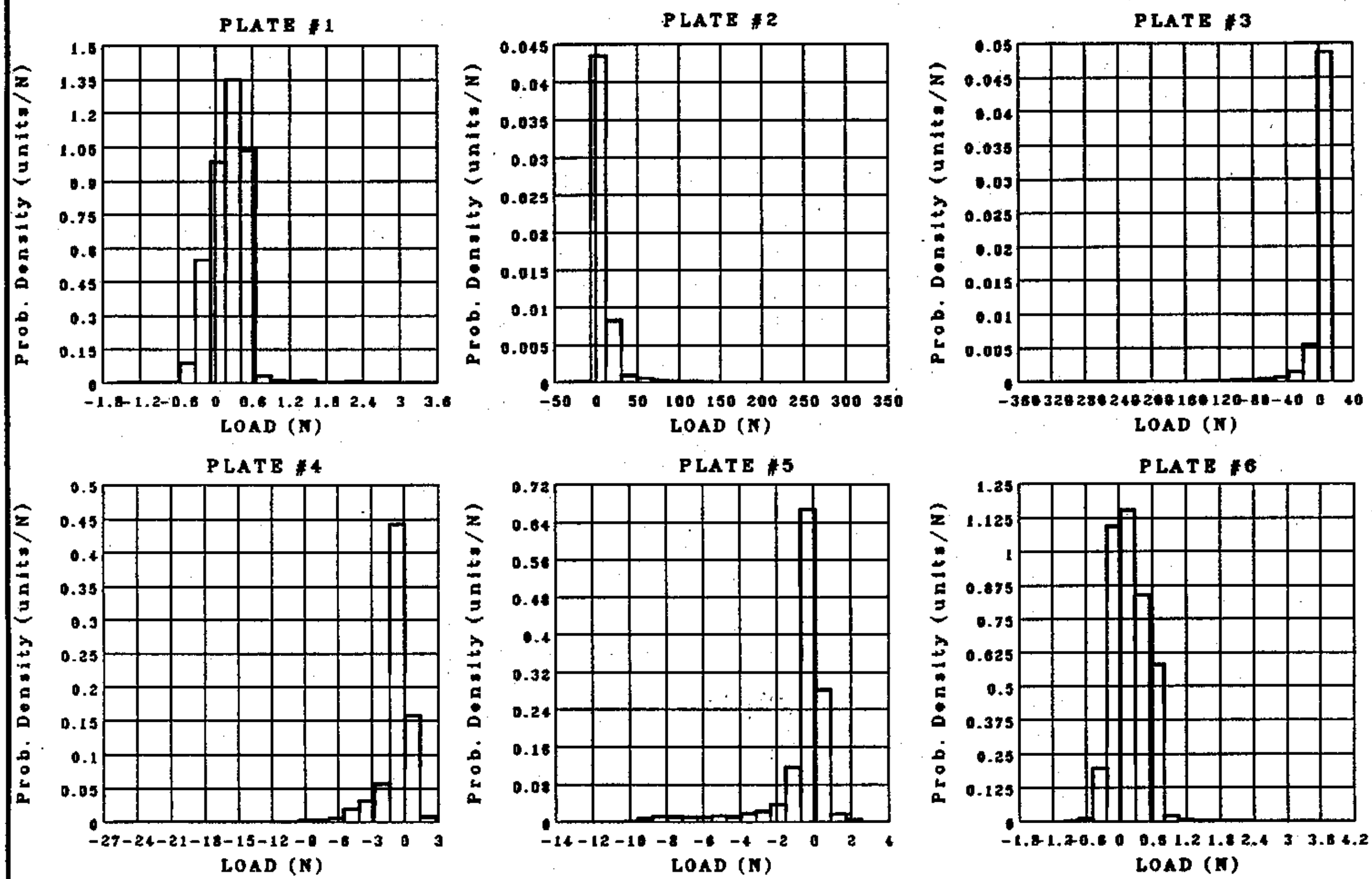
TN←012
TANGENTIAL LOAD



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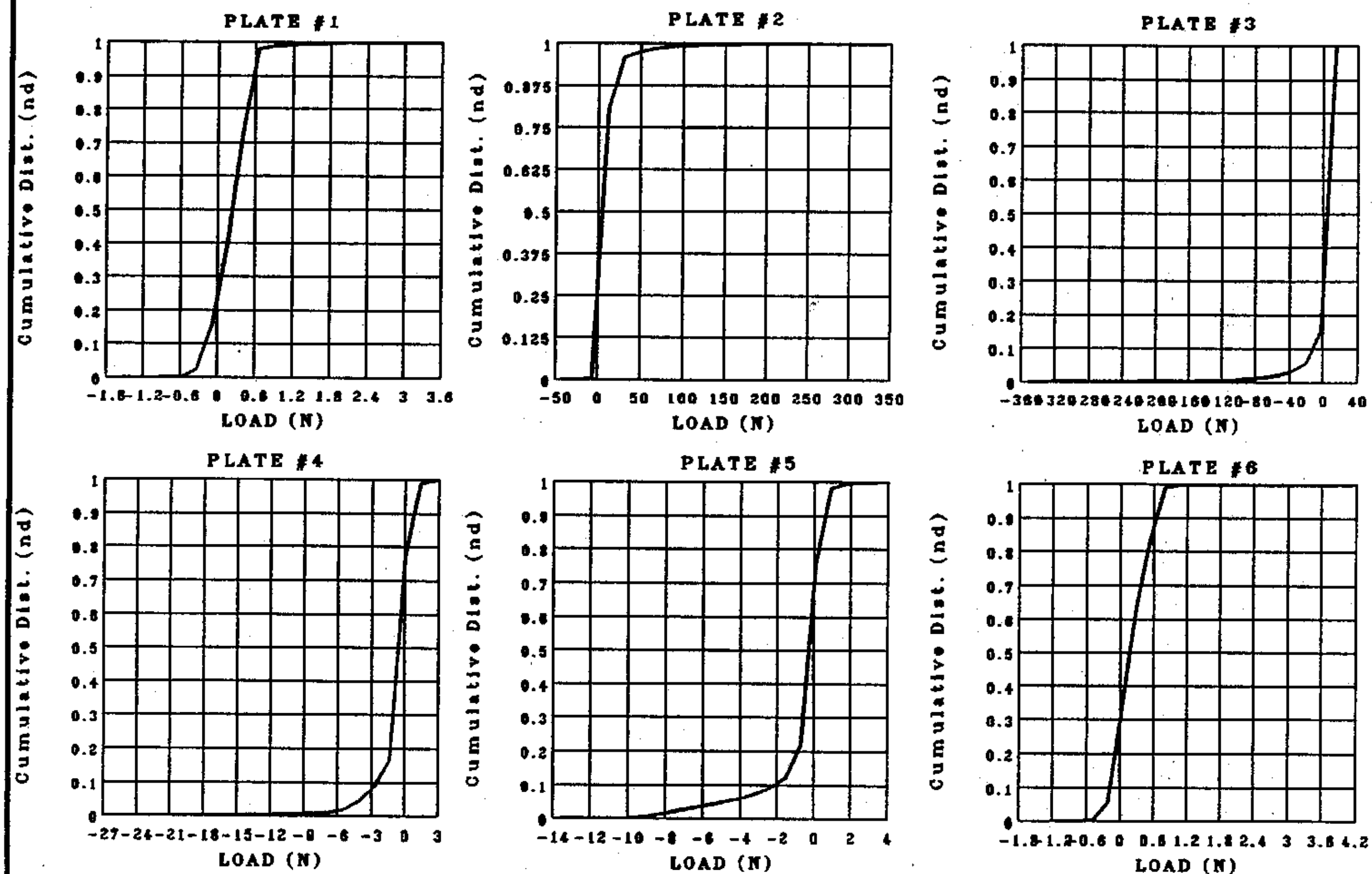
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←012
TANGENTIAL LOAD



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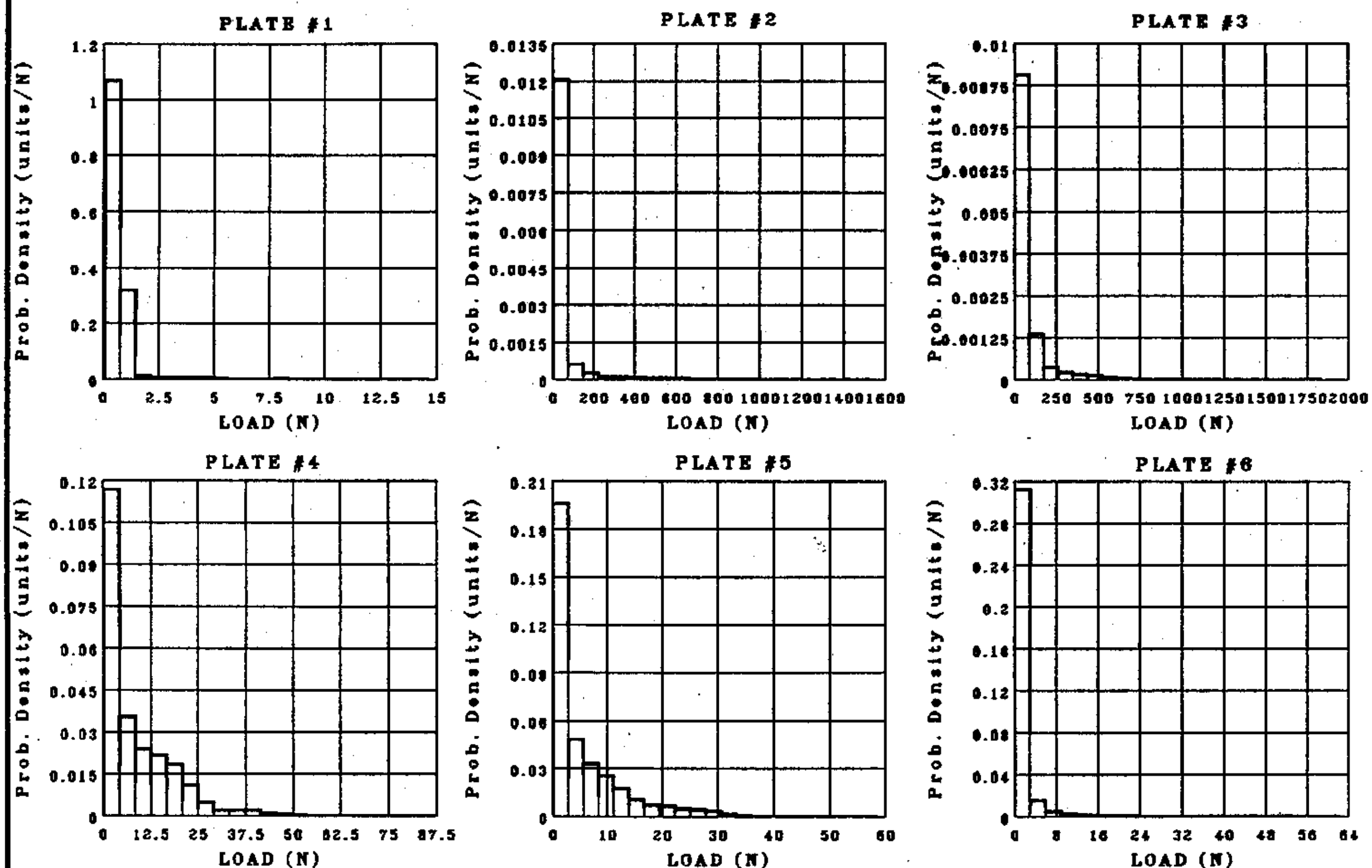
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←012
RESULTANT



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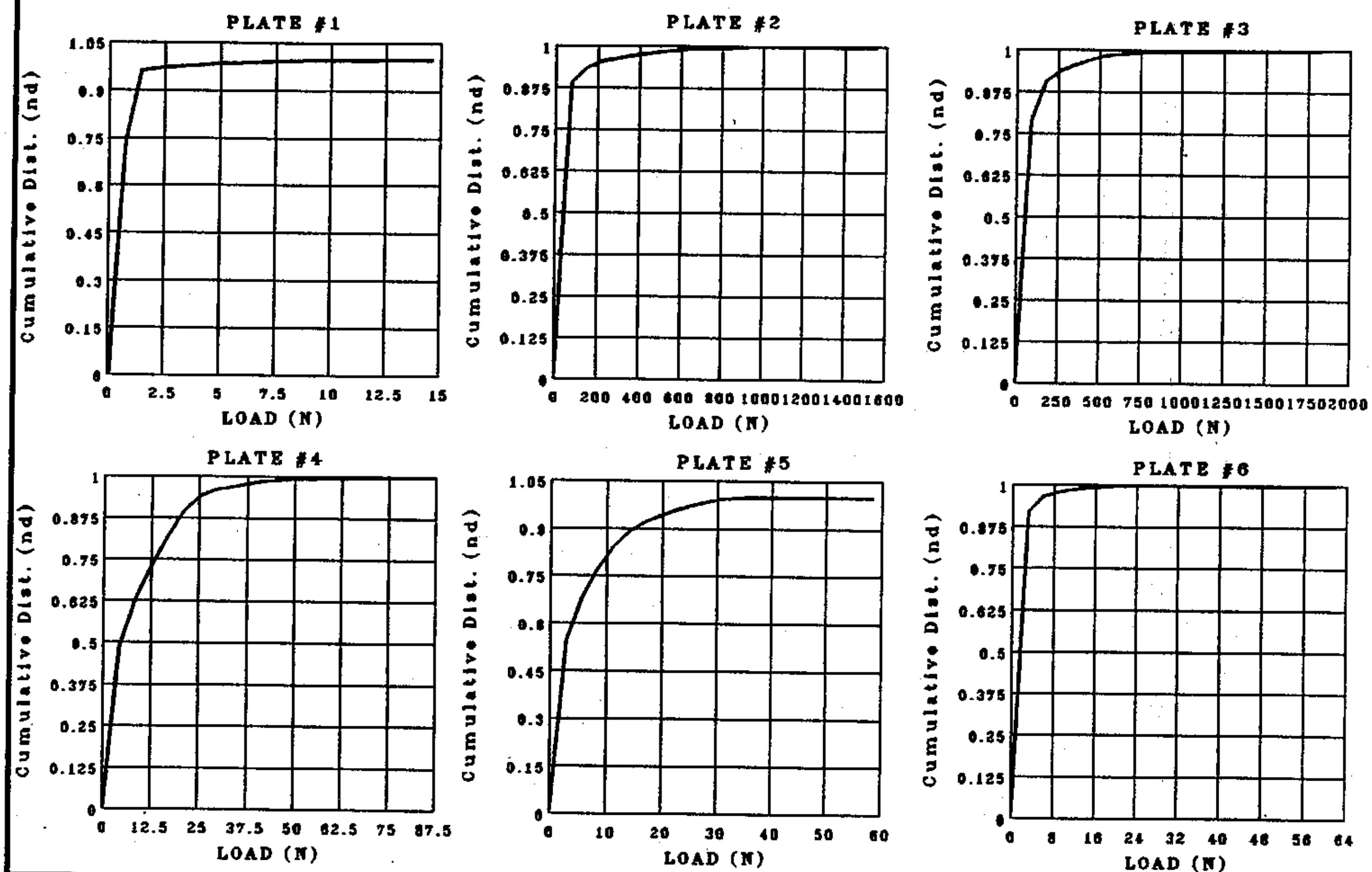
ICE PILEUP STUDY for CANADIAN COAST GUARD

TN←012
RESULTANT



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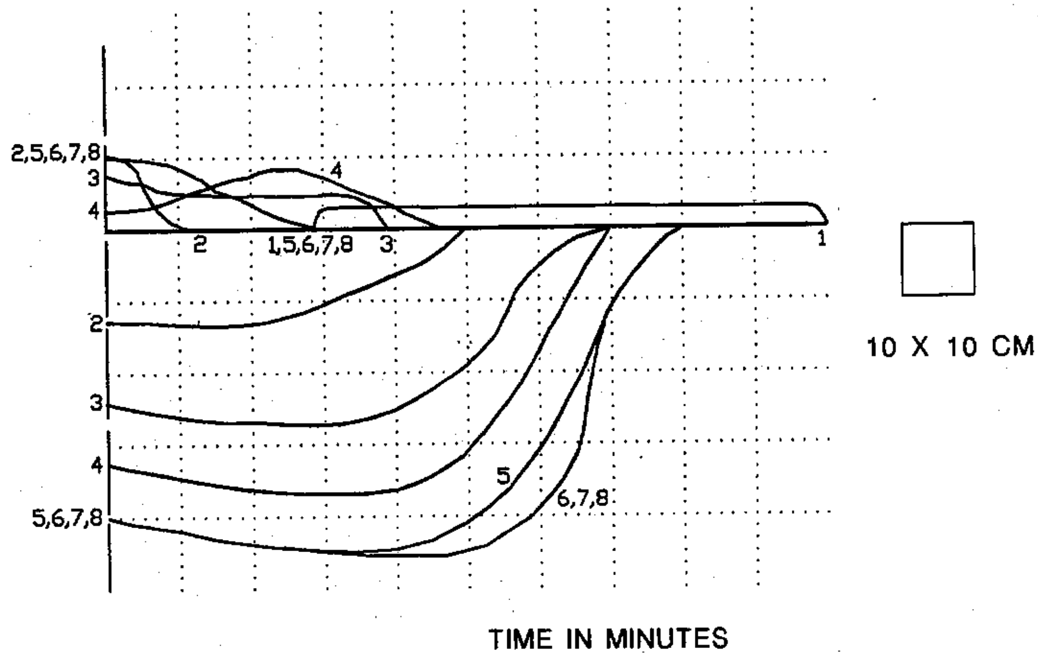
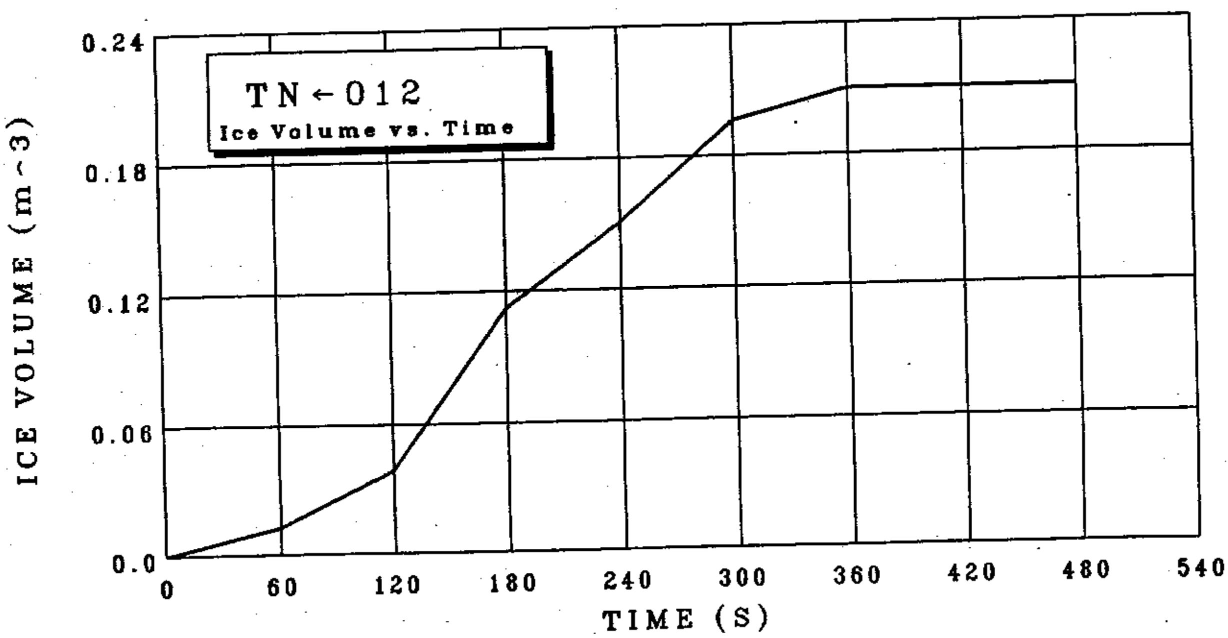
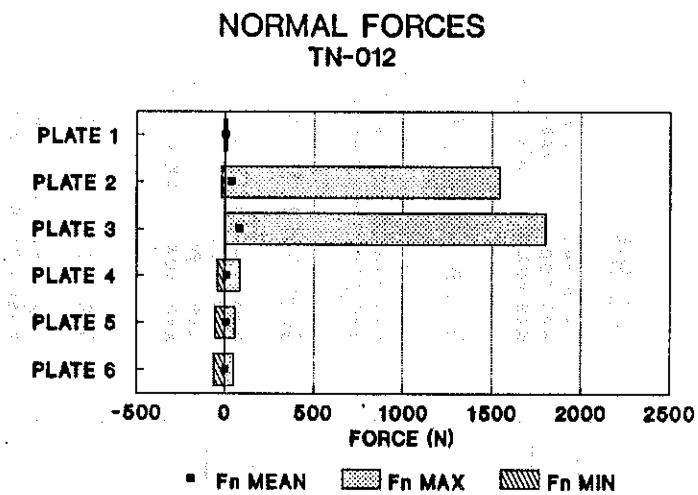
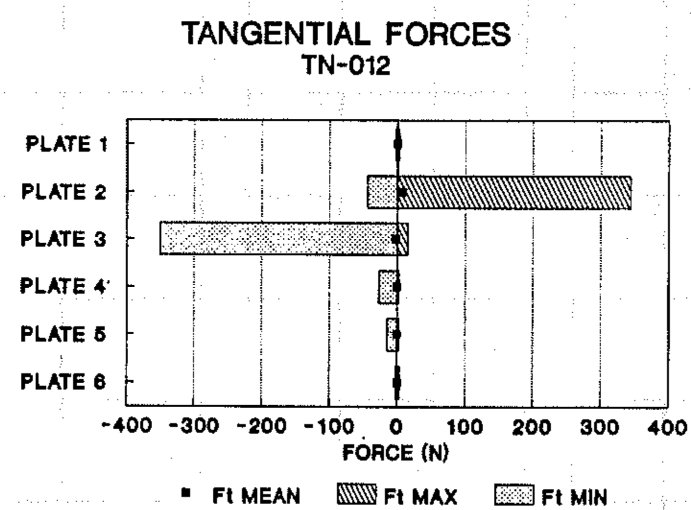
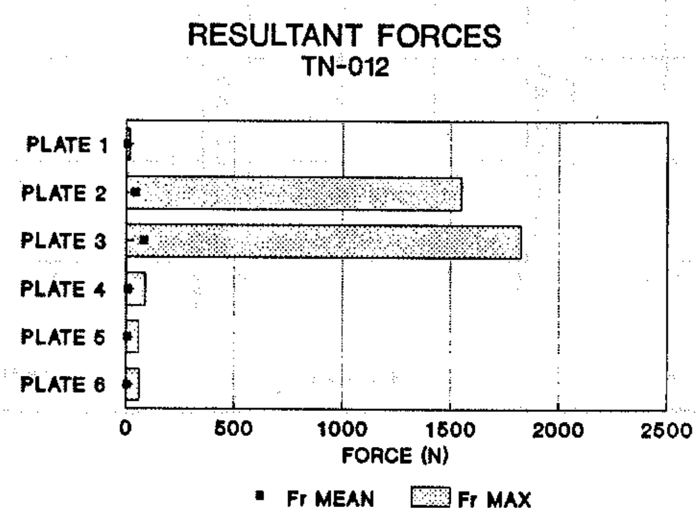
ICE PILEUP STUDY
for CANADIAN COAST GUARD

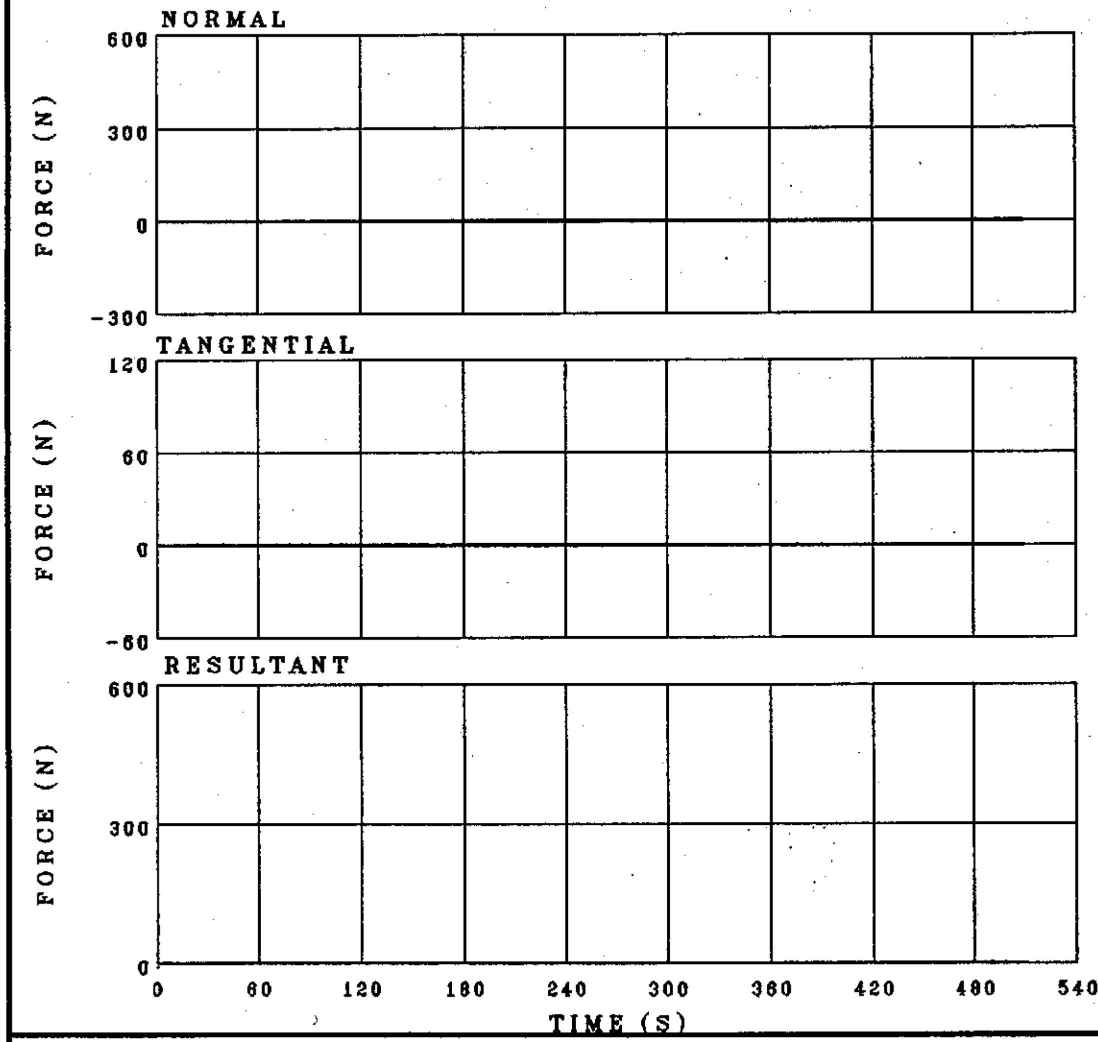

2,5,6,7,8
3
4
4
2
1,5,6,7,8
3
1
2
3
4
5,6,7,8
5
6,7,8
10 X 10 CM
TIME IN MINUTES


TN←012
Ice Volume vs. Time
ICE VOLUME (m^3)
0.24
0.18
0.12
0.06
0.0
0
60
120
180
240
300
360
420
480
540
TIME (S)


NORMAL FORCES
TN-012
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-500
0
500
1000
1500
2000
2500
FORCE (N)
Fn MEAN
Fn MAX
Fn MIN


TANGENTIAL FORCES
TN-012
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-400
-300
-200
-100
0
100
200
300
400
FORCE (N)
Ft MEAN
Ft MAX
Ft MIN


RESULTANT FORCES
TN-012
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
0
500
1000
1500
2000
2500
FORCE (N)
Fr MEAN
Fr MAX



FILE TN←013

PLATE #1

NORMAL

MEAN FORCE = −0.001783 N
MAX FORCE = 0.9281 N
MIN FORCE = −0.8735 N

TANGENTIAL

MEAN FORCE = 0.008109 N
MAX FORCE = 0.7583 N
MIN FORCE = −0.3593 N

RESULTANT

MEAN FORCE = 0.2414 N
MAX FORCE = 0.9315 N
MIN FORCE = 0.02407 N
AVERAGE ANGLE = −23.56 O

TEST CONDITIONS

BOARD ANGLE = −10.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 53.00 kPa
ICE THICKNESS = 3.200 cm
ICE DENSITY = 0.8500 g/cc

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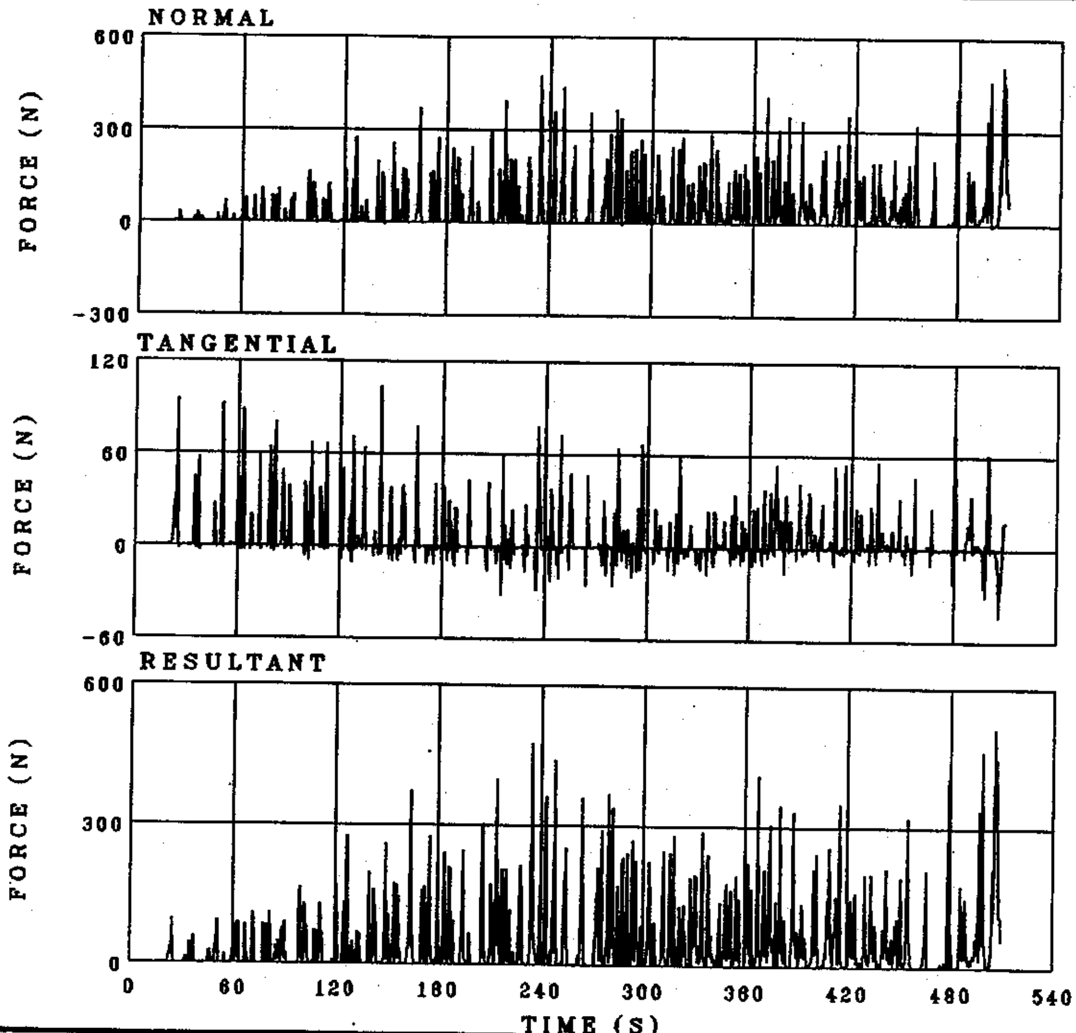
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN-013

PLATE #2

NORMAL

MEAN FORCE = 30.87 N
MAX FORCE = 511.6 N
MIN FORCE = -8.821 N

TANGENTIAL

MEAN FORCE = 3.756 N
MAX FORCE = 104.4 N
MIN FORCE = -44.06 N

RESULTANT

MEAN FORCE = 34.91 N
MAX FORCE = 513.5 N
MIN FORCE = 0.06377 N
AVERAGE ANGLE = 2.229 D

TEST CONDITIONS

BOARD ANGLE = -10.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 53.00 kPa
ICE THICKNESS = 3.200 cm
ICE DENSITY = 0.8500 g/cc

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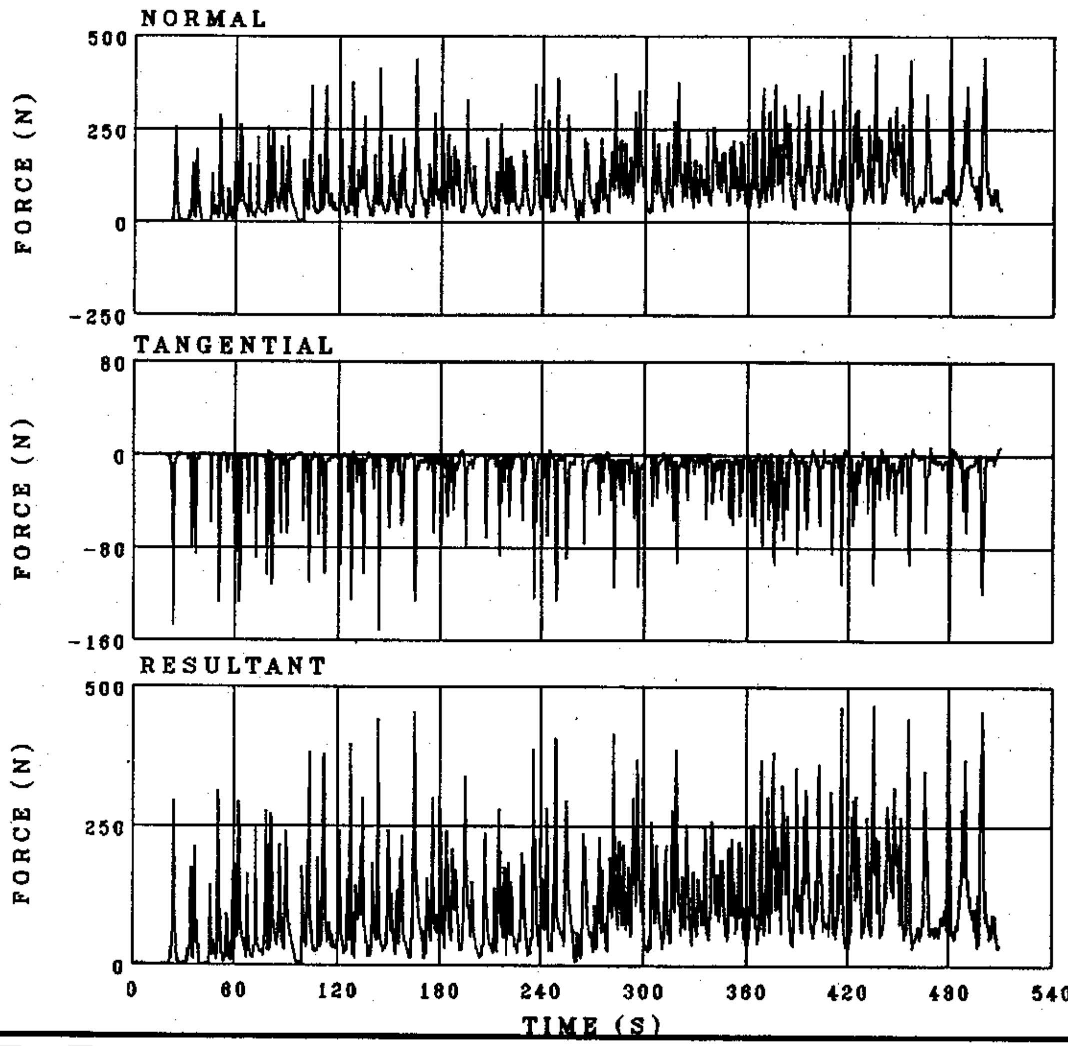
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←013

PLATE #3

NORMAL

MEAN FORCE = 92.58 N
MAX FORCE = 456.5 N
MIN FORCE = -4.152 N

TANGENTIAL

MEAN FORCE = -10.41 N
MAX FORCE = 7.834 N
MIN FORCE = -151.7 N

RESULTANT

MEAN FORCE = 93.66 N
MAX FORCE = 469.0 N
MIN FORCE = 0.07185 N
AVERAGE ANGLE = -3.448 O

TEST CONDITIONS

BOARD ANGLE = -10.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 53.00 kPa
ICE THICKNESS = 3.200 cm
ICE DENSITY = 0.8500 g/cc

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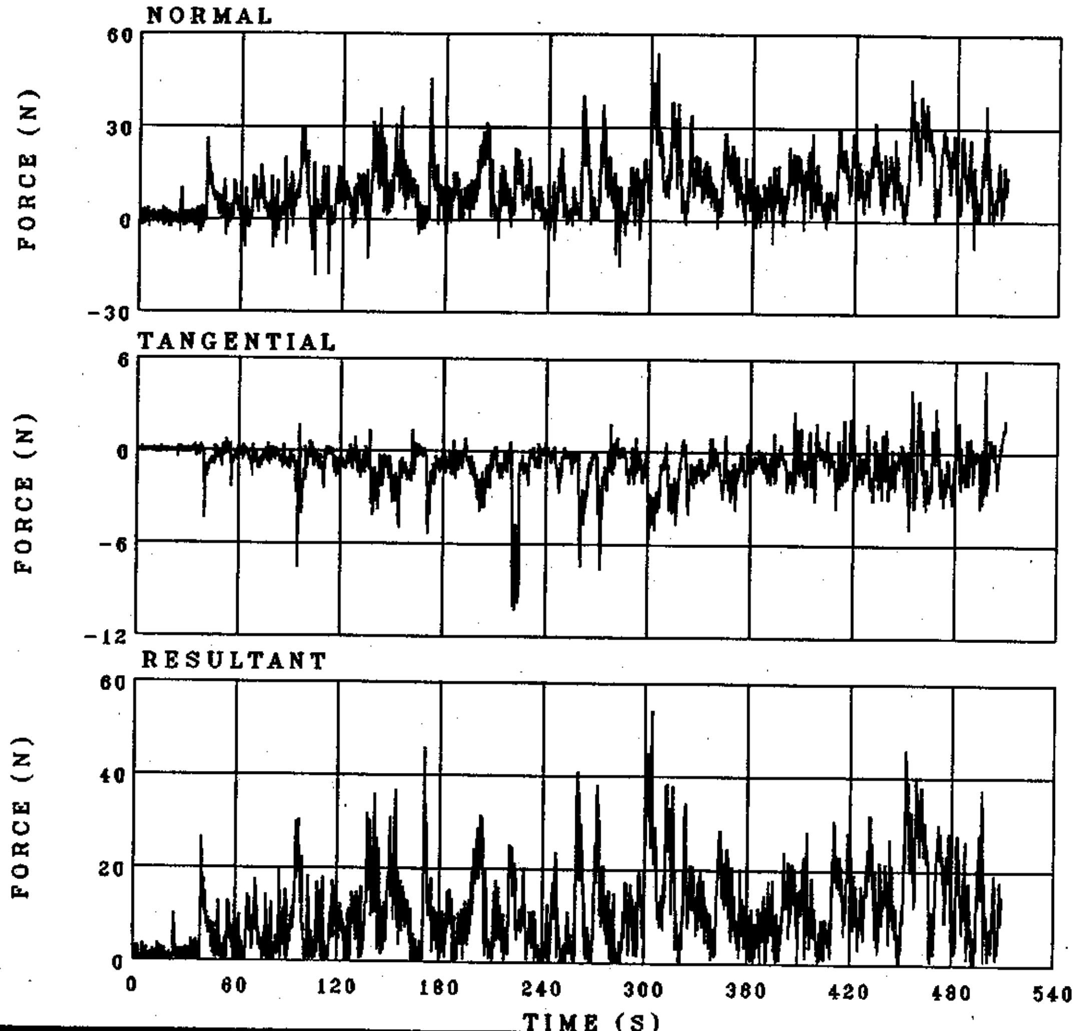
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←013

PLATE #4

NORMAL

MEAN FORCE = 9.970 N
MAX FORCE = 53.92 N
MIN FORCE = -18.27 N

TANGENTIAL

MEAN FORCE = -0.9460 N
MAX FORCE = 5.448 N
MIN FORCE = -10.37 N

RESULTANT

MEAN FORCE = 10.26 N
MAX FORCE = 54.15 N
MIN FORCE = 0.03417 N
AVERAGE ANGLE = 0.3263 O

TEST CONDITIONS

BOARD ANGLE = -10.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 53.00 kPa
ICE THICKNESS = 3.200 cm
ICE DENSITY = 0.8500 g/cc

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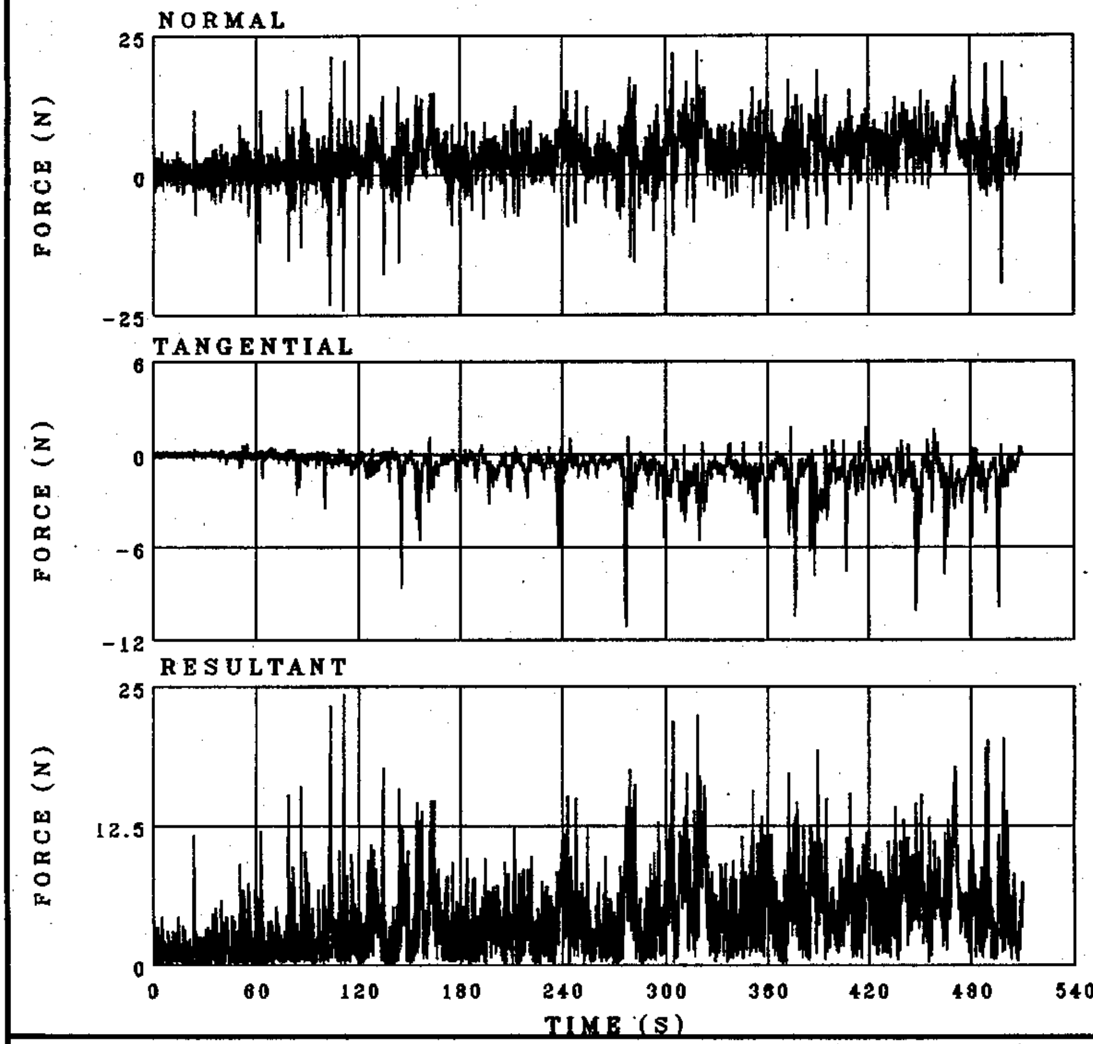
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←013

PLATE #5

NORMAL

MEAN FORCE = 3.285 N
MAX FORCE = 22.21 N
MIN FORCE = -24.35 N

TANGENTIAL

MEAN FORCE = -0.8855 N
MAX FORCE = 1.810 N
MIN FORCE = -11.14 N

RESULTANT

MEAN FORCE = 3.993 N
MAX FORCE = 24.35 N
MIN FORCE = 0.02787 N
AVERAGE ANGLE = -19.31 0

TEST CONDITIONS

BOARD ANGLE = -10.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 53.00 kPa
ICE THICKNESS = 3.200 cm
ICE DENSITY = 0.8500 g/cc

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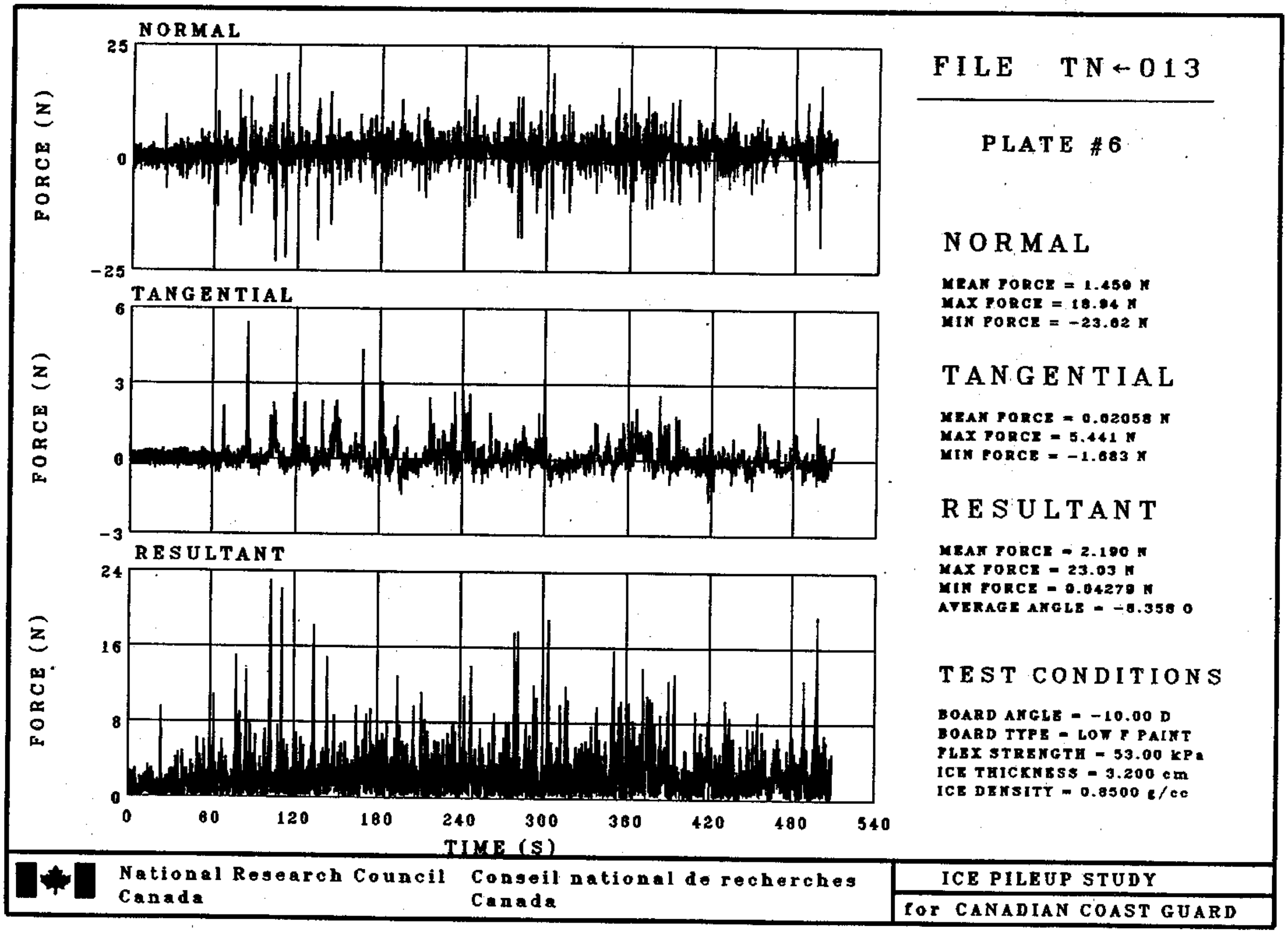
ICE PILEUP STUDY
for CANADIAN COAST GUARD


NORMAL
25
0
-25
FORCE (N)
TANGENTIAL
6
3
0
-3
FORCE (N)
RESULTANT
24
16
8
0
FORCE (N)
0 60 120 180 240 300 360 420 480 540
TIME (S)
FILE TN←013
PLATE #6
NORMAL
MEAN FORCE = 1.459 N
MAX FORCE = 18.94 N
MIN FORCE = -23.62 N
TANGENTIAL
MEAN FORCE = 0.02058 N
MAX FORCE = 5.441 N
MIN FORCE = -1.683 N
RESULTANT
MEAN FORCE = 2.190 N
MAX FORCE = 23.03 N
MIN FORCE = 0.04279 N
AVERAGE ANGLE = -6.358 O
TEST CONDITIONS
BOARD ANGLE = -10.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 53.00 kPa
ICE THICKNESS = 3.200 cm
ICE DENSITY = 0.8500 g/cc
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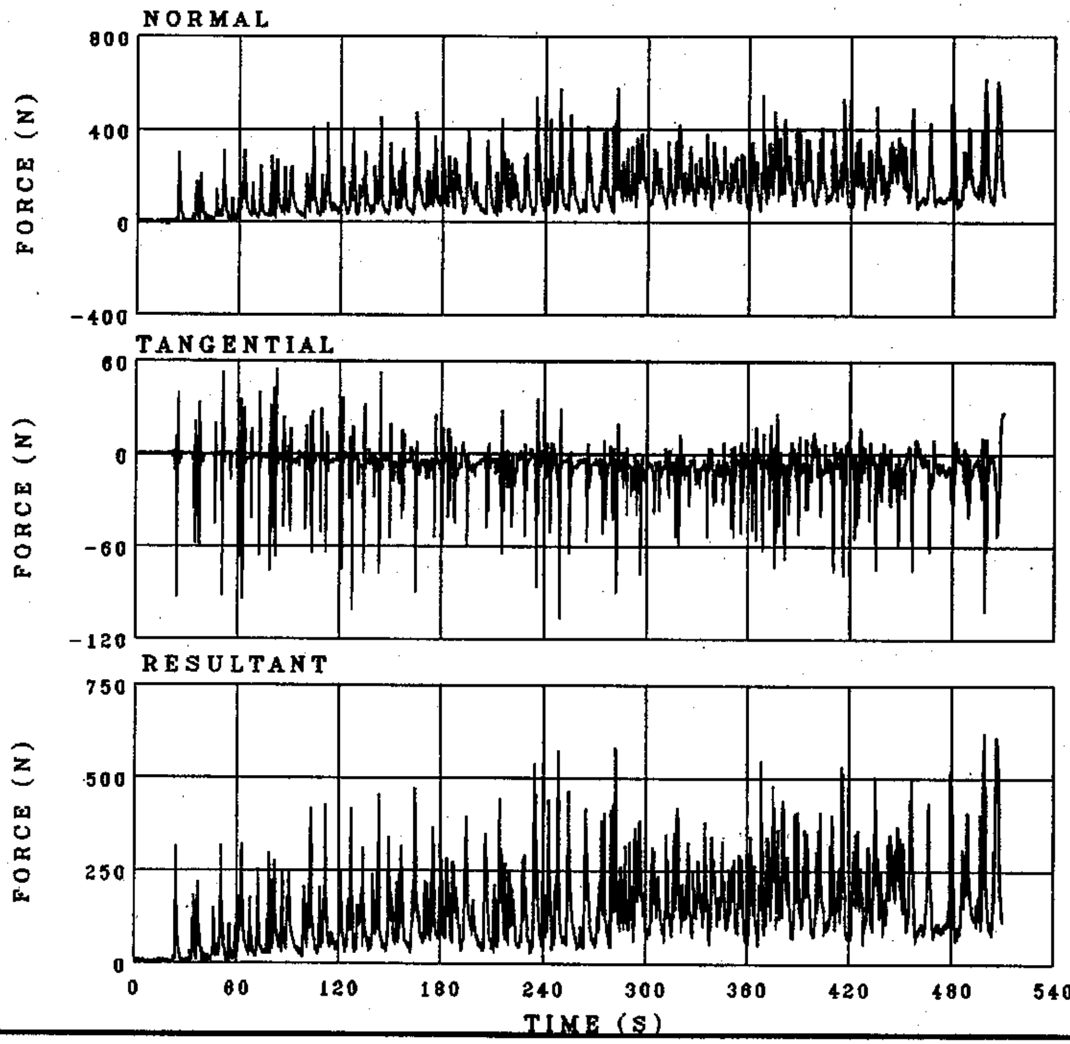
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN-013

TOTAL

NORMAL

MEAN FORCE = 138.2 N
MAX FORCE = 621.2 N
MIN FORCE = -26.94 N

TANGENTIAL

MEAN FORCE = -8.453 N
MAX FORCE = 55.70 N
MIN FORCE = -106.5 N

RESULTANT

MEAN FORCE = 138.9 N
MAX FORCE = 625.5 N
MIN FORCE = 0.05842 N
AVERAGE ANGLE = -1.587 0

TEST CONDITIONS

BOARD ANGLE = -10.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 53.00 kPa
ICE THICKNESS = 3.200 cm
ICE DENSITY = 0.8500 g/cc

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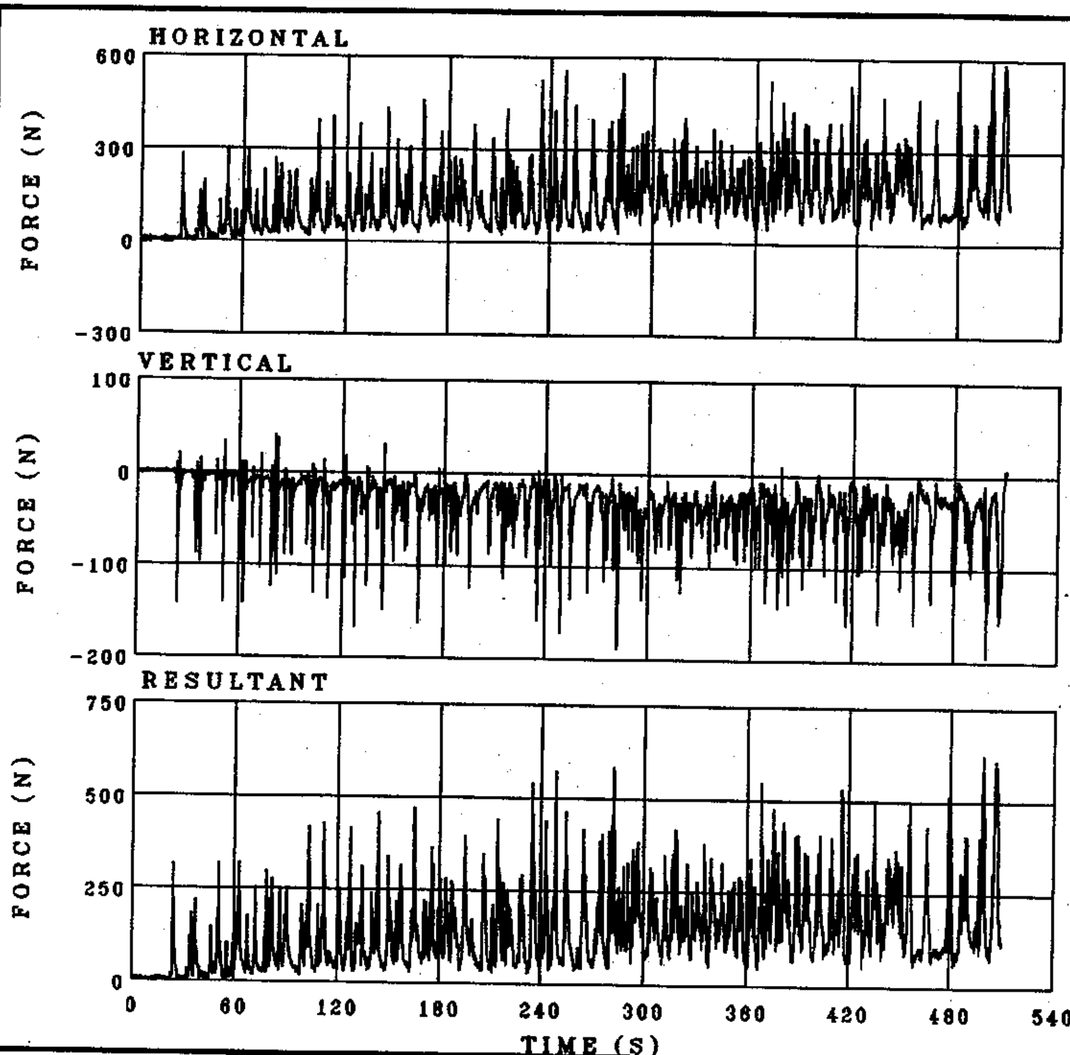
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN-013

TOTAL

HORIZONTAL

MEAN FORCE = -8.453 N
MAX FORCE = 55.70 N
MIN FORCE = -106.5 N

VERTICAL

MEAN FORCE = -8.453 N
MAX FORCE = 55.70 N
MIN FORCE = -106.5 N

RESULTANT

MEAN FORCE = -8.453 N
MAX FORCE = 55.70 N
MIN FORCE = -106.5 N
AVERAGE ANGLE = -8.453 O

TEST CONDITIONS

BOARD ANGLE = -10.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 53.00 kPa
ICE THICKNESS = 3.200 cm
ICE DENSITY = 0.8500 g/cc

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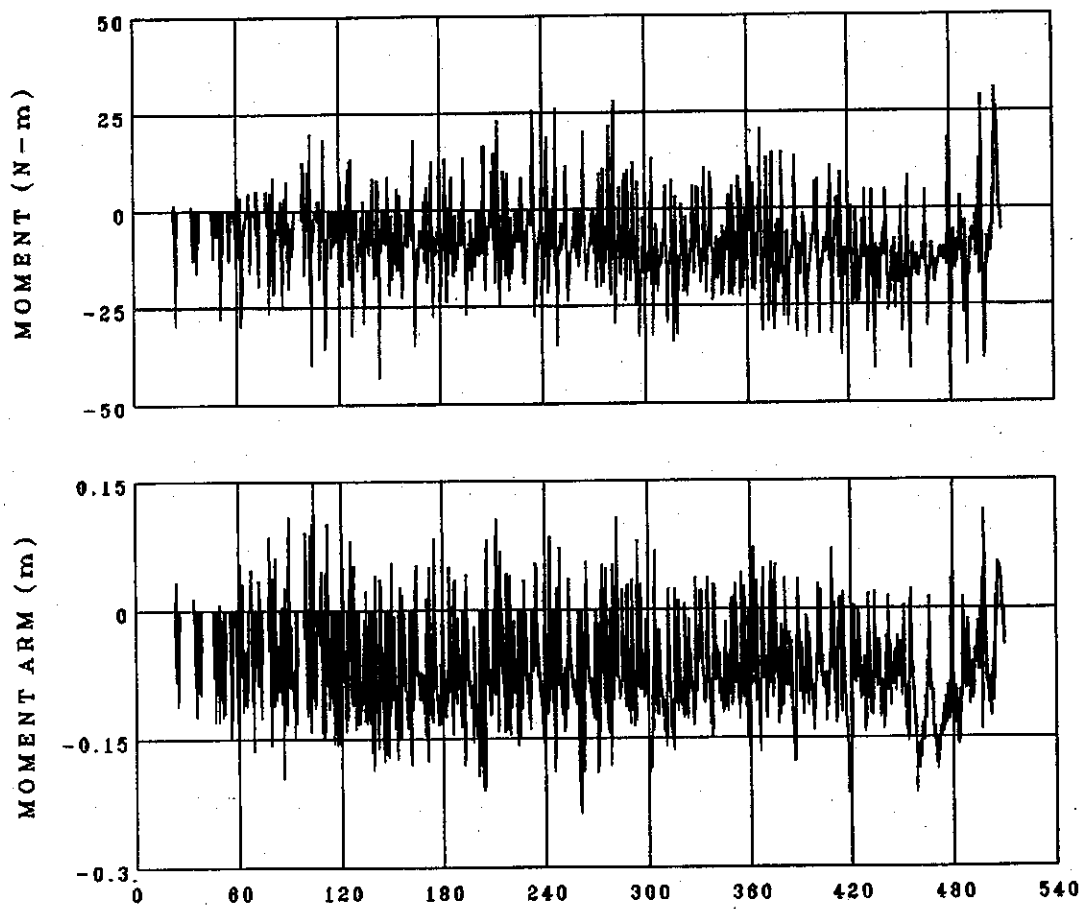
ICE PILEUP STUDY
for CANADIAN COAST GUARD

FILE TN←013

MOMENT



MOMENT

MEAN MOMENT = -6.352 N-m
MAX MOMENT = 31.08 N-m
MIN MOMENT = -43.41 N-m

MOMENT ARM

MEAN ARM = -0.06321 m
MAX ARM = 0.1487 m
MIN ARM = -0.2378 m

TEST CONDITIONS

BOARD ANGLE = -10.00 D
BOARD TYPE = LOW F PAINT
FLEX STRENGTH = 53.00 kPa
ICE THICKNESS = 3.200 cm
ICE DENSITY = 0.8500 g/cc

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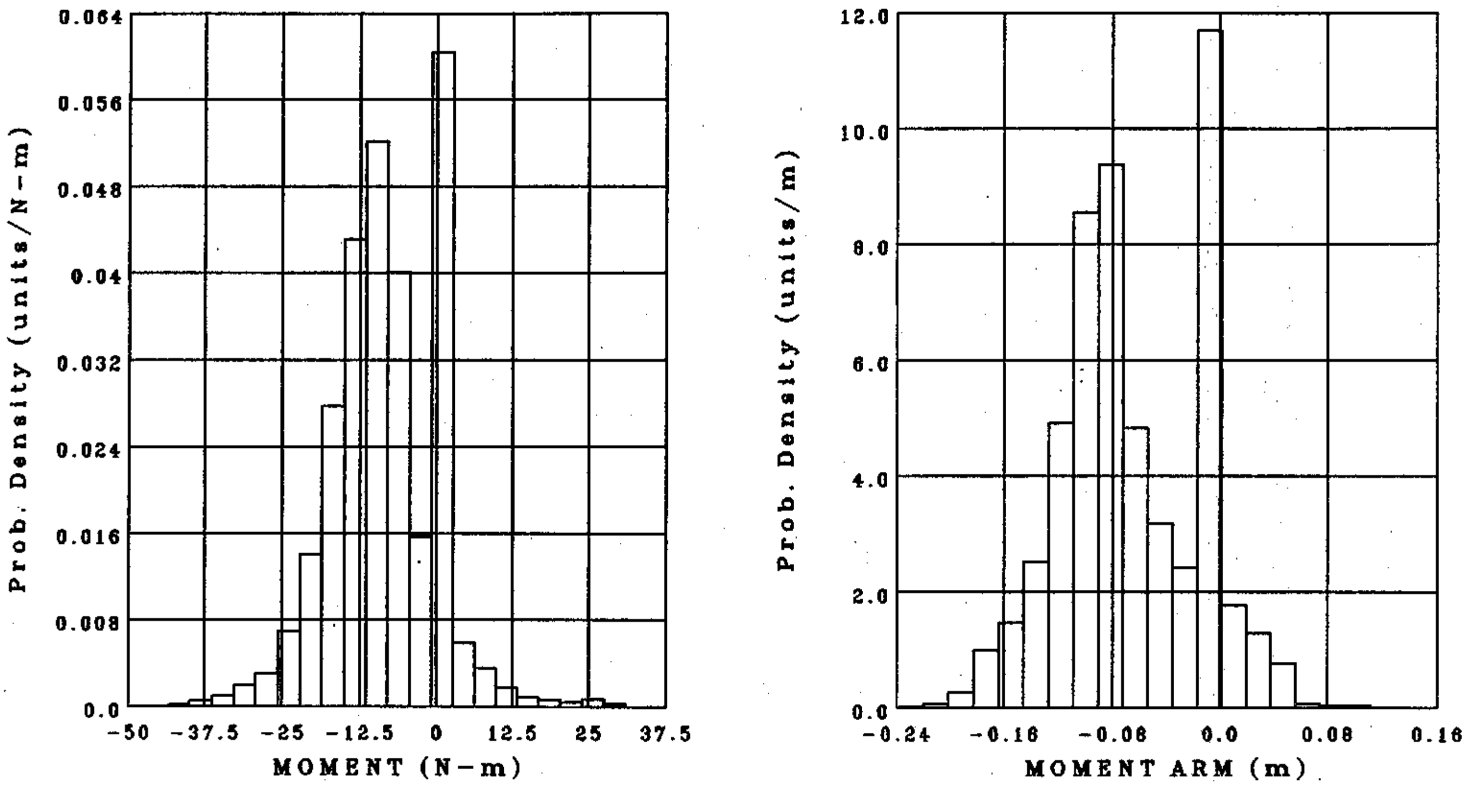
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←013



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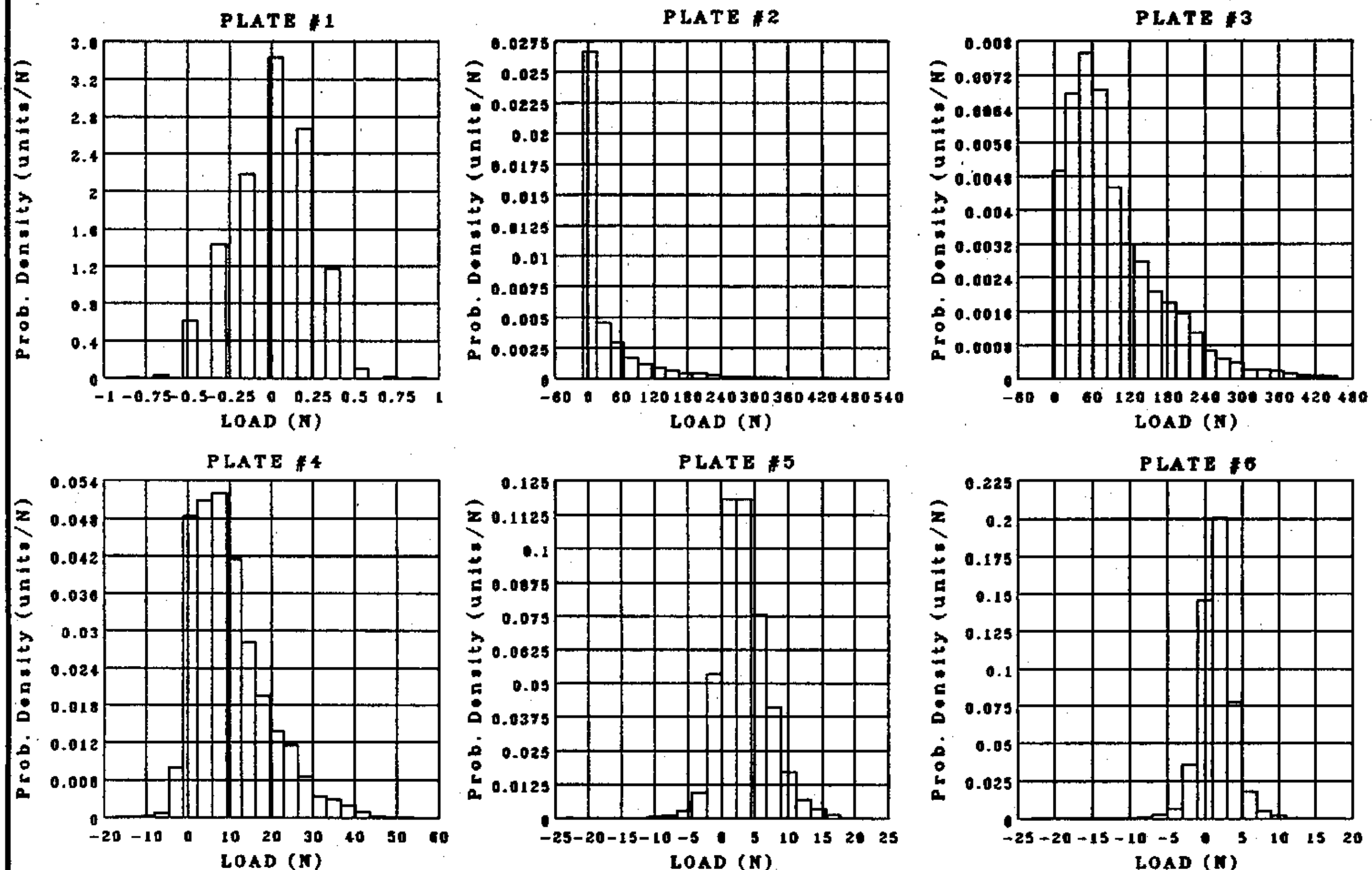
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←013

NORMAL LOAD



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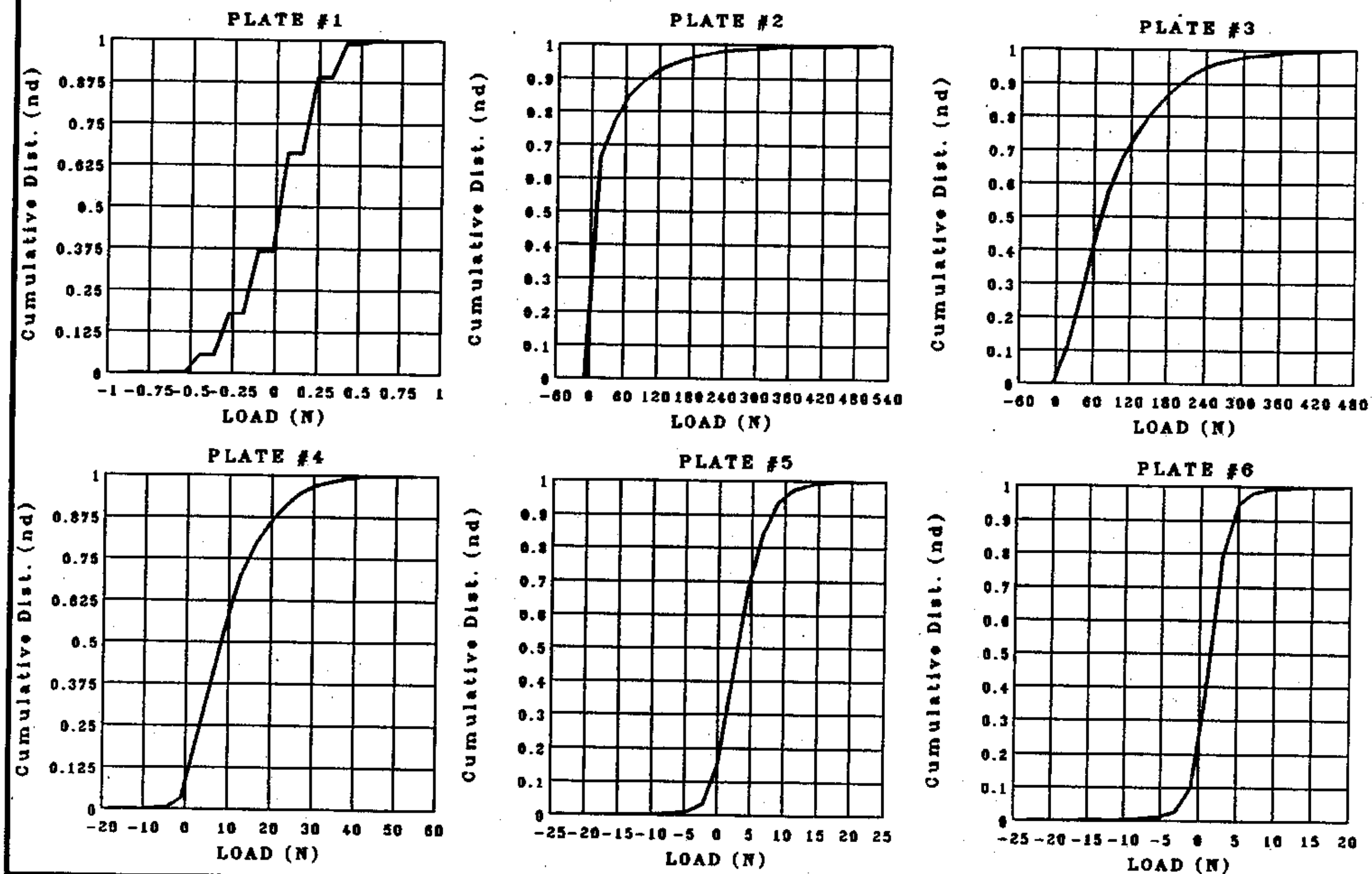
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←013
NORMAL LOAD



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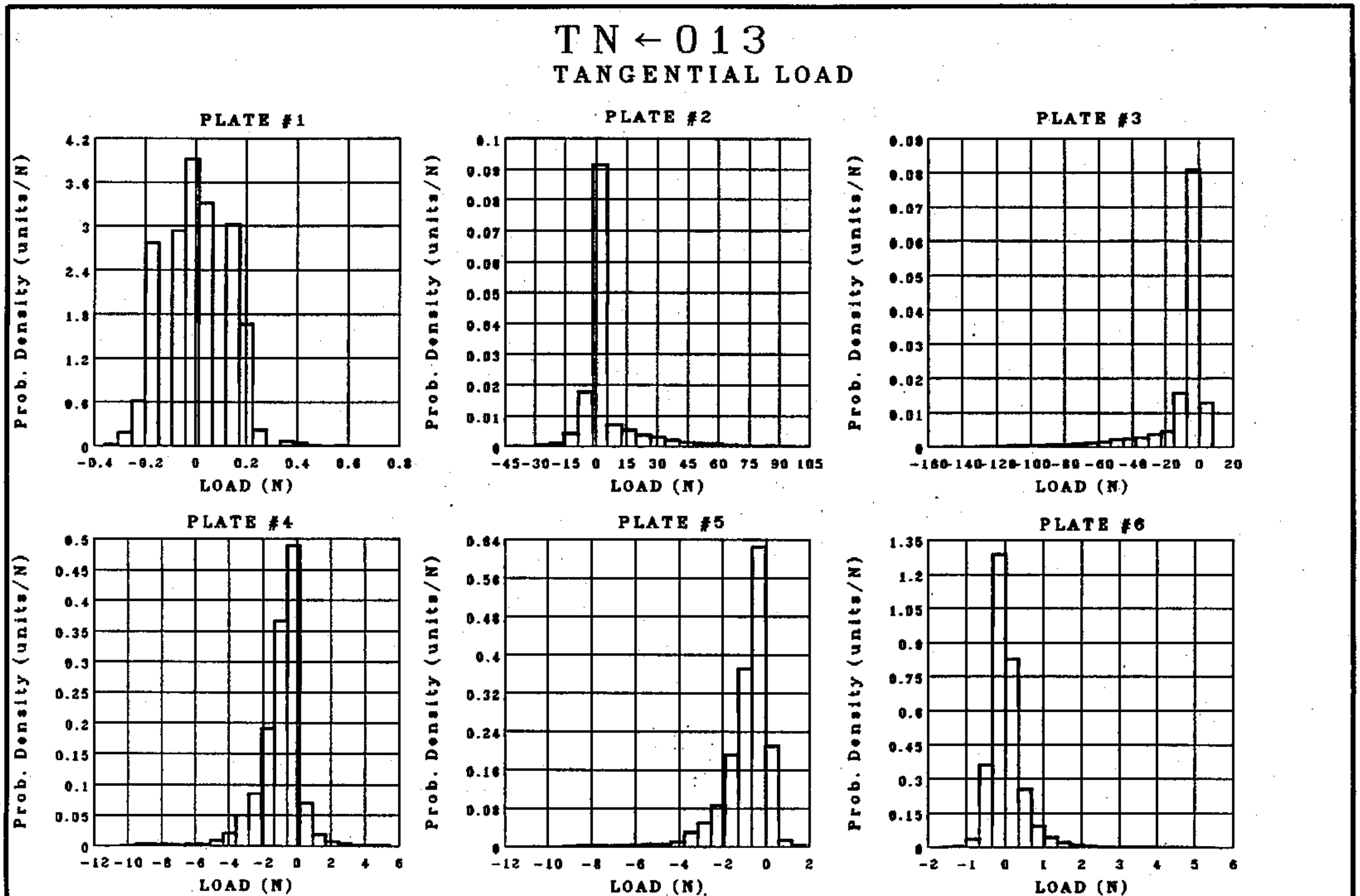
ICE PILEUP STUDY
for CANADIAN COAST GUARD



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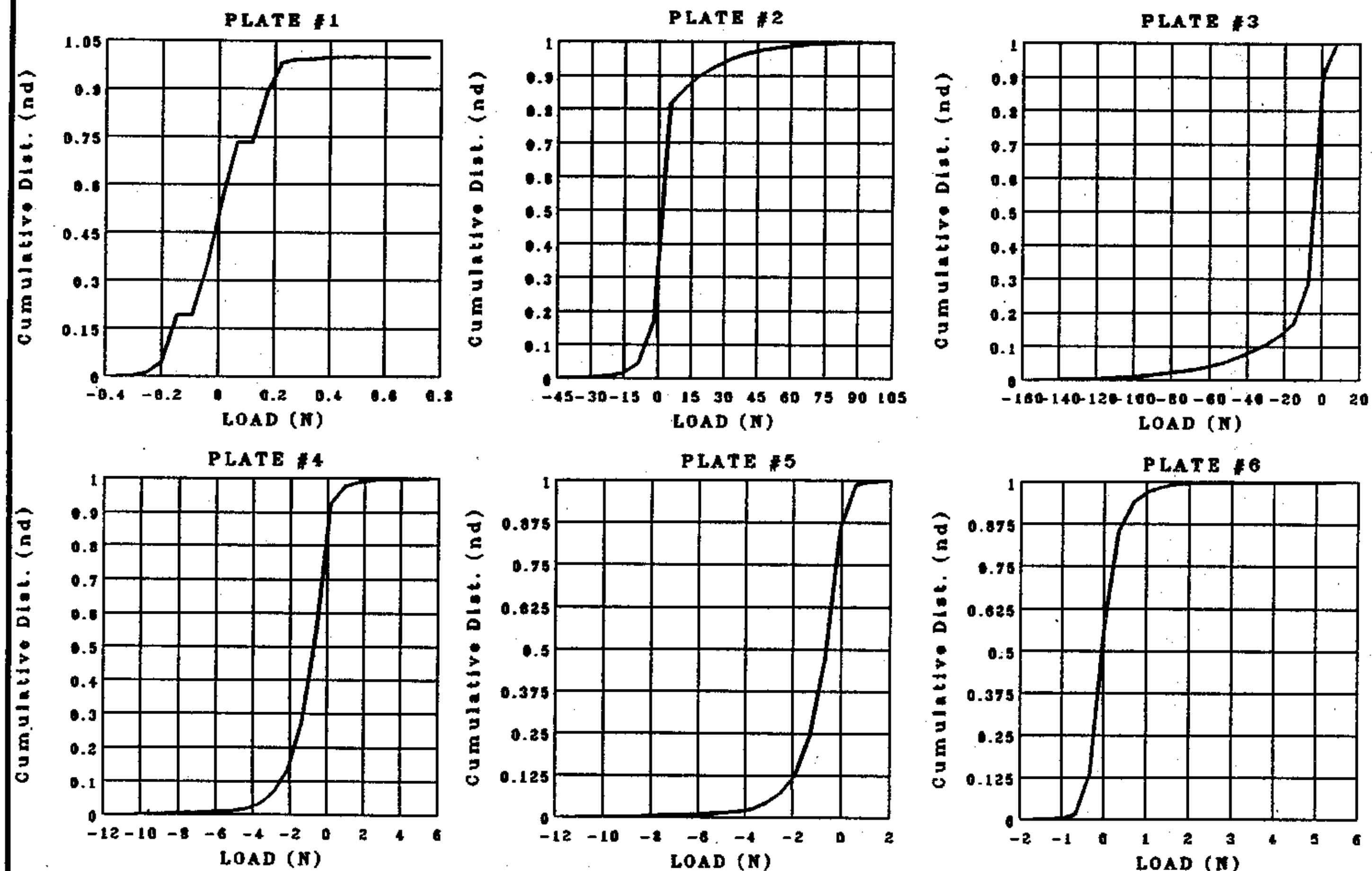
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←013
TANGENTIAL LOAD



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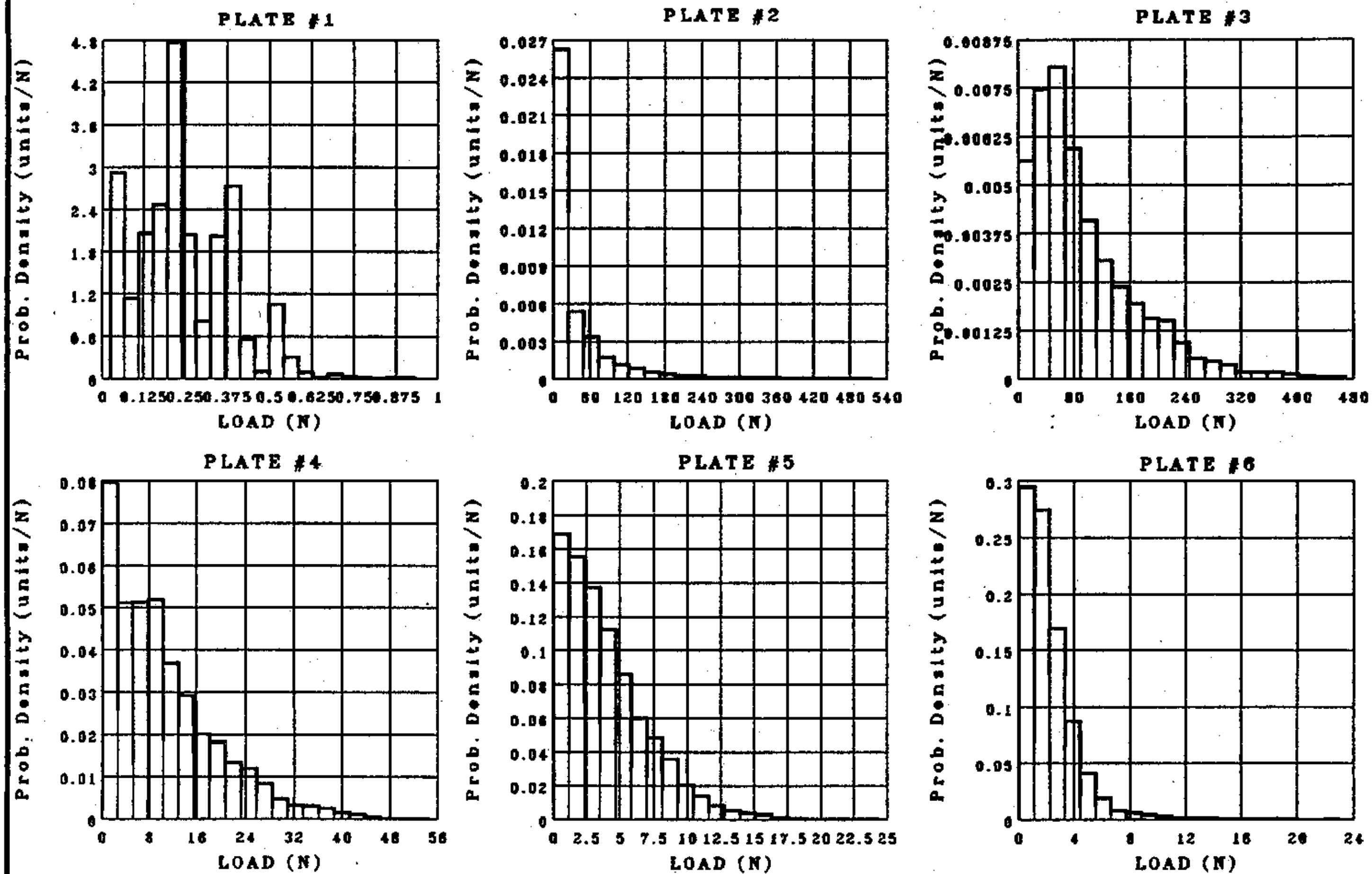
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←013
RESULTANT



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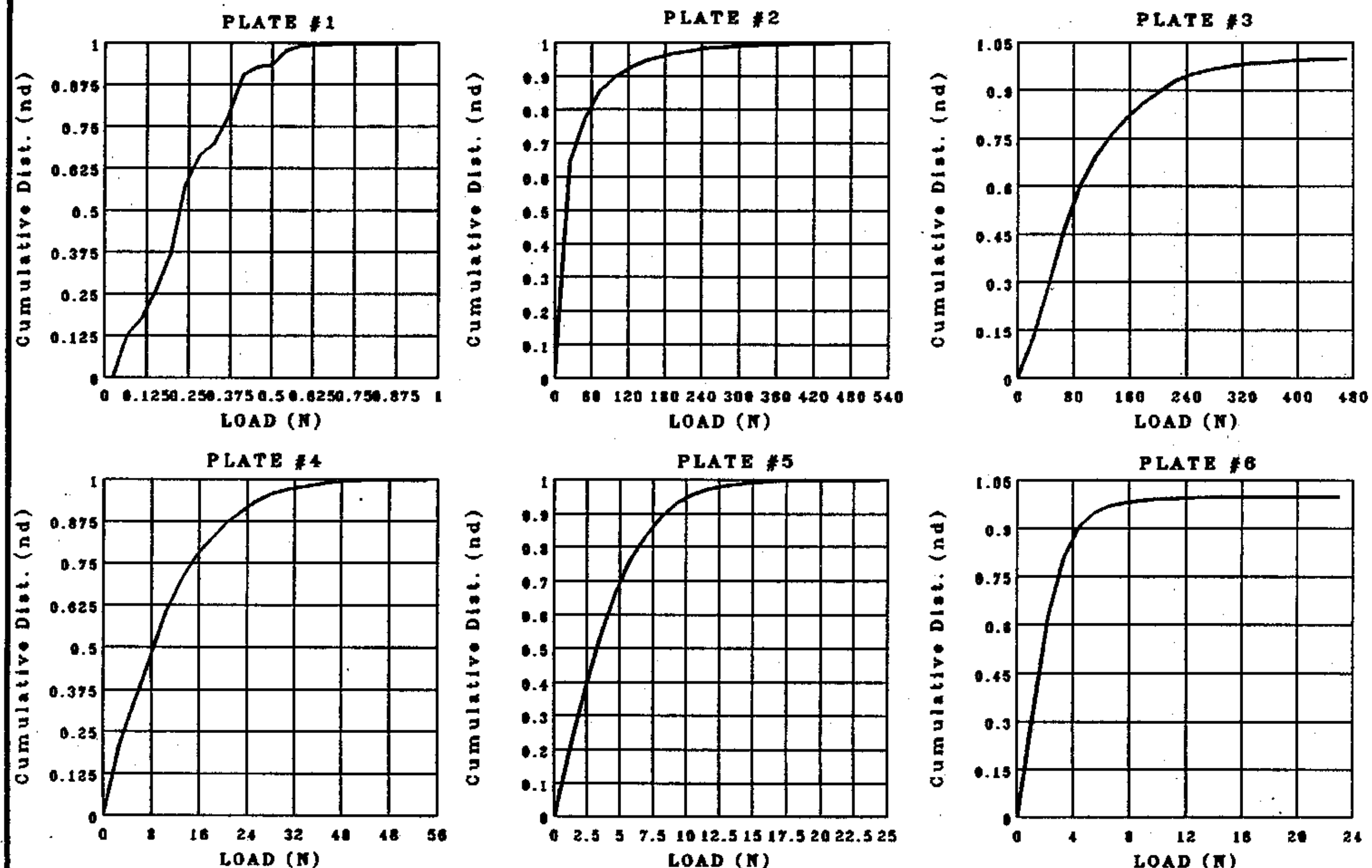
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN ← 013
RESULTANT



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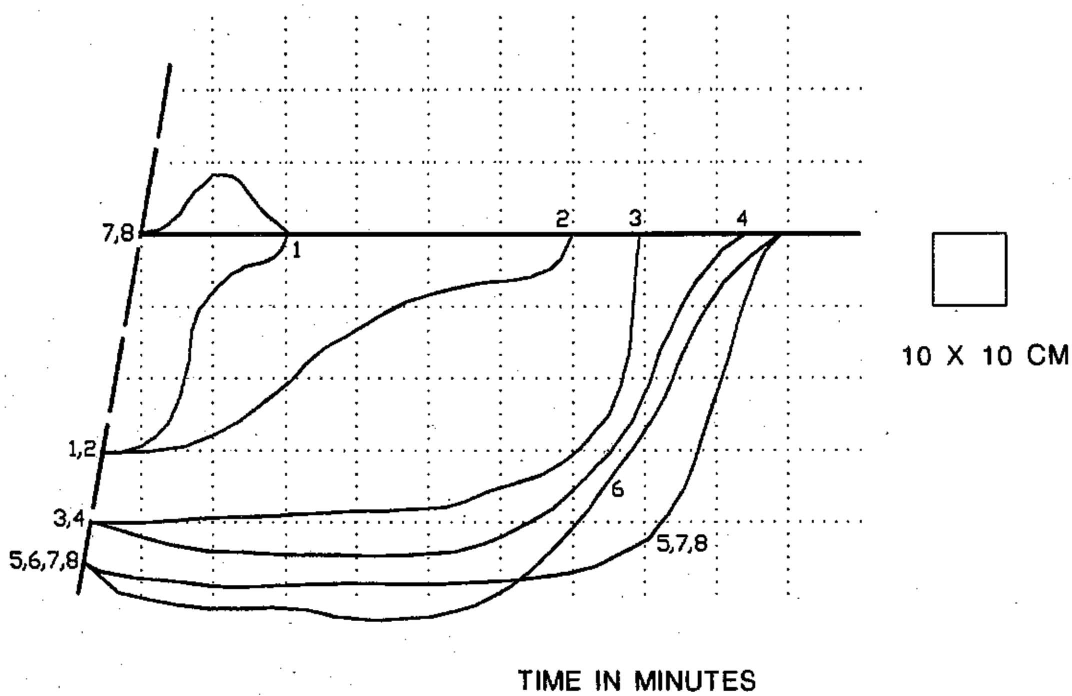
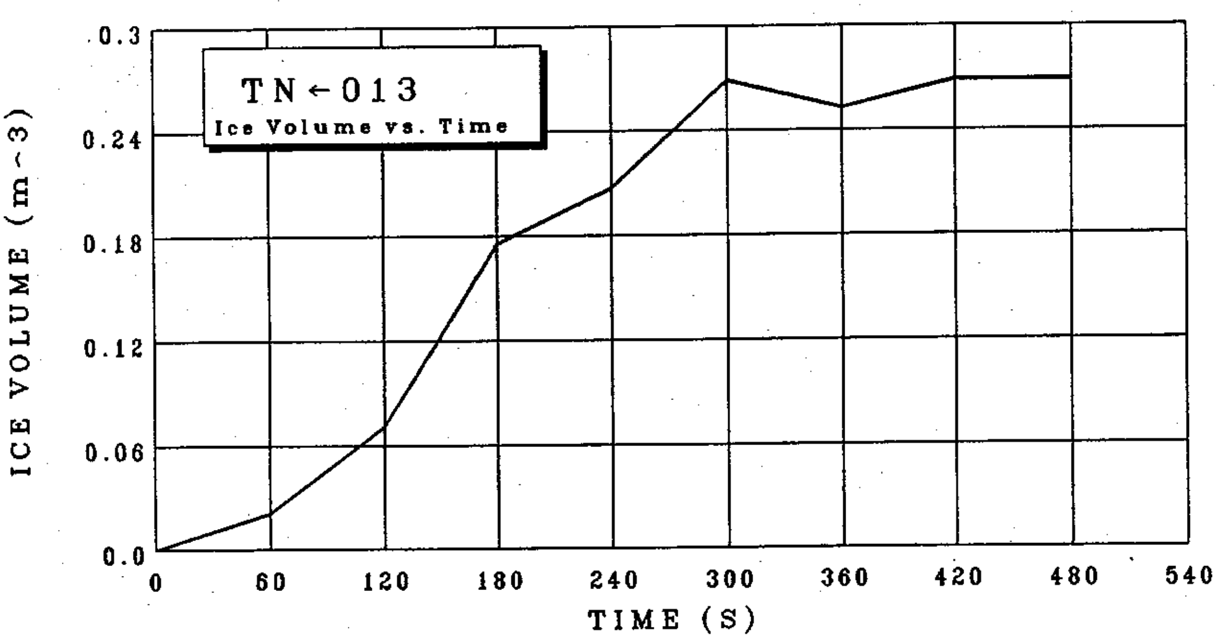
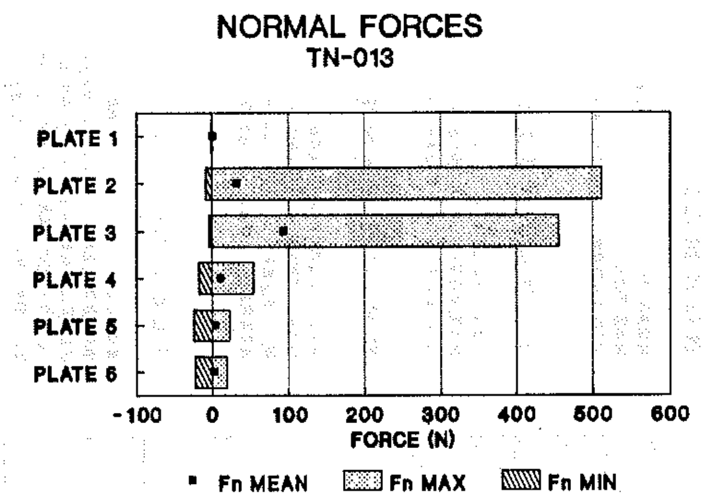
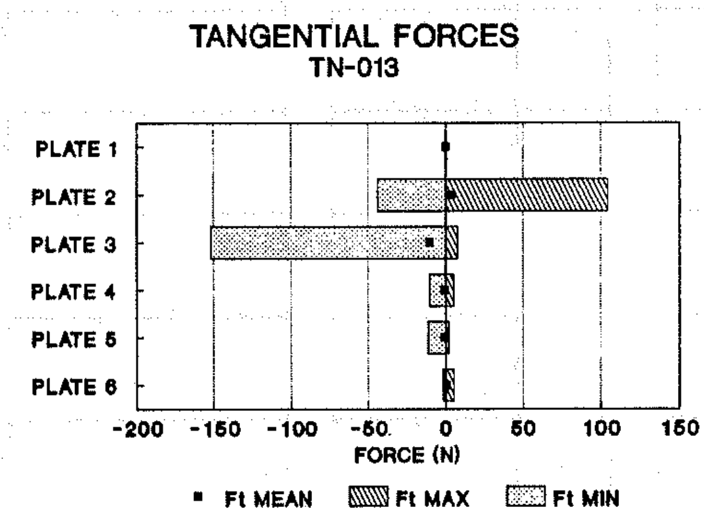
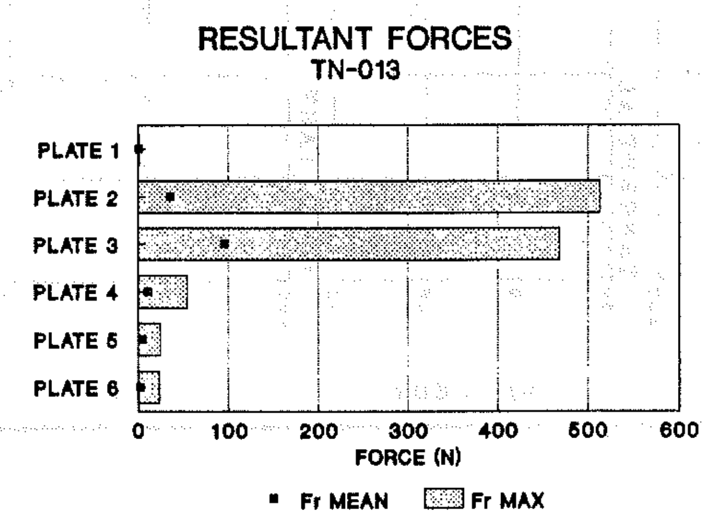
ICE PILEUP STUDY
for CANADIAN COAST GUARD

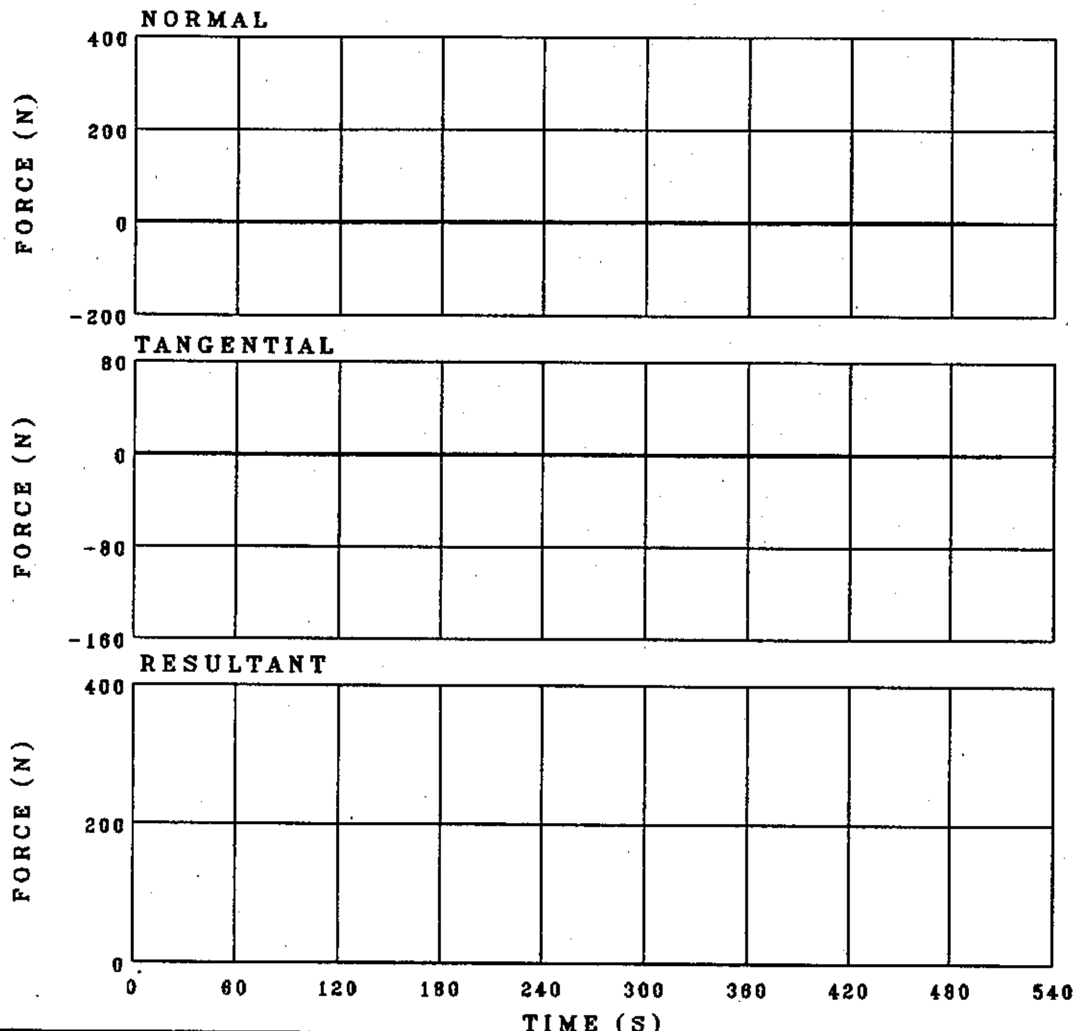

7,8
1
2
3
4
1,2
3,4
5,6,7,8
6
5,7,8
10 X 10 CM
TIME IN MINUTES


TN←013
Ice Volume vs. Time
ICE VOLUME (m^3)
0.3
0.24
0.18
0.12
0.06
0.0
0
60
120
180
240
300
360
420
480
540
TIME (S)


NORMAL FORCES
TN-013
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-100 0 100 200 300 400 500 600
FORCE (N)
Fn MEAN
Fn MAX
Fn MIN


TANGENTIAL FORCES
TN-013
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-200 -150 -100 -50 0 50 100 150
FORCE (N)
Ft MEAN
Ft MAX
Ft MIN


RESULTANT FORCES
TN-013
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
0 100 200 300 400 500 600
FORCE (N)
Fr MEAN
Fr MAX



FILE TN←014

PLATE #1

NORMAL

MEAN FORCE = -0.03458 N
MAX FORCE = 0.5404 N
MIN FORCE = -0.5386 N

TANGENTIAL

MEAN FORCE = 0.04872 N
MAX FORCE = 0.7969 N
MIN FORCE = -0.3195 N

RESULTANT

MEAN FORCE = 0.1666 N
MAX FORCE = 0.8159 N
MIN FORCE = 0.02904 N
AVERAGE ANGLE = 45.92 O

TEST CONDITIONS

BOARD ANGLE = -30.00 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 39.00 kPa
ICE THICKNESS = 3.400 cm
ICE DENSITY = 0.8900 g/cc

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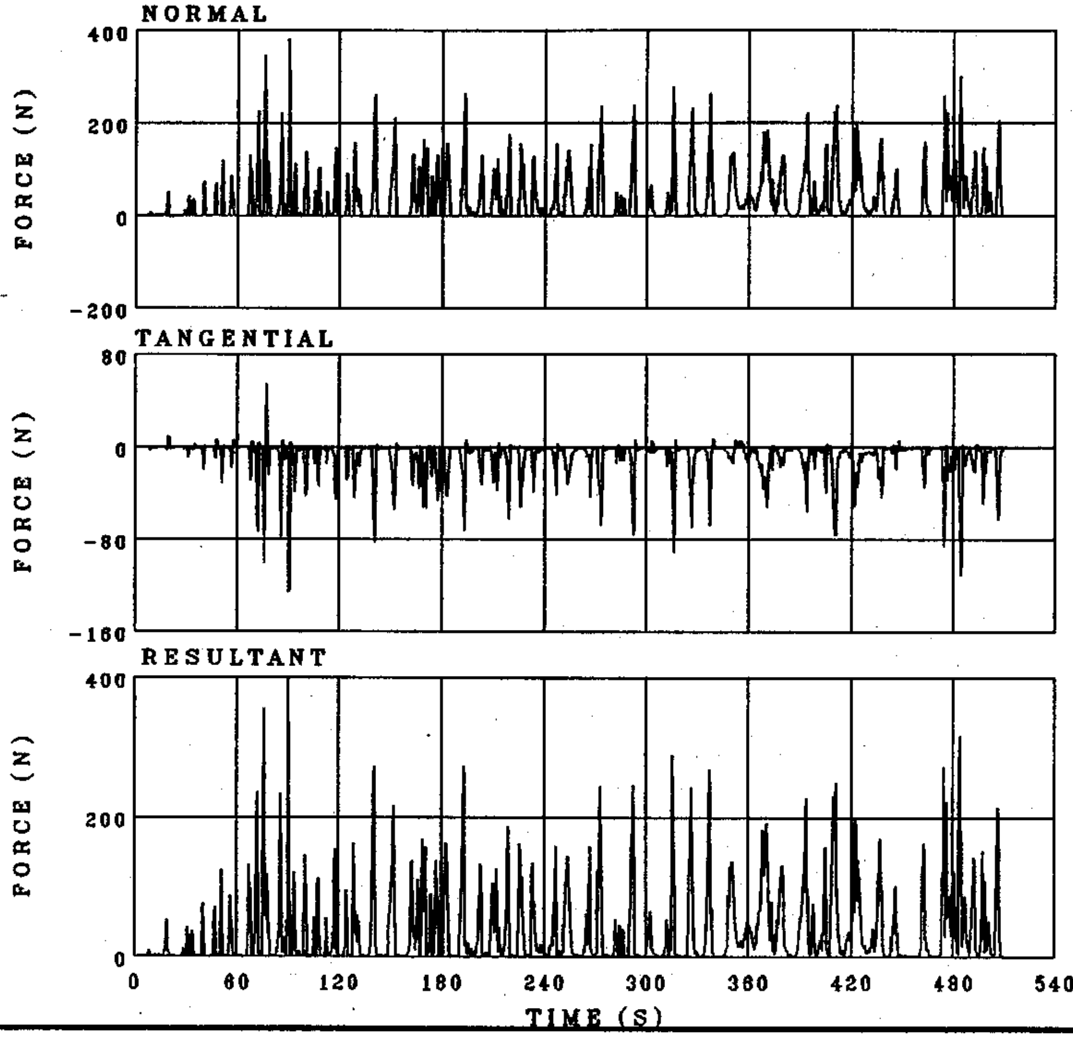
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←014

PLATE #2

NORMAL

MEAN FORCE = 33.15 N
MAX FORCE = 382.5 N
MIN FORCE = -3.210 N

TANGENTIAL

MEAN FORCE = -8.366 N
MAX FORCE = 54.66 N
MIN FORCE = -126.0 N

RESULTANT

MEAN FORCE = 35.31 N
MAX FORCE = 398.9 N
MIN FORCE = 0.05401 N
AVERAGE ANGLE = -42.78 O

TEST CONDITIONS

BOARD ANGLE = -30.00 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 39.00 kPa
ICE THICKNESS = 3.400 cm
ICE DENSITY = 0.8900 g/cc

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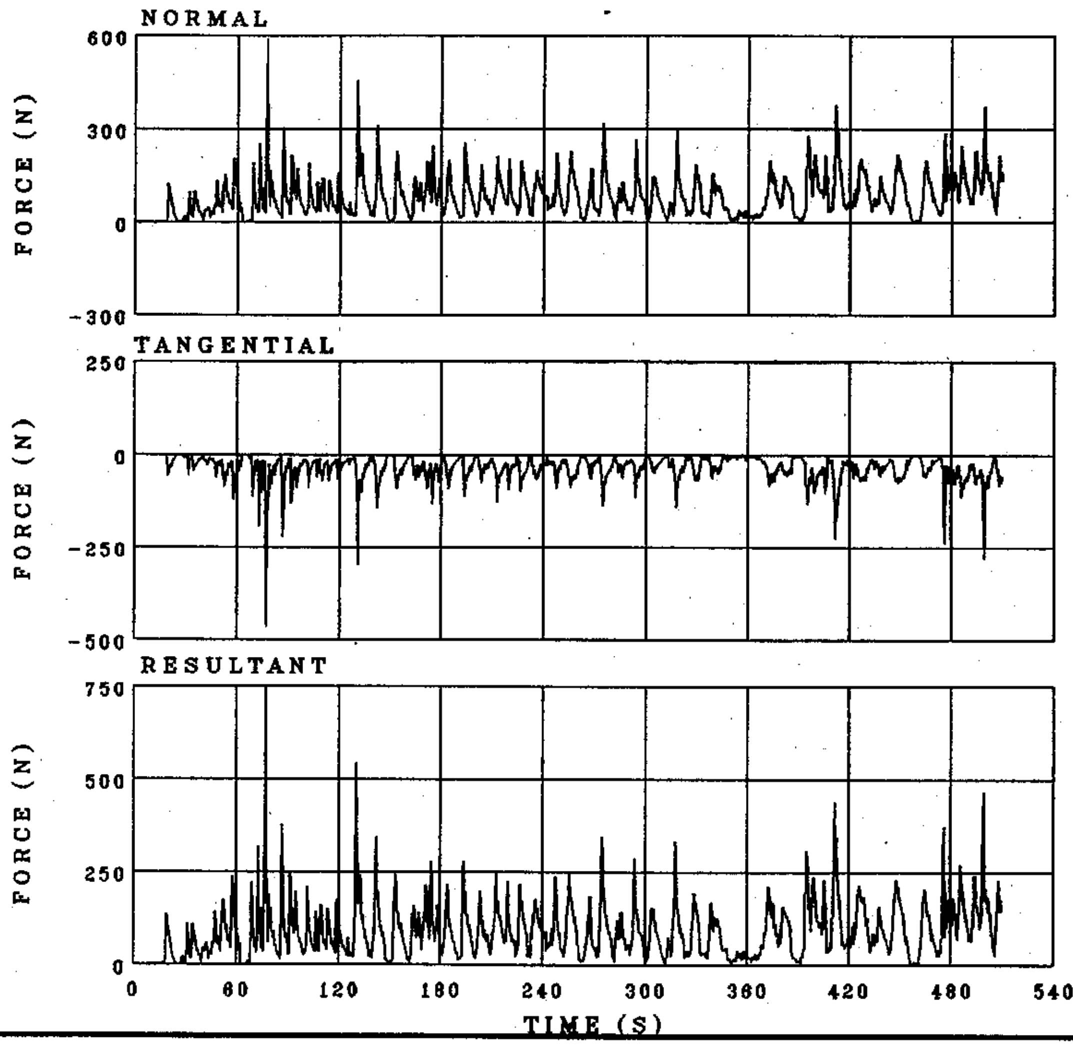
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←014

PLATE #3

NORMAL

MEAN FORCE = 79.34 N
MAX FORCE = 589.6 N
MIN FORCE = -2.892 N

TANGENTIAL

MEAN FORCE = -34.65 N
MAX FORCE = 2.555 N
MIN FORCE = -465.7 N

RESULTANT

MEAN FORCE = 86.92 N
MAX FORCE = 749.5 N
MIN FORCE = 0.05057 N
AVERAGE ANGLE = -20.85 O

TEST CONDITIONS

BOARD ANGLE = -30.00 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 39.00 kPa
ICE THICKNESS = 3.400 cm
ICE DENSITY = 0.8900 g/cc

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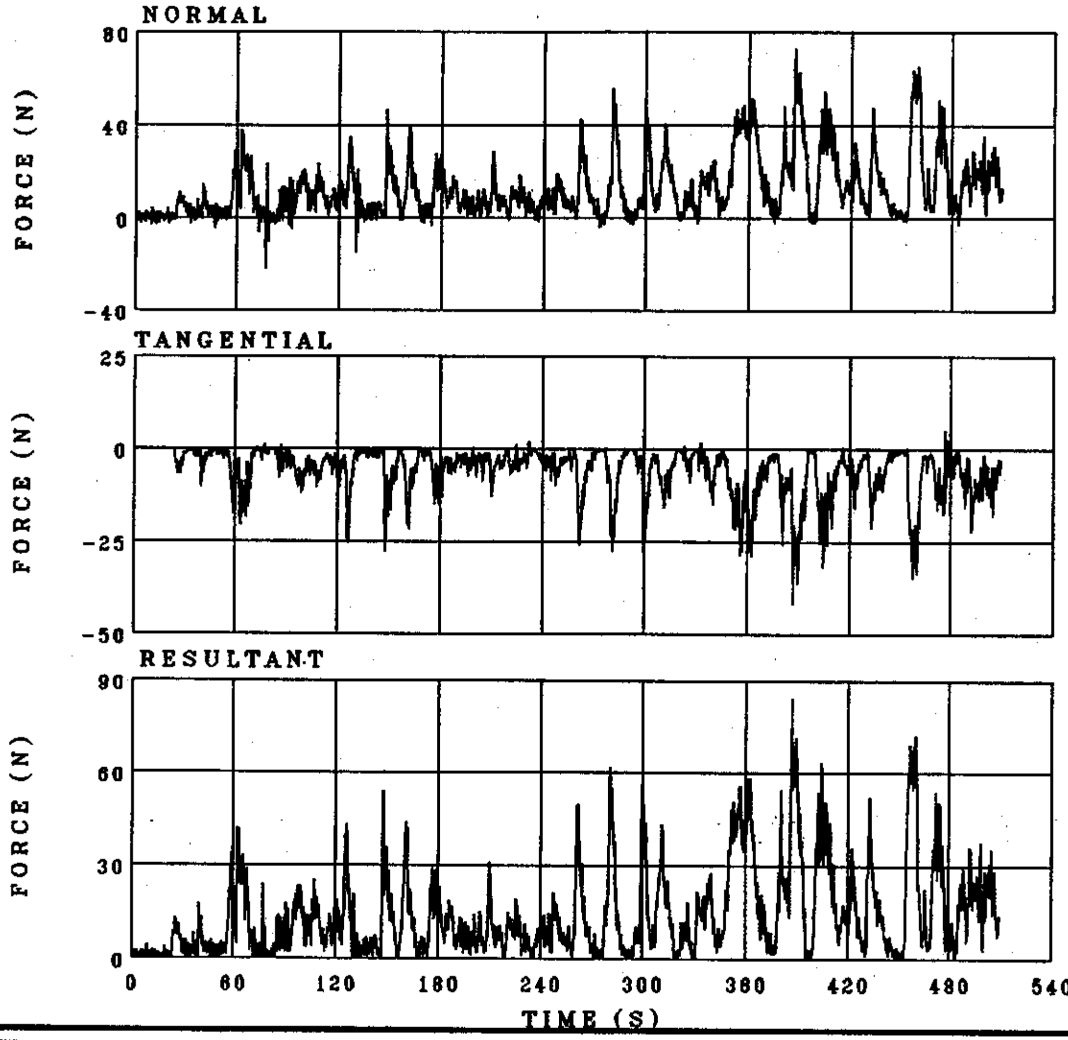
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←014

PLATE #4

NORMAL

MEAN FORCE = 12.57 N
MAX FORCE = 73.25 N
MIN FORCE = -22.45 N

TANGENTIAL

MEAN FORCE = -5.816 N
MAX FORCE = 5.152 N
MIN FORCE = -41.81 N

RESULTANT

MEAN FORCE = 14.09 N
MAX FORCE = 84.33 N
MIN FORCE = 0.07202 N
AVERAGE ANGLE = -28.40 O

TEST CONDITIONS

BOARD ANGLE = -30.00 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 39.00 kPa
ICE THICKNESS = 3.400 cm
ICE DENSITY = 0.8900 g/cc

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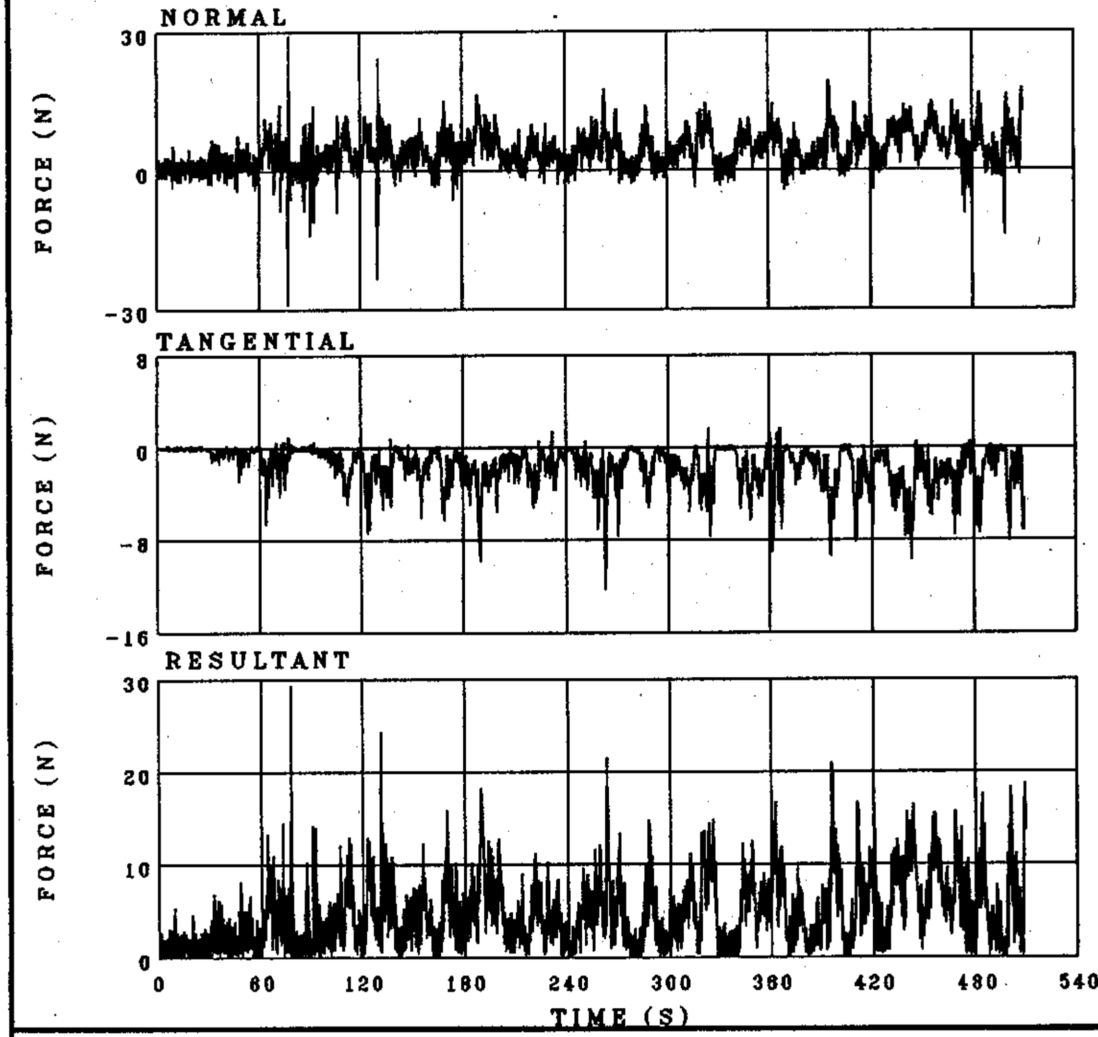
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←014

PLATE #5

NORMAL

MEAN FORCE = 3.903 N
MAX FORCE = 29.41 N
MIN FORCE = −28.99 N

TANGENTIAL

MEAN FORCE = −1.639 N
MAX FORCE = 1.674 N
MIN FORCE = −12.26 N

RESULTANT

MEAN FORCE = 4.583 N
MAX FORCE = 29.41 N
MIN FORCE = 0.01033 N
AVERAGE ANGLE = −22.59 O

TEST CONDITIONS

BOARD ANGLE = −30.00 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 39.00 kPa
ICE THICKNESS = 3.400 cm
ICE DENSITY = 0.8900 g/cc

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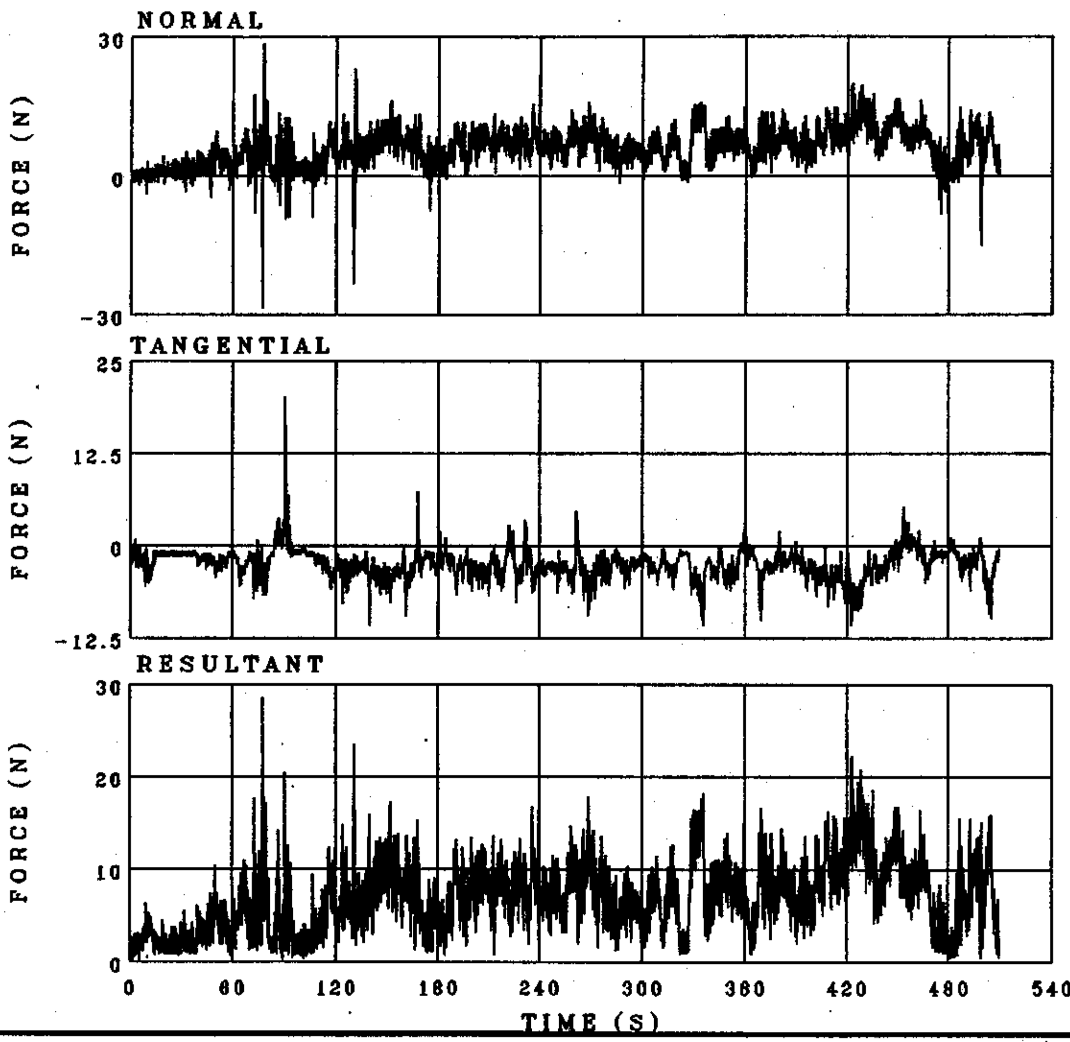
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←014

PLATE #6

NORMAL

MEAN FORCE = 5.854 N
MAX FORCE = 28.65 N
MIN FORCE = -28.63 N

TANGENTIAL

MEAN FORCE = -2.524 N
MAX FORCE = 20.16 N
MIN FORCE = -10.91 N

RESULTANT

MEAN FORCE = 6.697 N
MAX FORCE = 28.66 N
MIN FORCE = 0.1043 N
AVERAGE ANGLE = -29.87 O

TEST CONDITIONS

BOARD ANGLE = -30.00 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 39.00 kPa
ICE THICKNESS = 3.400 cm
ICE DENSITY = 0.8900 g/cc

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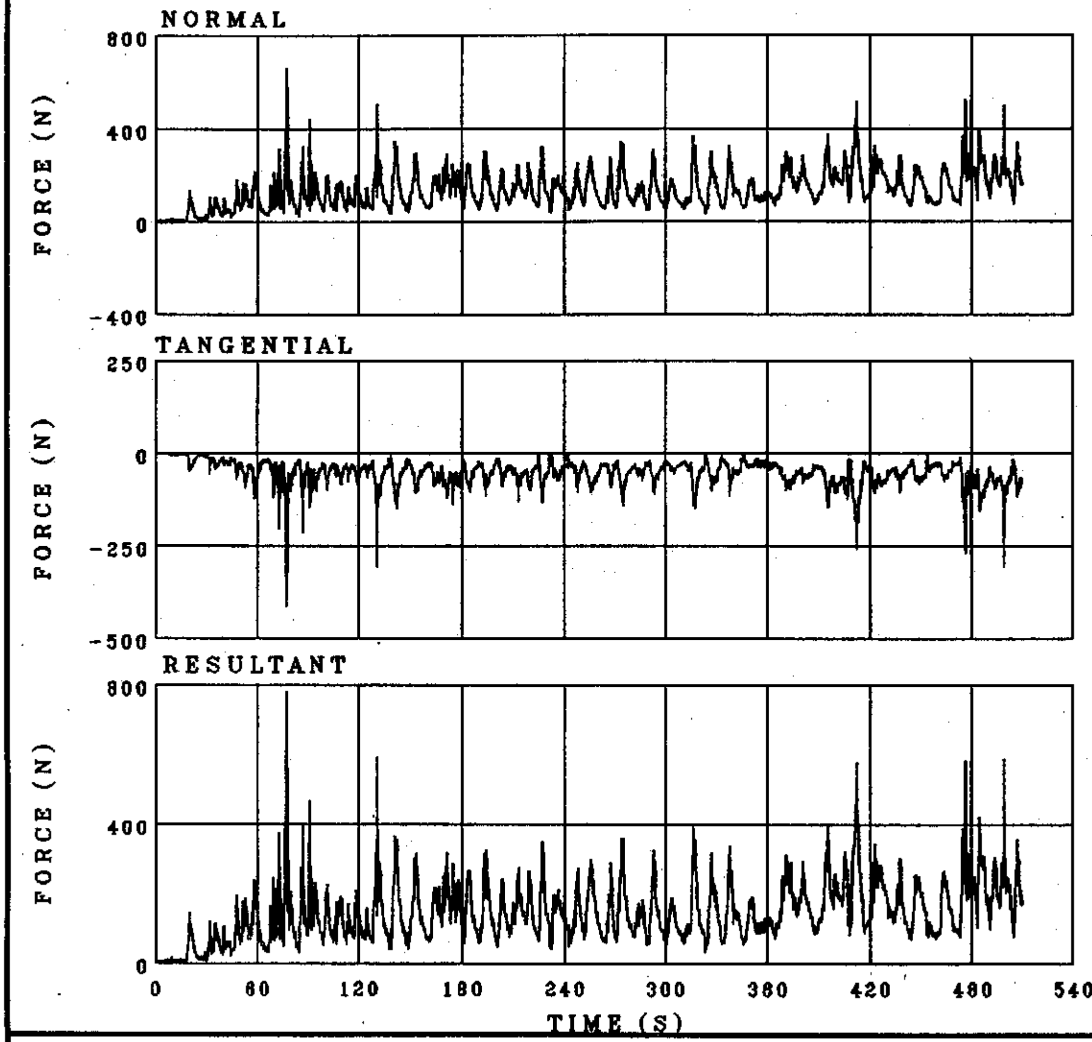
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←014

TOTAL

NORMAL

MEAN FORCE = 134.8 N
MAX FORCE = 663.5 N
MIN FORCE = -11.00 N

TANGENTIAL

MEAN FORCE = -52.95 N
MAX FORCE = 1.735 N
MIN FORCE = -414.0 N

RESULTANT

MEAN FORCE = 145.4 N
MAX FORCE = 781.8 N
MIN FORCE = 0.2788 N
AVERAGE ANGLE = -22.84 O

TEST CONDITIONS

BOARD ANGLE = -30.00 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 39.00 kPa
ICE THICKNESS = 3.400 cm
ICE DENSITY = 0.8900 g/cc

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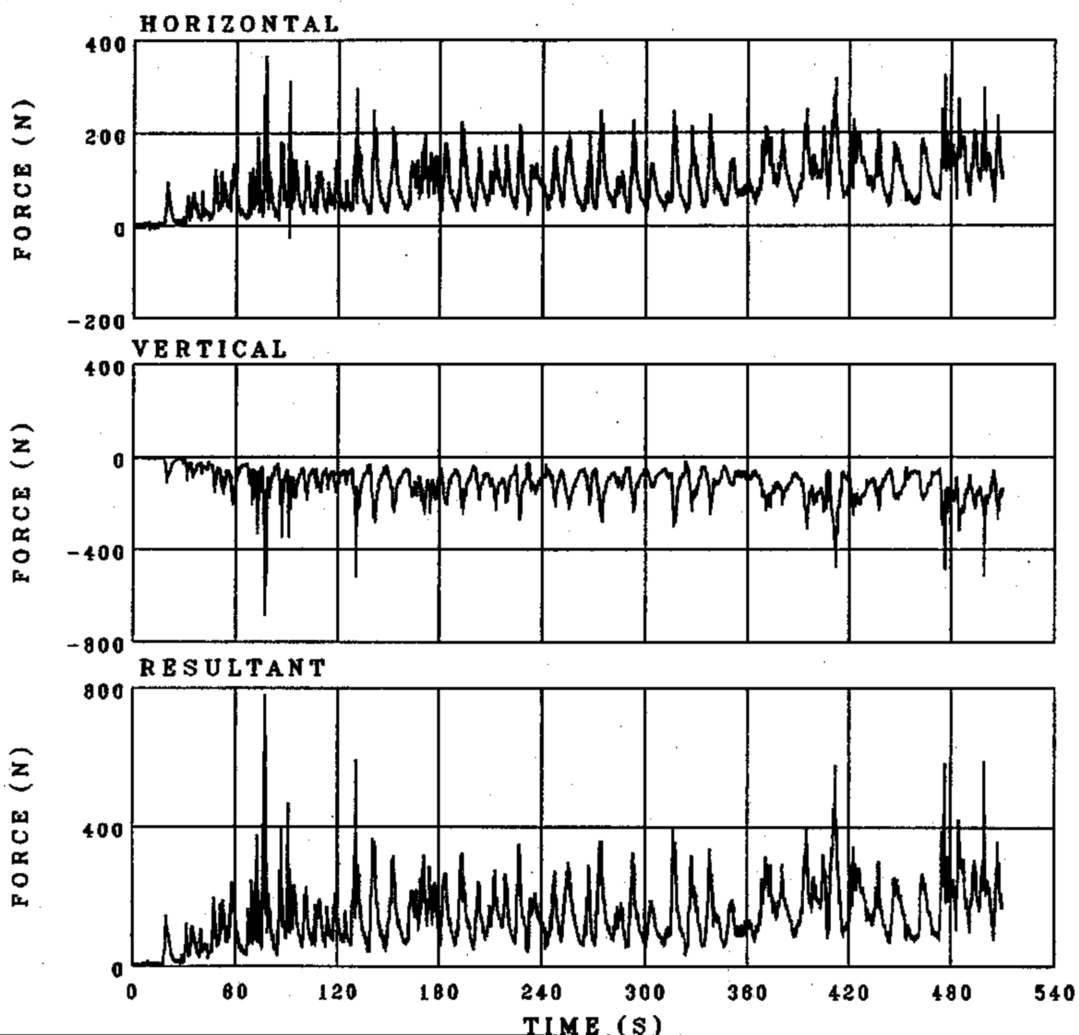
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←014

TOTAL

HORIZONTAL

MEAN FORCE = −52.95 N
MAX FORCE = 1.735 N
MIN FORCE = −414.0 N

VERTICAL

MEAN FORCE = −52.95 N
MAX FORCE = 1.735 N
MIN FORCE = −414.0 N

RESULTANT

MEAN FORCE = −52.95 N
MAX FORCE = 1.735 N
MIN FORCE = −414.0 N
AVERAGE ANGLE = −52.95 0

TEST CONDITIONS

BOARD ANGLE = −30.00 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 39.00 kPa
ICE THICKNESS = 3.400 cm
ICE DENSITY = 0.8900 g/cc

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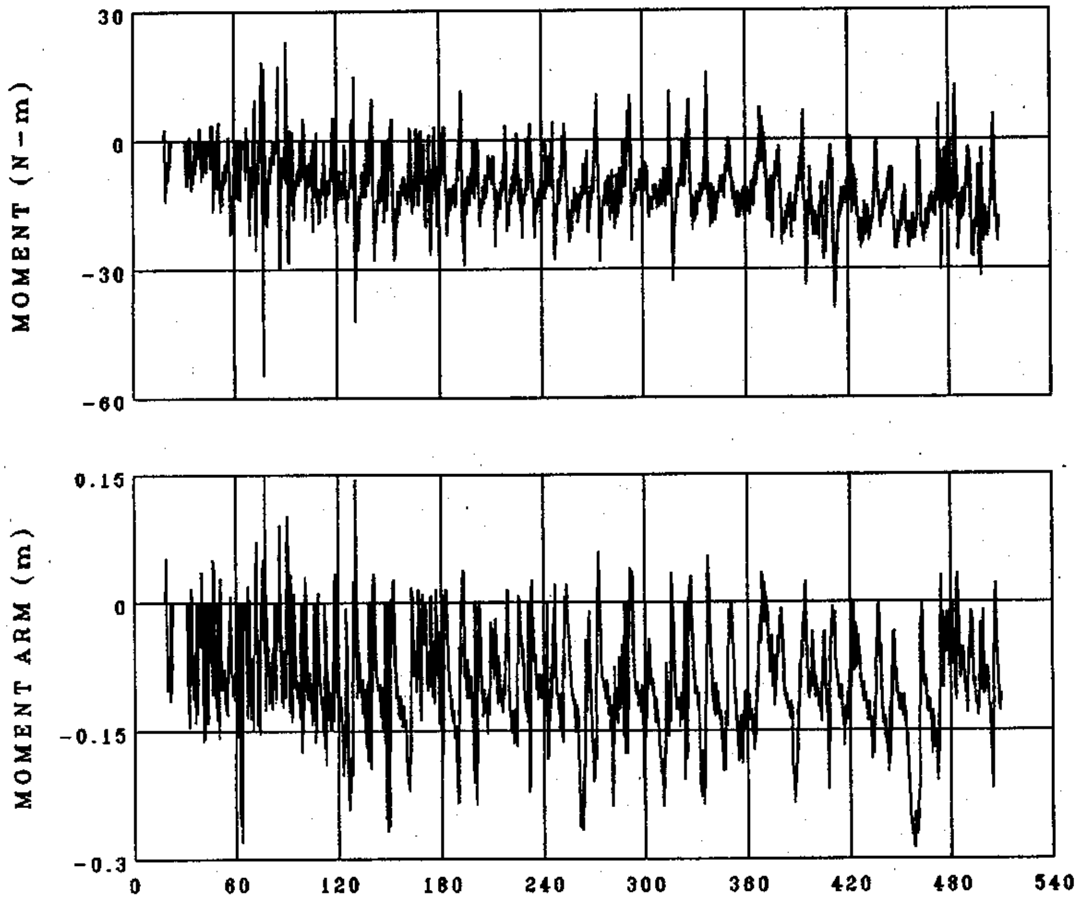
ICE PILEUP STUDY
for CANADIAN COAST GUARD

FILE TN←014



MOMENT

MOMENT

MEAN MOMENT = -10.54 N-m
MAX MOMENT = 23.22 N-m
MIN MOMENT = -66.03 N-m

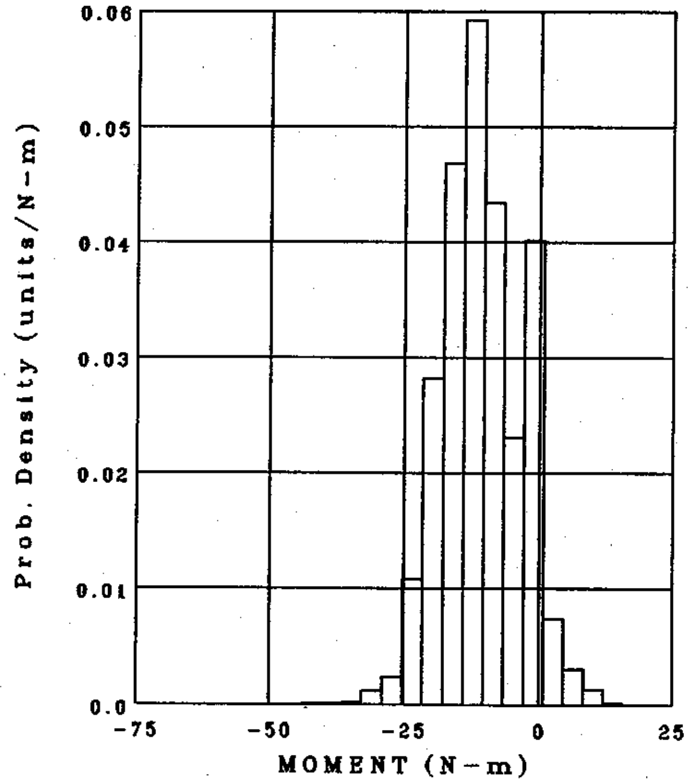
MOMENT ARM

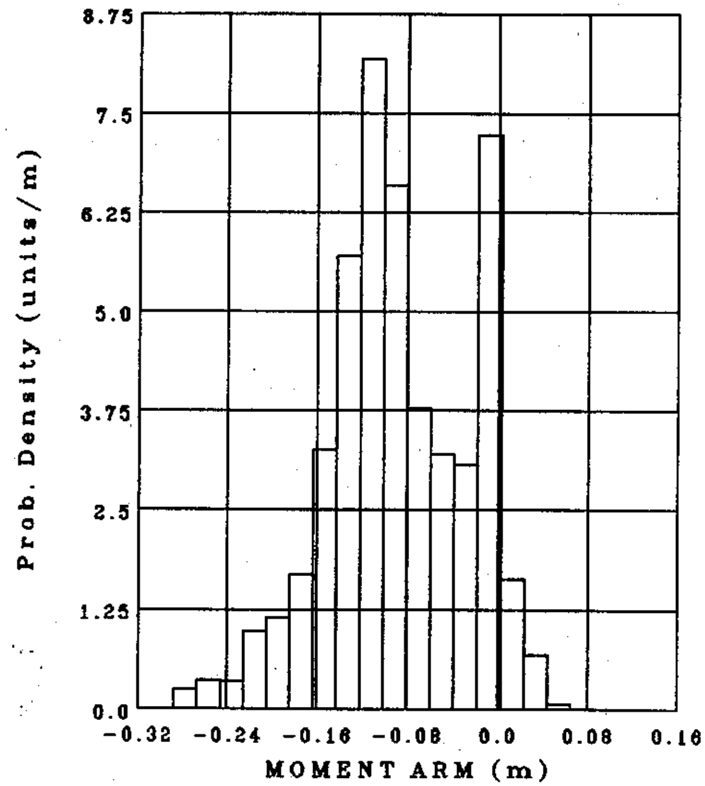
MEAN ARM = -0.08741 m
MAX ARM = 0.1479 m
MIN ARM = -0.2878 m

TEST CONDITIONS

BOARD ANGLE = -30.00 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 39.00 kPa
ICE THICKNESS = 3.400 cm
ICE DENSITY = 0.8900 g/cc

TN←014





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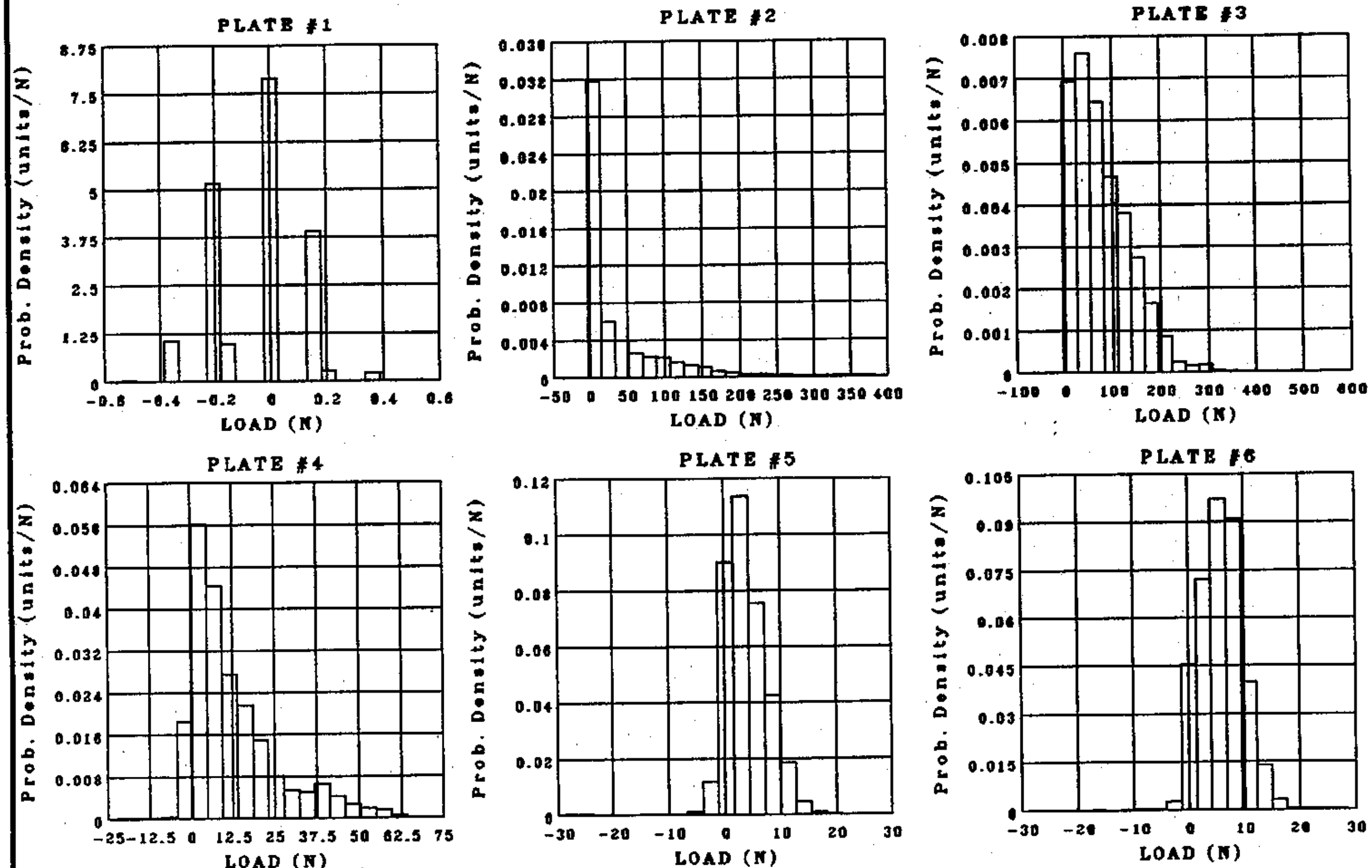
ICE PILEUP STUDY for CANADIAN COAST GUARD

TN←014
NORMAL LOAD



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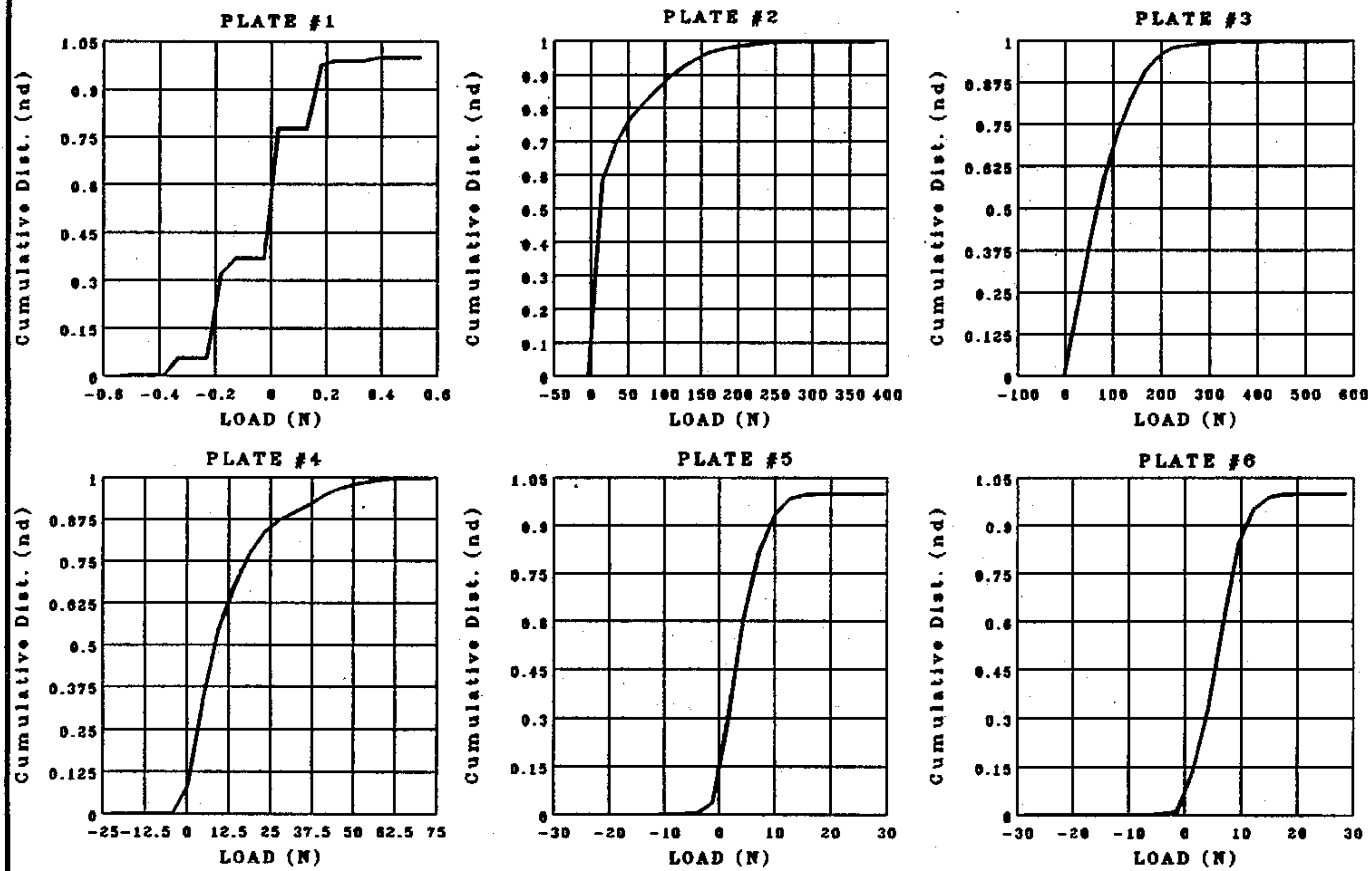
ICE PILEUP STUDY for CANADIAN COAST GUARD

TN←014
NORMAL LOAD



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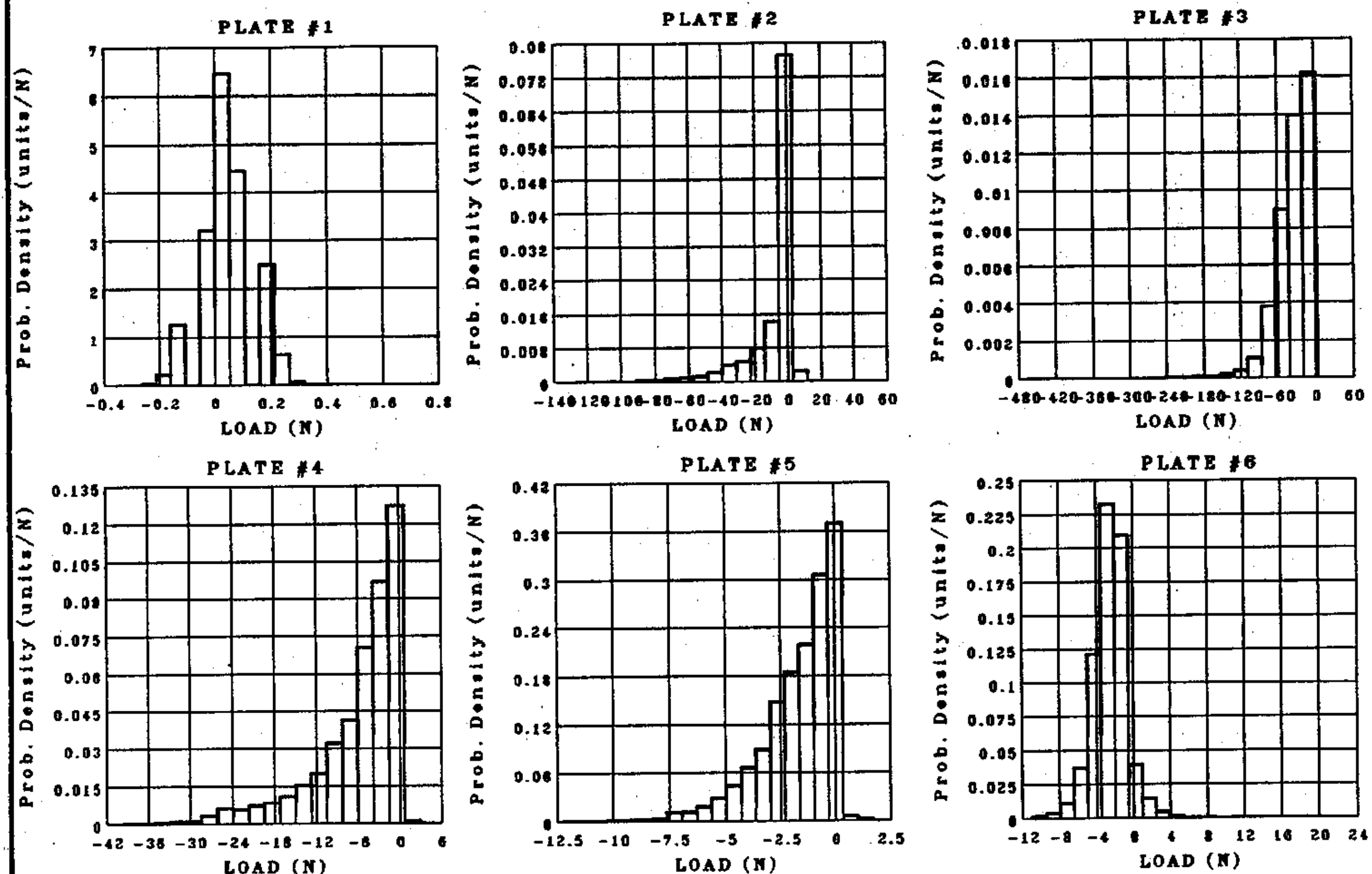
TN←014
TANGENTIAL LOAD



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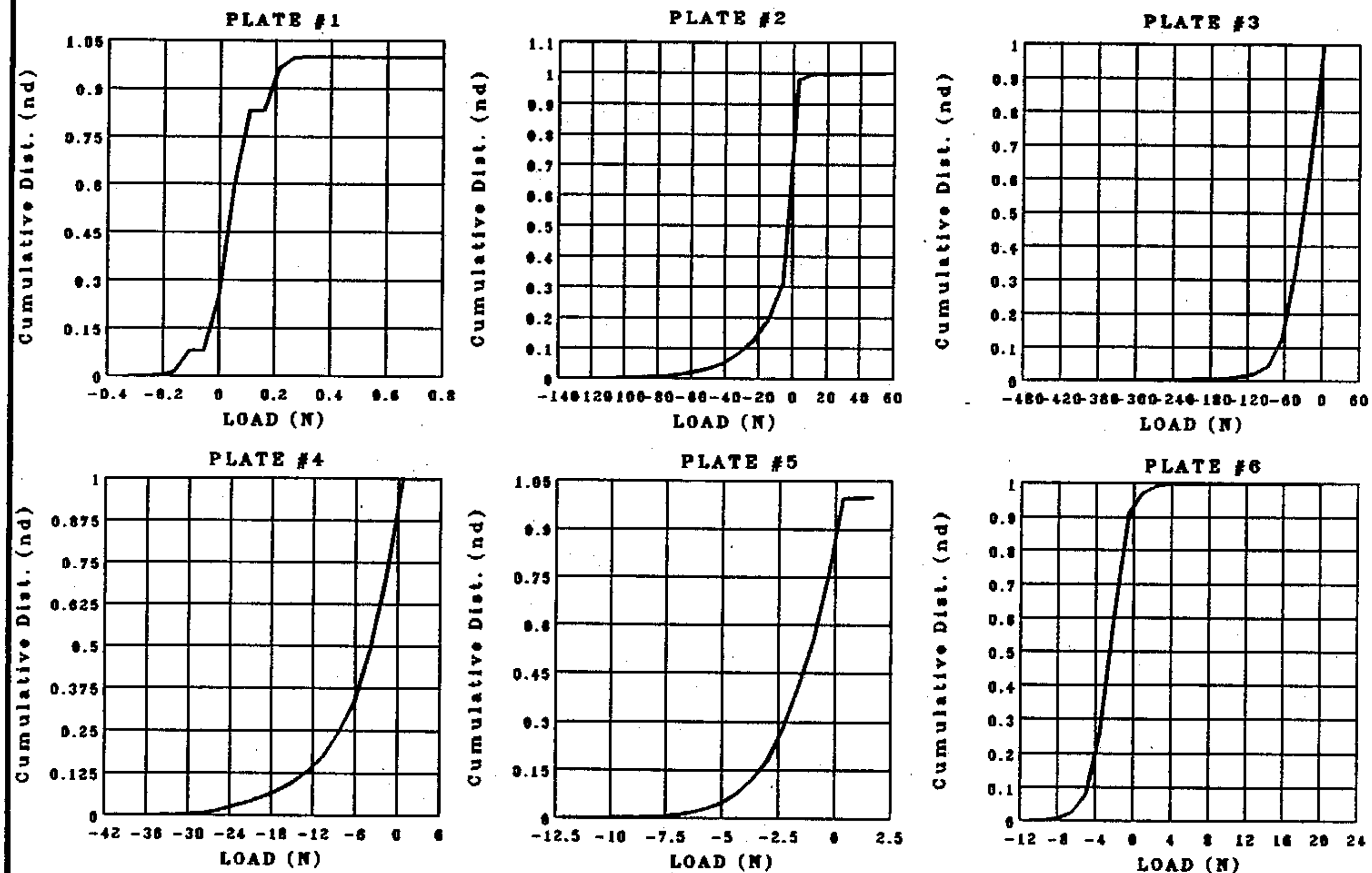
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN ← 014
TANGENTIAL LOAD



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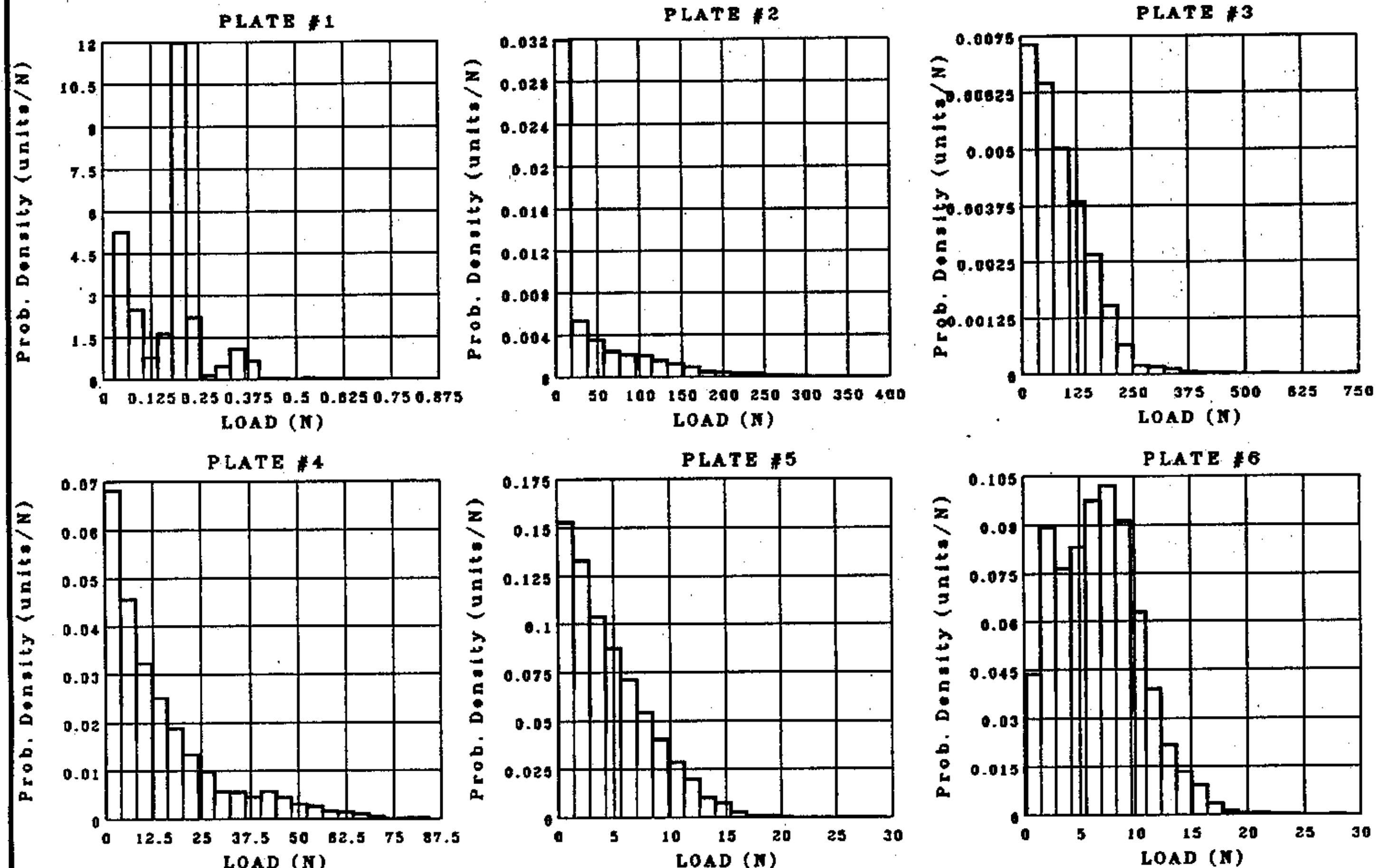
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←014
RESULTANT



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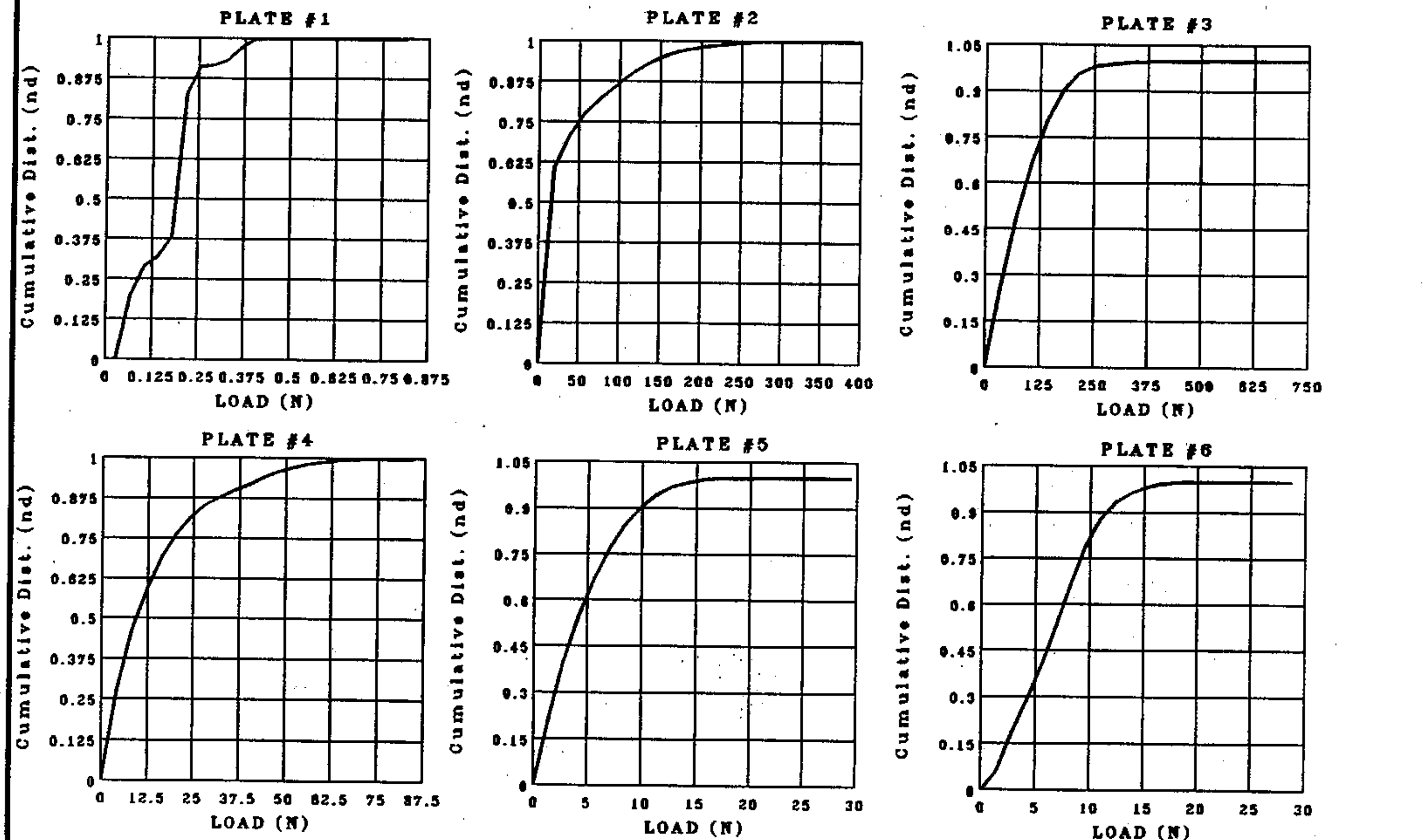
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN ← 014
RESULTANT



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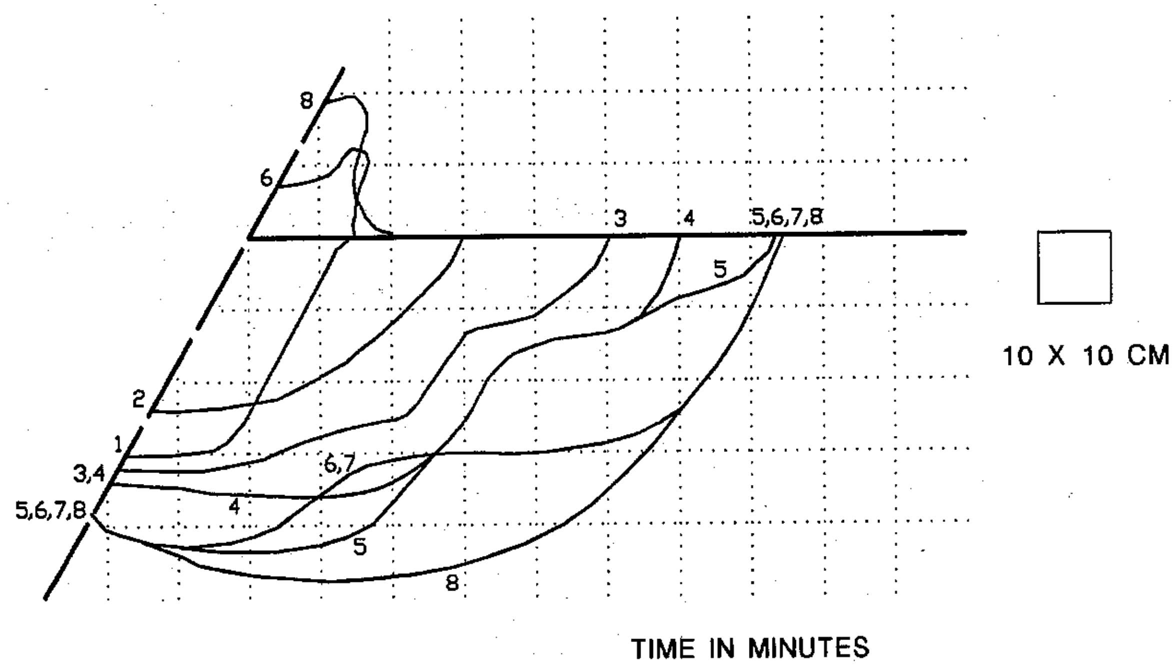
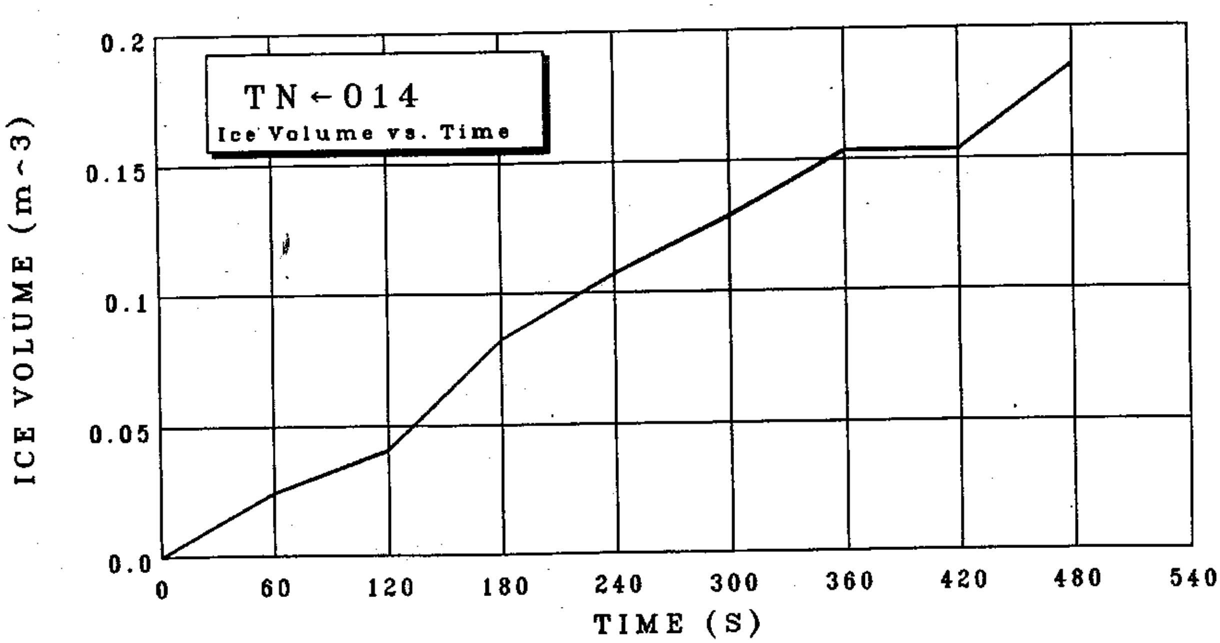
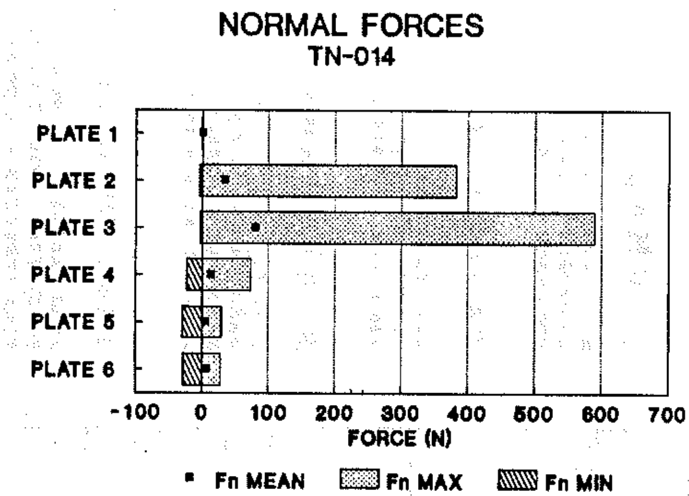
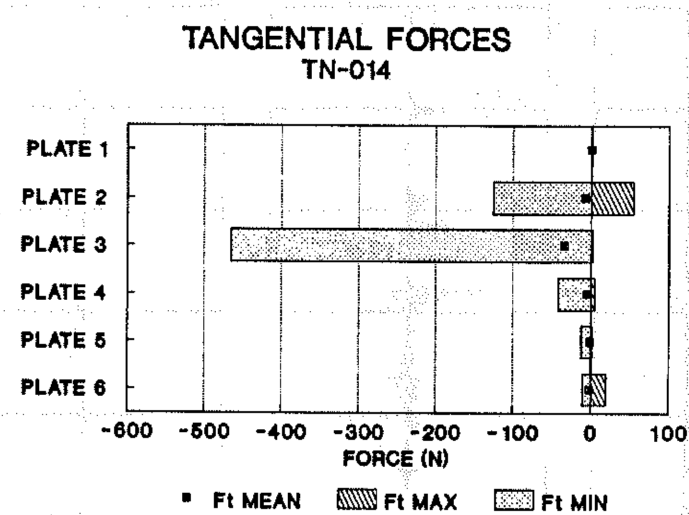
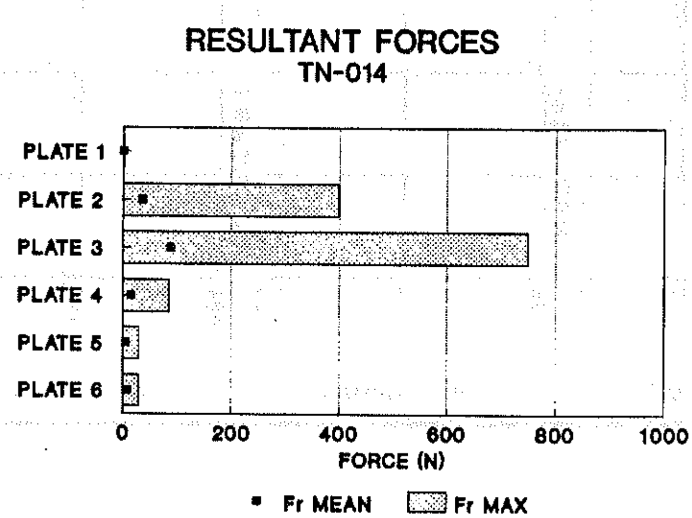
ICE PILEUP STUDY
for CANADIAN COAST GUARD

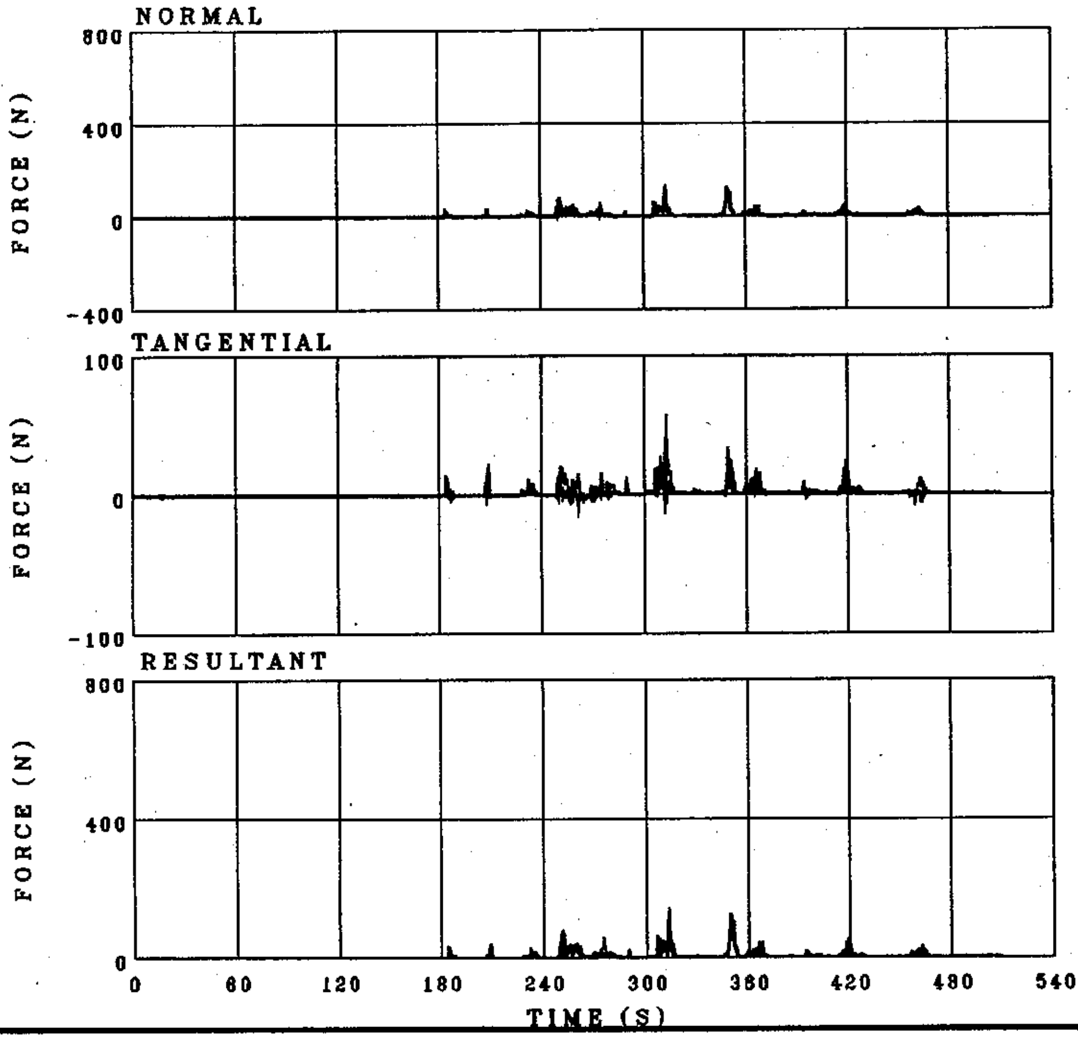

8
6
3
4
5,6,7,8
5
2
1
3,4
5,6,7,8
6,7
4
5
8
10 X 10 CM
TIME IN MINUTES


TN←014
Ice Volume vs. Time
ICE VOLUME (m^3)
0.2
0.15
0.1
0.05
0.0
0
60
120
180
240
300
360
420
480
540
TIME (S)


NORMAL FORCES
TN-014
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-100 0 100 200 300 400 500 600 700
FORCE (N)
Fn MEAN
Fn MAX
Fn MIN


TANGENTIAL FORCES
TN-014
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-600 -500 -400 -300 -200 -100 0 100
FORCE (N)
Ft MEAN
Ft MAX
Ft MIN


RESULTANT FORCES
TN-014
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
0 200 400 600 800 1000
FORCE (N)
Fr MEAN
Fr MAX



FILE TN←015

PLATE #1

NORMAL

MEAN FORCE = 3.076 N
MAX FORCE = 116.3 N
MIN FORCE = -1.514 N

TANGENTIAL

MEAN FORCE = 1.186 N
MAX FORCE = 40.47 N
MIN FORCE = -5.979 N

RESULTANT

MEAN FORCE = 3.830 N
MAX FORCE = 118.8 N
MIN FORCE = 0.06452 N
AVERAGE ANGLE = 16.30 O

TEST CONDITIONS

BOARD ANGLE = -12.00 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 35.00 kPa
ICE THICKNESS = 3.400 cm
ICE DENSITY = 0.8900 g/cc

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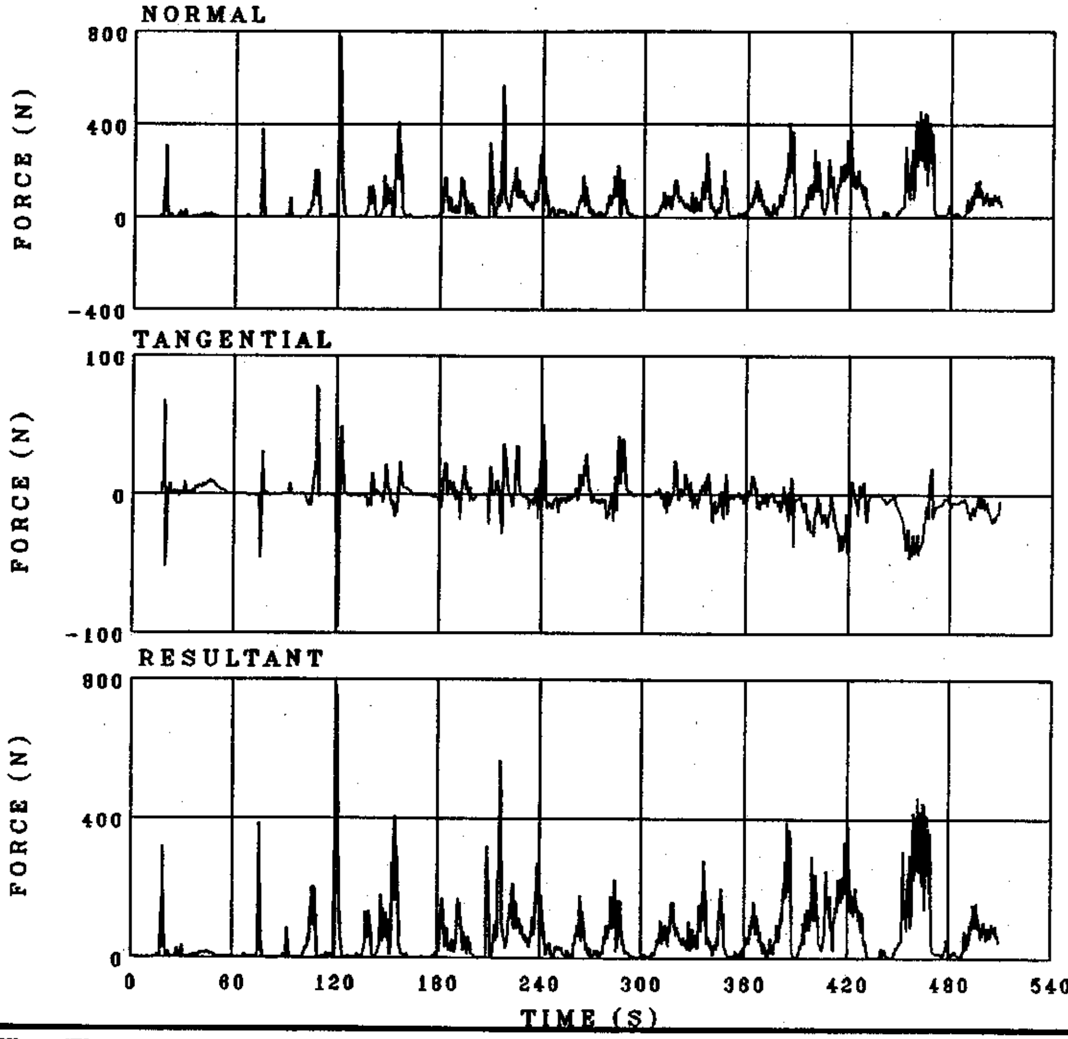
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←015

PLATE #2

NORMAL

MEAN FORCE = 59.55 N
MAX FORCE = 777.1 N
MIN FORCE = −1.757 N

TANGENTIAL

MEAN FORCE = −2.422 N
MAX FORCE = 78.11 N
MIN FORCE = −96.22 N

RESULTANT

MEAN FORCE = 60.87 N
MAX FORCE = 783.0 N
MIN FORCE = 0.01143 N
AVERAGE ANGLE = −6.704 D

TEST CONDITIONS

BOARD ANGLE = −12.00 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 35.00 kPa
ICE THICKNESS = 3.400 cm
ICE DENSITY = 0.8900 g/cc

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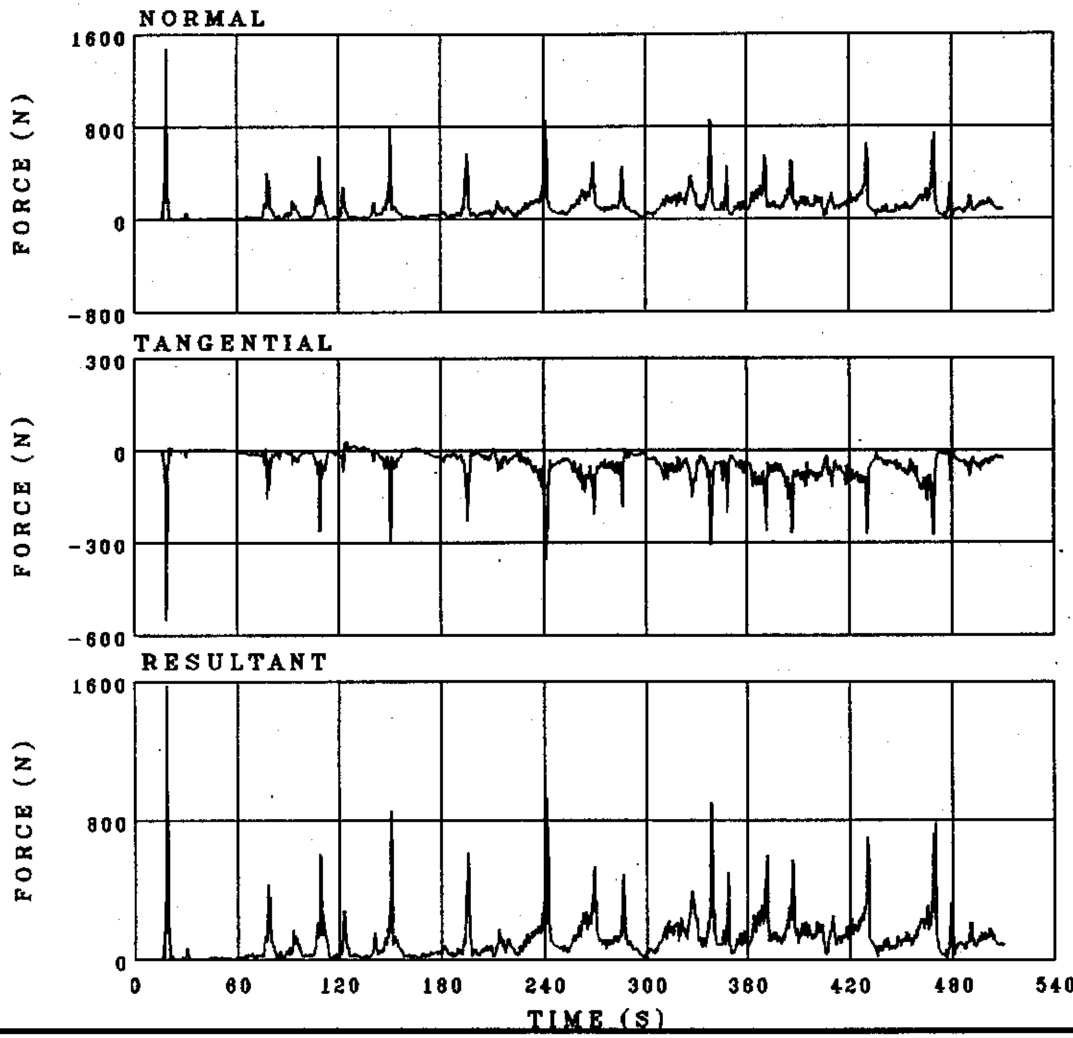
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←015

PLATE #3

NORMAL

MEAN FORCE = 106.9 N
MAX FORCE = 1481.0 N
MIN FORCE = -4.964 N

TANGENTIAL

MEAN FORCE = -43.61 N
MAX FORCE = 30.31 N
MIN FORCE = -552.5 N

RESULTANT

MEAN FORCE = 111.2 N
MAX FORCE = 1581.0 N
MIN FORCE = 0.02549 N
AVERAGE ANGLE = -17.74 O

TEST CONDITIONS

BOARD ANGLE = -12.00 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 35.00 kPa
ICE THICKNESS = 3.400 cm
ICE DENSITY = 0.8900 g/cc

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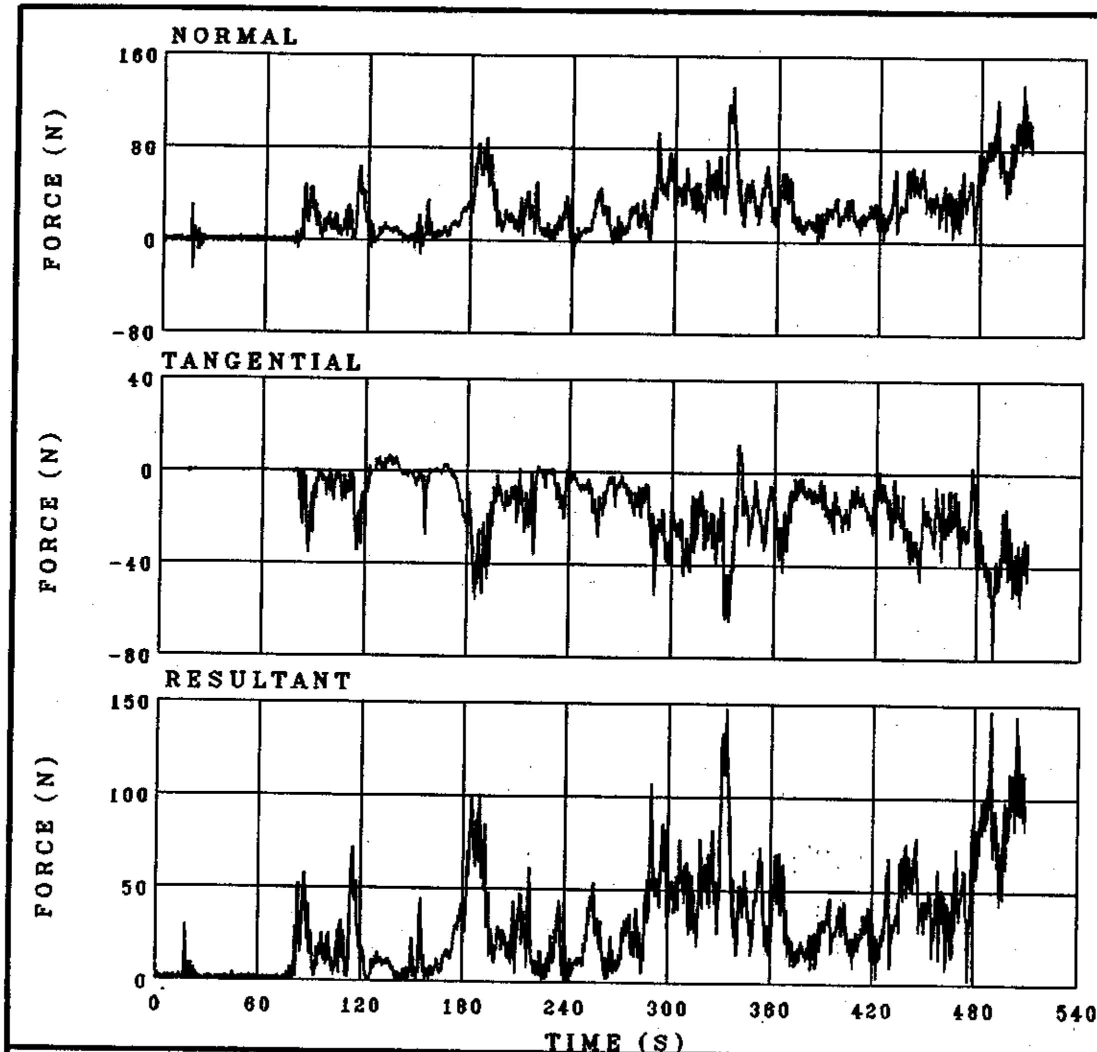
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←015

PLATE #4

NORMAL

MEAN FORCE = 25.69 N
MAX FORCE = 136.7 N
MIN FORCE = -26.52 N

TANGENTIAL

MEAN FORCE = -13.67 N
MAX FORCE = 12.61 N
MIN FORCE = -79.77 N

RESULTANT

MEAN FORCE = 29.72 N
MAX FORCE = 147.7 N
MIN FORCE = 0.005010 N
AVERAGE ANGLE = -22.69 O

TEST CONDITIONS

BOARD ANGLE = -12.00 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 35.00 kPa
ICE THICKNESS = 3.400 cm
ICE DENSITY = 0.8900 g/cc

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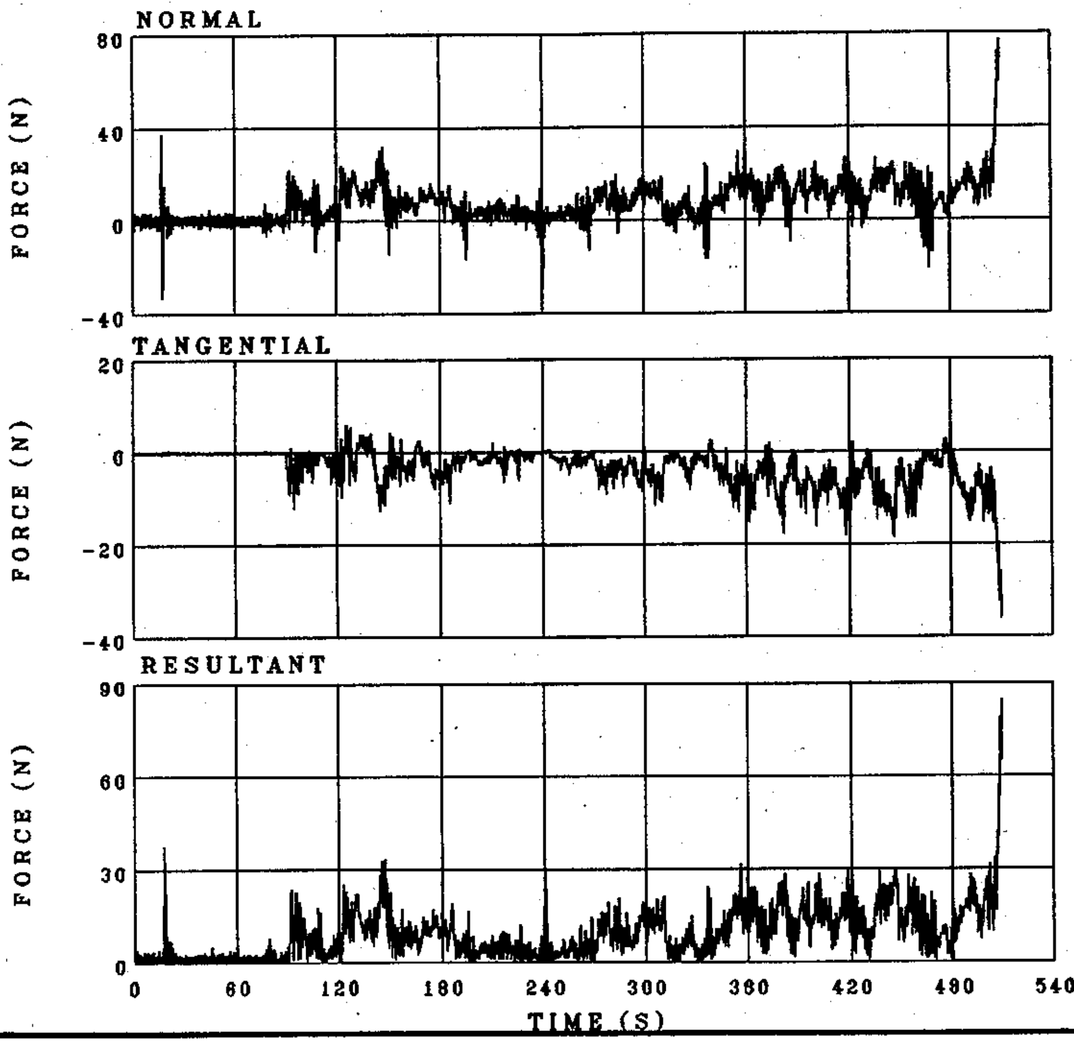
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←015

PLATE #5

NORMAL

MEAN FORCE = 7.494 N
MAX FORCE = 77.19 N
MIN FORCE = -32.97 N

TANGENTIAL

MEAN FORCE = -3.498 N
MAX FORCE = 5.914 N
MIN FORCE = -36.26 N

RESULTANT

MEAN FORCE = 8.972 N
MAX FORCE = 84.79 N
MIN FORCE = 0.01998 N
AVERAGE ANGLE = -22.11 0

TEST CONDITIONS

BOARD ANGLE = -12.00 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 35.00 kPa
ICE THICKNESS = 3.400 cm
ICE DENSITY = 0.8900 g/cc

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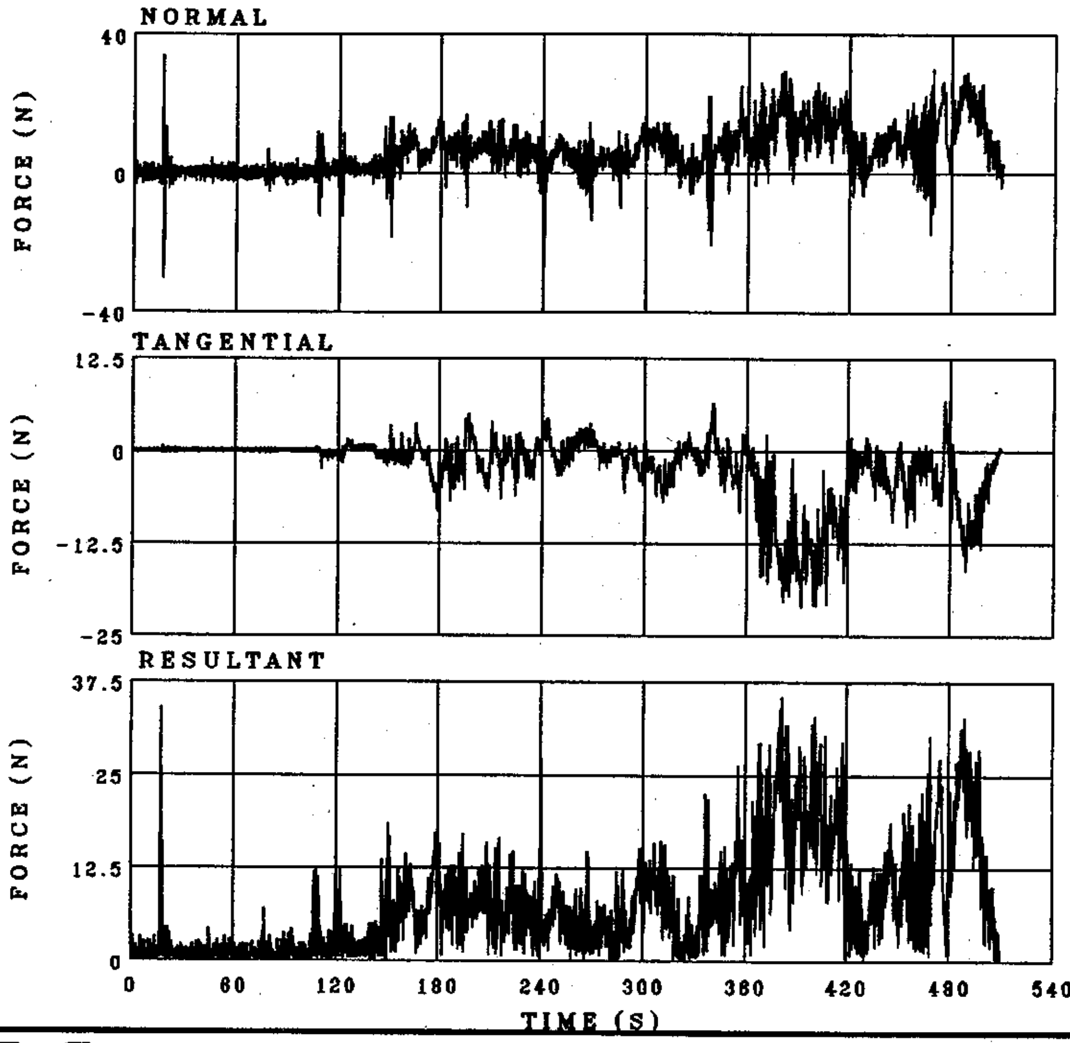
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←015

PLATE #6

NORMAL

MEAN FORCE = 5.964 N
MAX FORCE = 34.06 N
MIN FORCE = -30.46 N

TANGENTIAL

MEAN FORCE = -2.293 N
MAX FORCE = 6.914 N
MIN FORCE = -21.13 N

RESULTANT

MEAN FORCE = 7.282 N
MAX FORCE = 35.51 N
MIN FORCE = 0.08462 N
AVERAGE ANGLE = -8.797 D

TEST CONDITIONS

BOARD ANGLE = -12.00 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 35.00 kPa
ICE THICKNESS = 3.400 cm
ICE DENSITY = 0.8900 g/cc

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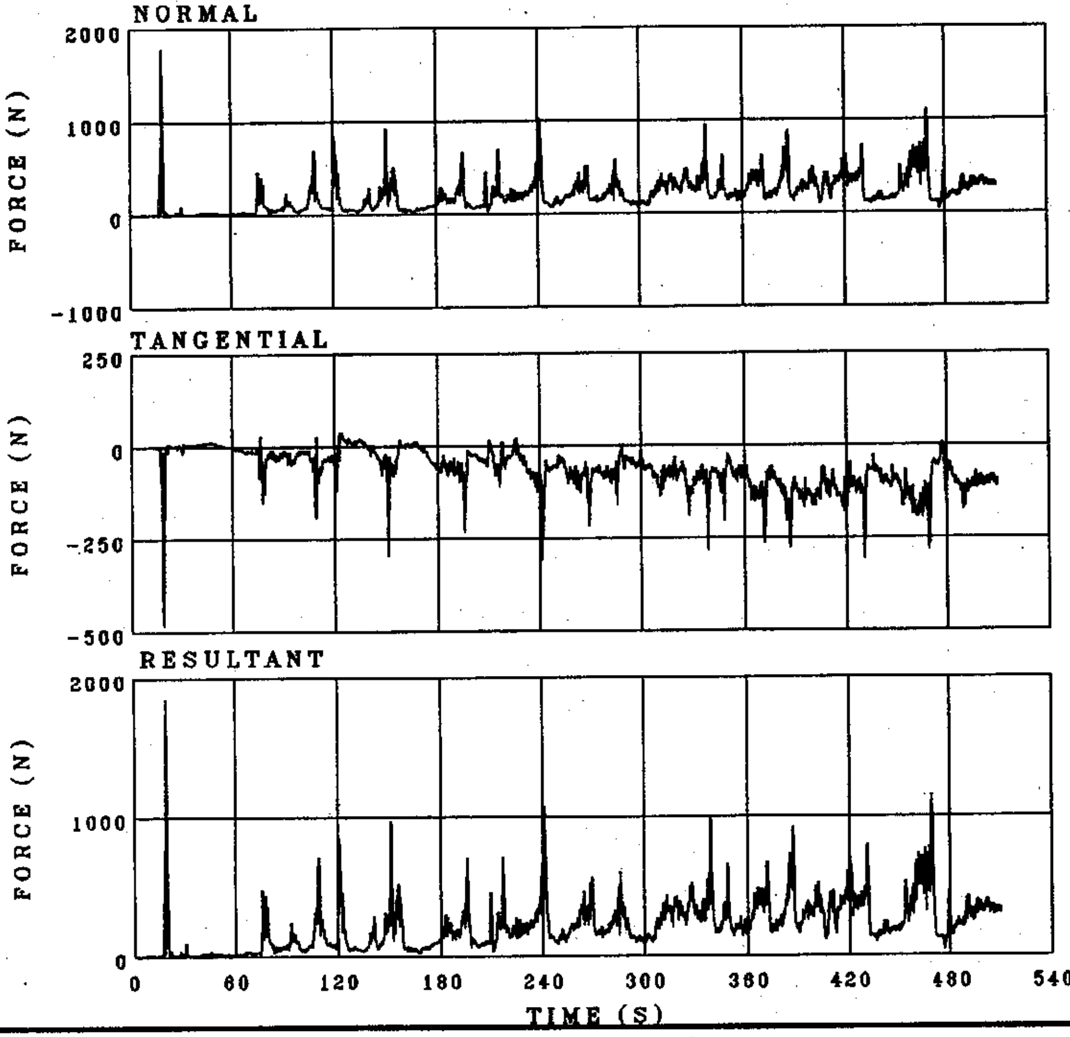
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←015

TOTAL

NORMAL

MEAN FORCE = 202.6 N
MAX FORCE = 1786.0 N
MIN FORCE = -20.66 N

TANGENTIAL

MEAN FORCE = -64.31 N
MAX FORCE = 39.60 N
MIN FORCE = -485.0 N

RESULTANT

MEAN FORCE = 214.8 N
MAX FORCE = 1850.0 N
MIN FORCE = 0.1196 N
AVERAGE ANGLE = -13.82 O

TEST CONDITIONS

BOARD ANGLE = -12.00 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 35.00 kPa
ICE THICKNESS = 3.400 cm
ICE DENSITY = 0.8900 g/cc

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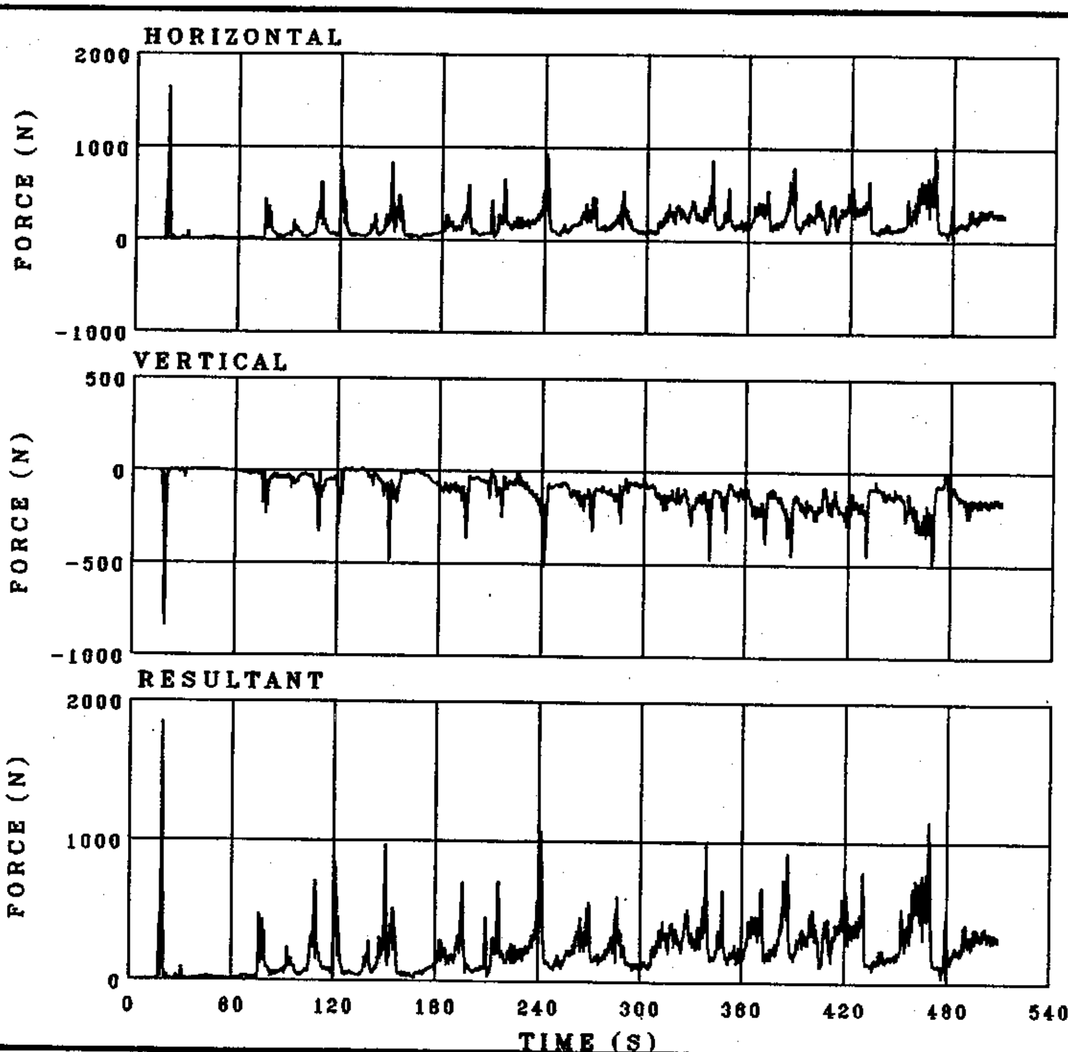
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←015

TOTAL

HORIZONTAL

MEAN FORCE = -64.31 N
MAX FORCE = 39.60 N
MIN FORCE = -485.0 N

VERTICAL

MEAN FORCE = -64.31 N
MAX FORCE = 39.60 N
MIN FORCE = -485.0 N

RESULTANT

MEAN FORCE = -64.31 N
MAX FORCE = 39.60 N
MIN FORCE = -485.0 N
AVERAGE ANGLE = -64.31 D

TEST CONDITIONS

BOARD ANGLE = -12.00 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 35.00 kPa
ICE THICKNESS = 3.400 cm
ICE DENSITY = 0.8900 g/cc

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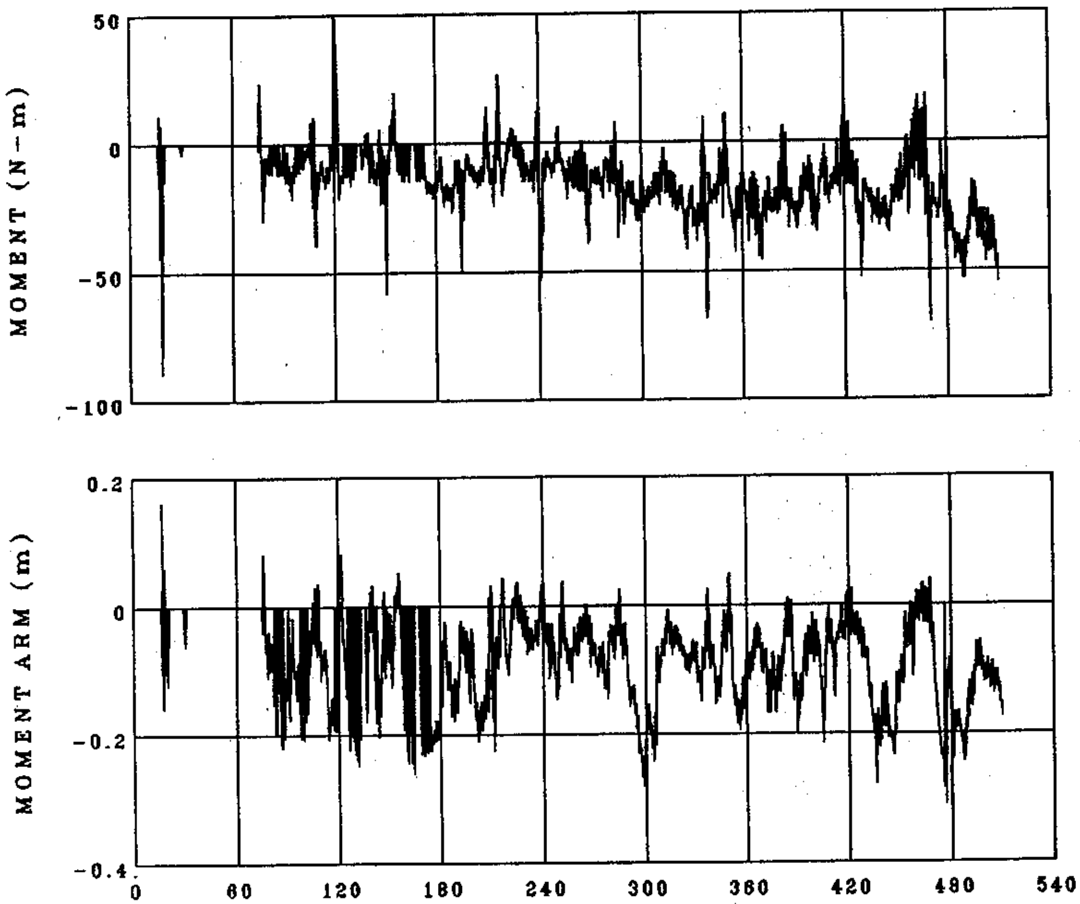
ICE PILEUP STUDY
for CANADIAN COAST GUARD

FILE TN←015

MOMENT



MOMENT

MEAN MOMENT = -13.71 N-m
MAX MOMENT = 49.79 N-m
MIN MOMENT = -89.85 N-m

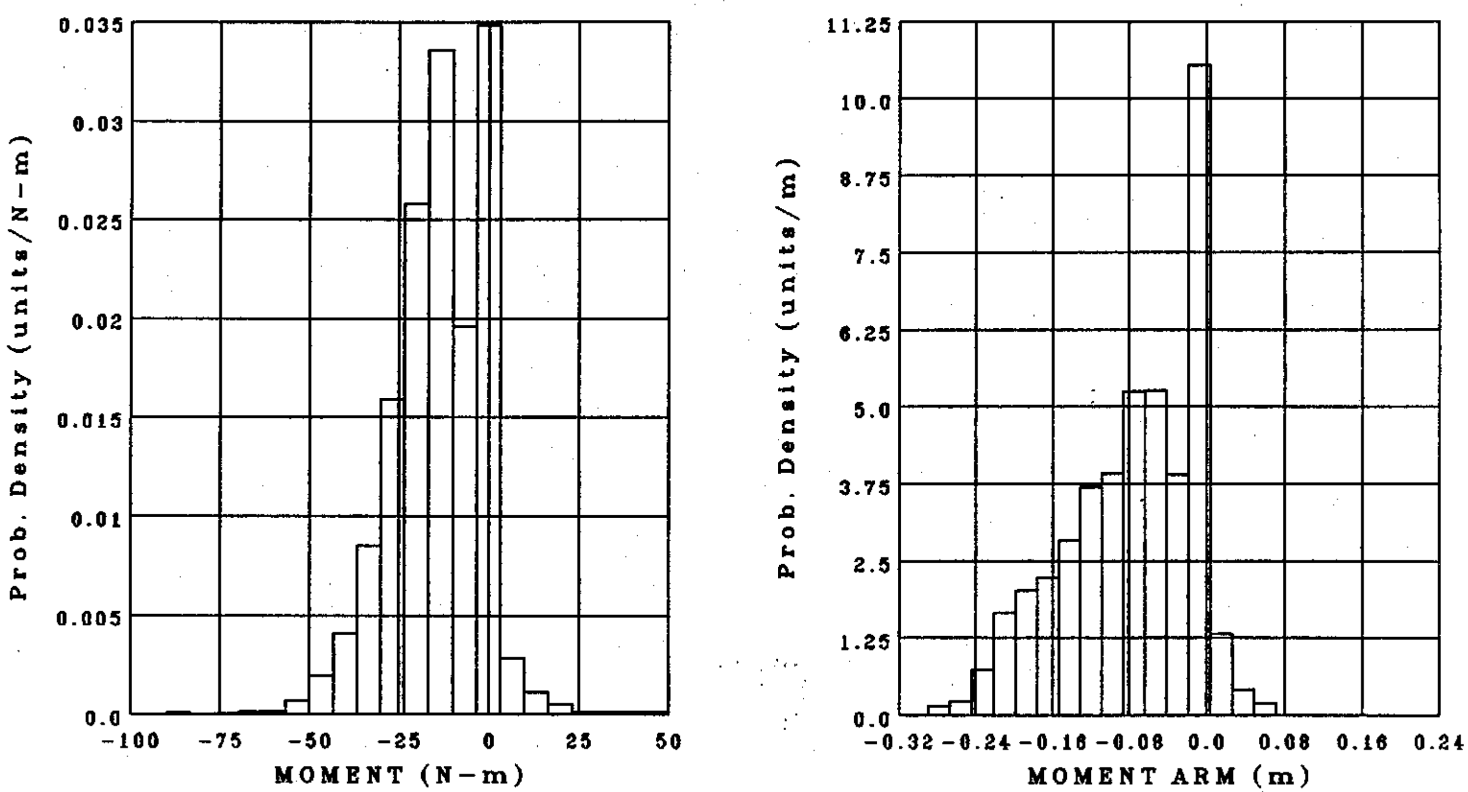
MOMENT ARM

MEAN ARM = -0.07566 m
MAX ARM = 0.1616 m
MIN ARM = -0.3116 m

TEST CONDITIONS

BOARD ANGLE = -12.00 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 35.00 kPa
ICE THICKNESS = 3.400 cm
ICE DENSITY = 0.8900 g/cc

TN ← 015



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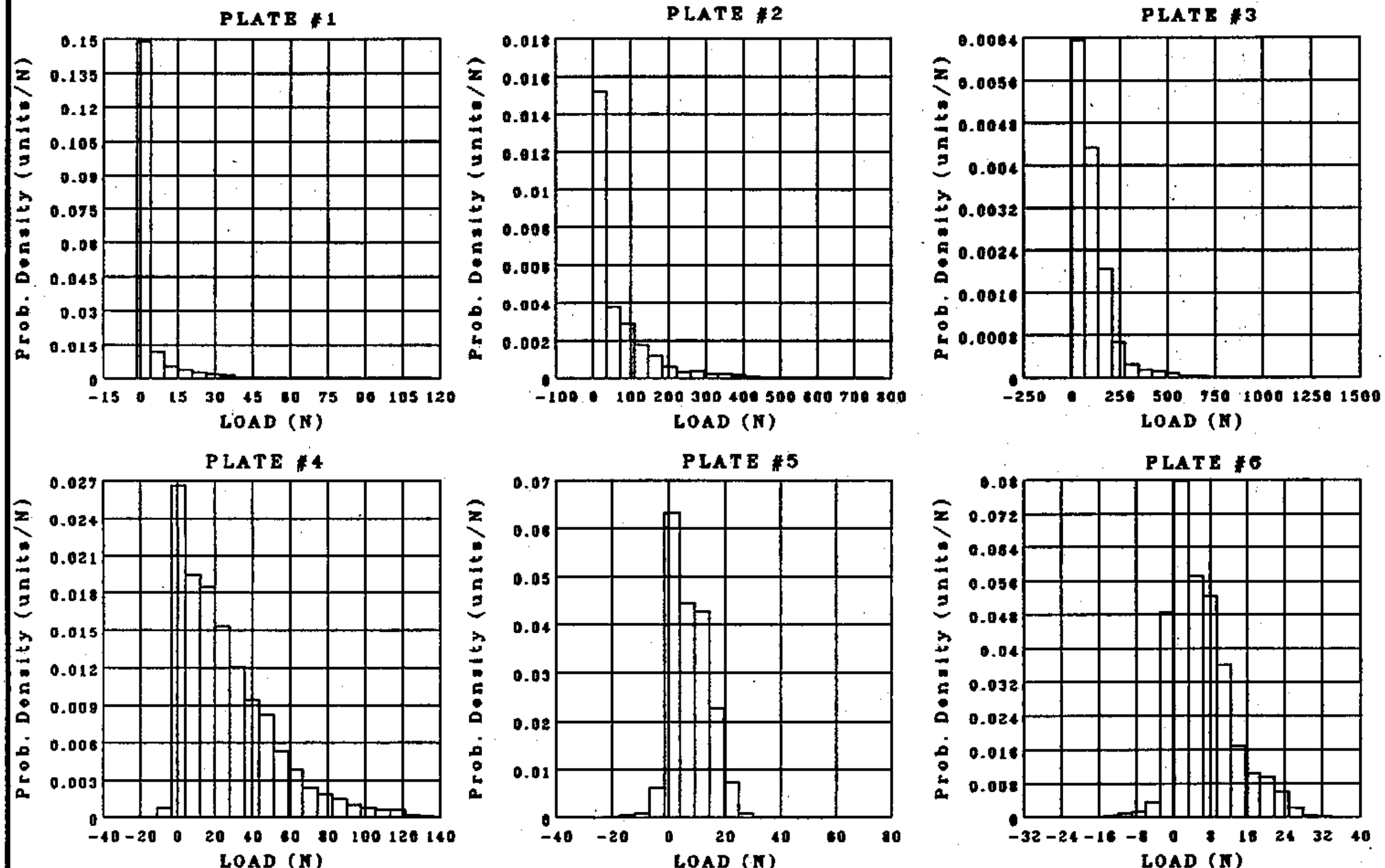
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←015
NORMAL LOAD



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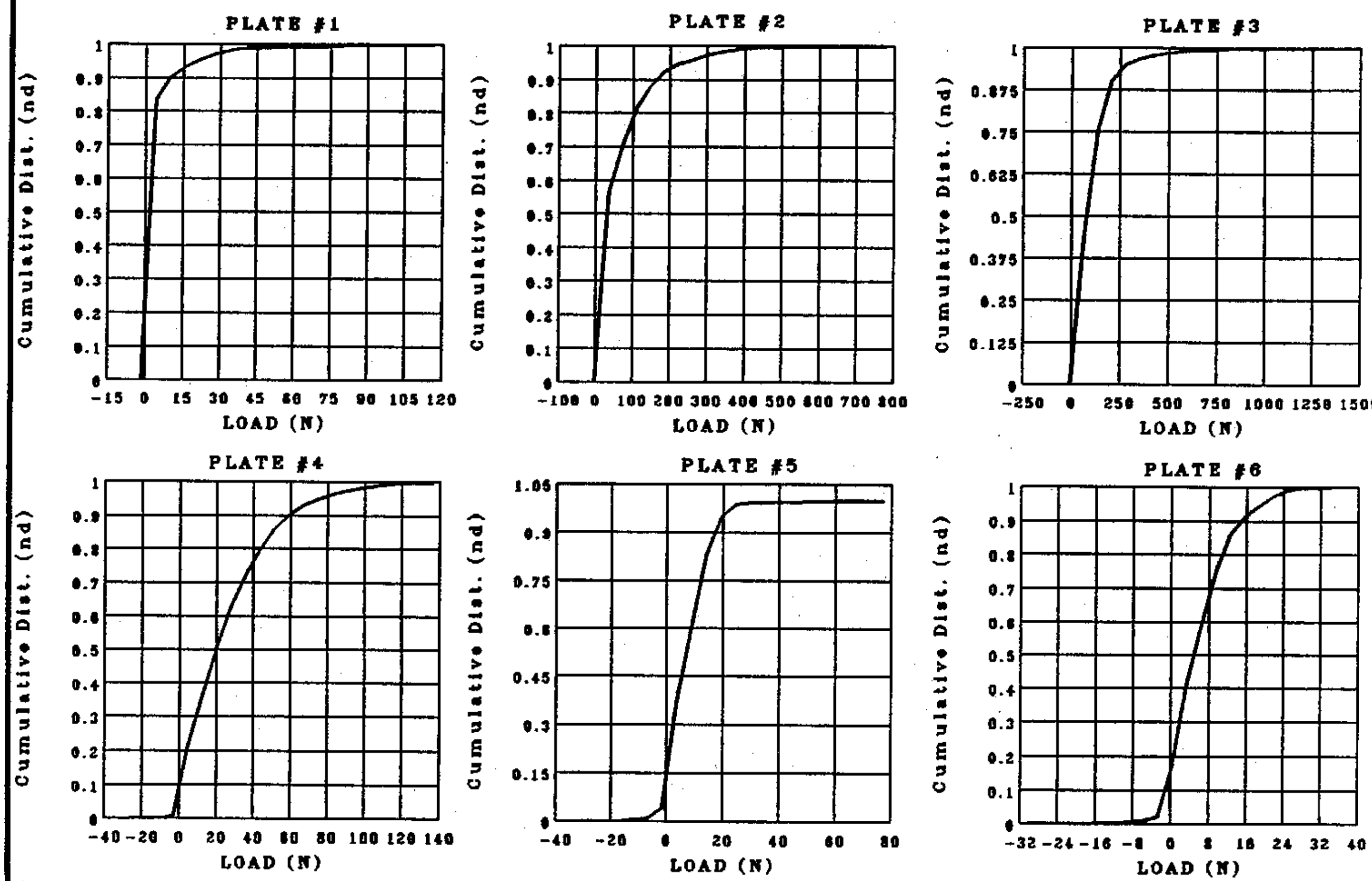
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN ← 015

NORMAL LOAD



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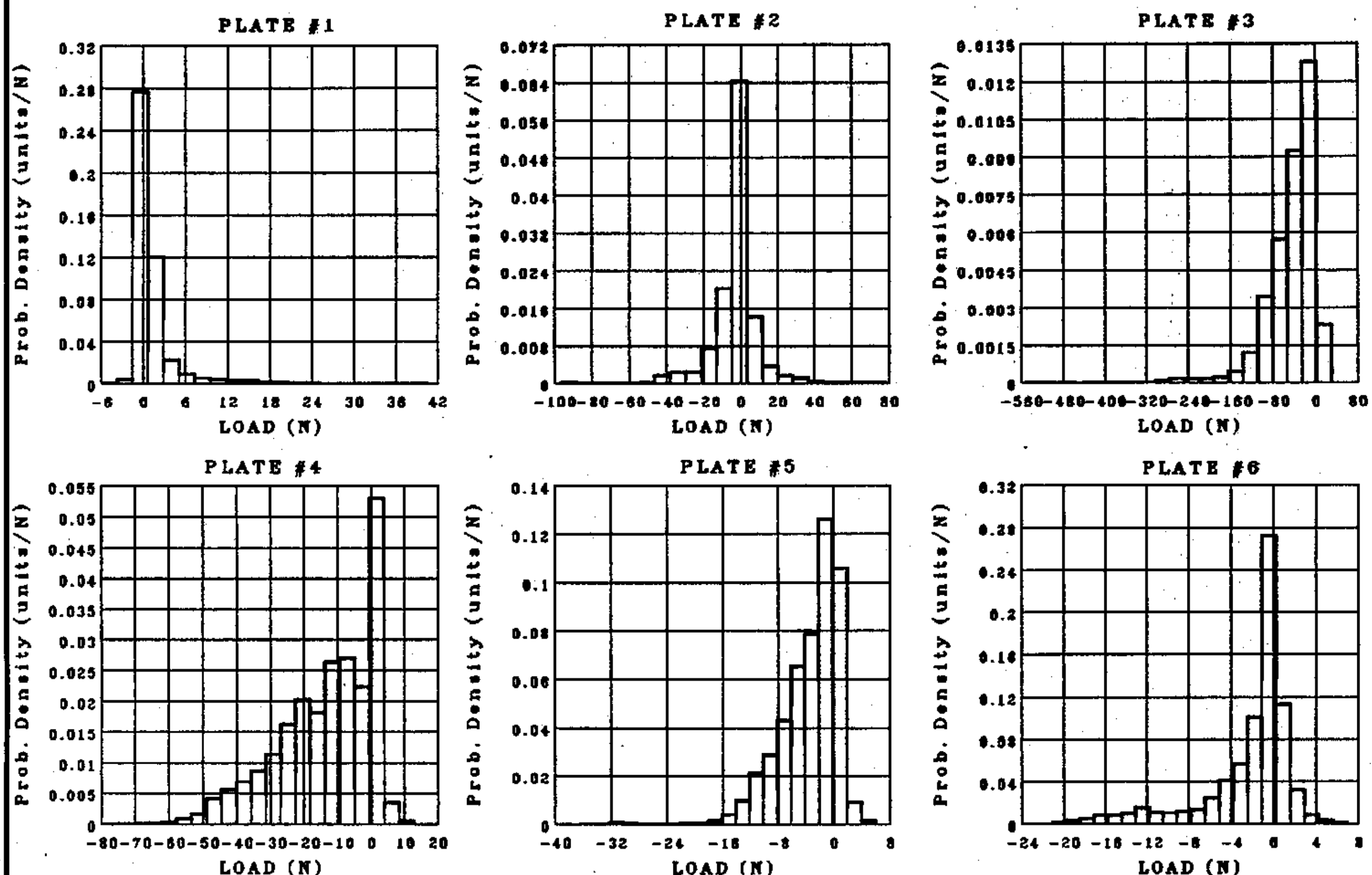
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN ← 015

TANGENTIAL LOAD



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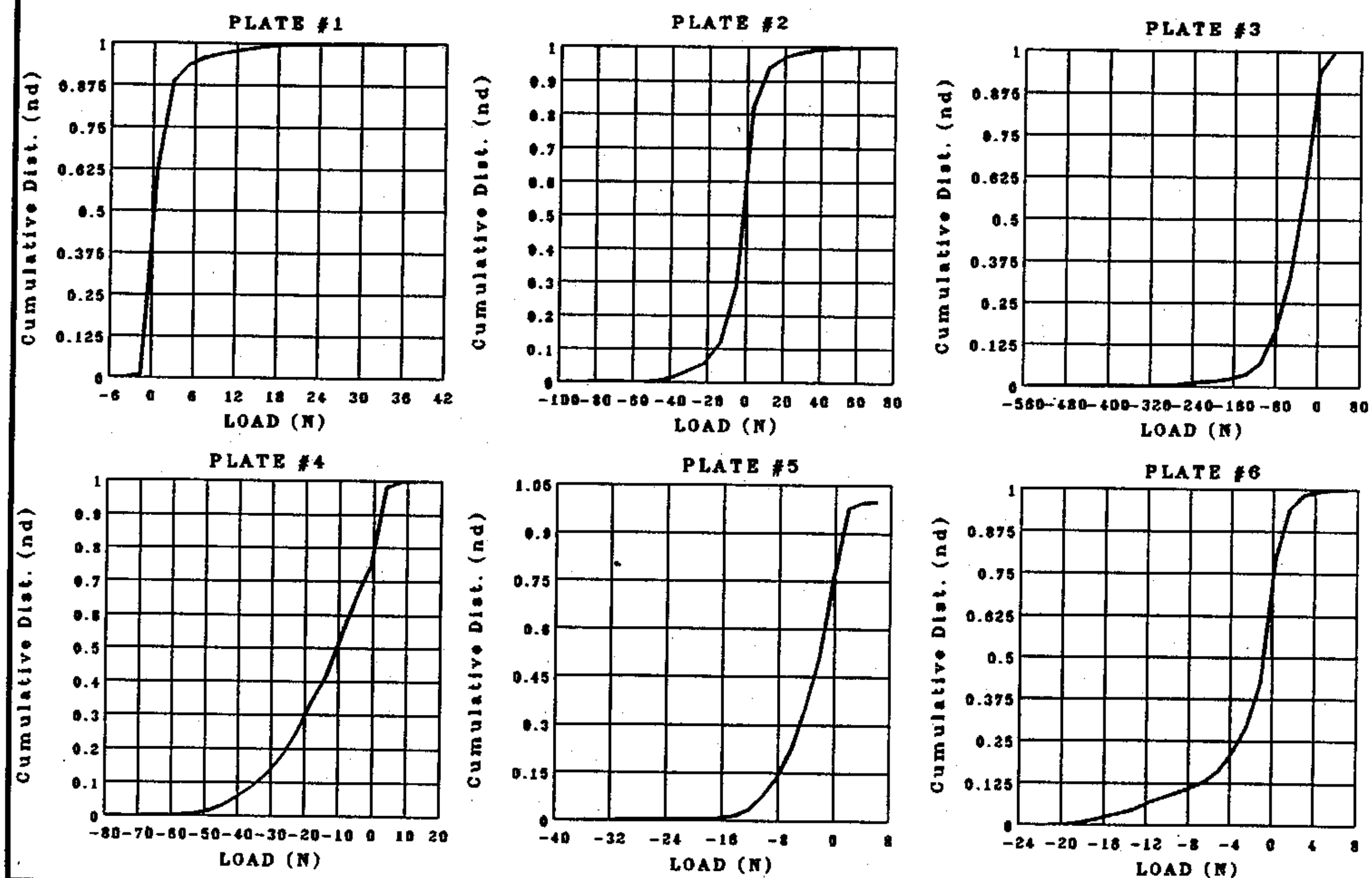
ICE PILEUP STUDY for CANADIAN COAST GUARD

TN←015
TANGENTIAL LOAD



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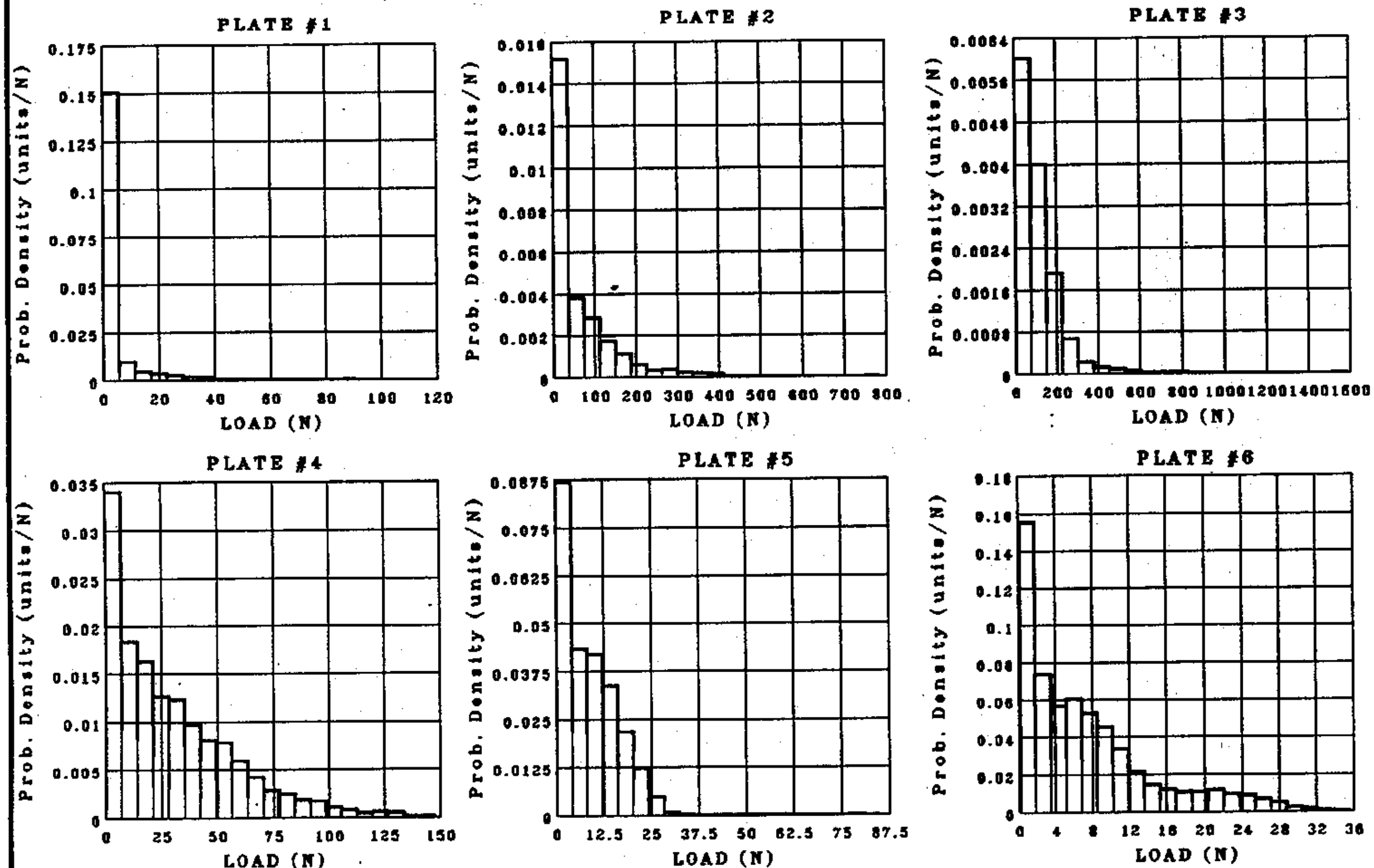
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←015
RESULTANT



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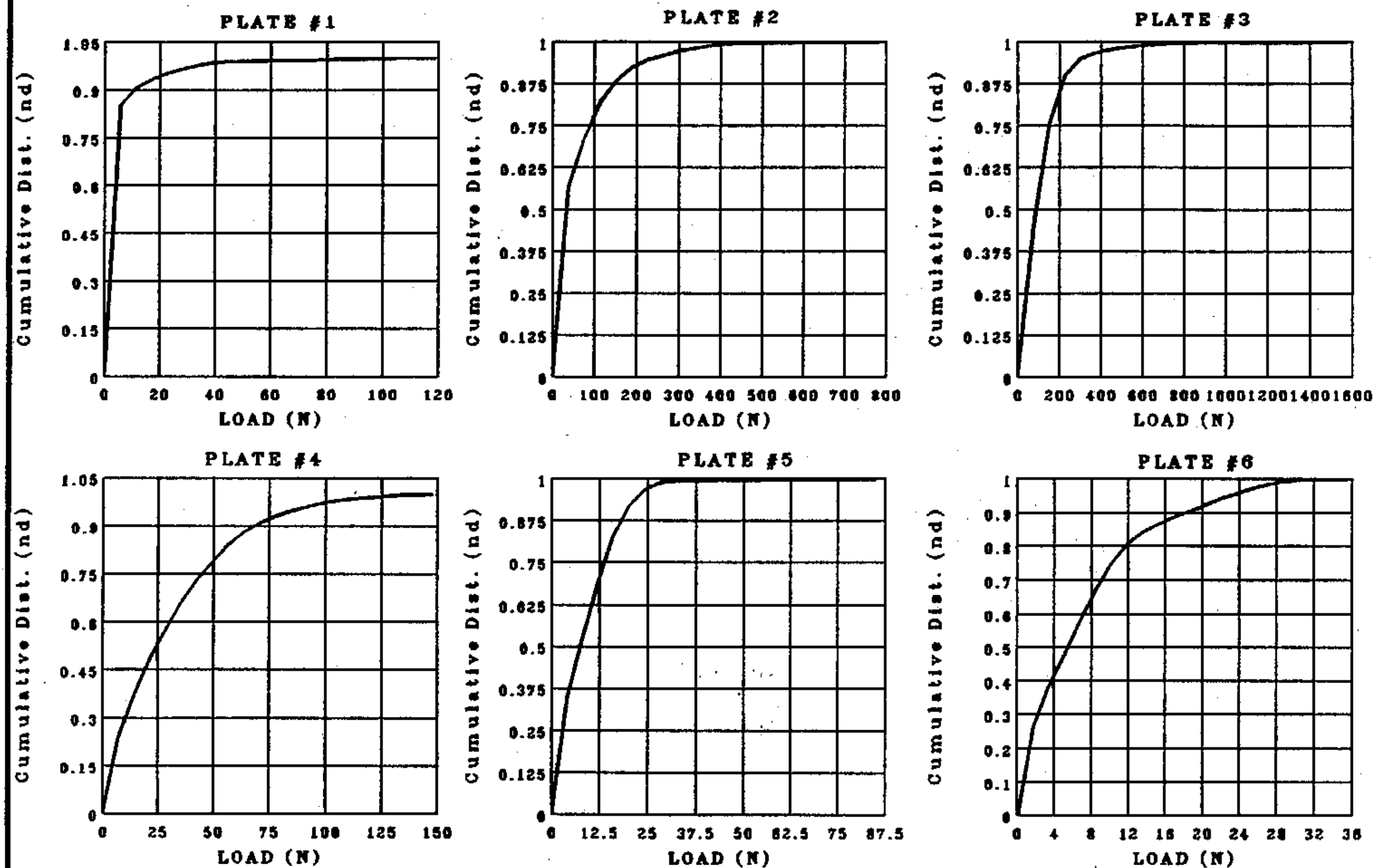
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←015

RESULTANT



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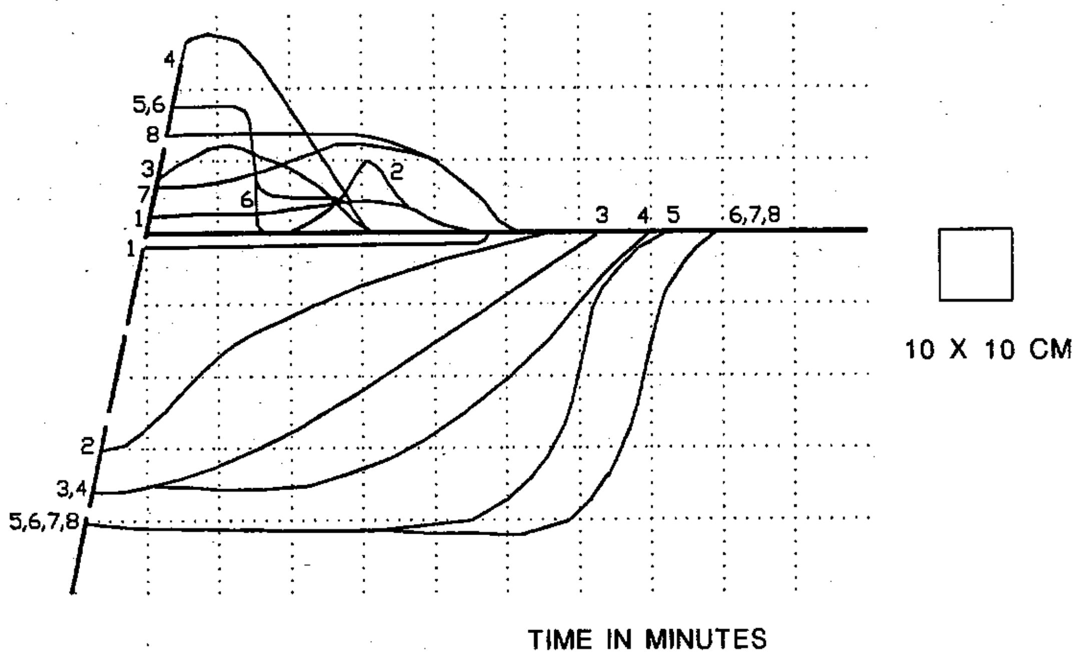
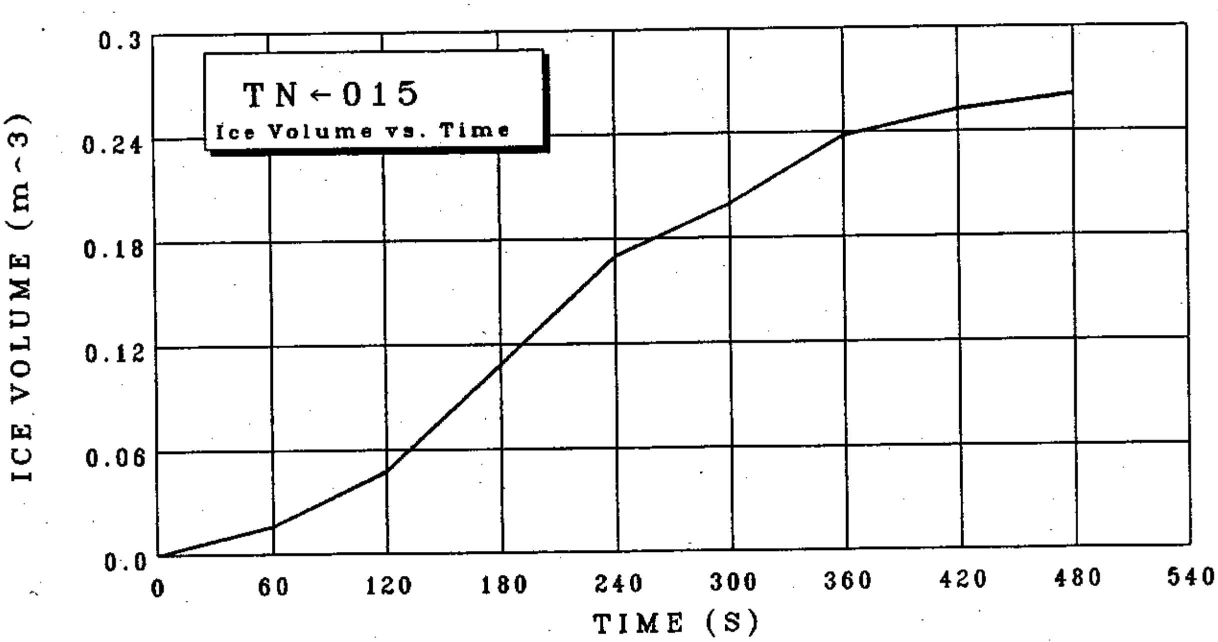
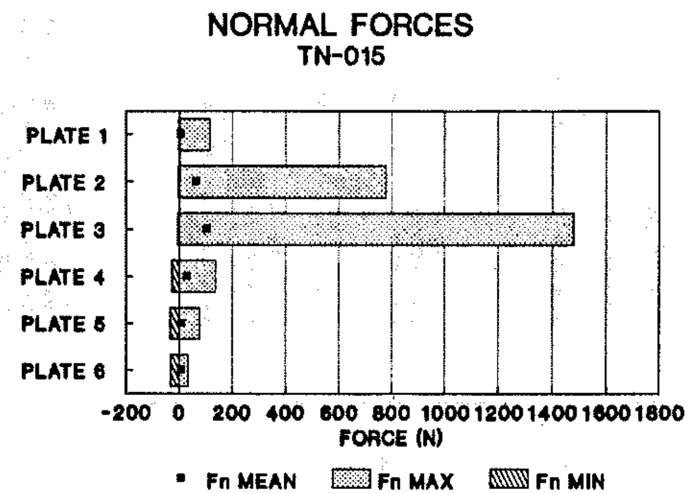
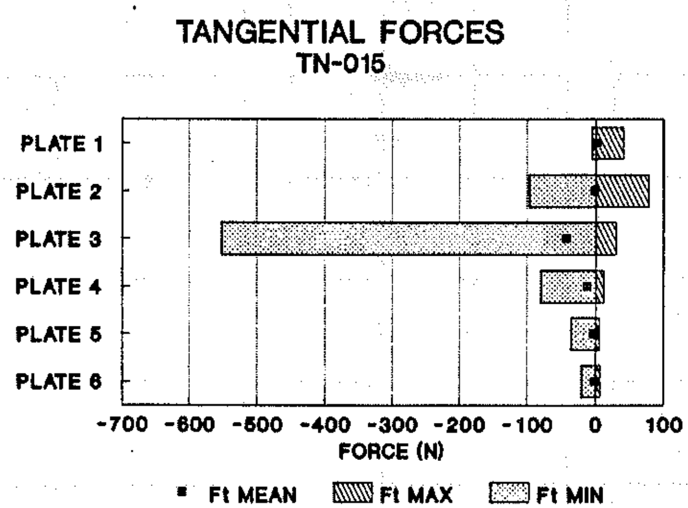


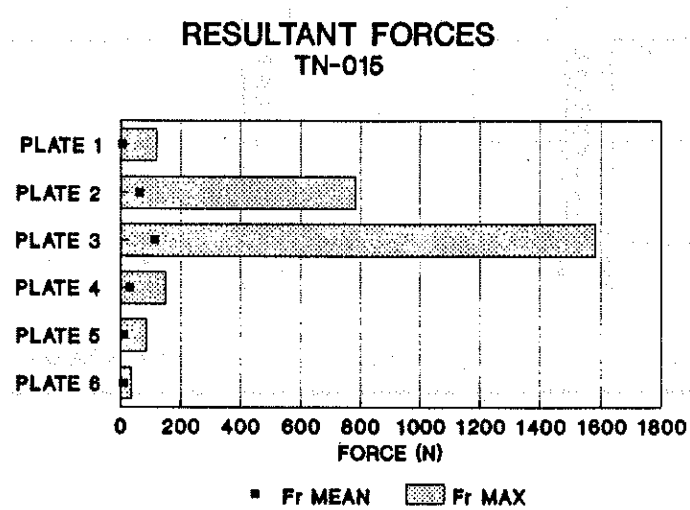
4
5,6
8
3
7
1
1
6
2
2
3,4
5,6,7,8
3
4
5
6,7,8
TIME IN MINUTES
10 X 10 CM

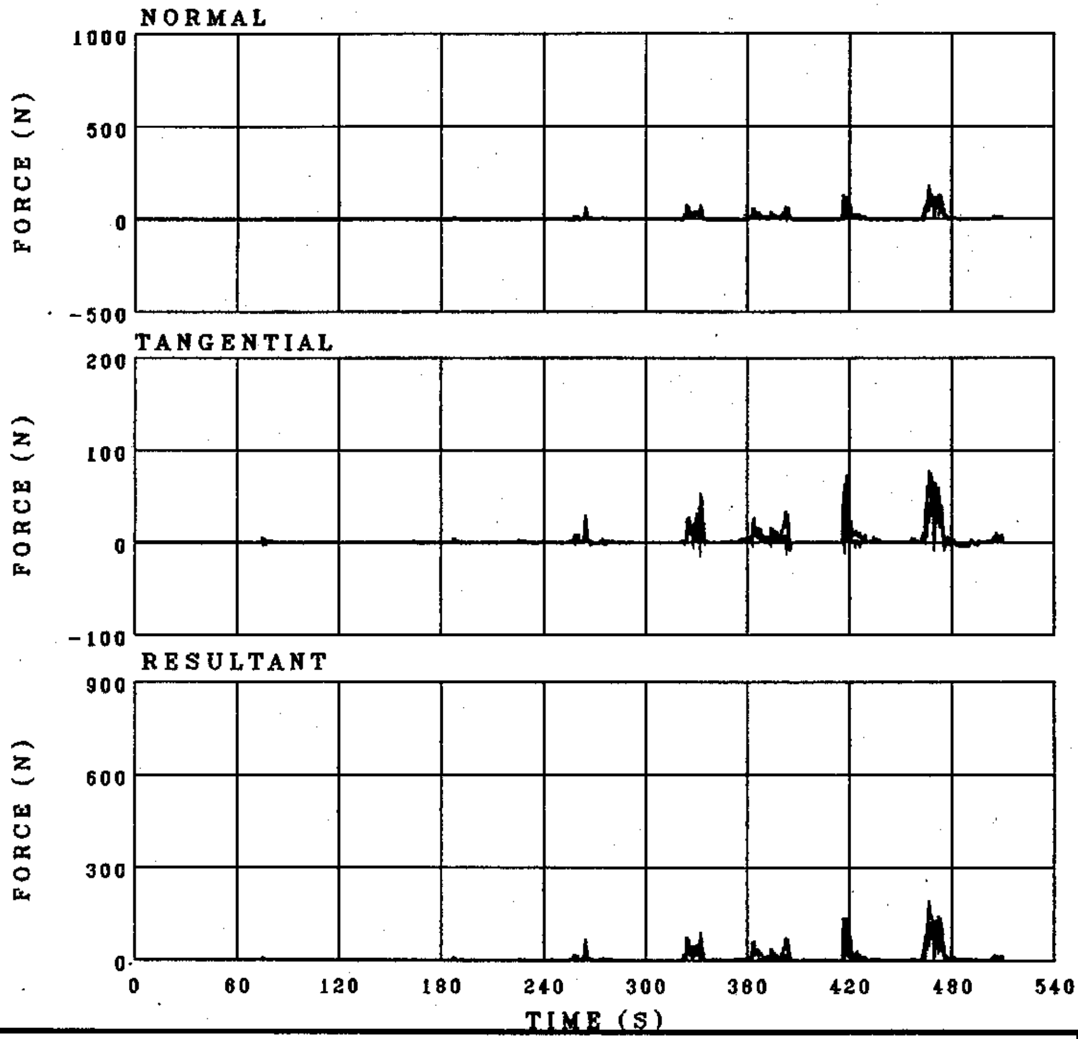


TN←015
Ice Volume vs. Time
ICE VOLUME (m~3)
0.0
0.06
0.12
0.18
0.24
0.3
0
60
120
180
240
300
360
420
480
540
TIME (S)


NORMAL FORCES
TN-015
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-200 0 200 400 600 800 1000 1200 1400 1600 1800
FORCE (N)
Fn MEAN
Fn MAX
Fn MIN


TANGENTIAL FORCES
TN-015
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-700 -600 -500 -400 -300 -200 -100 0 100
FORCE (N)
Ft MEAN
Ft MAX
Ft MIN


RESULTANT FORCES
TN-015
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
0 200 400 600 800 1000 1200 1400 1600 1800
FORCE (N)
Fr MEAN
Fr MAX



FILE TN←016

PLATE #1

NORMAL

MEAN FORCE = 3.925 N
MAX FORCE = 133.9 N
MIN FORCE = -4.534 N

TANGENTIAL

MEAN FORCE = 2.115 N
MAX FORCE = 66.73 N
MIN FORCE = -6.319 N

RESULTANT

MEAN FORCE = 5.271 N
MAX FORCE = 147.3 N
MIN FORCE = 0.008186 N
AVERAGE ANGLE = 57.87 D

TEST CONDITIONS

BOARD ANGLE = 0.0 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 64.00 kPa
ICE THICKNESS = 3.300 cm
ICE DENSITY = 0.8800 g/cc

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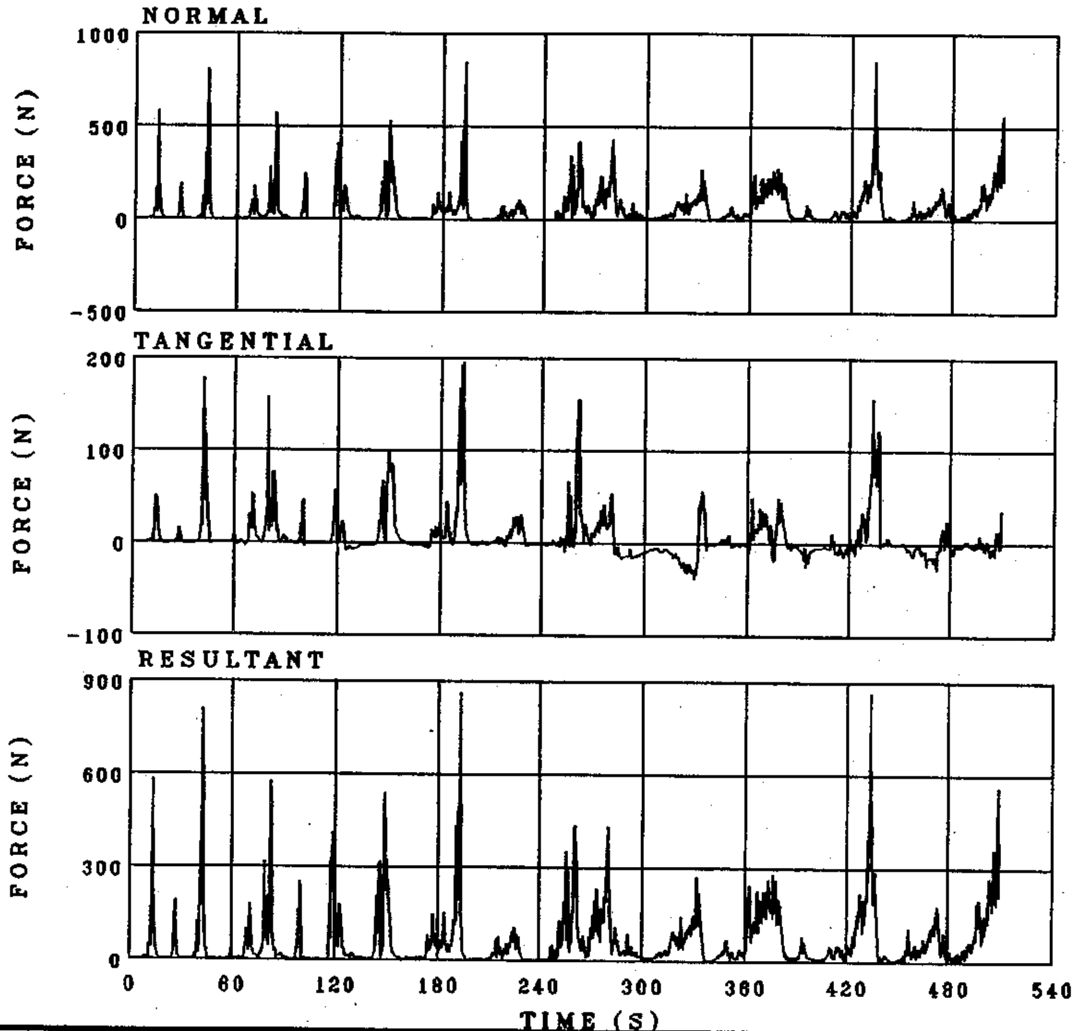
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←016

PLATE #2

NORMAL

MEAN FORCE = 59.96 N
MAX FORCE = 853.3 N
MIN FORCE = −2.813 N

TANGENTIAL

MEAN FORCE = 6.098 N
MAX FORCE = 196.5 N
MIN FORCE = −38.56 N

RESULTANT

MEAN FORCE = 62.39 N
MAX FORCE = 866.9 N
MIN FORCE = 0.06546 N
AVERAGE ANGLE = −14.75 O

TEST CONDITIONS

BOARD ANGLE = 0.0 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 64.00 kPa
ICE THICKNESS = 3.300 cm
ICE DENSITY = 0.8800 g/cc

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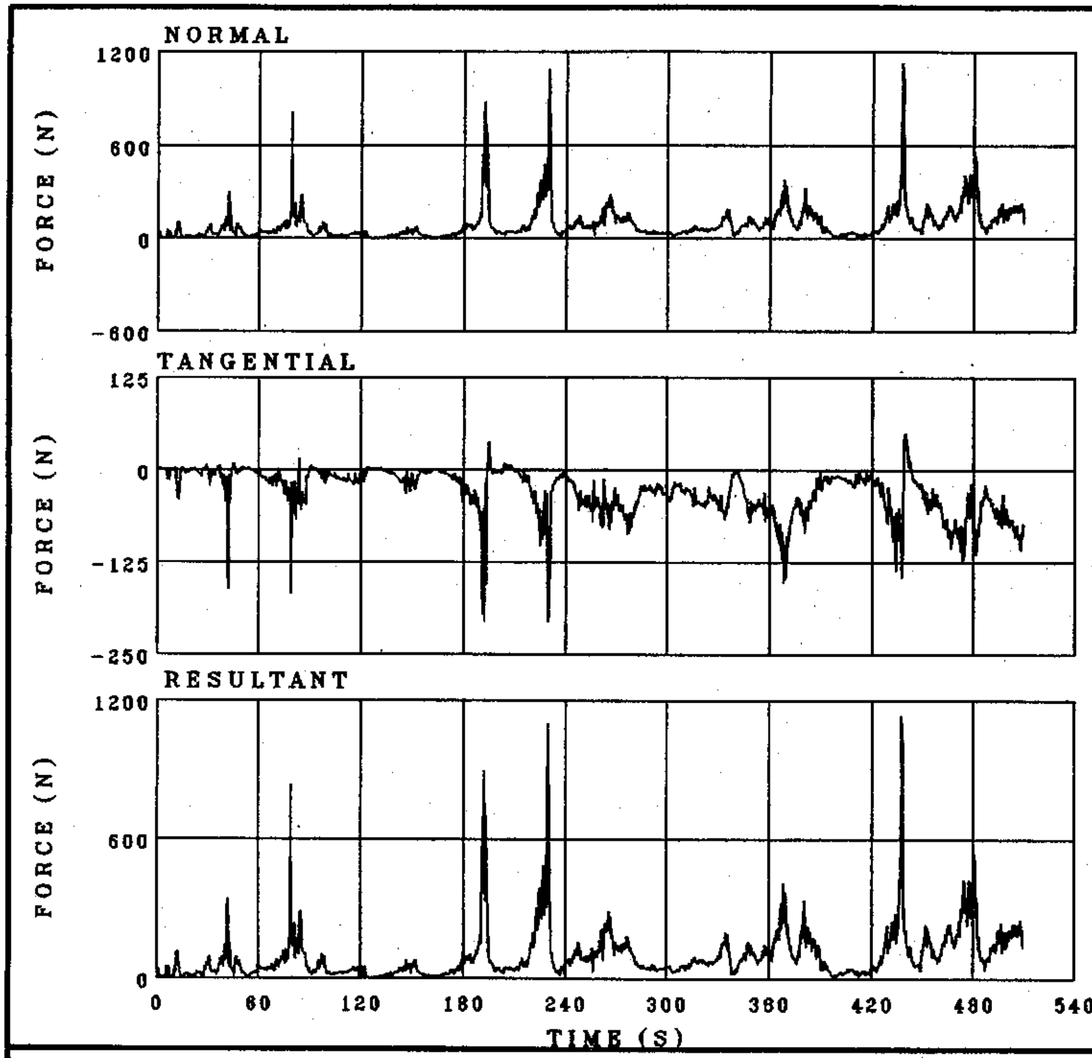
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←016

PLATE #3

NORMAL

MEAN FORCE = 91.29 N
MAX FORCE = 1130.0 N
MIN FORCE = -6.438 N

TANGENTIAL

MEAN FORCE = -30.30 N
MAX FORCE = 49.86 N
MIN FORCE = -205.9 N

RESULTANT

MEAN FORCE = 97.78 N
MAX FORCE = 1136.0 N
MIN FORCE = 0.1680 N
AVERAGE ANGLE = -17.53 O

TEST CONDITIONS

BOARD ANGLE = 0.0 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 64.00 kPa
ICE THICKNESS = 3.300 cm
ICE DENSITY = 0.8800 g/cc

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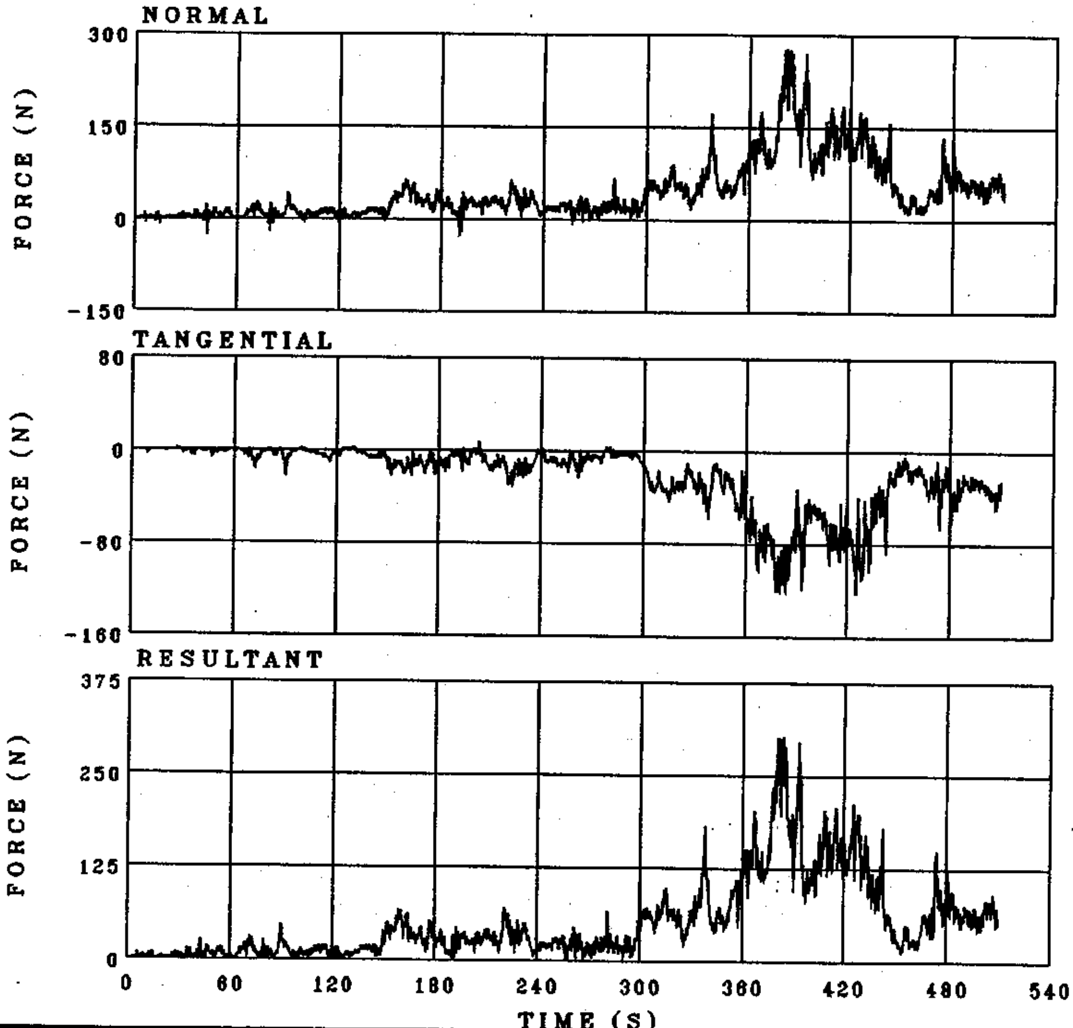
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←016

PLATE #4

NORMAL

MEAN FORCE = 45.54 N
MAX FORCE = 278.5 N
MIN FORCE = -27.86 N

TANGENTIAL

MEAN FORCE = -22.62 N
MAX FORCE = 8.032 N
MIN FORCE = -123.2 N

RESULTANT

MEAN FORCE = 51.44 N
MAX FORCE = 302.6 N
MIN FORCE = 0.08349 N
AVERAGE ANGLE = -19.87 D

TEST CONDITIONS

BOARD ANGLE = 0.0 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 64.00 kPa
ICE THICKNESS = 3.300 cm
ICE DENSITY = 0.8800 g/cc

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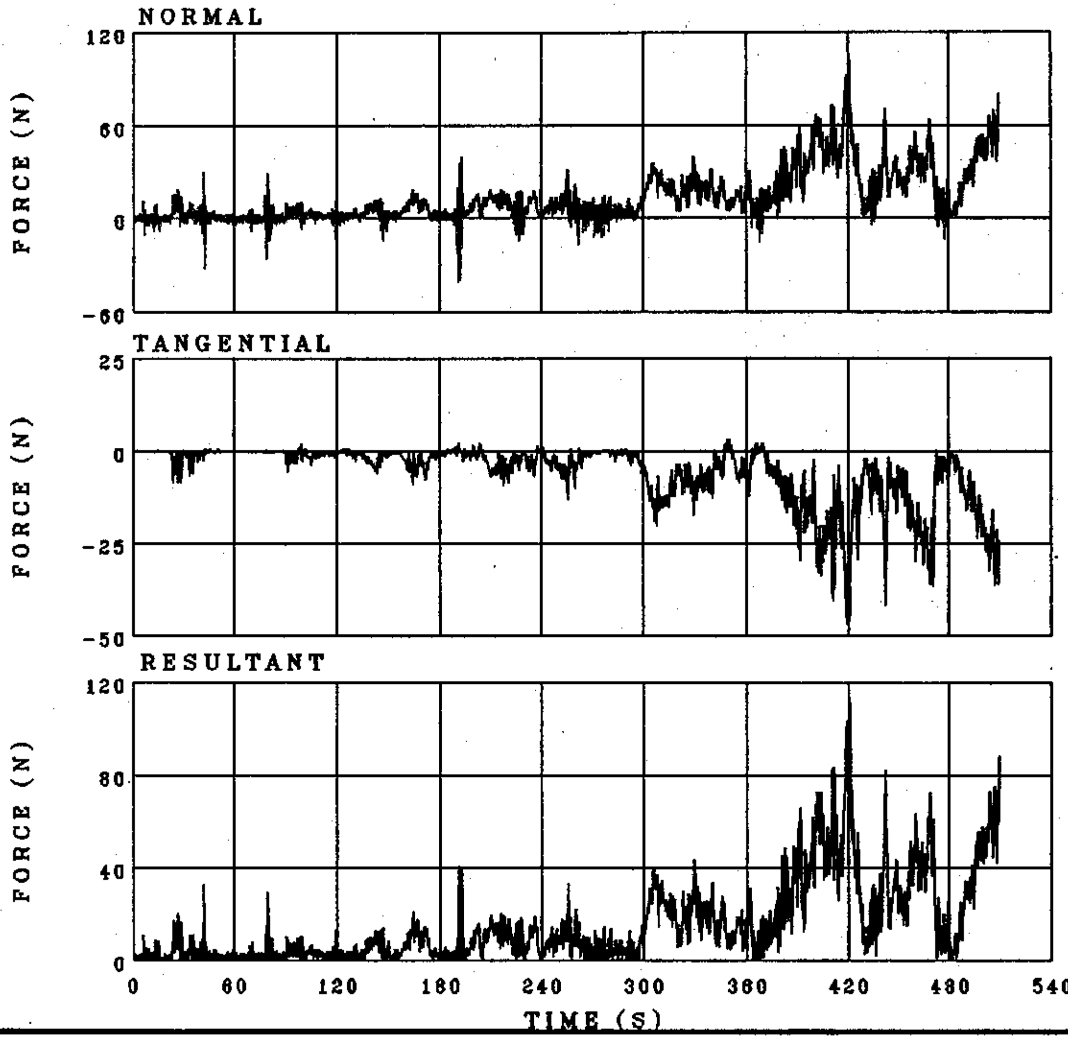
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←016

PLATE #5

NORMAL

MEAN FORCE = 13.26 N
MAX FORCE = 104.9 N
MIN FORCE = -40.77 N

TANGENTIAL

MEAN FORCE = -5.947 N
MAX FORCE = 3.217 N
MIN FORCE = -46.94 N

RESULTANT

MEAN FORCE = 15.28 N
MAX FORCE = 113.6 N
MIN FORCE = 0.01567 N
AVERAGE ANGLE = -17.35 O

TEST CONDITIONS

BOARD ANGLE = 0.0 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 64.00 kPa
ICE THICKNESS = 3.300 cm
ICE DENSITY = 0.8800 g/cc

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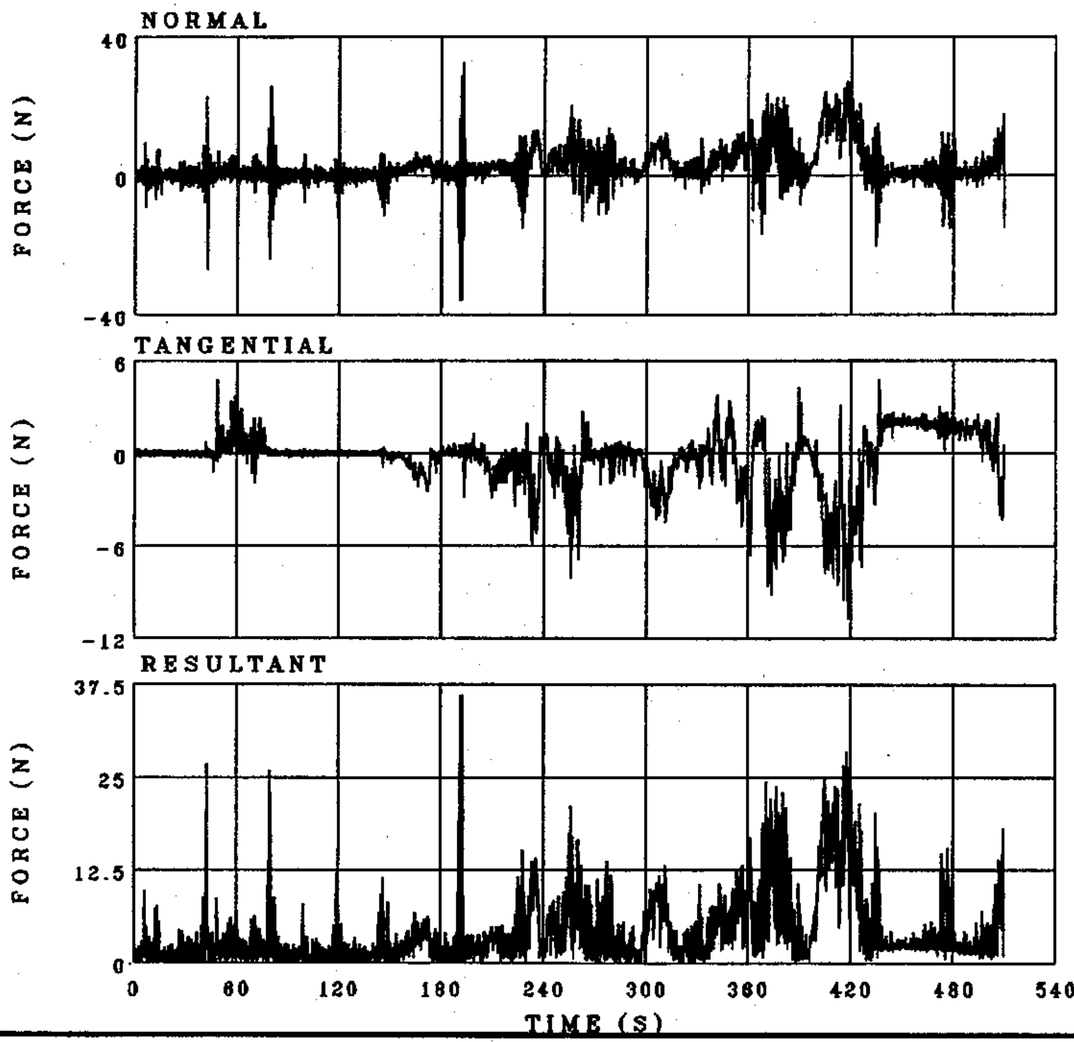
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←016

PLATE #6

NORMAL

MEAN FORCE = 2.813 N
MAX FORCE = 32.67 N
MIN FORCE = -36.00 N

TANGENTIAL

MEAN FORCE = -0.4084 N
MAX FORCE = 4.808 N
MIN FORCE = -10.76 N

RESULTANT

MEAN FORCE = 3.921 N
MAX FORCE = 36.00 N
MIN FORCE = 0.02598 N
AVERAGE ANGLE = 1.874 D

TEST CONDITIONS

BOARD ANGLE = 0.0 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 64.00 kPa
ICE THICKNESS = 3.300 cm
ICE DENSITY = 0.8800 g/cc

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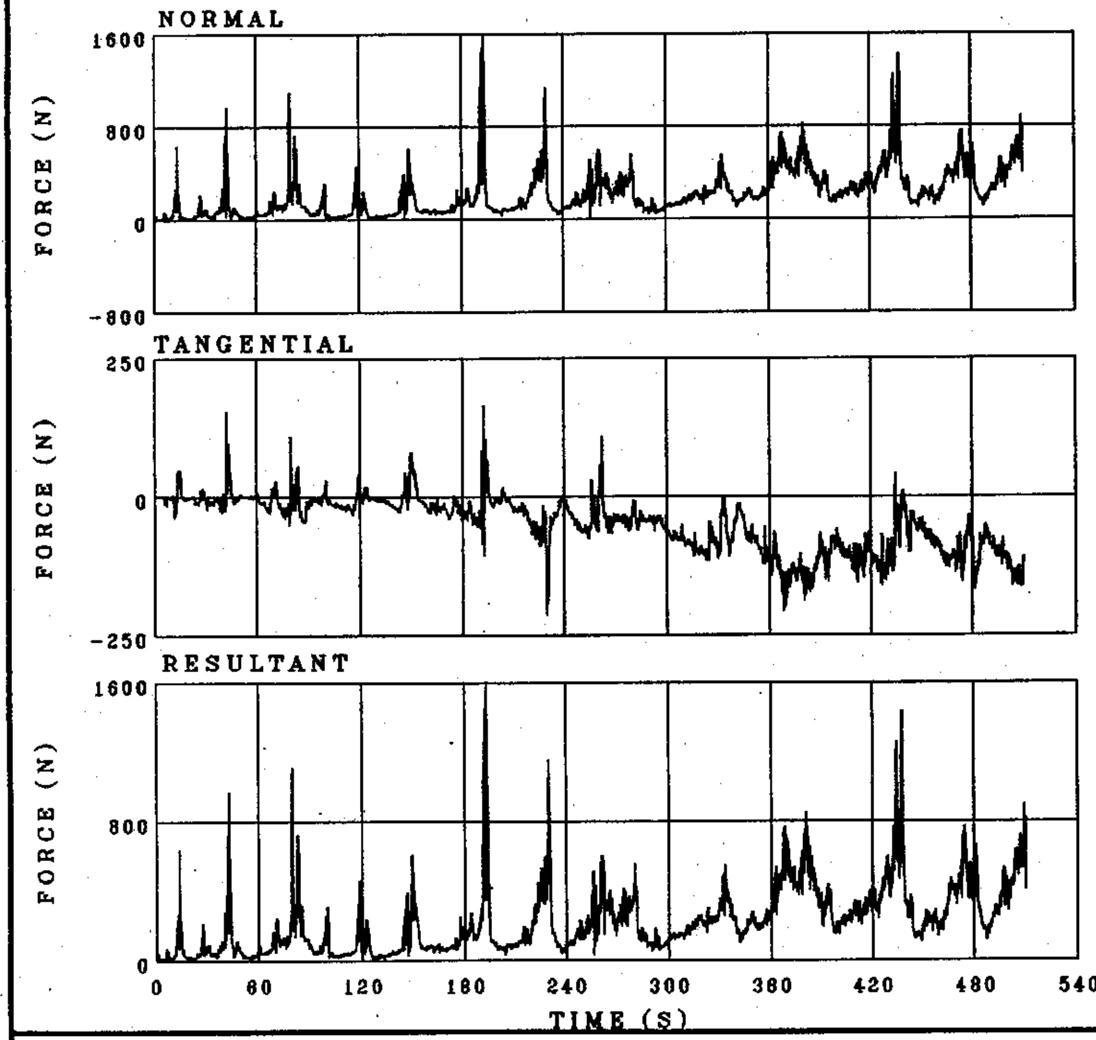
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←016

TOTAL

NORMAL

MEAN FORCE = 216.8 N
MAX FORCE = 1586.0 N
MIN FORCE = -18.80 N

TANGENTIAL

MEAN FORCE = -51.06 N
MAX FORCE = 166.1 N
MIN FORCE = -212.5 N

RESULTANT

MEAN FORCE = 226.0 N
MAX FORCE = 1586.0 N
MIN FORCE = 0.5119 N
AVERAGE ANGLE = -13.78 O

TEST CONDITIONS

BOARD ANGLE = 0.0 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 64.00 kPa
ICE THICKNESS = 3.300 cm
ICE DENSITY = 0.8800 g/cc

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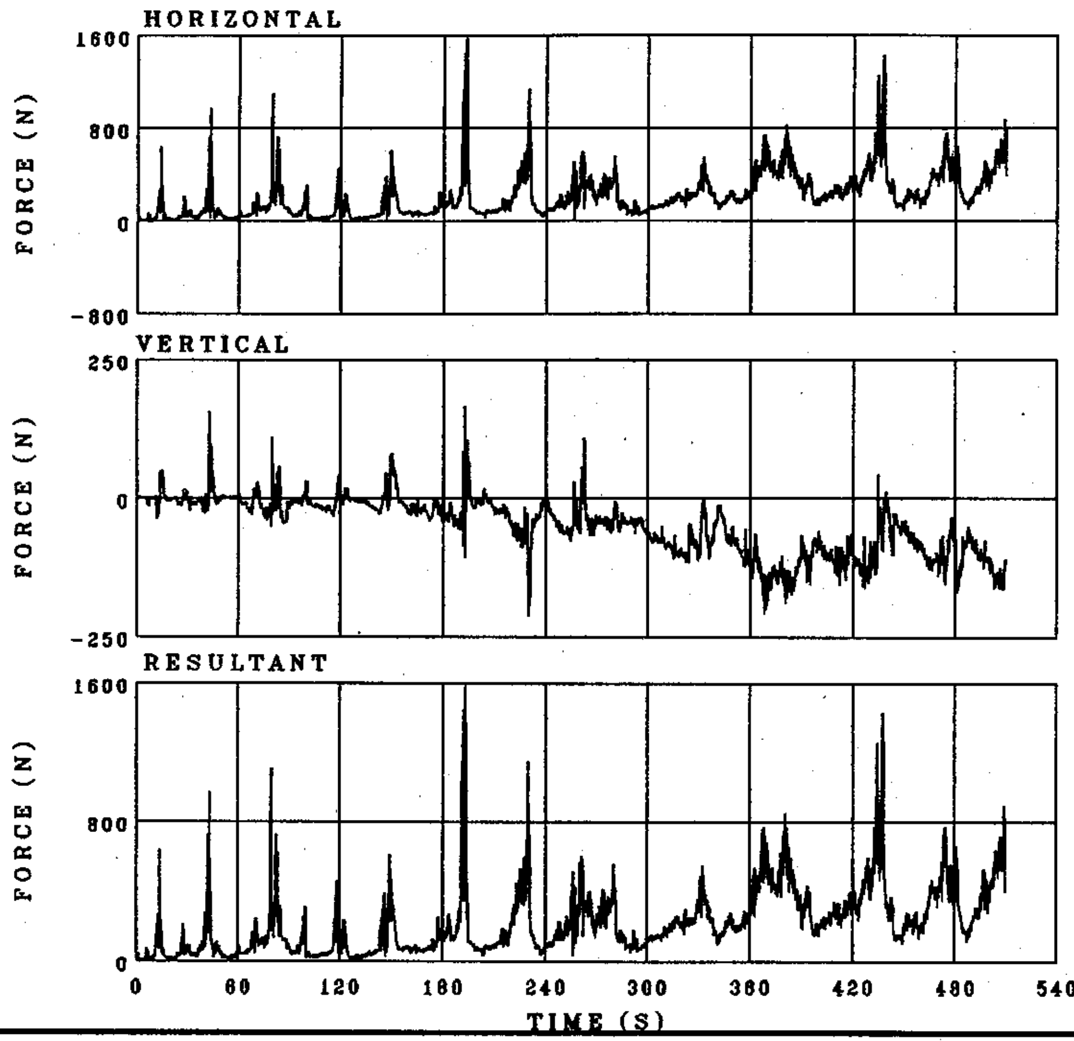
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN-016

TOTAL

HORIZONTAL

MEAN FORCE = -51.06 N
MAX FORCE = 166.1 N
MIN FORCE = -212.5 N

VERTICAL

MEAN FORCE = -51.06 N
MAX FORCE = 166.1 N
MIN FORCE = -212.5 N

RESULTANT

MEAN FORCE = -51.06 N
MAX FORCE = 166.1 N
MIN FORCE = -212.5 N
AVERAGE ANGLE = -51.06 O

TEST CONDITIONS

BOARD ANGLE = 0.0 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 64.00 kPa
ICE THICKNESS = 3.300 cm
ICE DENSITY = 0.8800 g/cc

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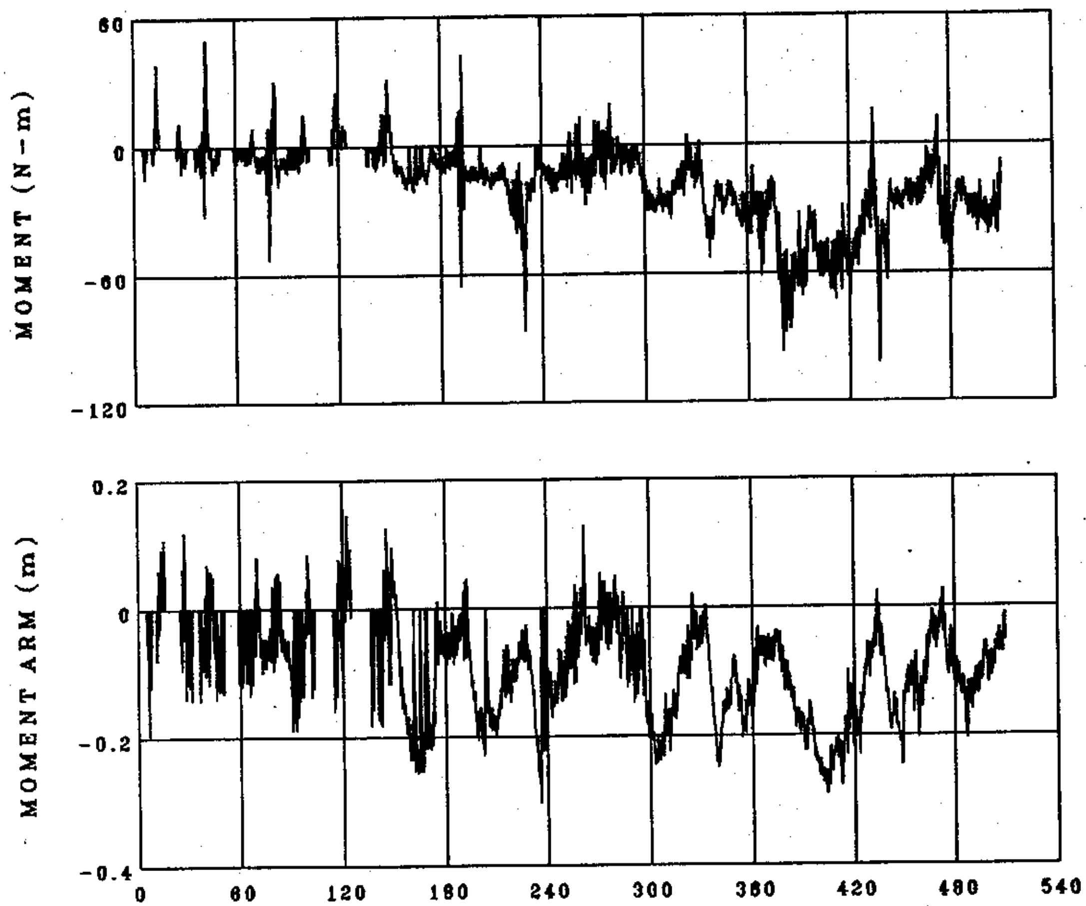
ICE PILEUP STUDY
for CANADIAN COAST GUARD

FILE TN←016

MOMENT



MOMENT

MEAN MOMENT = −17.66 N−m
MAX MOMENT = 50.05 N−m
MIN MOMENT = −102.4 N−m

MOMENT ARM

MEAN ARM = −0.08598 m
MAX ARM = 0.1960 m
MIN ARM = −0.3045 m

TEST CONDITIONS

BOARD ANGLE = 0.0 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 64.00 kPa
ICE THICKNESS = 3.300 cm
ICE DENSITY = 0.8800 g/cc

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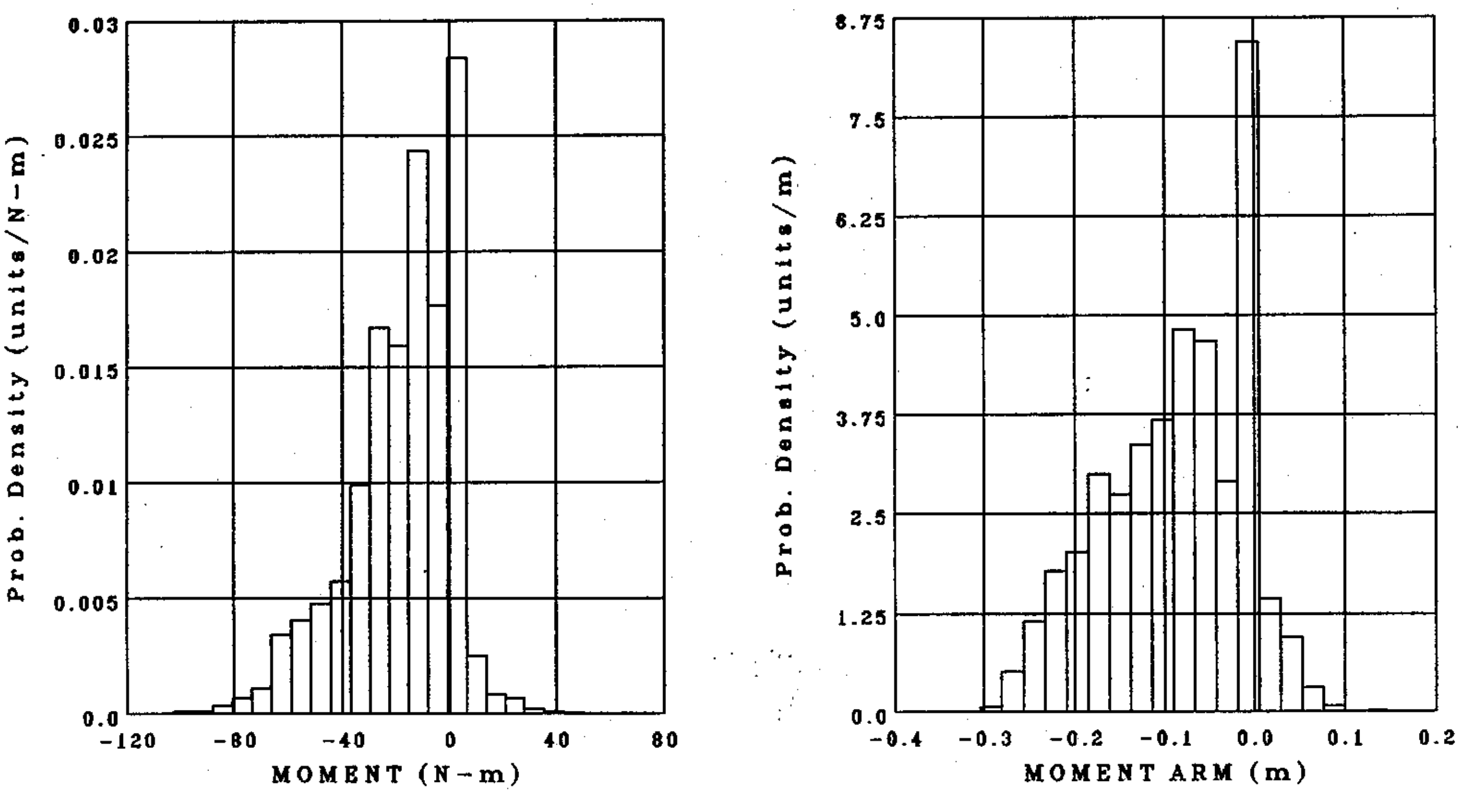
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←016



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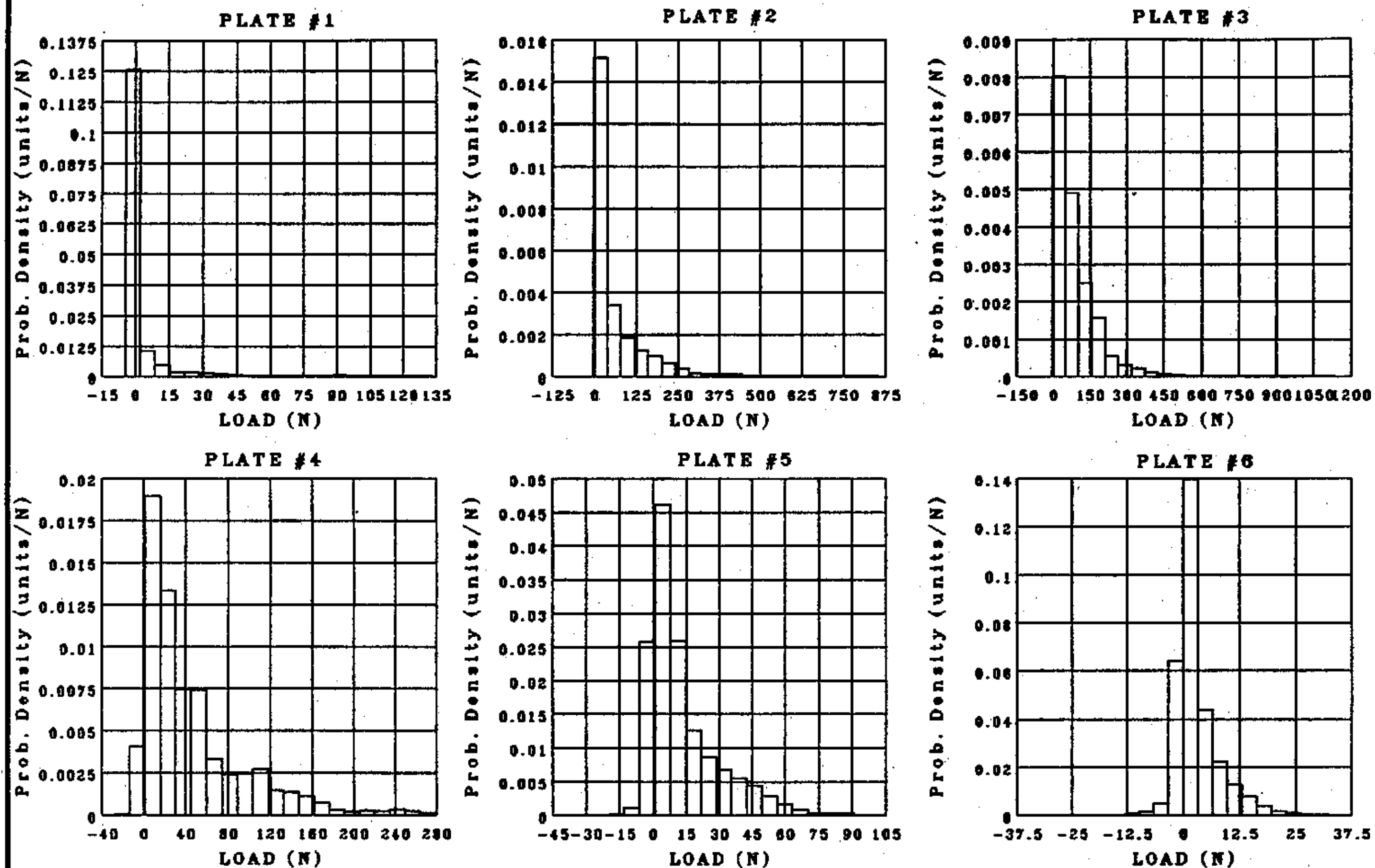
ICE PILEUP STUDY for CANADIAN COAST GUARD

TN←016

NORMAL LOAD



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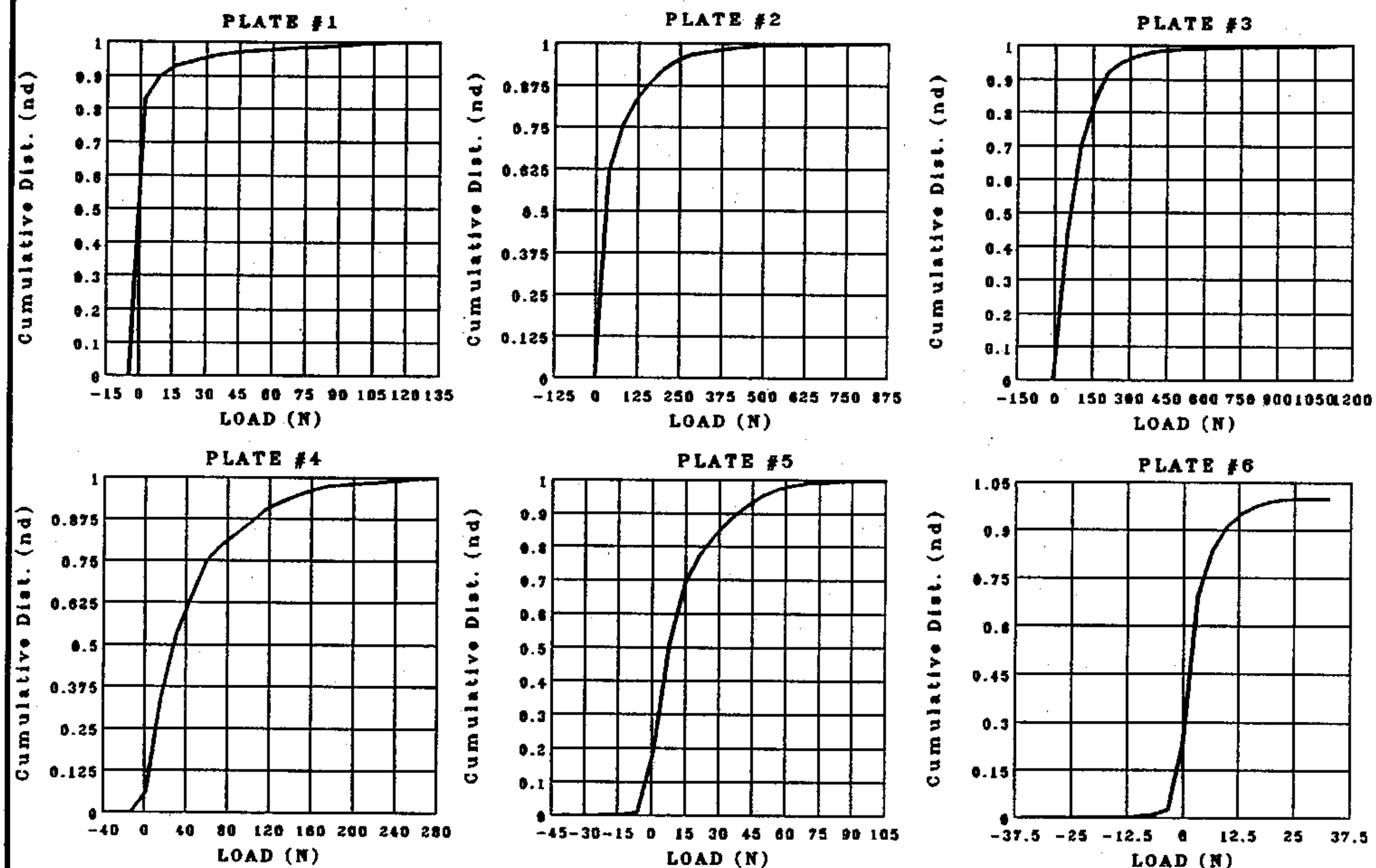
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←016
NORMAL LOAD



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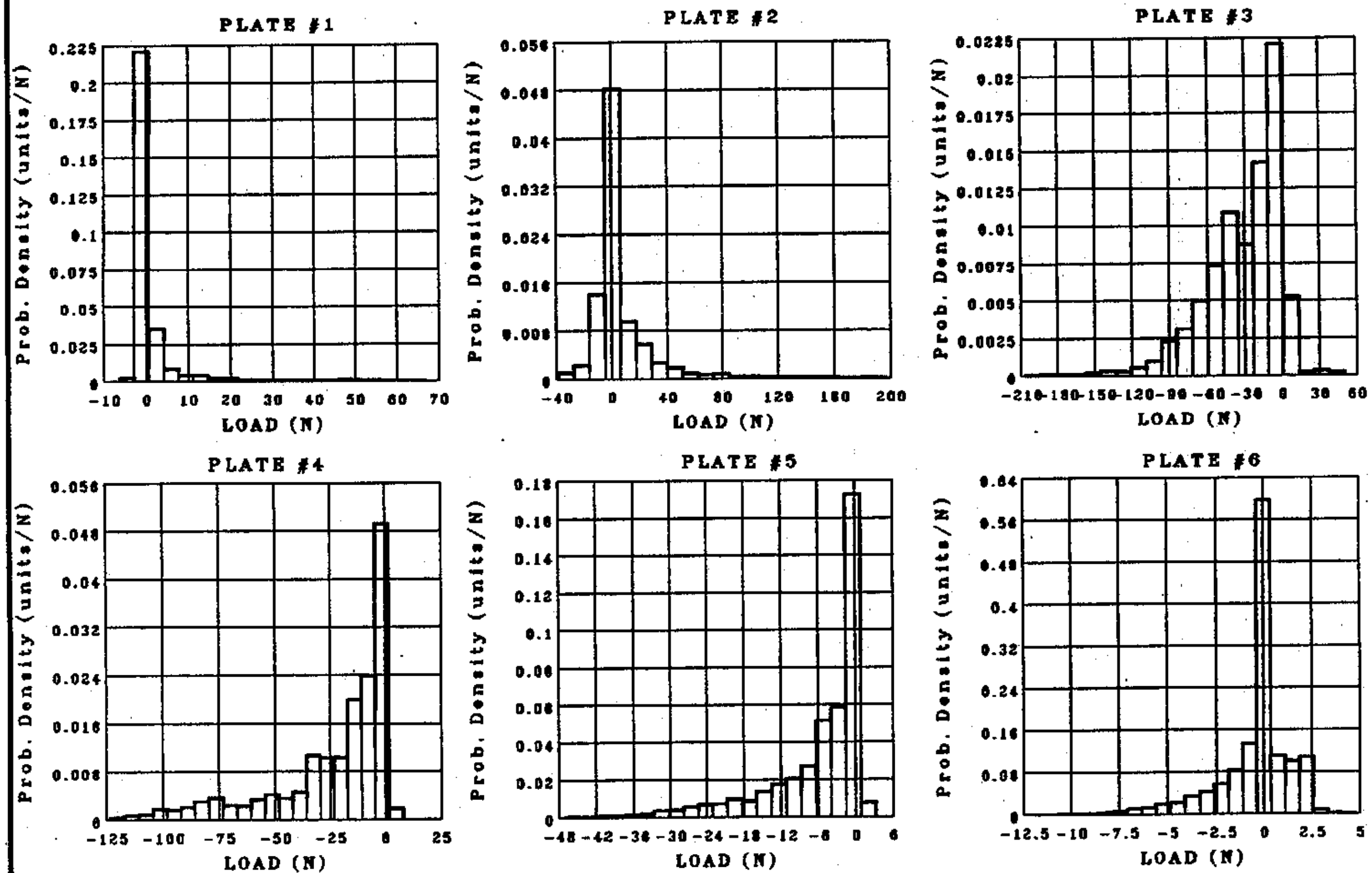
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←016
TANGENTIAL LOAD



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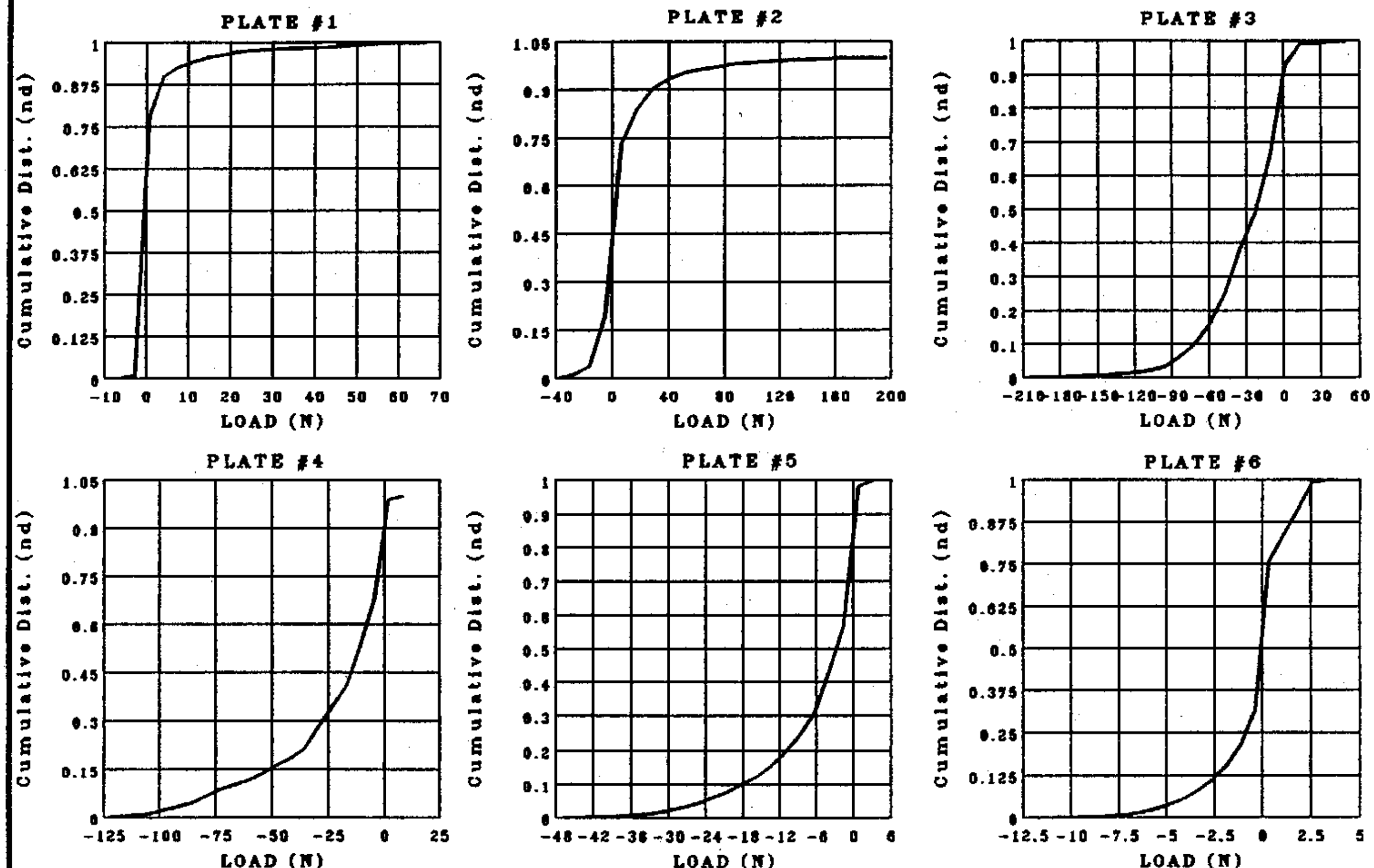
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←016
TANGENTIAL LOAD



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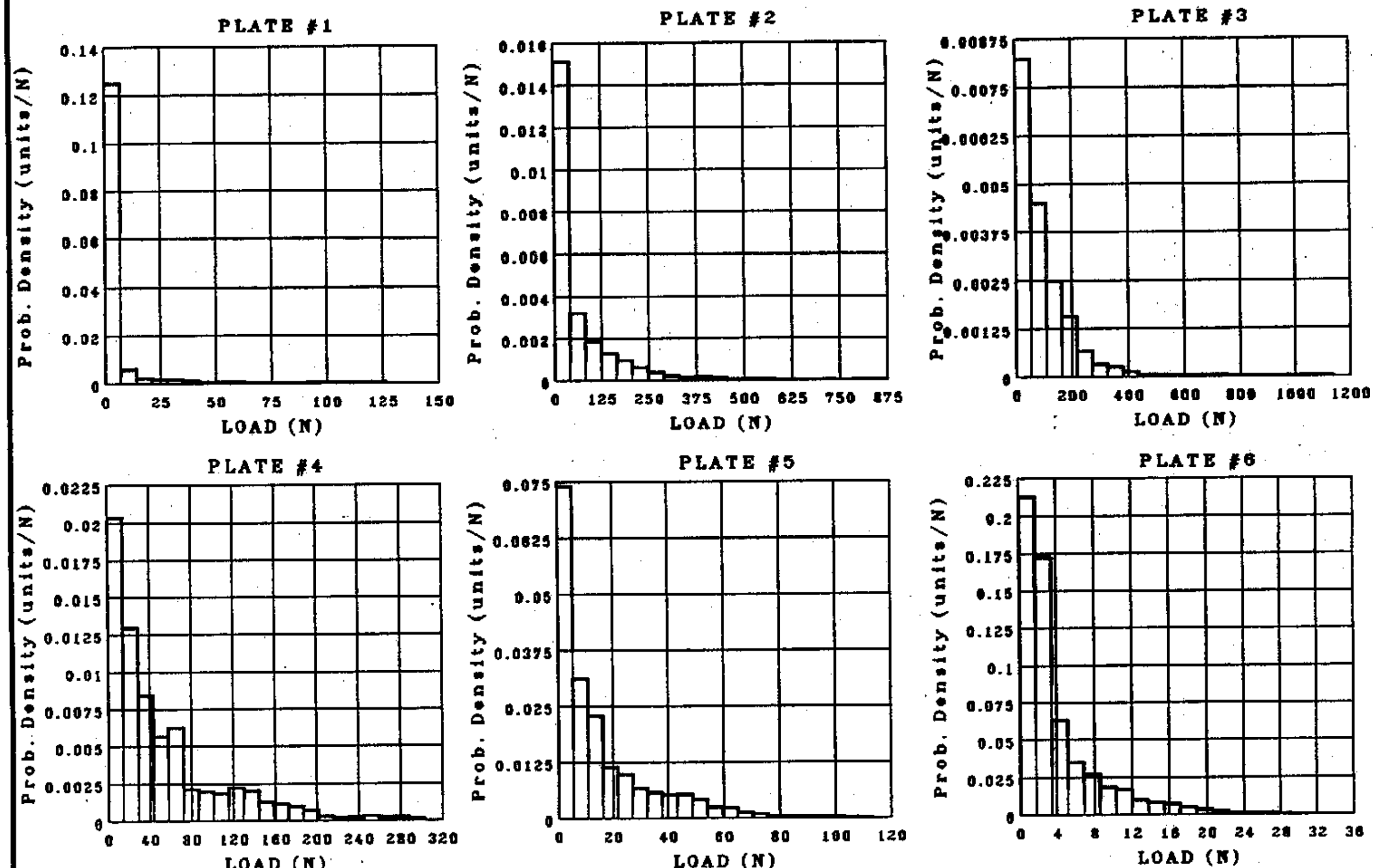
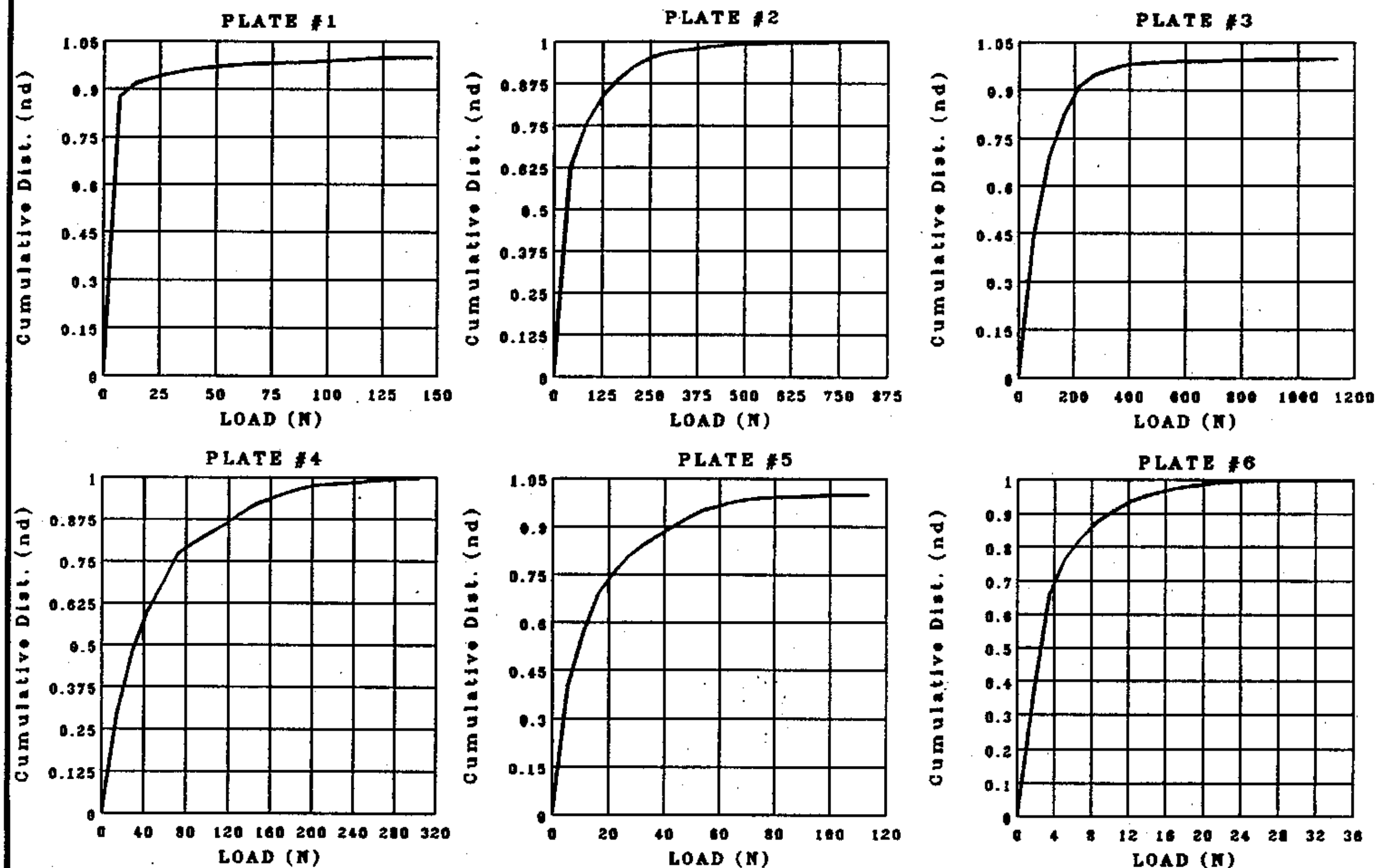
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←016
RESULTANT



National Research Council Canada	Conseil national de recherches Canada	ICE PILEUP STUDY for CANADIAN COAST GUARD

TN←016
RESULTANT



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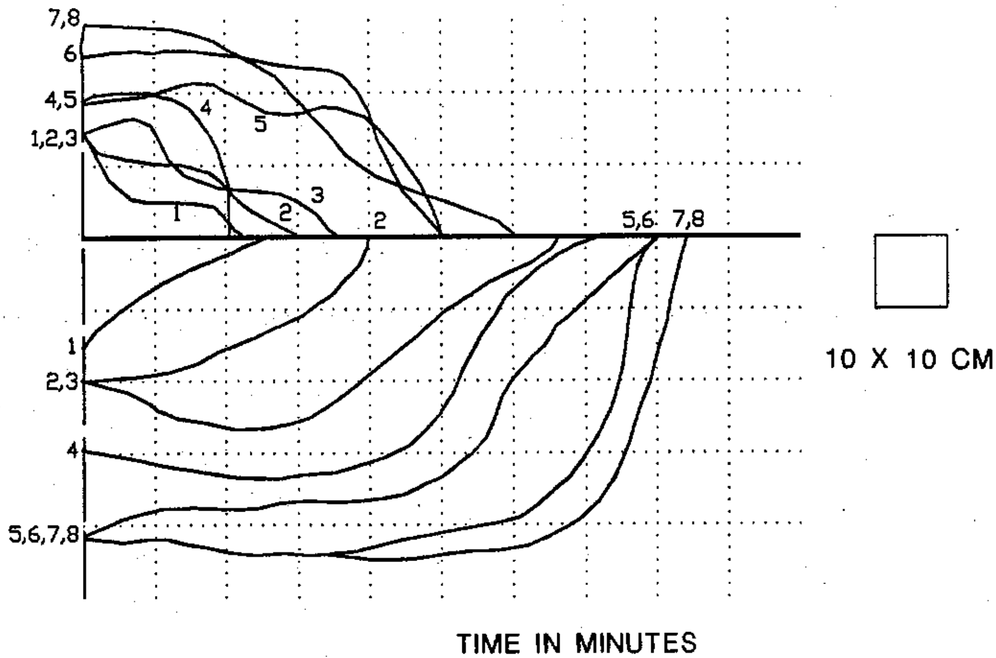
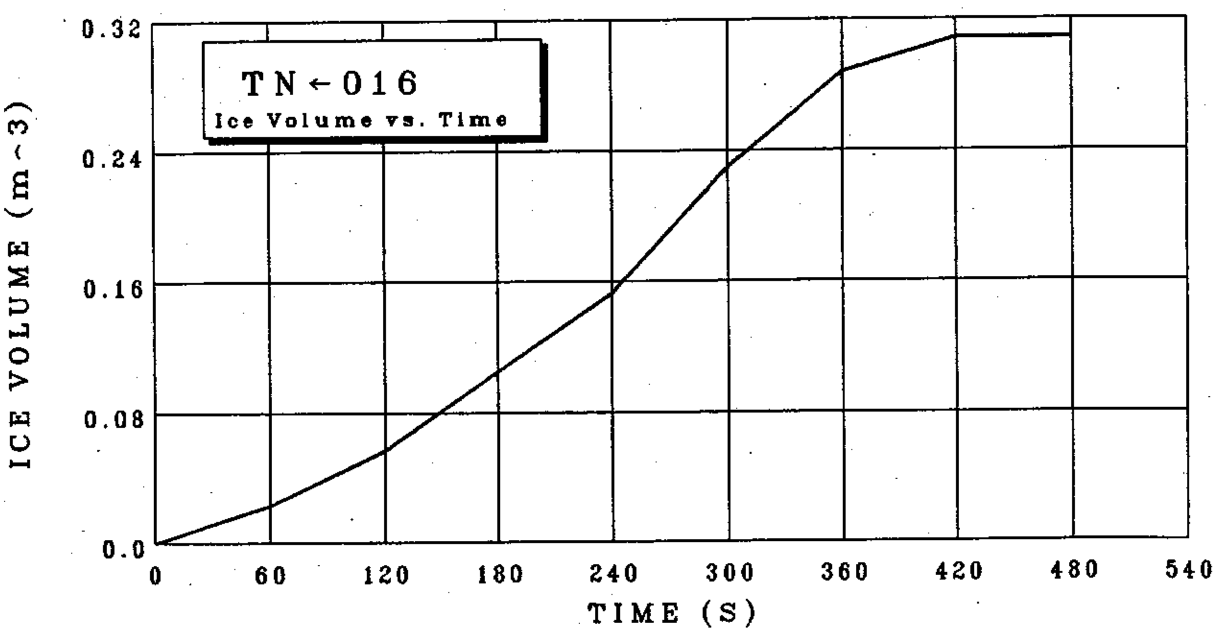
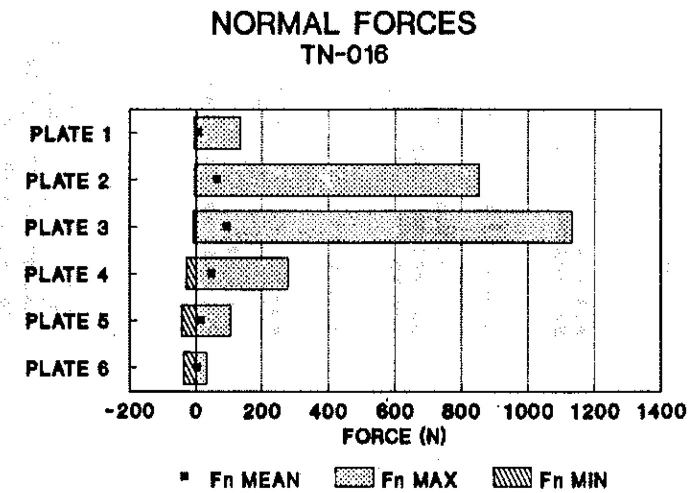
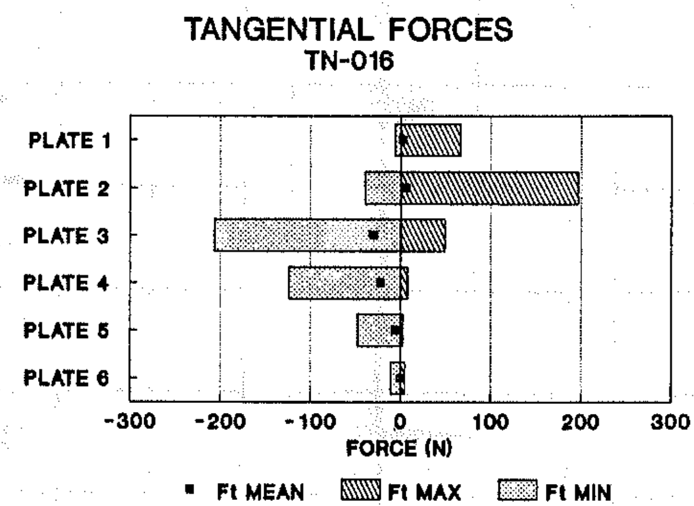
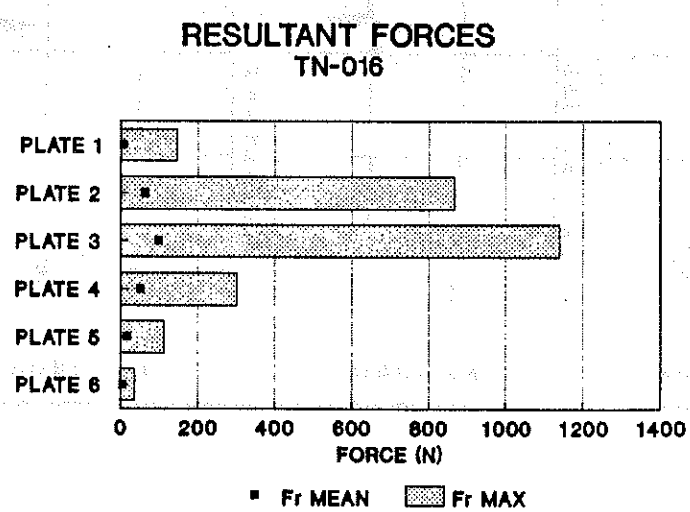
ICE PILEUP STUDY
for CANADIAN COAST GUARD

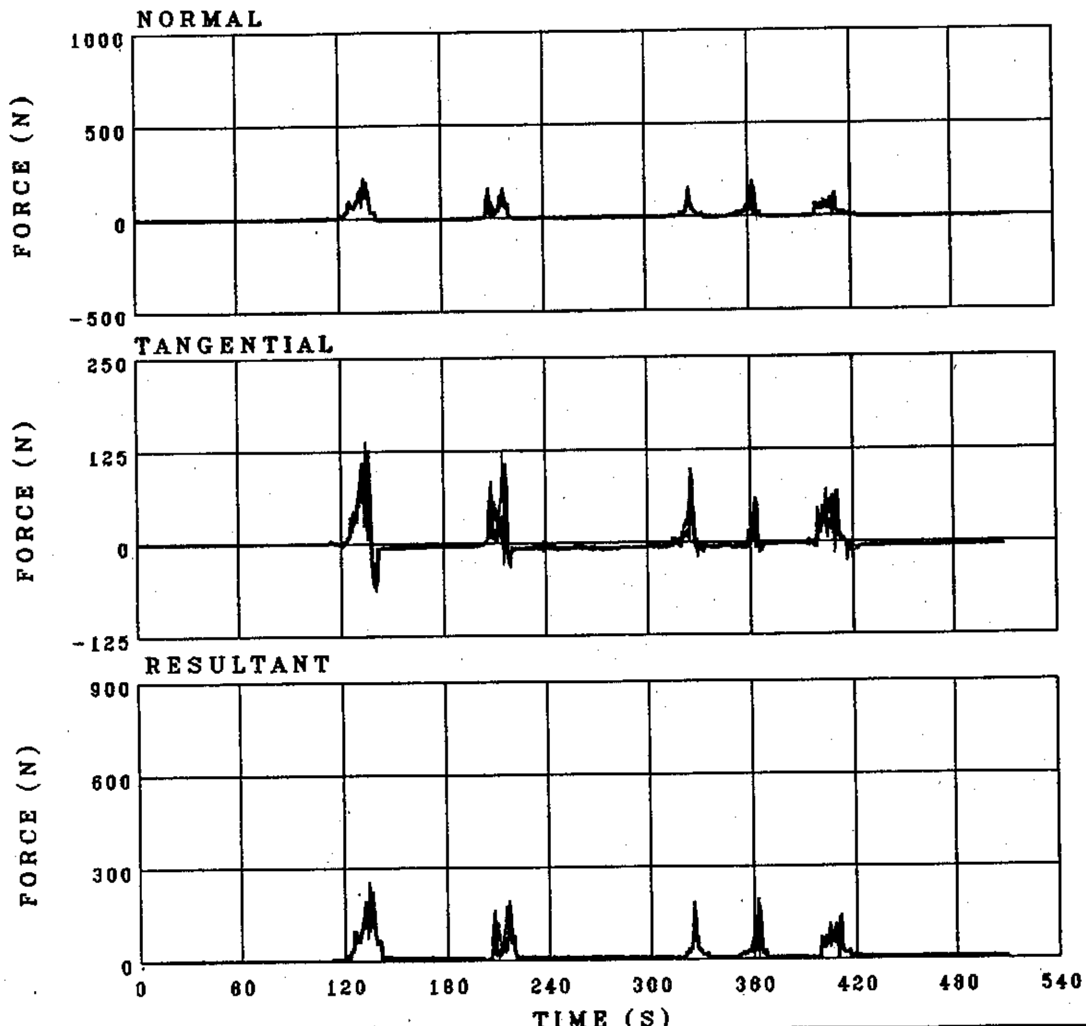

7,8
6
4,5
1,2,3
4
5
3
1
2
2
5,6
7,8
1
2,3
4
5,6,7,8
10 X 10 CM
TIME IN MINUTES


TN←016
Ice Volume vs. Time
ICE VOLUME (m^3)
0.32
0.24
0.16
0.08
0.0
0
60
120
180
240
300
360
420
480
540
TIME (S)


NORMAL FORCES
TN-016
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-200 0 200 400 600 800 1000 1200 1400
FORCE (N)
Fn MEAN
Fn MAX
Fn MIN


TANGENTIAL FORCES
TN-016
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-300 -200 -100 0 100 200 300
FORCE (N)
Ft MEAN
Ft MAX
Ft MIN


RESULTANT FORCES
TN-016
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
0 200 400 600 800 1000 1200 1400
FORCE (N)
Fr MEAN
Fr MAX



FILE TN←017

PLATE #1

NORMAL

MEAN FORCE = 5.697 N
MAX FORCE = 178.0 N
MIN FORCE = −16.43 N

TANGENTIAL

MEAN FORCE = −0.006427 N
MAX FORCE = 116.2 N
MIN FORCE = −60.31 N

RESULTANT

MEAN FORCE = 14.28 N
MAX FORCE = 207.5 N
MIN FORCE = 0.1582 N
AVERAGE ANGLE = −43.57 O

TEST CONDITIONS

BOARD ANGLE = 24.00 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 50.00 kPa
ICE THICKNESS = 3.400 cm
ICE DENSITY = 0.9000 g/cc

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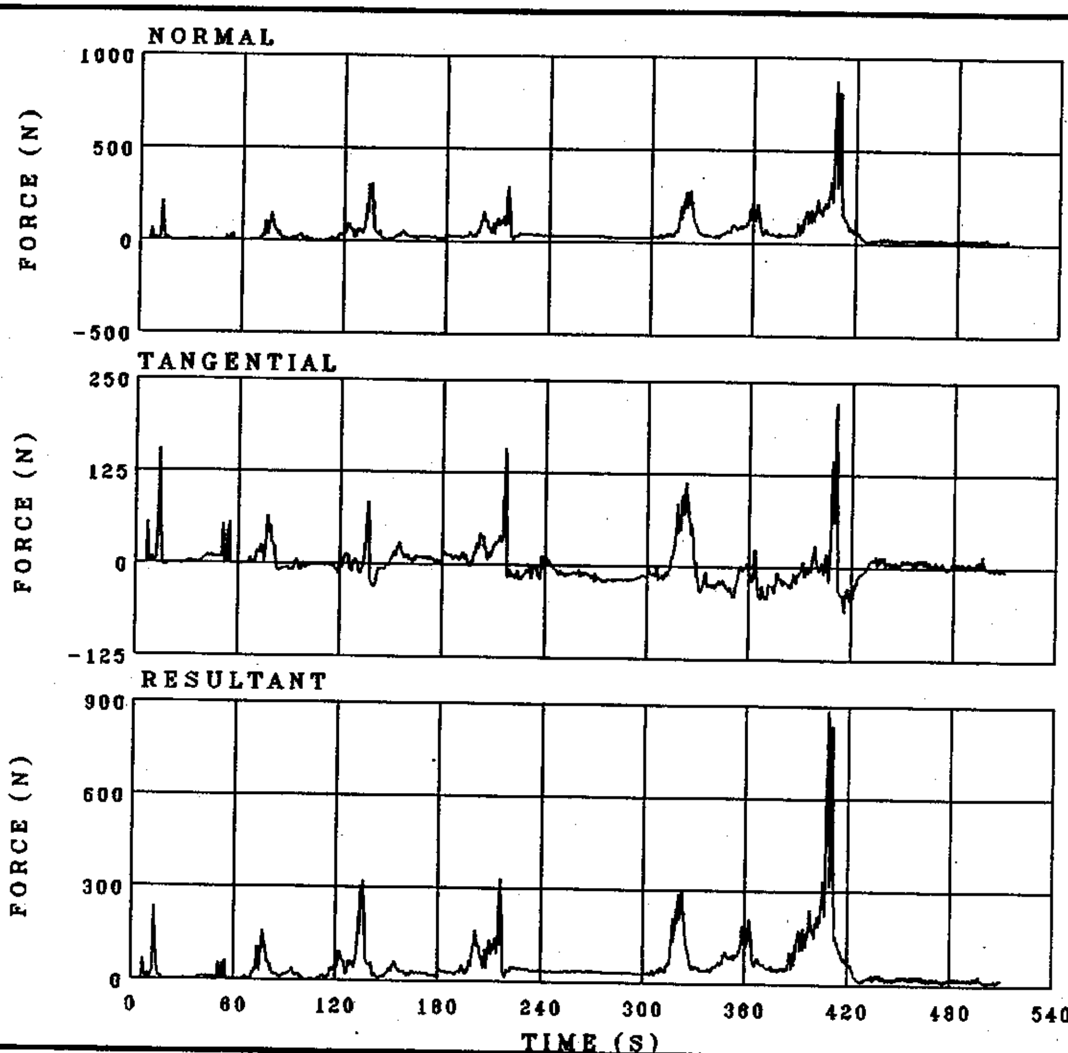
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←017

PLATE #2

NORMAL

MEAN FORCE = 49.52 N
MAX FORCE = 880.5 N
MIN FORCE = -0.7558 N

TANGENTIAL

MEAN FORCE = 0.9108 N
MAX FORCE = 223.0 N
MIN FORCE = -60.91 N

RESULTANT

MEAN FORCE = 52.84 N
MAX FORCE = 888.5 N
MIN FORCE = 0.05290 N
AVERAGE ANGLE = -6.090 O

TEST CONDITIONS

BOARD ANGLE = 24.00 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 50.00 kPa
ICE THICKNESS = 3.400 cm
ICE DENSITY = 0.9000 g/cc

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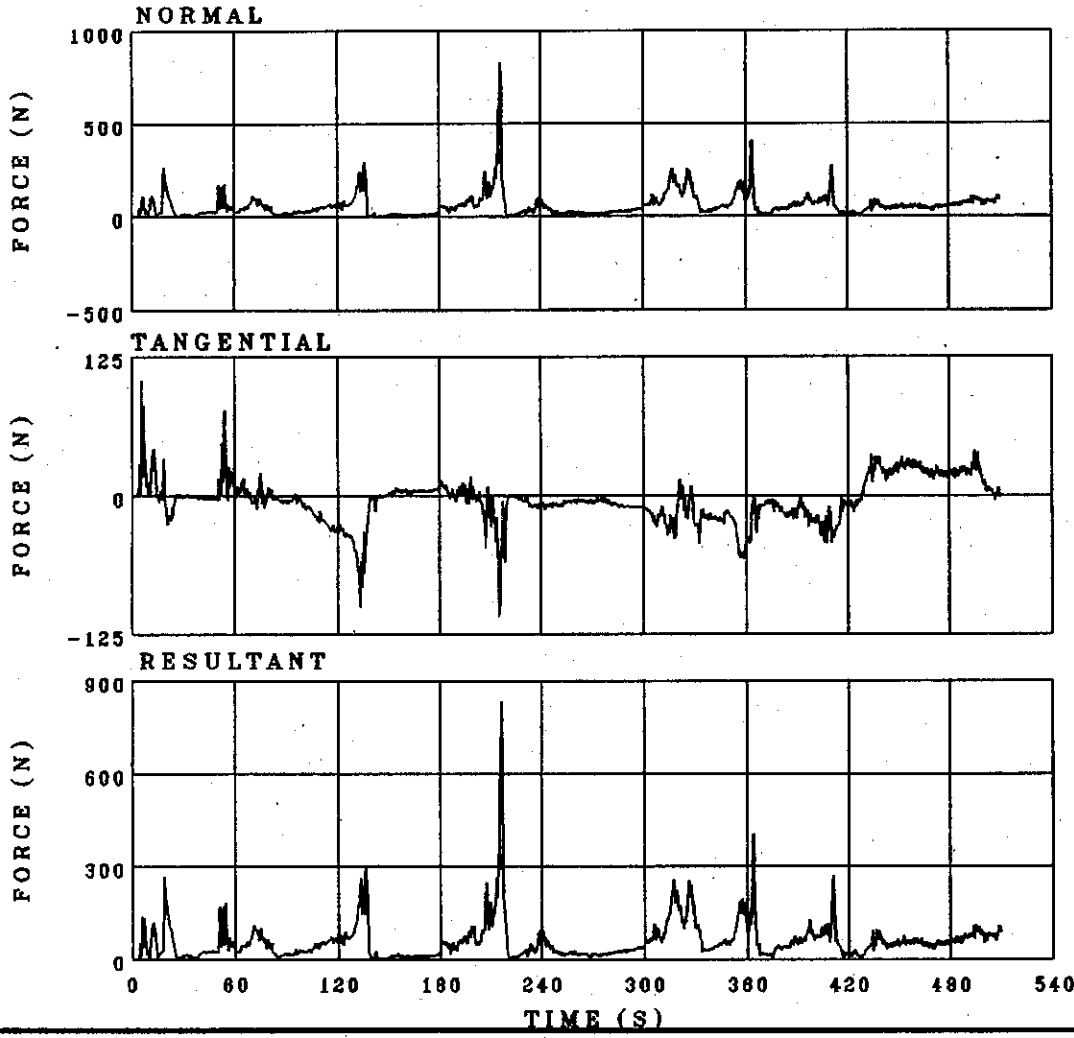
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←017

PLATE #3

NORMAL

MEAN FORCE = 56.73 N
MAX FORCE = 828.4 N
MIN FORCE = -5.836 N

TANGENTIAL

MEAN FORCE = -4.731 N
MAX FORCE = 104.3 N
MIN FORCE = -109.2 N

RESULTANT

MEAN FORCE = 58.41 N
MAX FORCE = 833.3 N
MIN FORCE = 0.04091 N
AVERAGE ANGLE = -5.252 O

TEST CONDITIONS

BOARD ANGLE = 24.00 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 50.00 kPa
ICE THICKNESS = 3.400 cm
ICE DENSITY = 0.9000 g/cc

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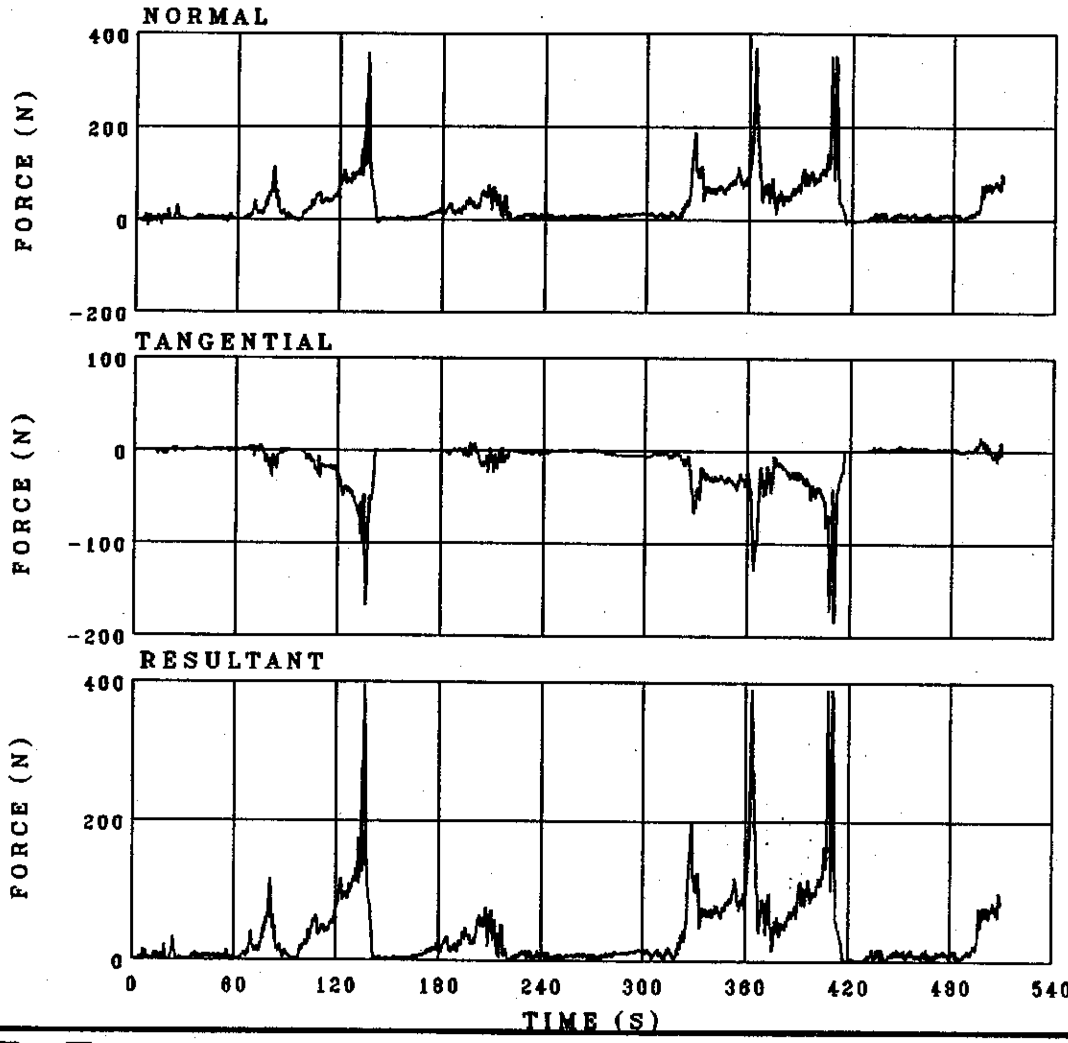
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←017

PLATE #4

NORMAL

MEAN FORCE = 32.52 N
MAX FORCE = 369.5 N
MIN FORCE = -15.54 N

TANGENTIAL

MEAN FORCE = -11.10 N
MAX FORCE = 15.15 N
MIN FORCE = -184.6 N

RESULTANT

MEAN FORCE = 35.44 N
MAX FORCE = 396.4 N
MIN FORCE = 0.04776 N
AVERAGE ANGLE = -3.628 O

TEST CONDITIONS

BOARD ANGLE = 24.00 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 50.00 kPa
ICE THICKNESS = 3.400 cm
ICE DENSITY = 0.9000 g/cc

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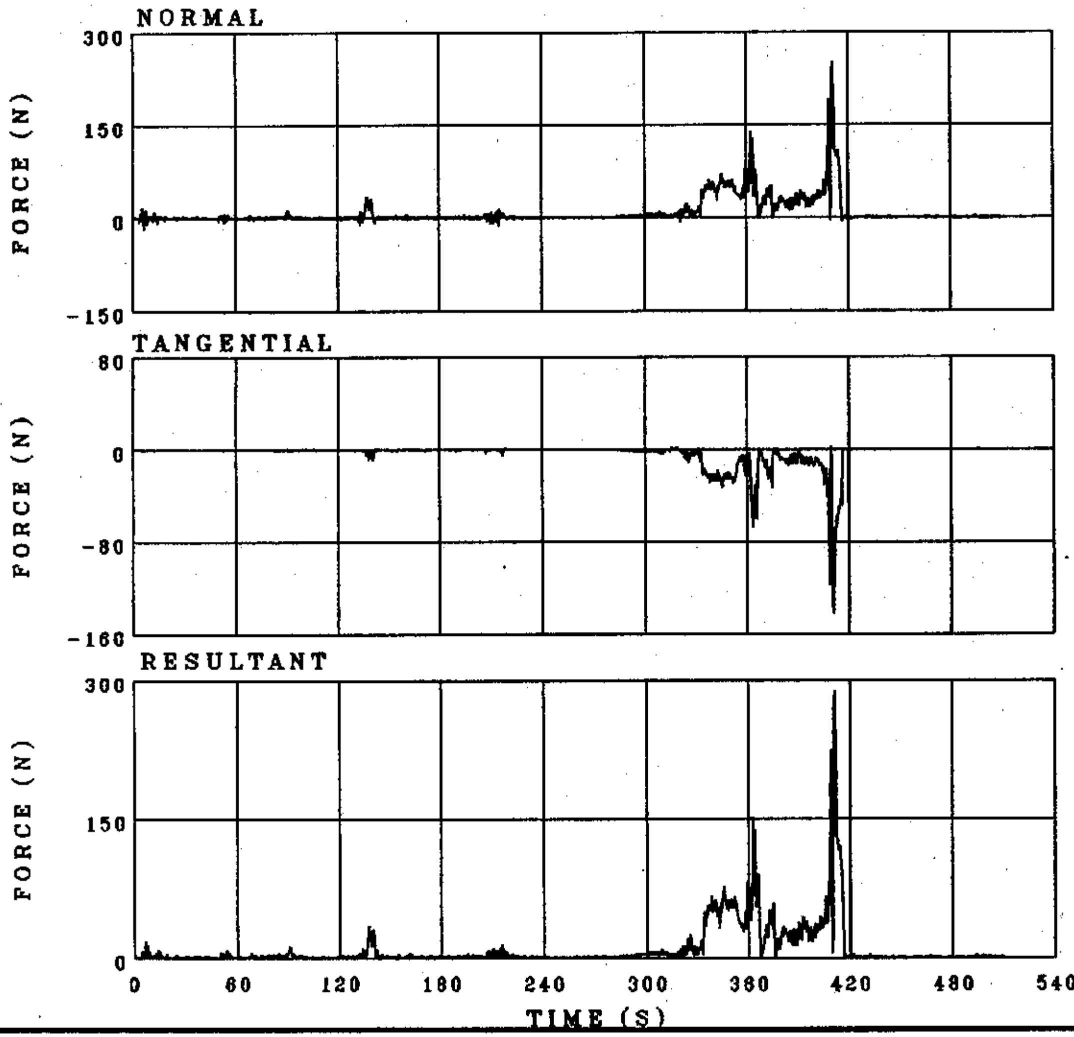
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←017

PLATE #5

NORMAL

MEAN FORCE = 8.439 N
MAX FORCE = 251.7 N
MIN FORCE = −10.28 N

TANGENTIAL

MEAN FORCE = −3.724 N
MAX FORCE = 2.947 N
MIN FORCE = −142.7 N

RESULTANT

MEAN FORCE = 9.990 N
MAX FORCE = 289.3 N
MIN FORCE = 0.03079 N
AVERAGE ANGLE = −5.029 O

TEST CONDITIONS

BOARD ANGLE = 24.00 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 50.00 kPa
ICE THICKNESS = 3.400 cm
ICE DENSITY = 0.9000 g/cc

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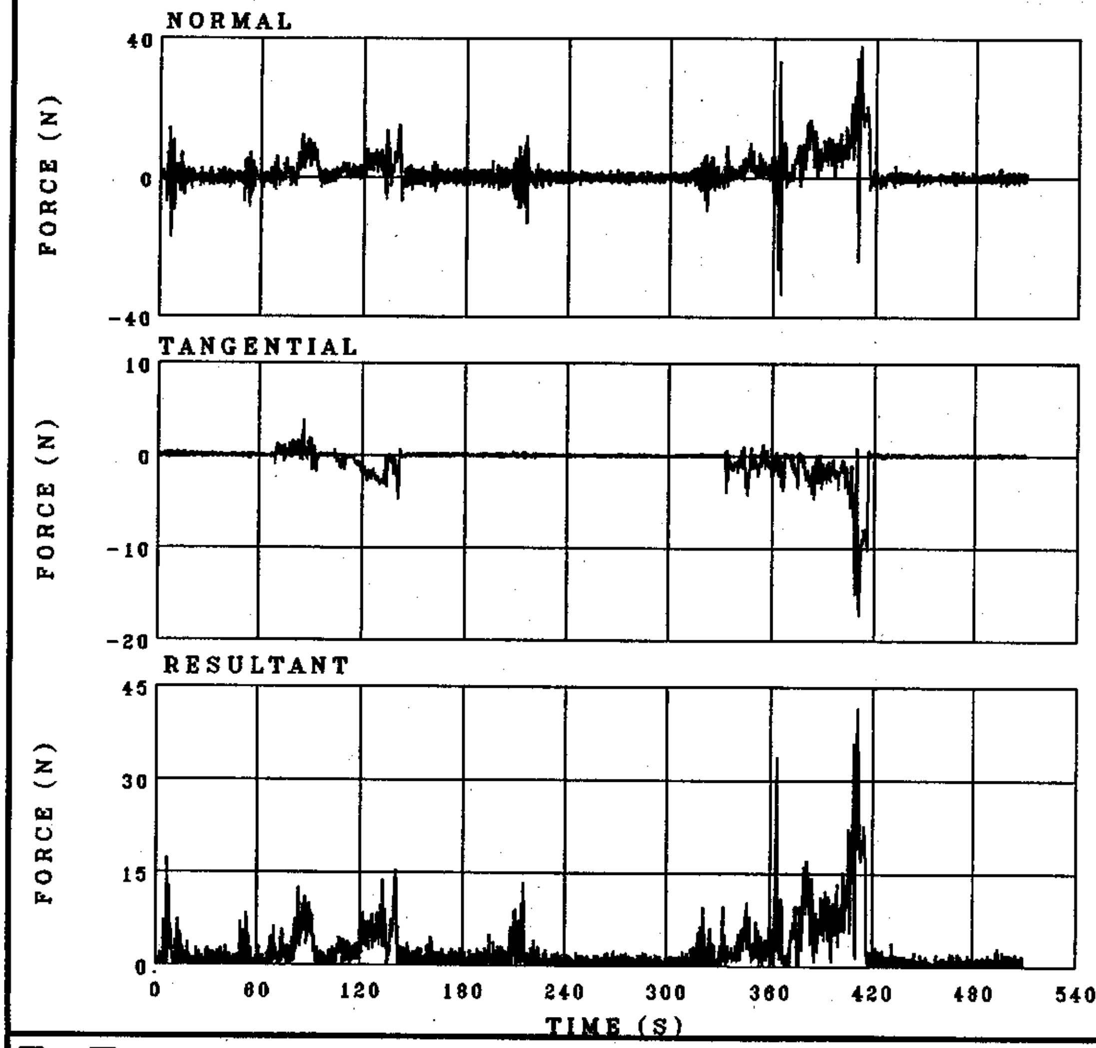
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←017

PLATE #6

NORMAL

MEAN FORCE = 1.418 N
MAX FORCE = 38.01 N
MIN FORCE = -33.83 N

TANGENTIAL

MEAN FORCE = -0.4055 N
MAX FORCE = 3.865 N
MIN FORCE = -17.30 N

RESULTANT

MEAN FORCE = 2.308 N
MAX FORCE = 41.65 N
MIN FORCE = 0.02649 N
AVERAGE ANGLE = 3.471 O

TEST CONDITIONS

BOARD ANGLE = 24.00 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 50.00 kPa
ICE THICKNESS = 3.400 cm
ICE DENSITY = 0.9000 g/cc

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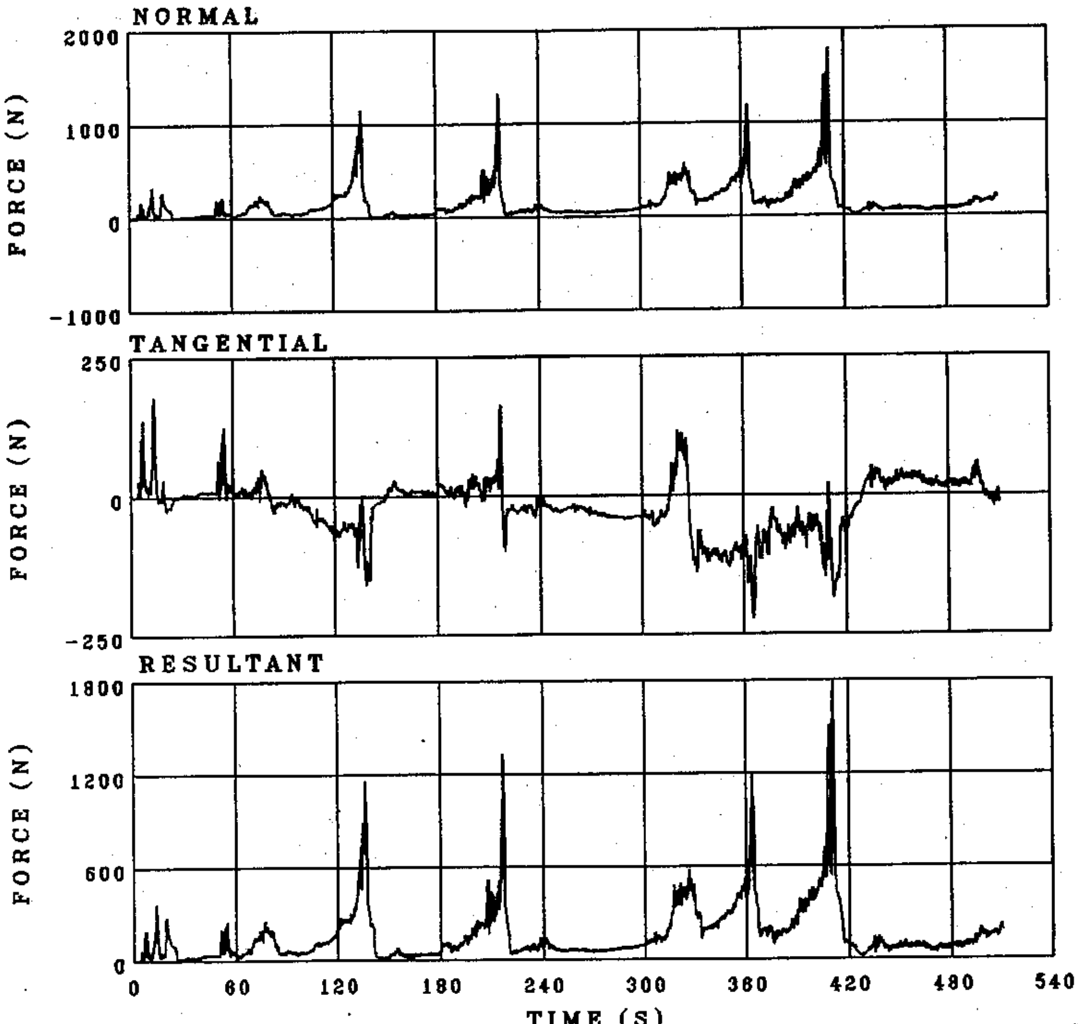
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←017

TOTAL

NORMAL

MEAN FORCE = 153.3 N
MAX FORCE = 1793.0 N
MIN FORCE = -19.20 N

TANGENTIAL

MEAN FORCE = -19.06 N
MAX FORCE = 178.1 N
MIN FORCE = -222.9 N

RESULTANT

MEAN FORCE = 160.6 N
MAX FORCE = 1795.0 N
MIN FORCE = 0.1318 N
AVERAGE ANGLE = -6.169 O

TEST CONDITIONS

BOARD ANGLE = 24.00 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 50.00 kPa
ICE THICKNESS = 3.400 cm
ICE DENSITY = 0.9000 g/cc

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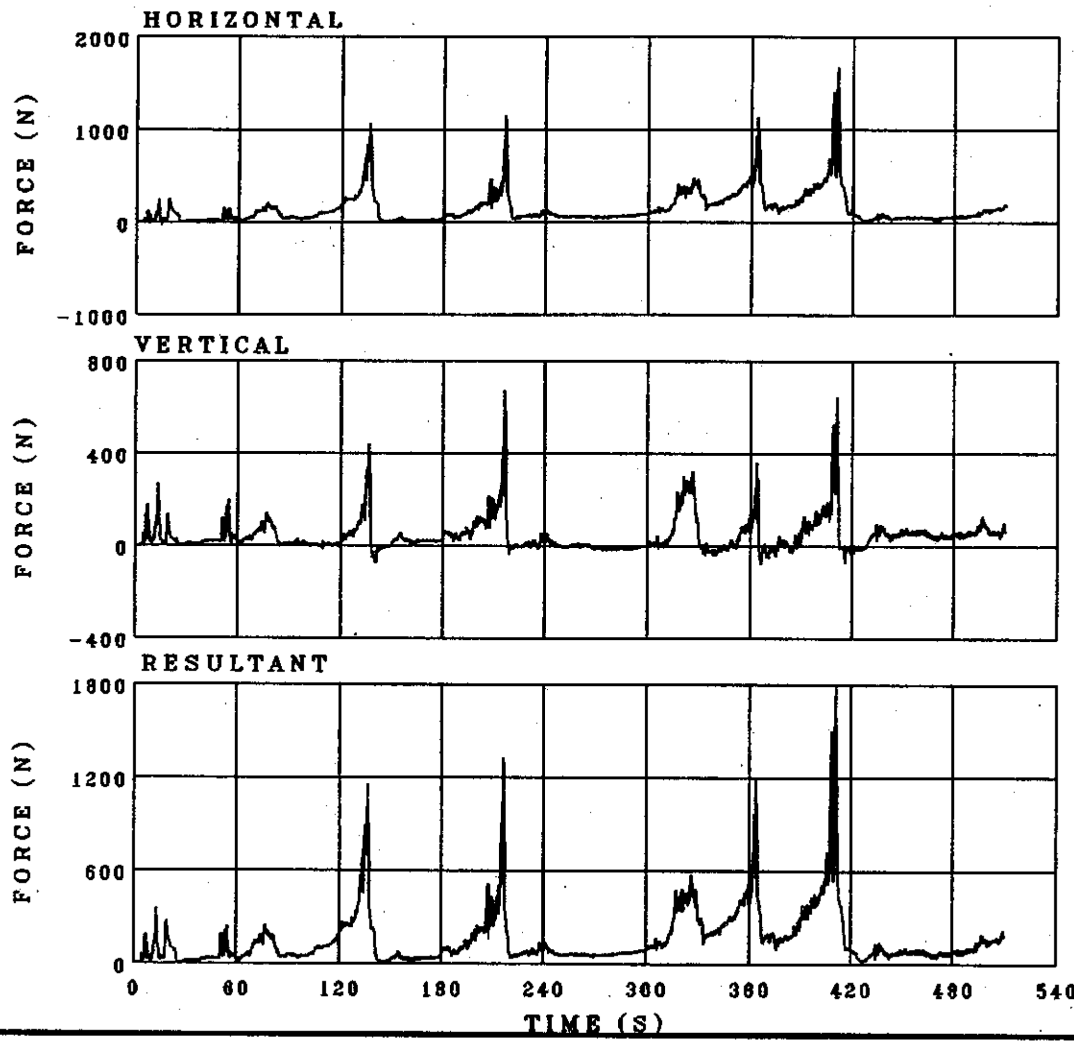
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←017

TOTAL

HORIZONTAL

MEAN FORCE = −19.06 N
MAX FORCE = 178.1 N
MIN FORCE = −222.9 N

VERTICAL

MEAN FORCE = −19.06 N
MAX FORCE = 178.1 N
MIN FORCE = −222.9 N

RESULTANT

MEAN FORCE = −19.06 N
MAX FORCE = 178.1 N
MIN FORCE = −222.9 N
AVERAGE ANGLE = −19.06 O

TEST CONDITIONS

BOARD ANGLE = 24.00 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 50.00 kPa
ICE THICKNESS = 3.400 cm
ICE DENSITY = 0.9000 g/cc

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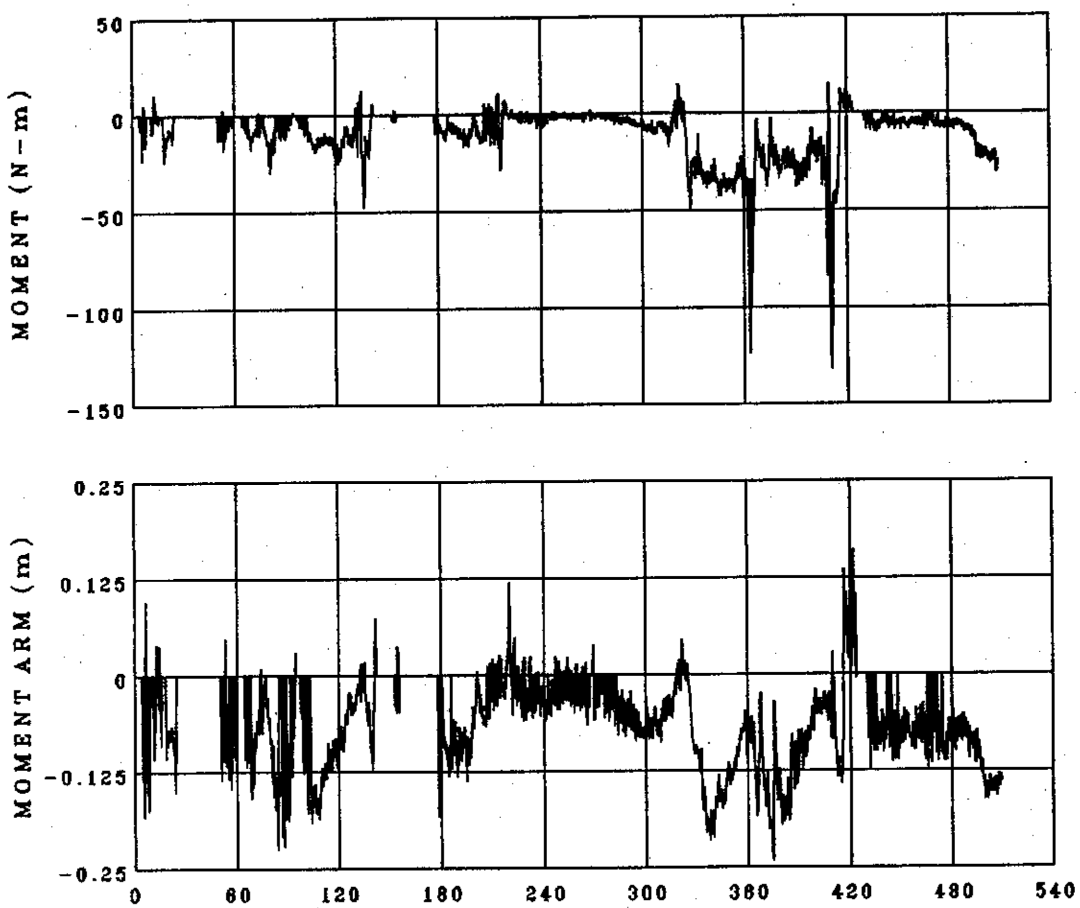
ICE PILEUP STUDY
for CANADIAN COAST GUARD

FILE TN←017



MOMENT

MOMENT

MEAN MOMENT = -9.984 N-m
MAX MOMENT = 15.12 N-m
MIN MOMENT = -132.4 N-m

MOMENT ARM

MEAN ARM = -0.05685 m
MAX ARM = 0.1610 m
MIN ARM = -0.2426 m

TEST CONDITIONS

BOARD ANGLE = 24.00 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 50.00 kPa
ICE THICKNESS = 3.400 cm
ICE DENSITY = 0.9000 g/cc

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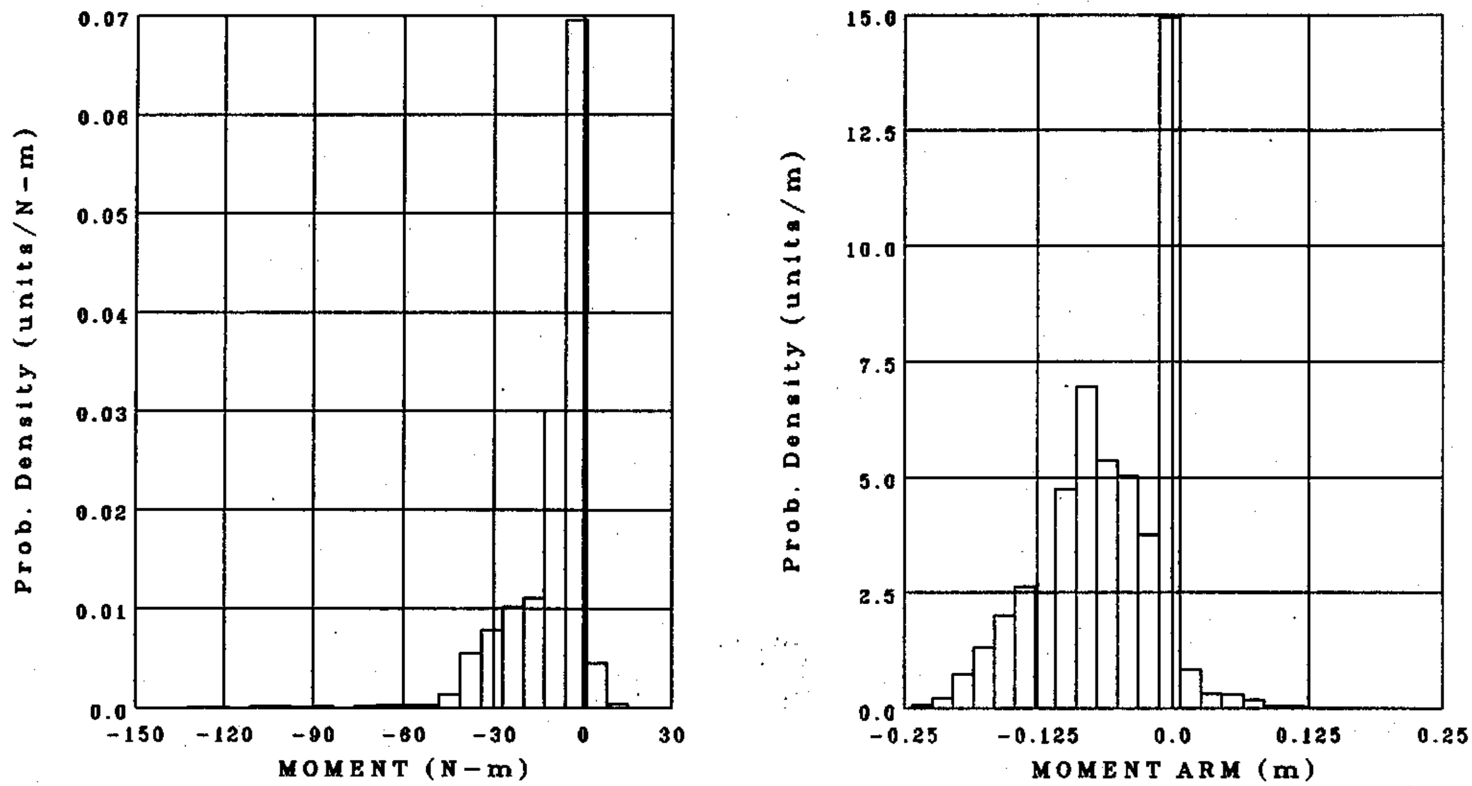
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←017



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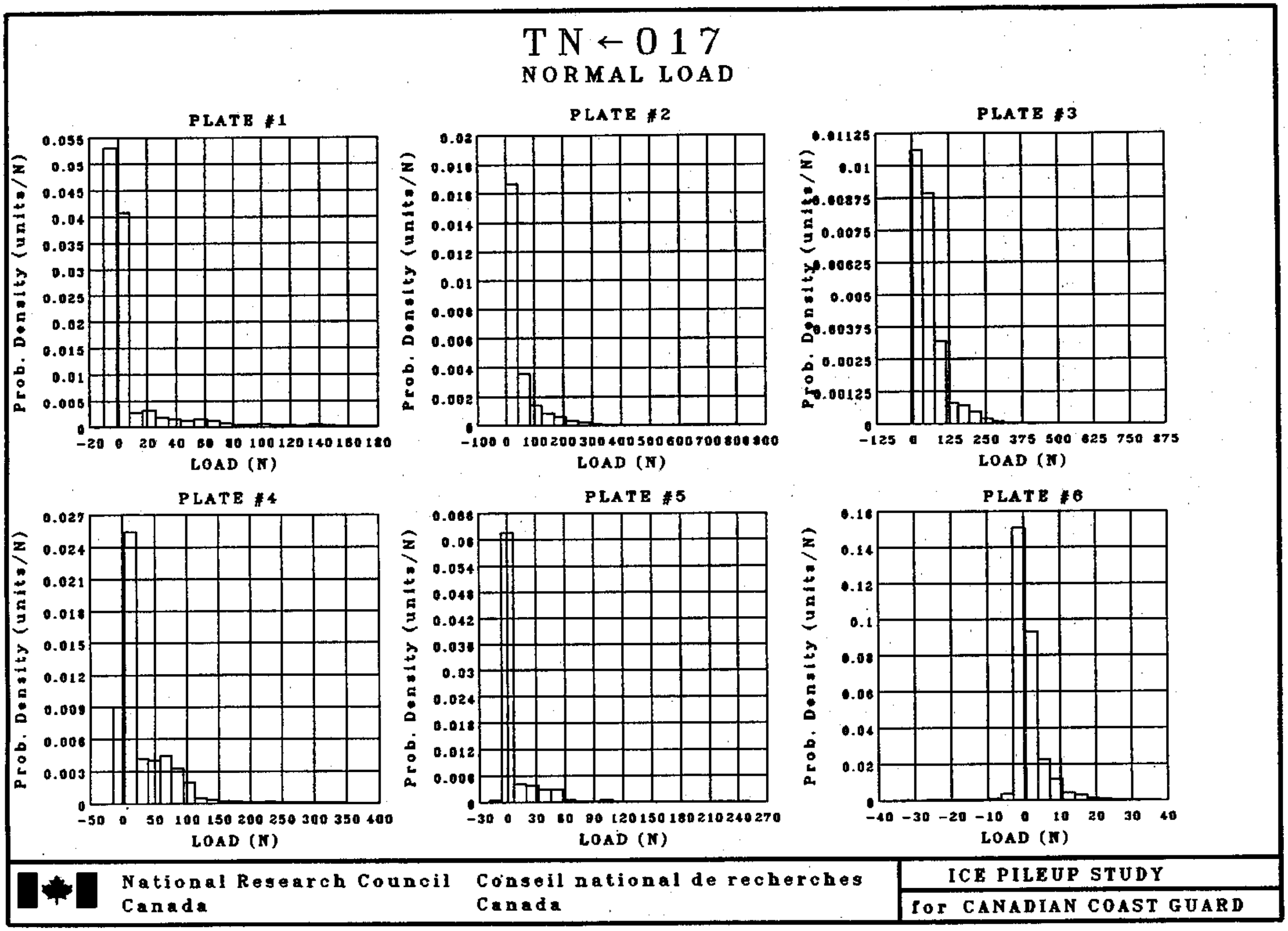
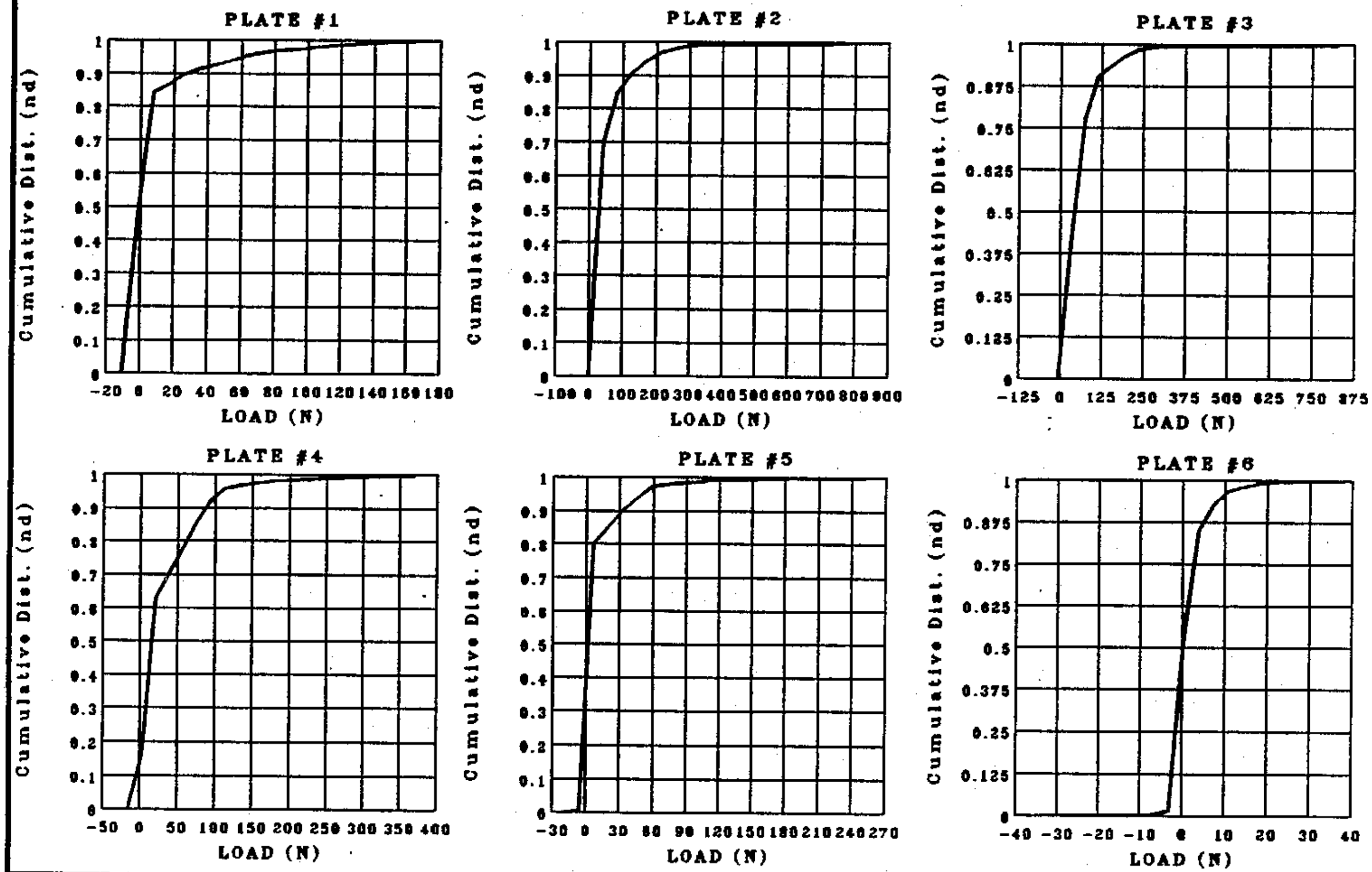
ICE PILEUP STUDY
for CANADIAN COAST GUARD


TN←017
NORMAL LOAD
PLATE #1
PLATE #2
PLATE #3
PLATE #4
PLATE #5
PLATE #6
Prob. Density (units/N)
LOAD (N)
National Research Council Canada
Conseil national de recherches Canada
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←017
NORMAL LOAD



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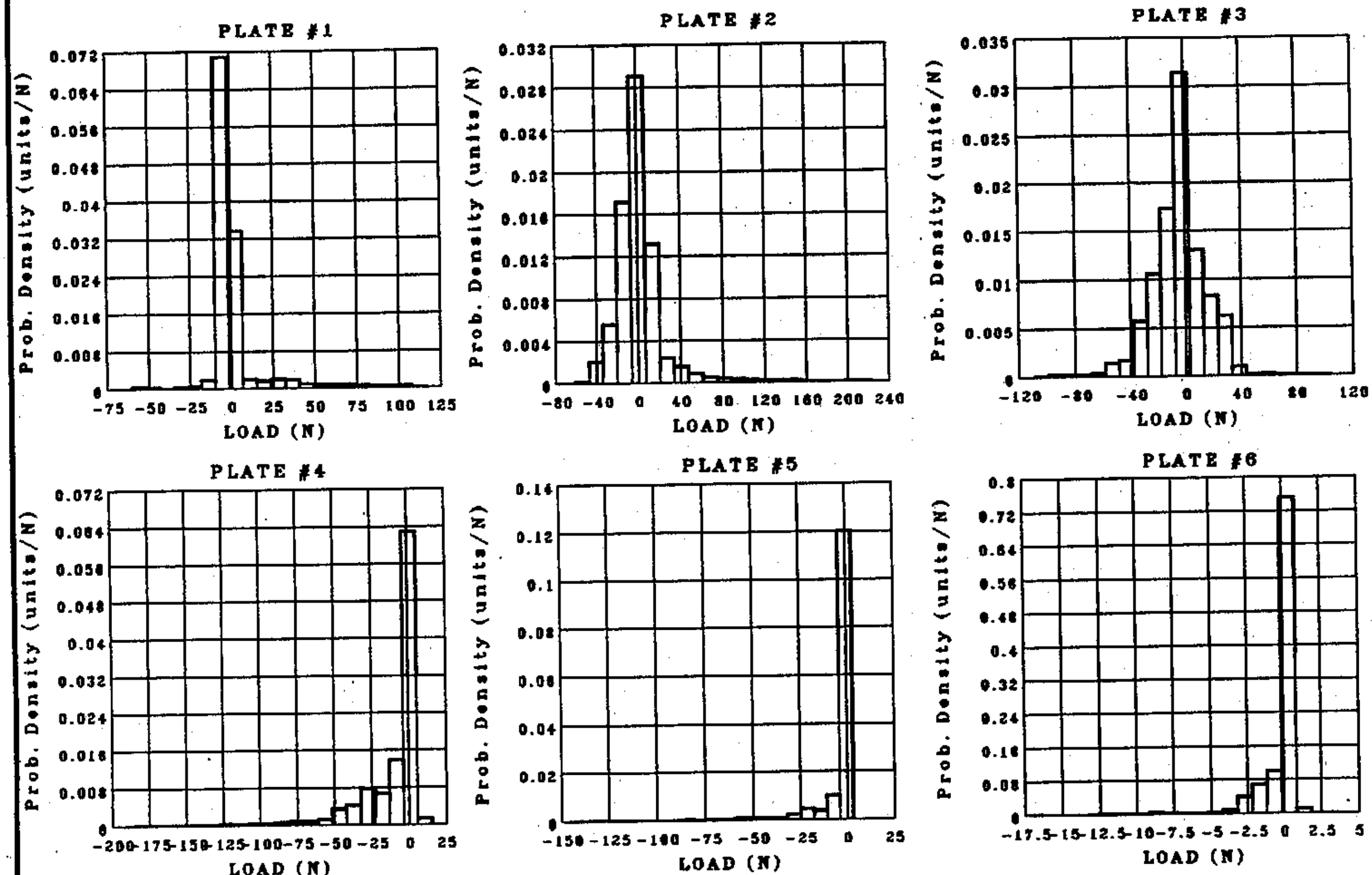
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←017
TANGENTIAL LOAD



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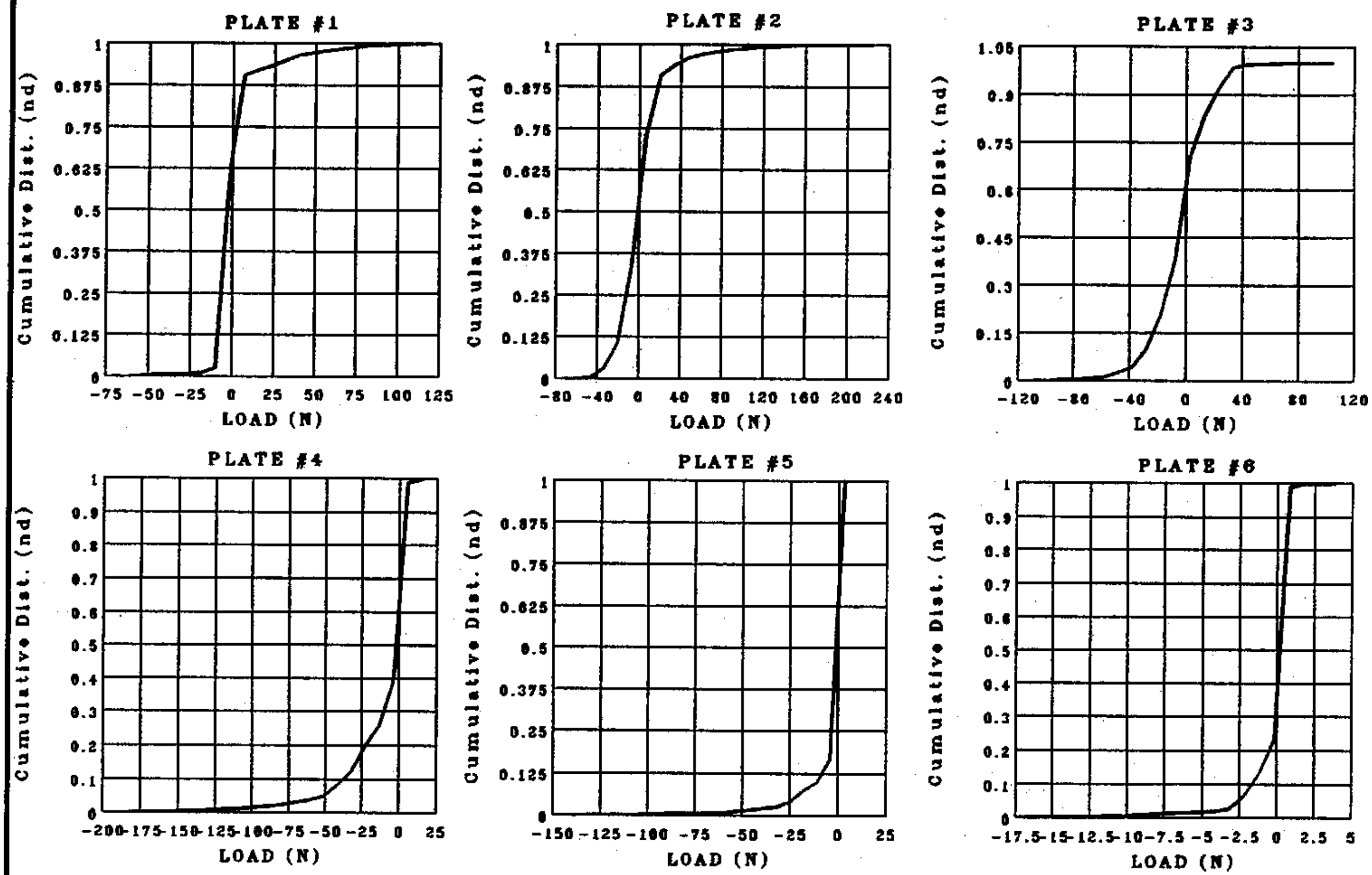
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←017
TANGENTIAL LOAD



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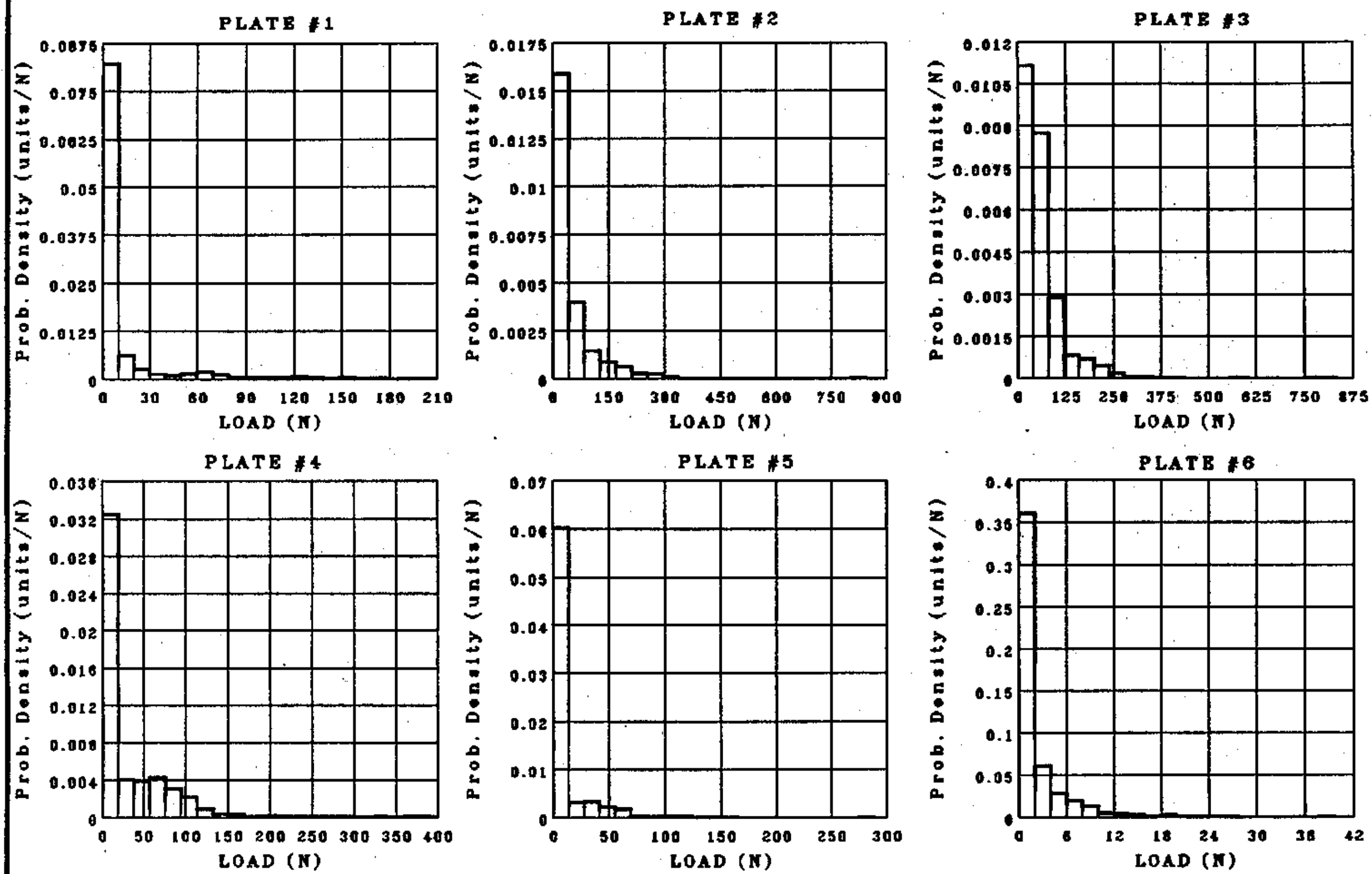
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←017
RESULTANT



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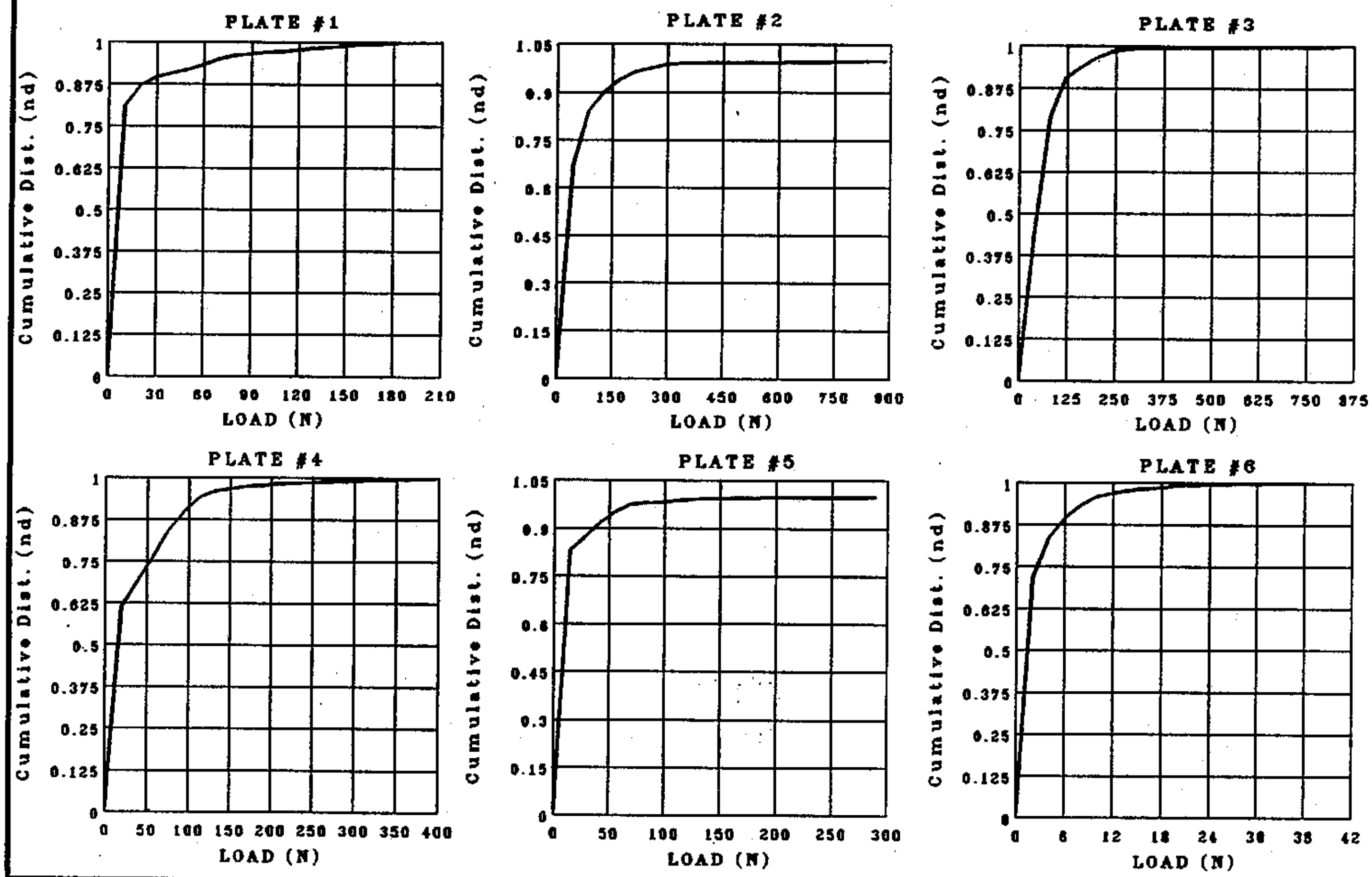
ICE PILEUP STUDY for CANADIAN COAST GUARD

TN←017
RESULTANT



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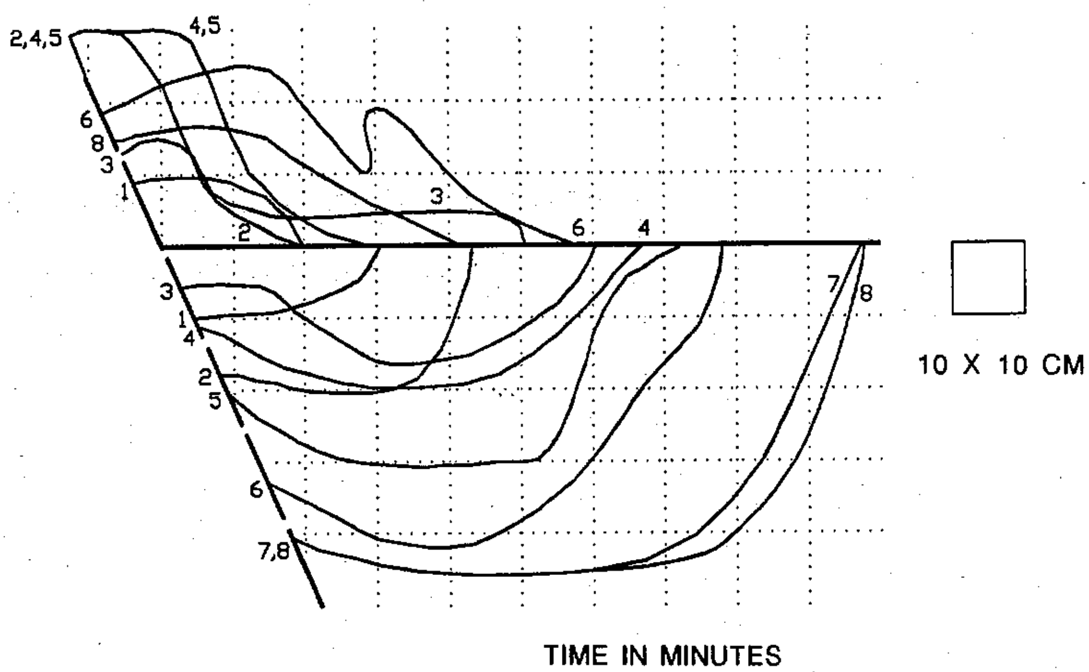
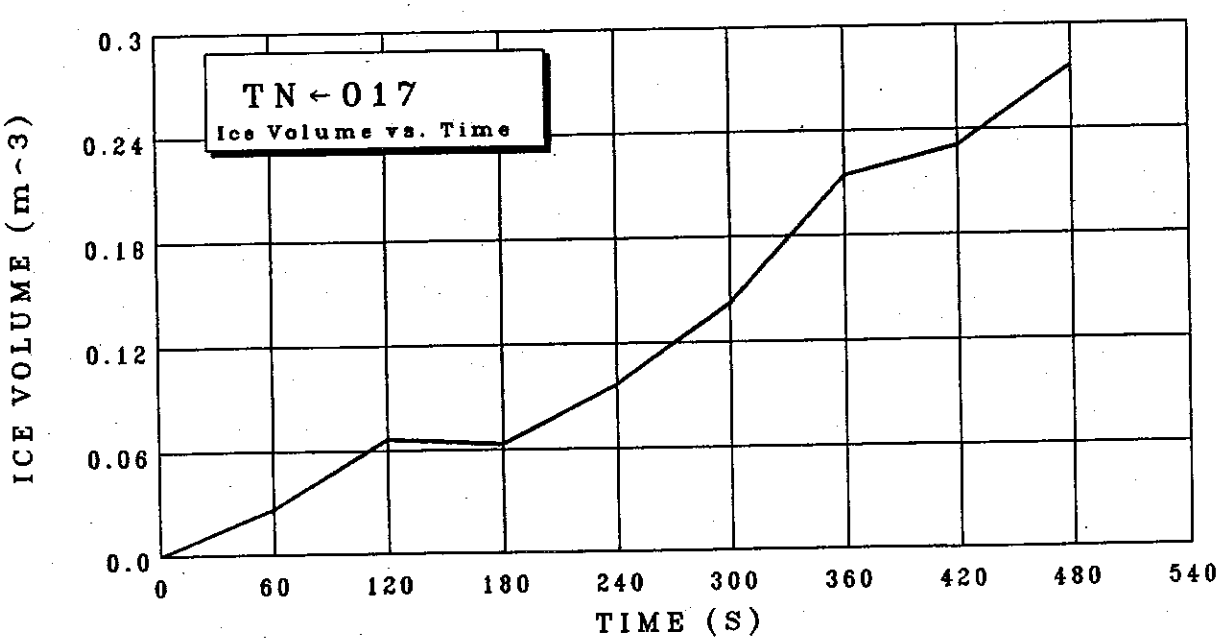
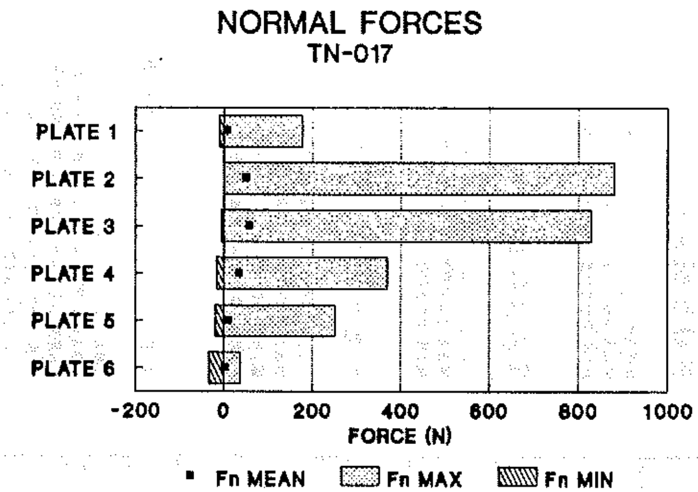
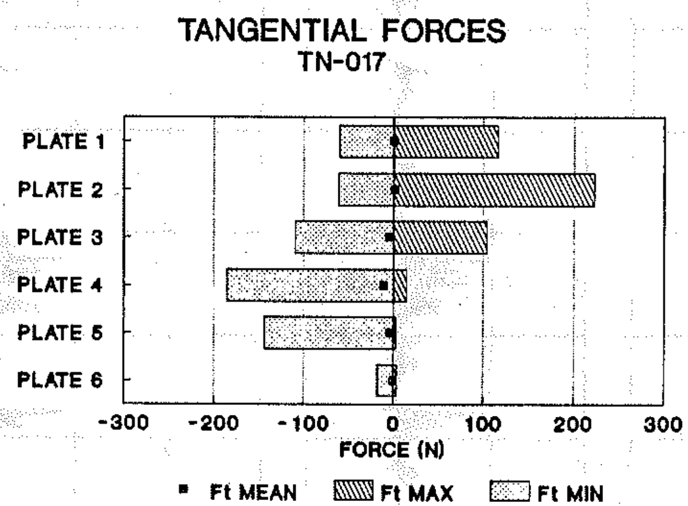
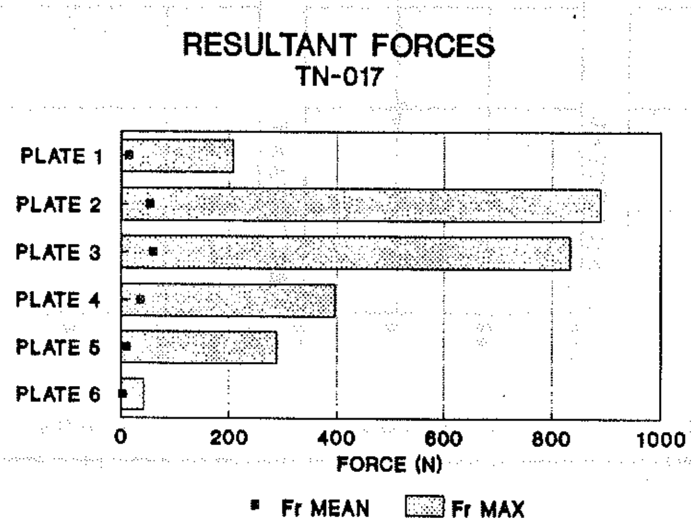
ICE PILEUP STUDY
for CANADIAN COAST GUARD

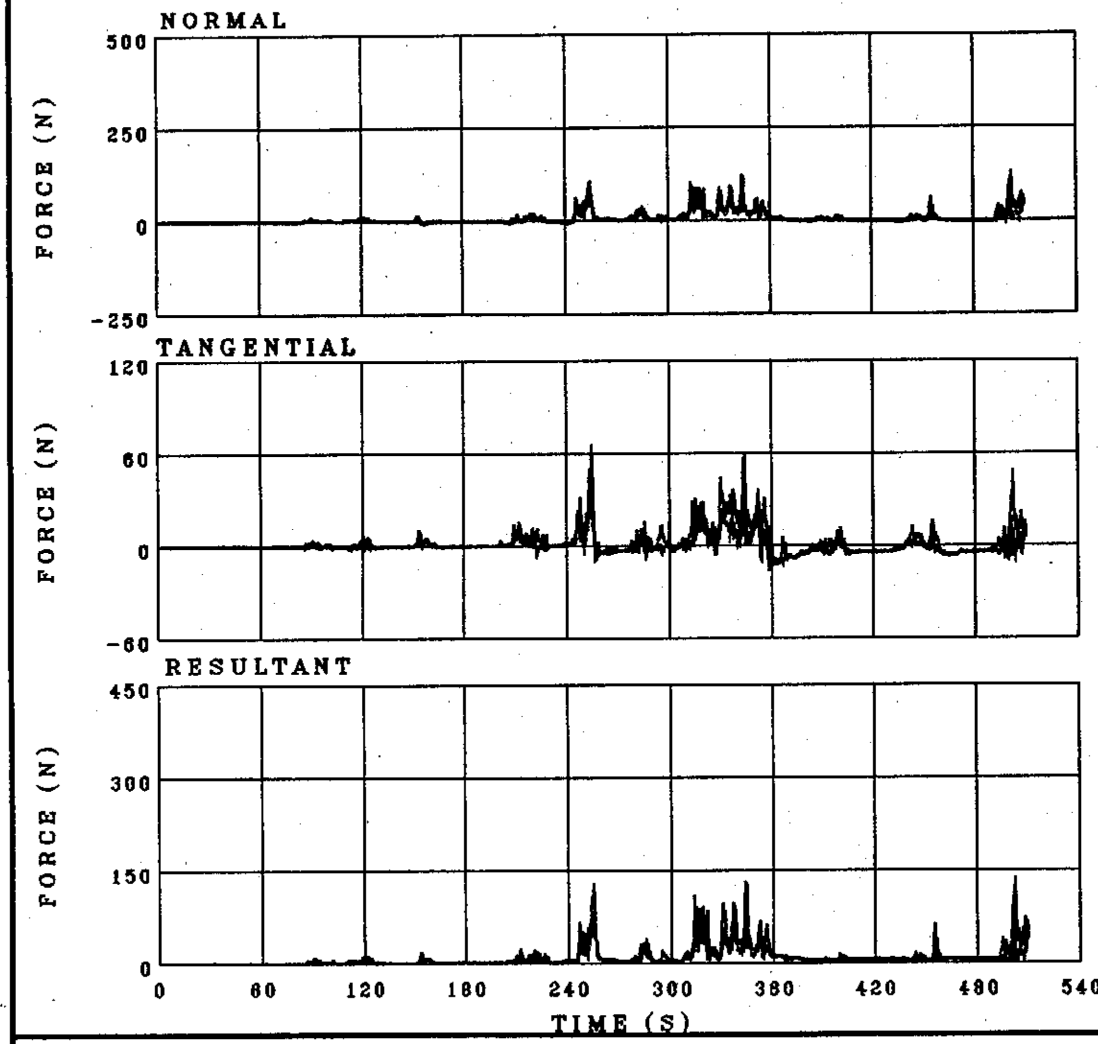

2,4,5
4,5
6
8
3
1
2
3
6
4
3
1
4
2
5
6
7,8
7
8
10 X 10 CM
TIME IN MINUTES


TN←017
Ice Volume vs. Time
ICE VOLUME (m^3)
0.3
0.24
0.18
0.12
0.06
0.0
0
60
120
180
240
300
360
420
480
540
TIME (S)


NORMAL FORCES
TN-017
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-200
0
200
400
600
800
1000
FORCE (N)
Fn MEAN
Fn MAX
Fn MIN


TANGENTIAL FORCES
TN-017
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-300
-200
-100
0
100
200
300
FORCE (N)
Ft MEAN
Ft MAX
Ft MIN


RESULTANT FORCES
TN-017
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
0
200
400
600
800
1000
FORCE (N)
Fr MEAN
Fr MAX



FILE TN←018

PLATE #1

NORMAL

MEAN FORCE = 5.377 N
MAX FORCE = 116.0 N
MIN FORCE = -6.890 N

TANGENTIAL

MEAN FORCE = 1.110 N
MAX FORCE = 57.44 N
MIN FORCE = -11.81 N

RESULTANT

MEAN FORCE = 8.345 N
MAX FORCE = 128.9 N
MIN FORCE = 0.01779 N
AVERAGE ANGLE = 0.6476 O

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 61.00 kPa
ICE THICKNESS = 3.000 cm
ICE DENSITY = 0.8500 g/cc

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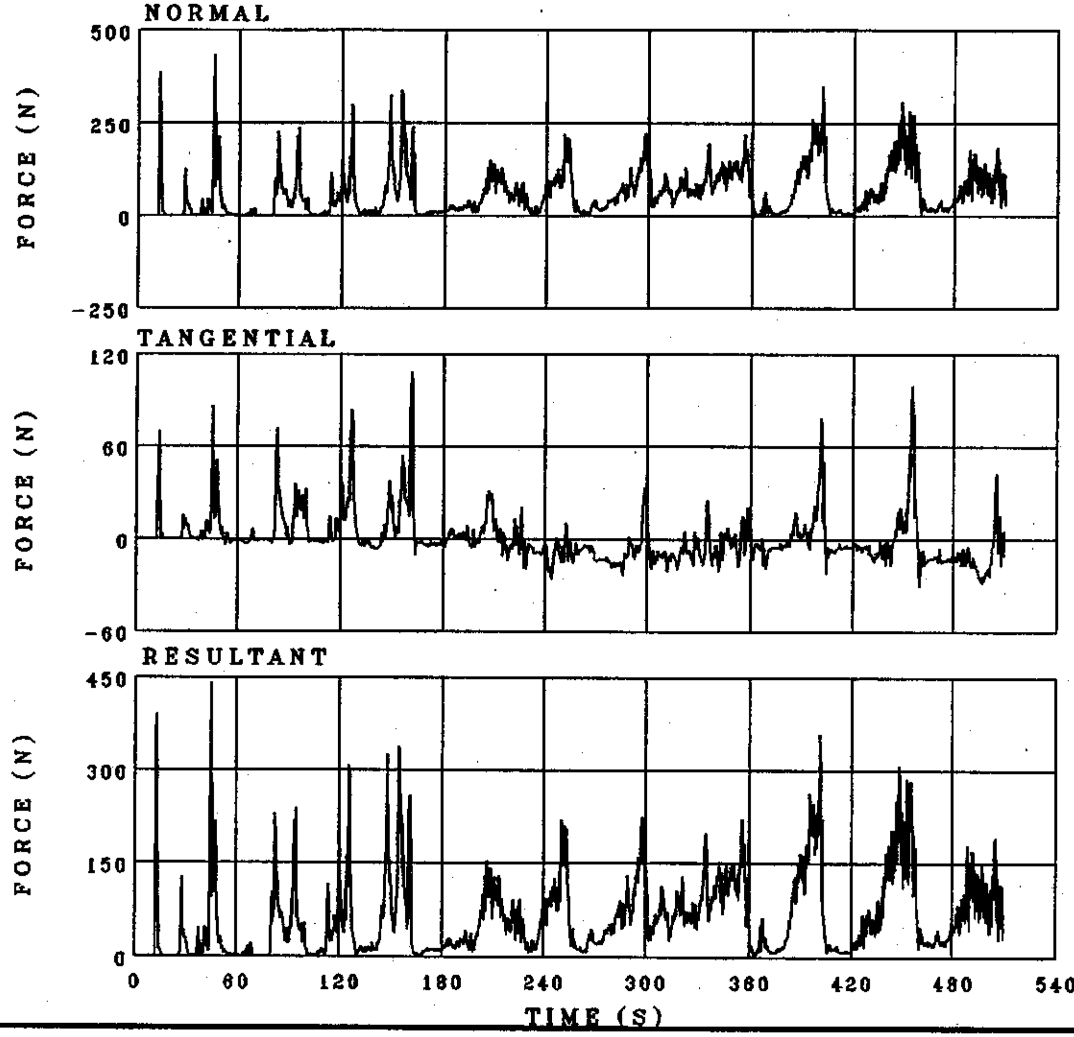
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←018

PLATE #2

NORMAL

MEAN FORCE = 59.92 N
MAX FORCE = 433.2 N
MIN FORCE = −0.8815 N

TANGENTIAL

MEAN FORCE = 0.07518 N
MAX FORCE = 108.6 N
MIN FORCE = −30.93 N

RESULTANT

MEAN FORCE = 61.57 N
MAX FORCE = 441.7 N
MIN FORCE = 0.06308 N
AVERAGE ANGLE = −7.722 O

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 61.00 kPa
ICE THICKNESS = 3.000 cm
ICE DENSITY = 0.8500 g/cc

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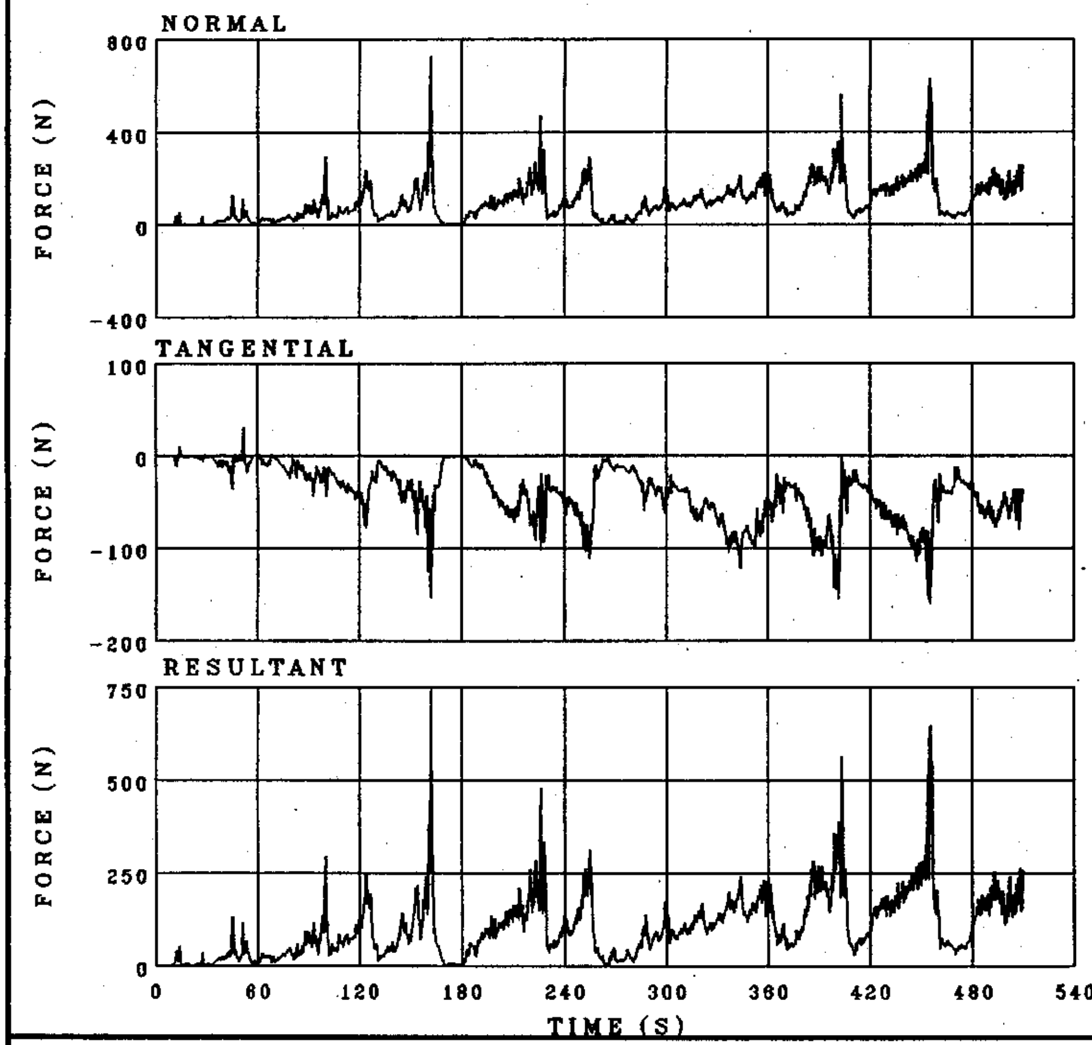
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←018

PLATE #3

NORMAL

MEAN FORCE = 95.57 N
MAX FORCE = 728.9 N
MIN FORCE = -2.803 N

TANGENTIAL

MEAN FORCE = -40.32 N
MAX FORCE = 30.85 N
MIN FORCE = -160.1 N

RESULTANT

MEAN FORCE = 104.7 N
MAX FORCE = 744.8 N
MIN FORCE = 0.05411 N
AVERAGE ANGLE = -24.63 O

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 61.00 kPa
ICE THICKNESS = 3.000 cm
ICE DENSITY = 0.8500 g/cc

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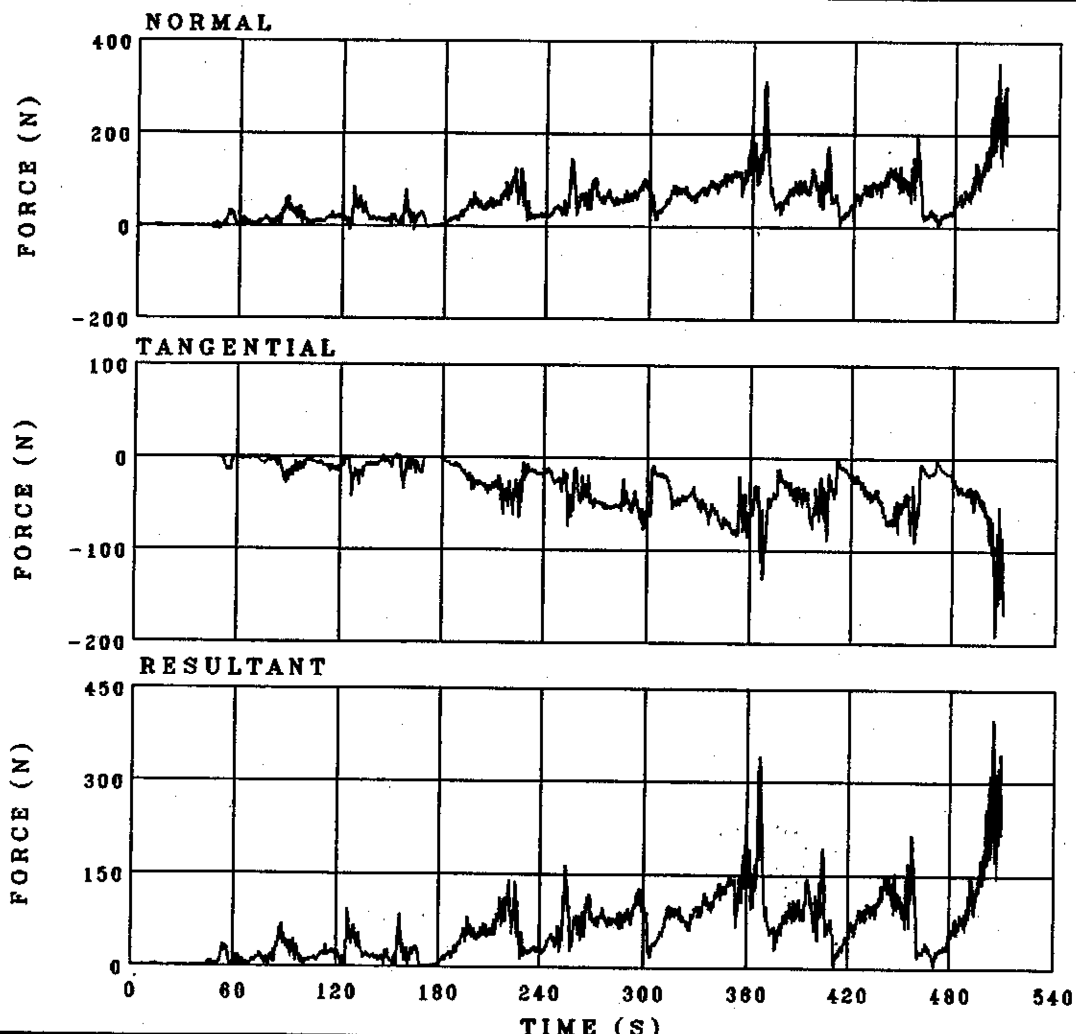
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←018

PLATE #4

NORMAL

MEAN FORCE = 52.99 N
MAX FORCE = 355.6 N
MIN FORCE = -9.704 N

TANGENTIAL

MEAN FORCE = -28.28 N
MAX FORCE = 3.594 N
MIN FORCE = -192.3 N

RESULTANT

MEAN FORCE = 60.60 N
MAX FORCE = 402.8 N
MIN FORCE = 0.02672 N
AVERAGE ANGLE = -22.14 O

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 61.00 kPa
ICE THICKNESS = 3.000 cm
ICE DENSITY = 0.8500 g/cc

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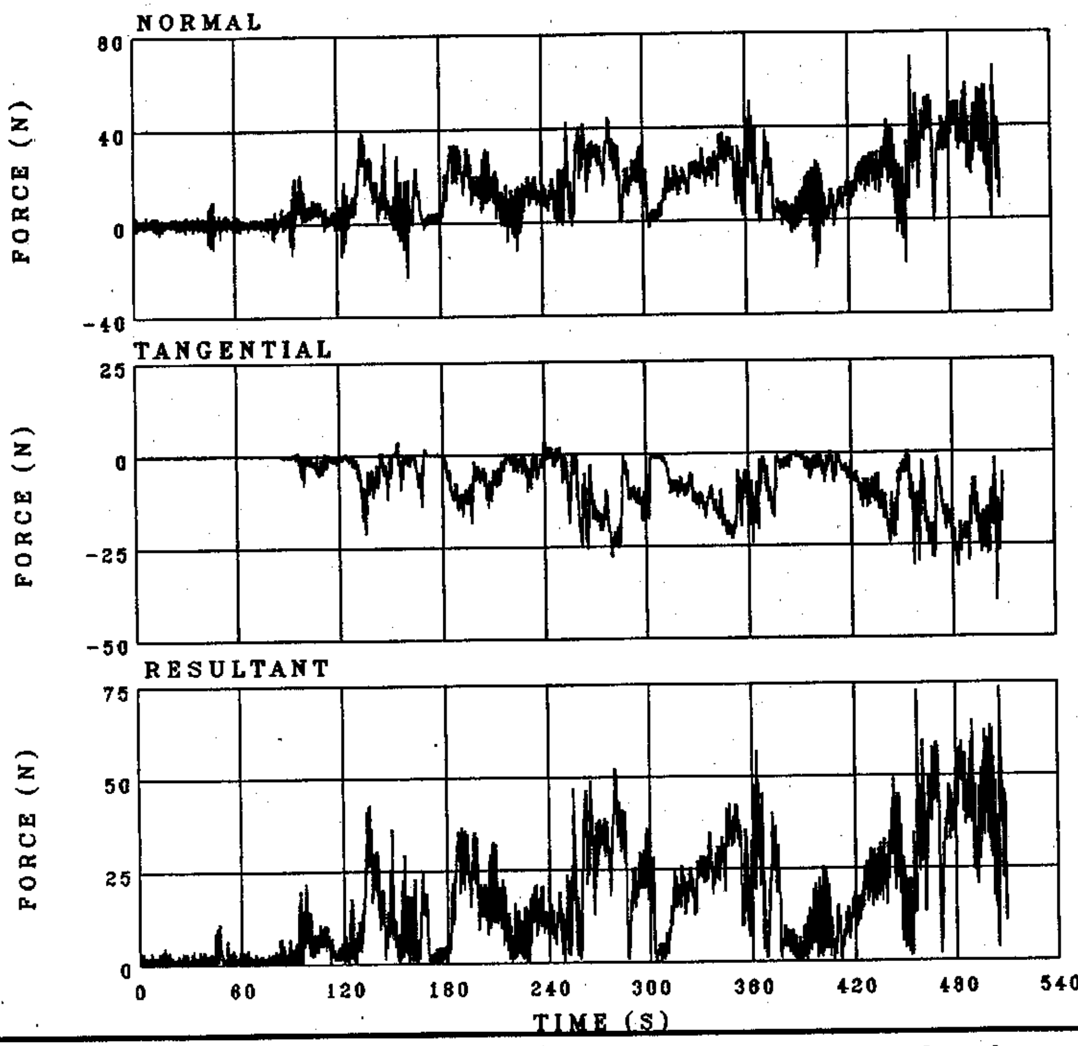
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←018

PLATE #5

NORMAL

MEAN FORCE = 13.58 N
MAX FORCE = 69.44 N
MIN FORCE = −22.90 N

TANGENTIAL

MEAN FORCE = −6.959 N
MAX FORCE = 3.797 N
MIN FORCE = −40.39 N

RESULTANT

MEAN FORCE = 15.88 N
MAX FORCE = 73.86 N
MIN FORCE = 0.02744 N
AVERAGE ANGLE = −23.53 O

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 61.00 kPa
ICE THICKNESS = 3.000 cm
ICE DENSITY = 0.8500 g/cc

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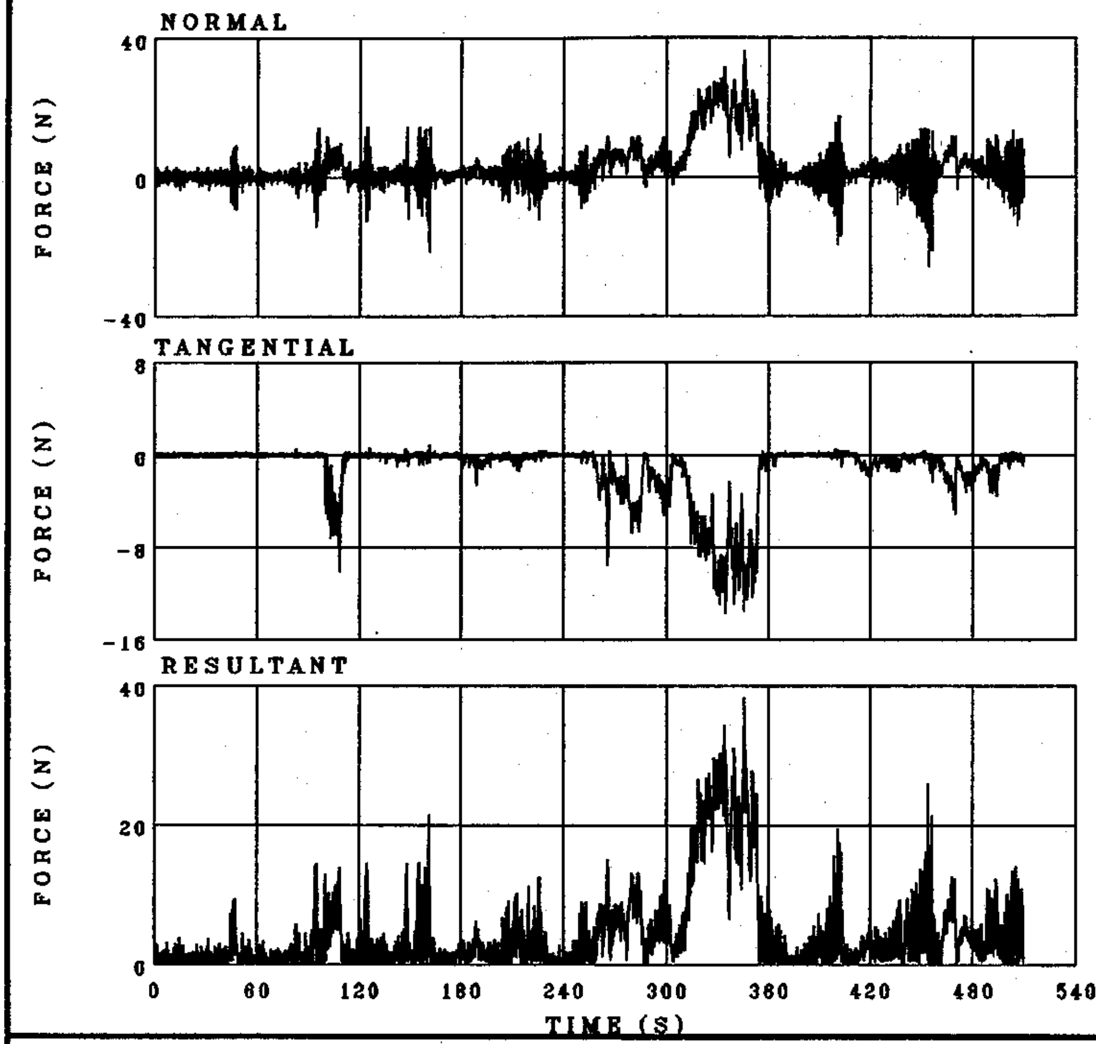
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←018

PLATE #6

NORMAL

MEAN FORCE = 2.771 N
MAX FORCE = 36.23 N
MIN FORCE = −25.89 N

TANGENTIAL

MEAN FORCE = −1.219 N
MAX FORCE = 0.9481 N
MIN FORCE = −13.75 N

RESULTANT

MEAN FORCE = 4.169 N
MAX FORCE = 38.47 N
MIN FORCE = 0.04224 N
AVERAGE ANGLE = −18.84 D

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 61.00 kPa
ICE THICKNESS = 3.000 cm
ICE DENSITY = 0.8500 g/cc

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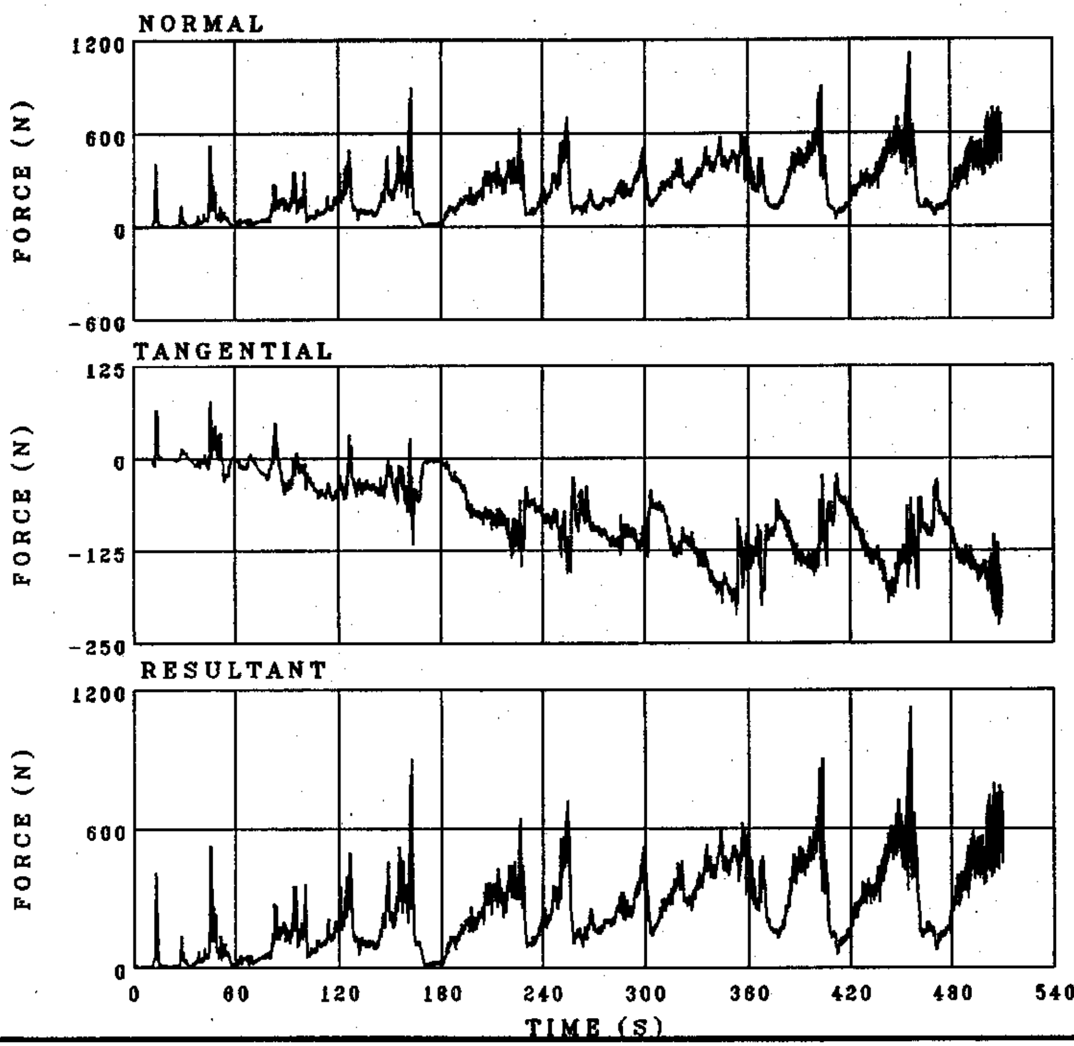
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←018

TOTAL

NORMAL

MEAN FORCE = 236.2 N
MAX FORCE = 1116.0 N
MIN FORCE = -9.735 N

TANGENTIAL

MEAN FORCE = -75.59 N
MAX FORCE = 77.71 N
MIN FORCE = -226.6 N

RESULTANT

MEAN FORCE = 245.0 N
MAX FORCE = 1126.0 N
MIN FORCE = 0.03894 N
AVERAGE ANGLE = -18.49 O

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F.PAINT
FLEX STRENGTH = 61.00 kPa
ICE THICKNESS = 3.000 cm
ICE DENSITY = 0.8500 g/cc

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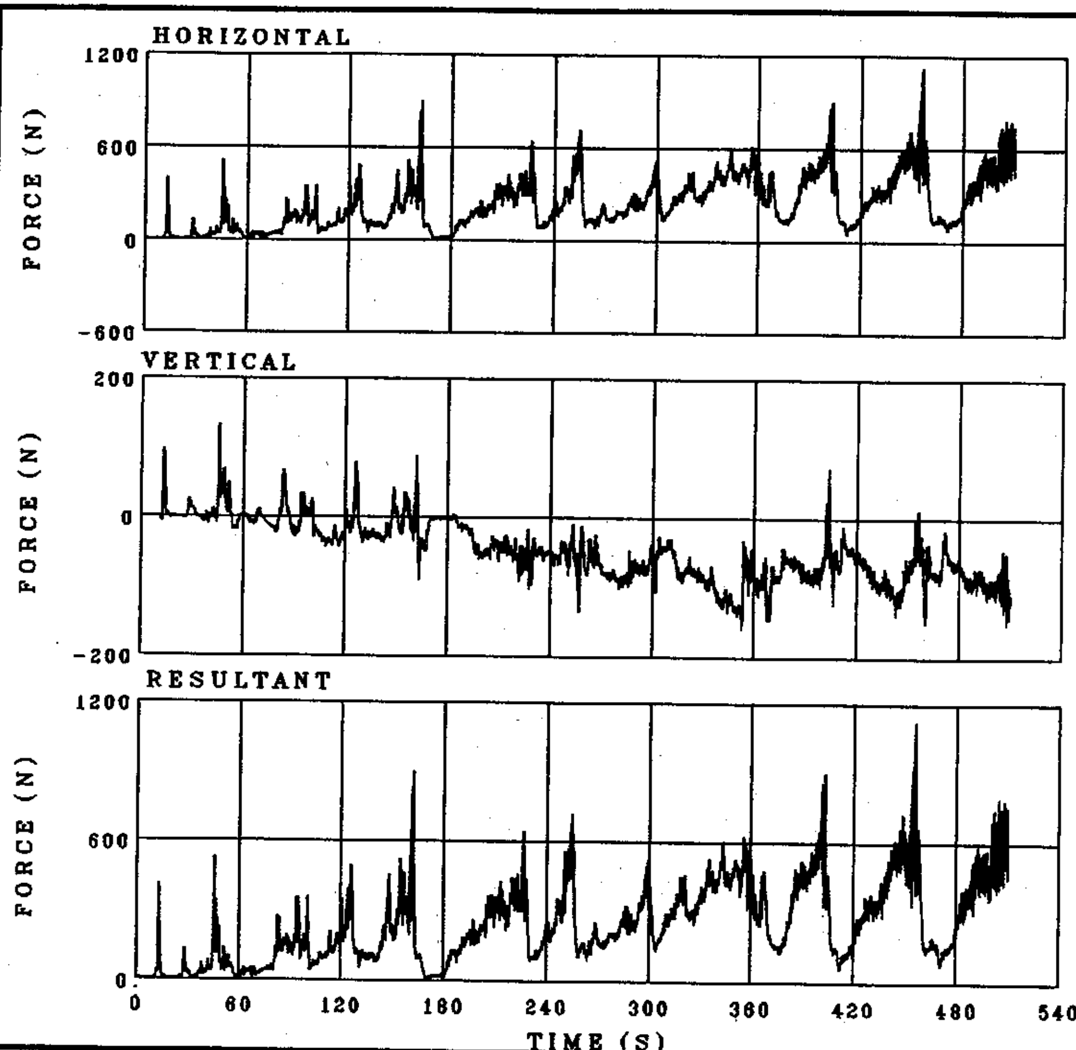
ICE PILEUP STUDY for CANADIAN COAST GUARD



FILE TN←018

TOTAL

HORIZONTAL

MEAN FORCE = -75.59 N
MAX FORCE = 77.71 N
MIN FORCE = -226.6 N

VERTICAL

MEAN FORCE = -75.59 N
MAX FORCE = 77.71 N
MIN FORCE = -226.6 N

RESULTANT

MEAN FORCE = -75.59 N
MAX FORCE = 77.71 N
MIN FORCE = -226.6 N
AVERAGE ANGLE = -75.59 O

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 61.00 kPa
ICE THICKNESS = 3.000 cm
ICE DENSITY = 0.8500 g/cc

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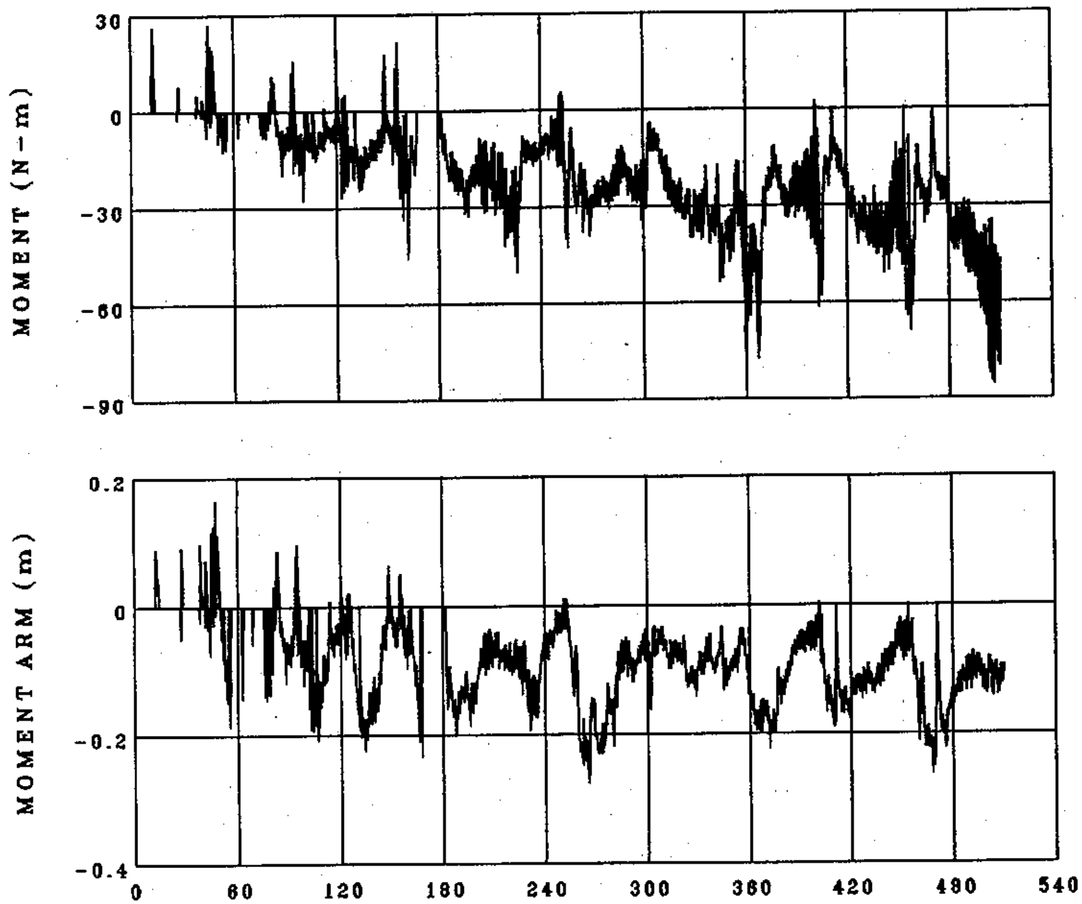
ICE PILEUP STUDY
for CANADIAN COAST GUARD

FILE TN←018

MOMENT



MOMENT

MEAN MOMENT = -19.69 N-m
MAX MOMENT = 27.10 N-m
MIN MOMENT = -85.80 N-m

MOMENT ARM

MEAN ARM = -0.08351 m
MAX ARM = 0.1654 m
MIN ARM = -0.2775 m

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 61.00 kPa
ICE THICKNESS = 3.000 cm
ICE DENSITY = 0.8500 g/cc

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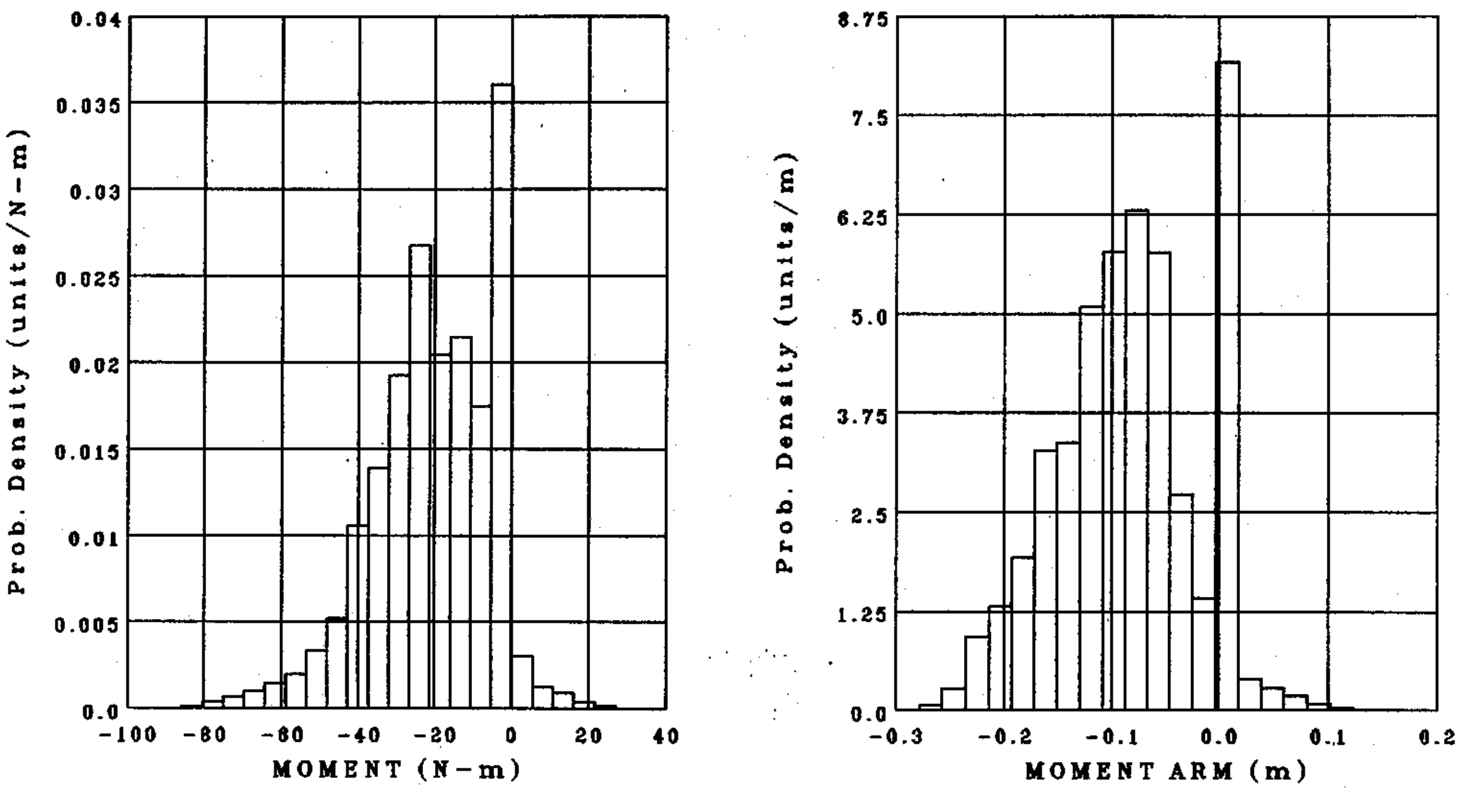
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←018



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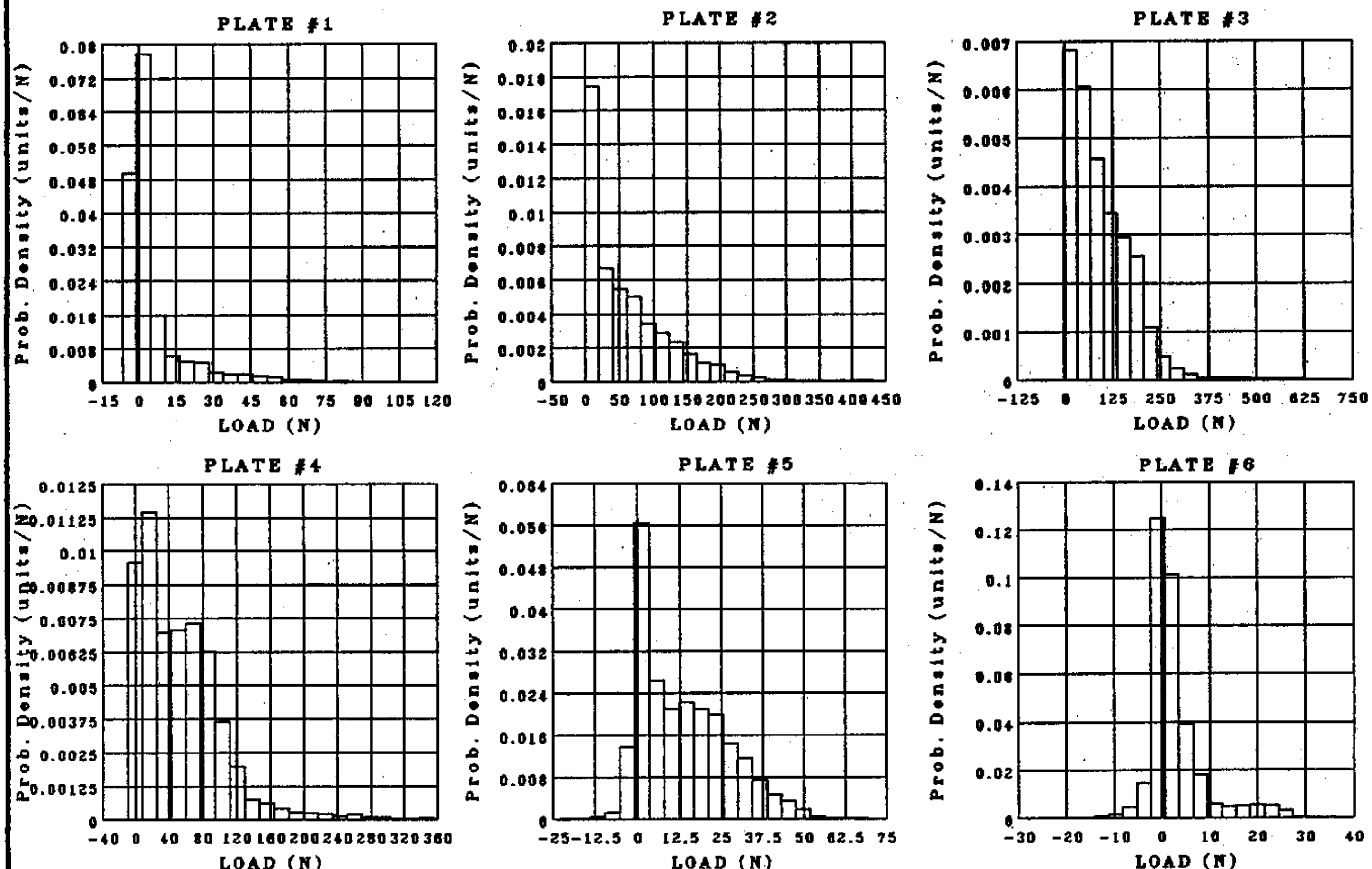
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←018
NORMAL LOAD



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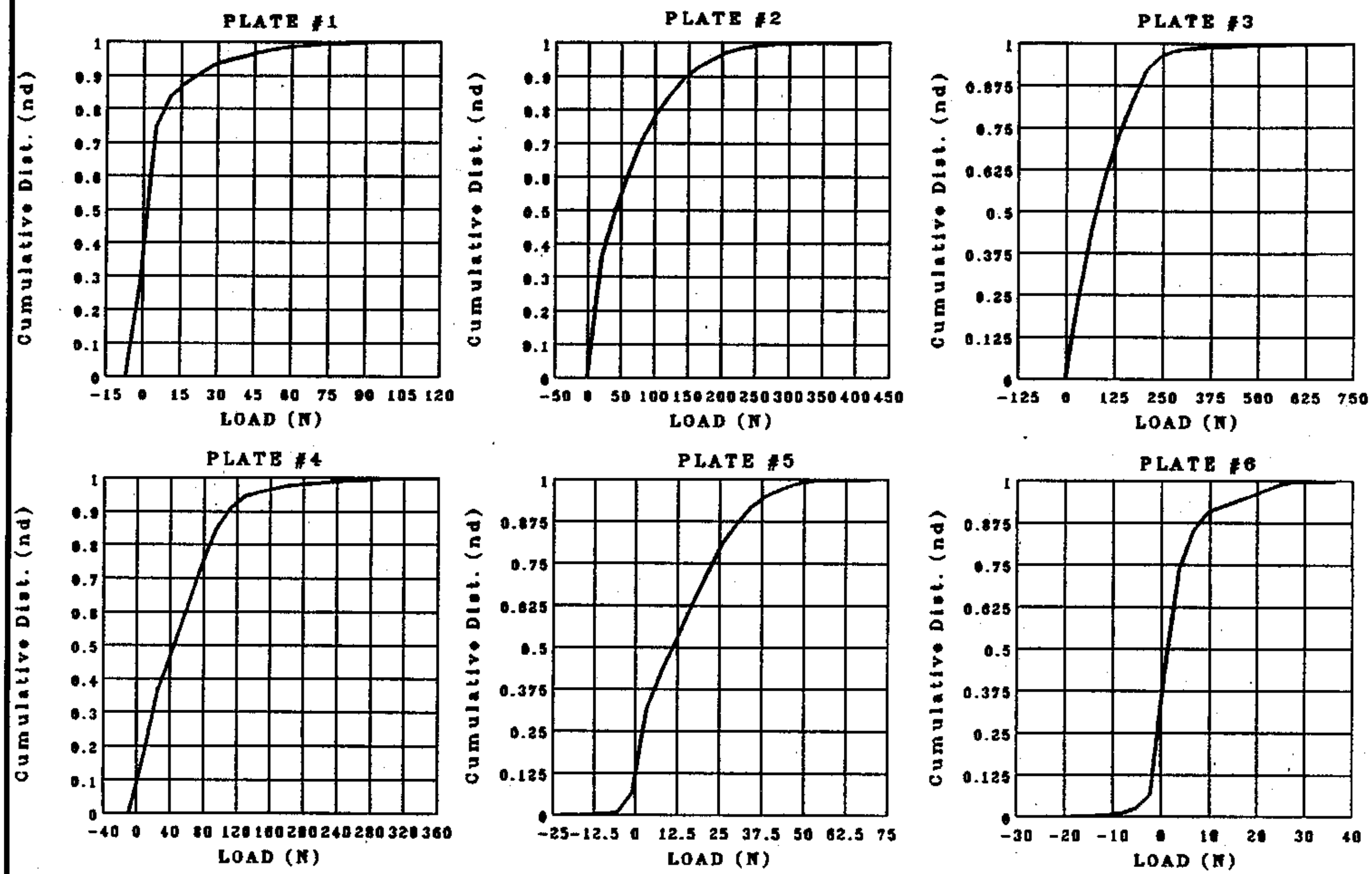
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←018
NORMAL LOAD



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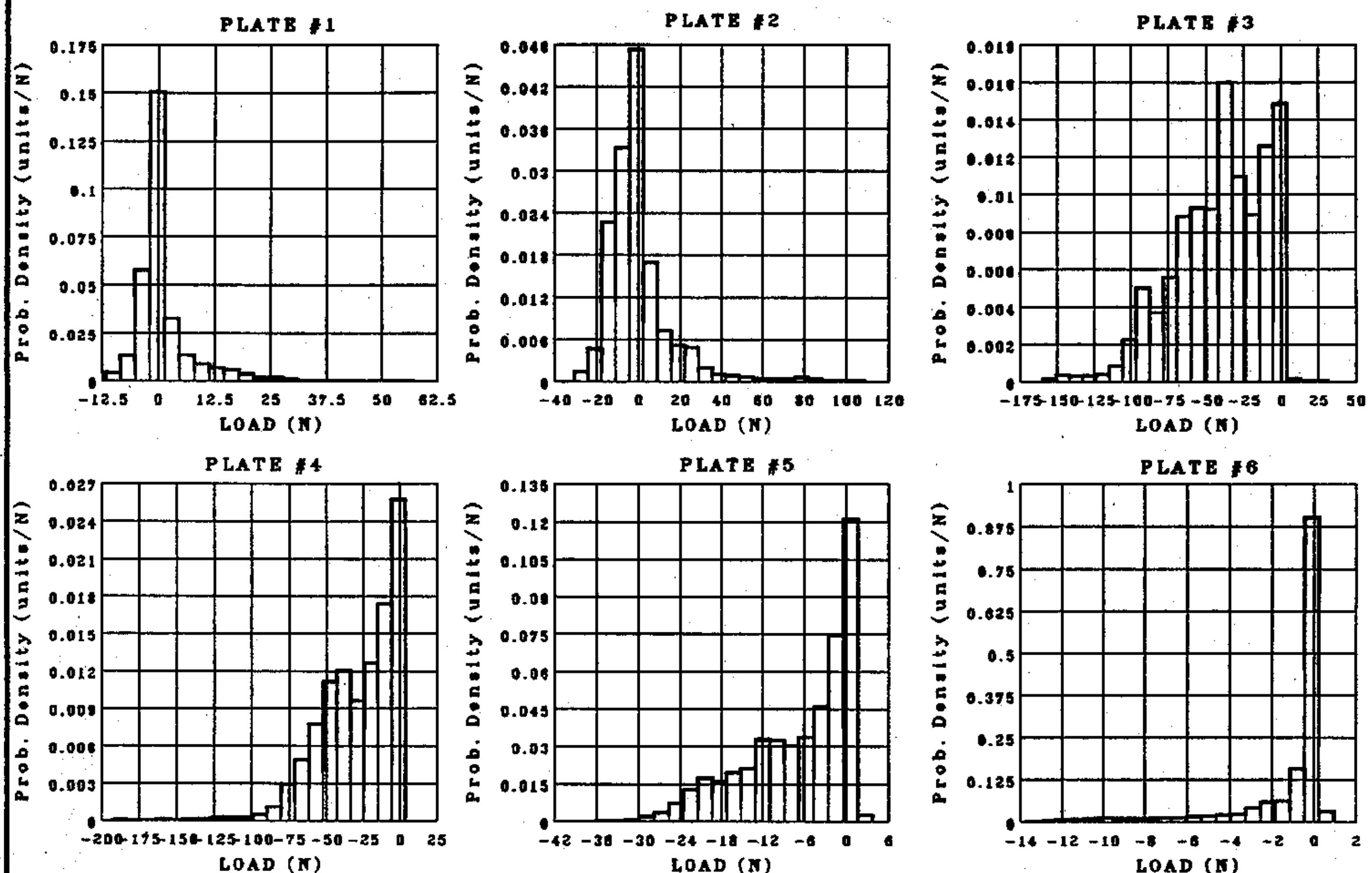
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←018
TANGENTIAL LOAD



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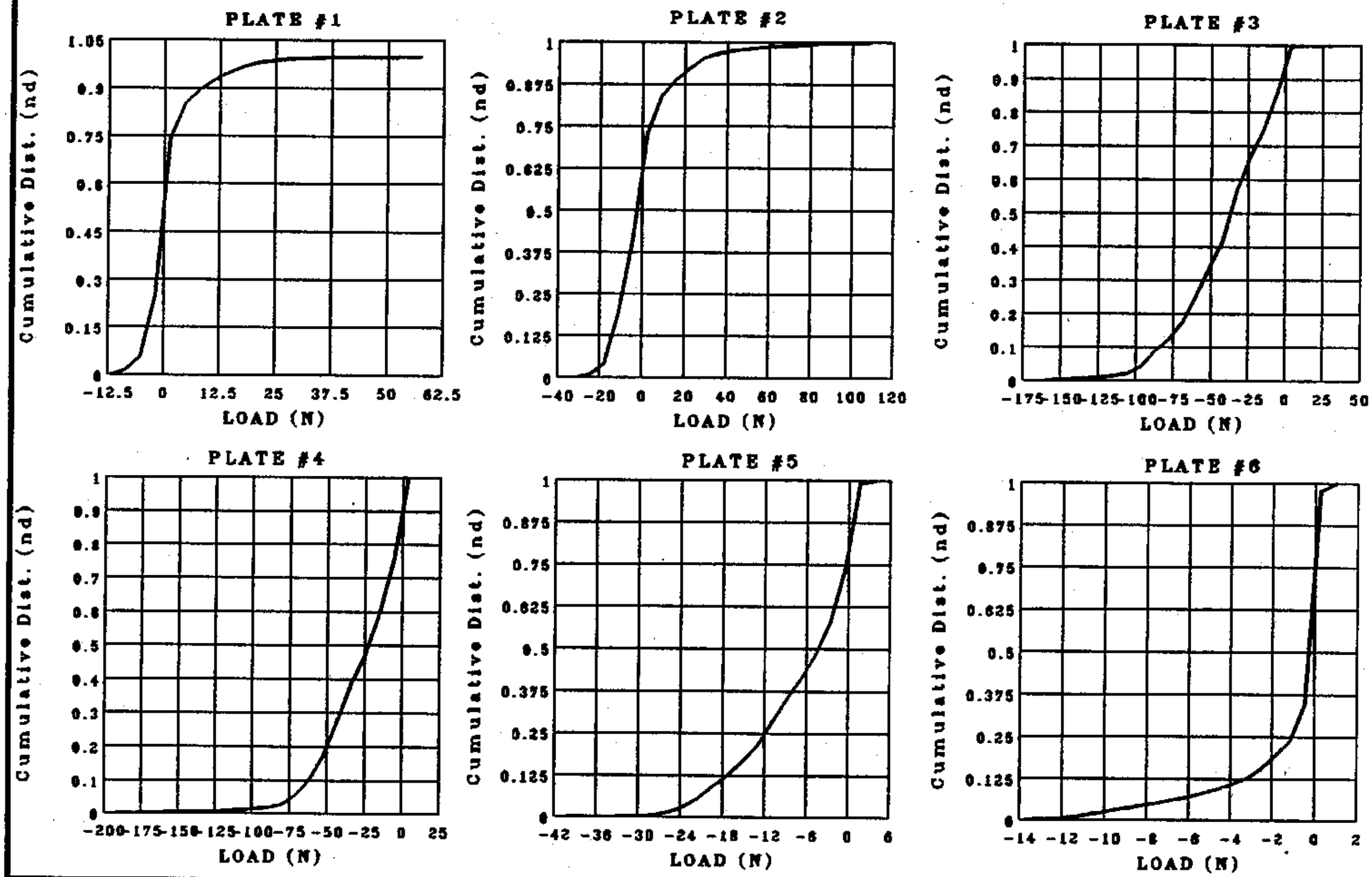
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←018
TANGENTIAL LOAD



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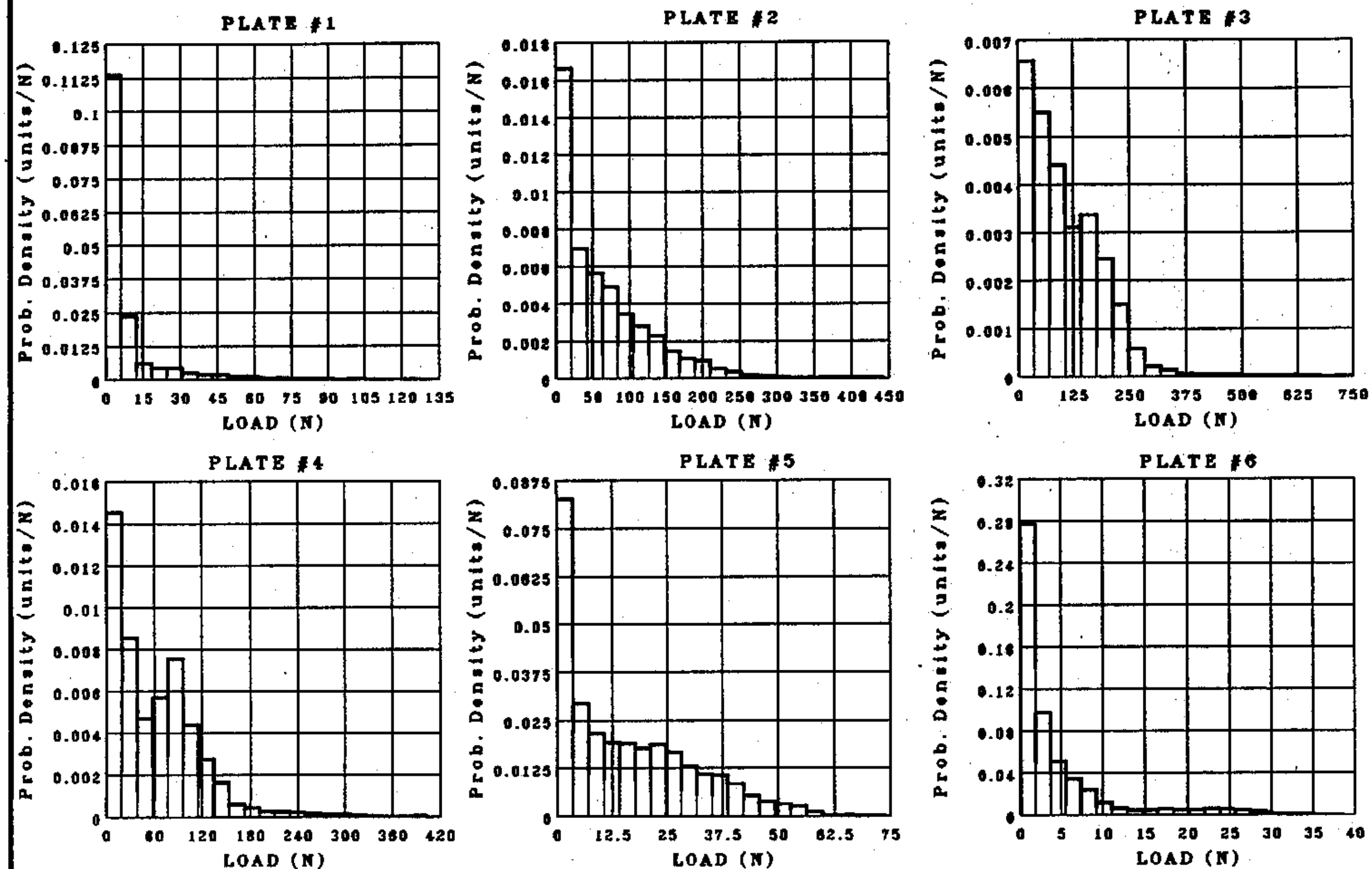
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←018
RESULTANT



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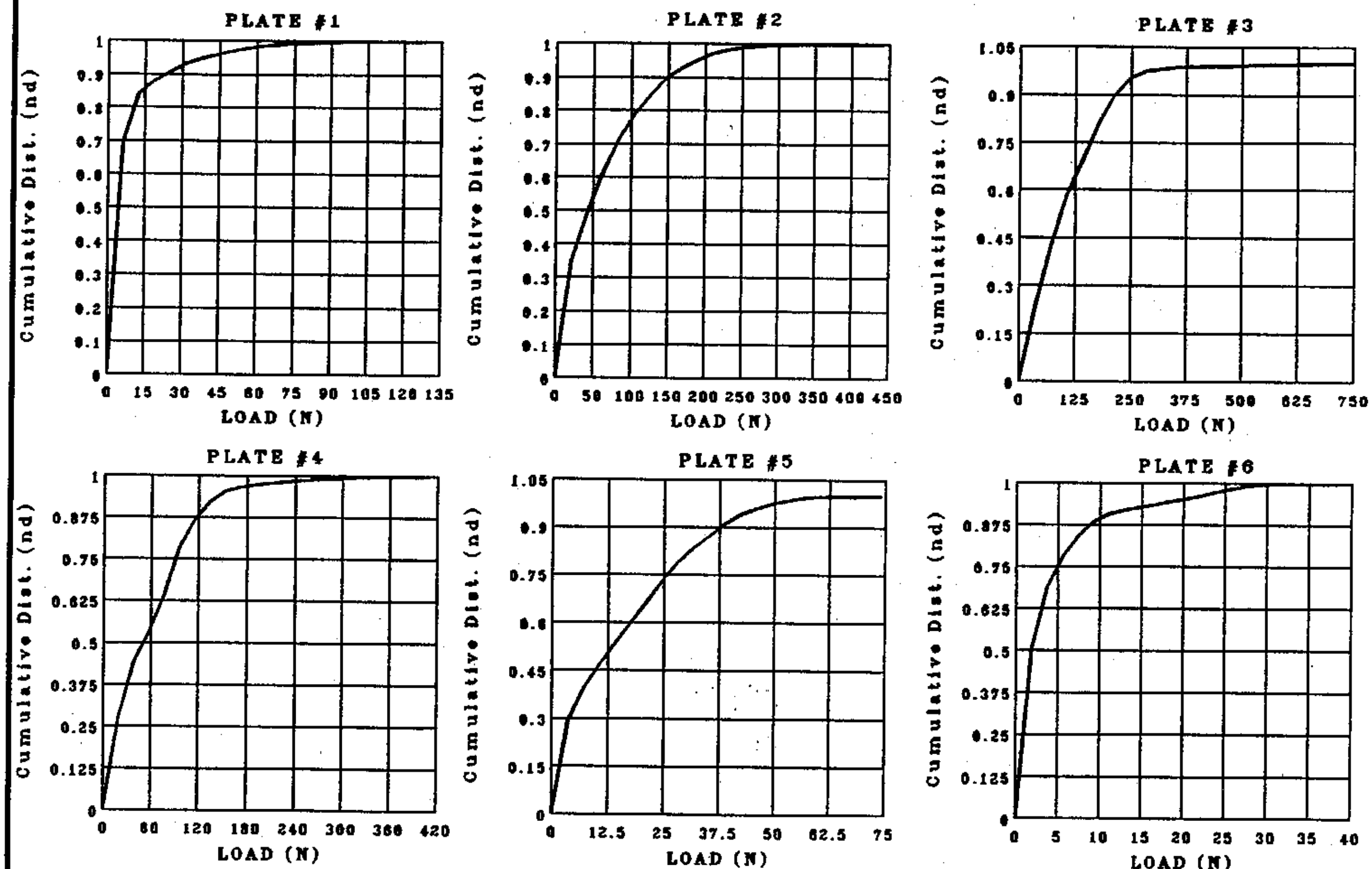
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←018
RESULTANT



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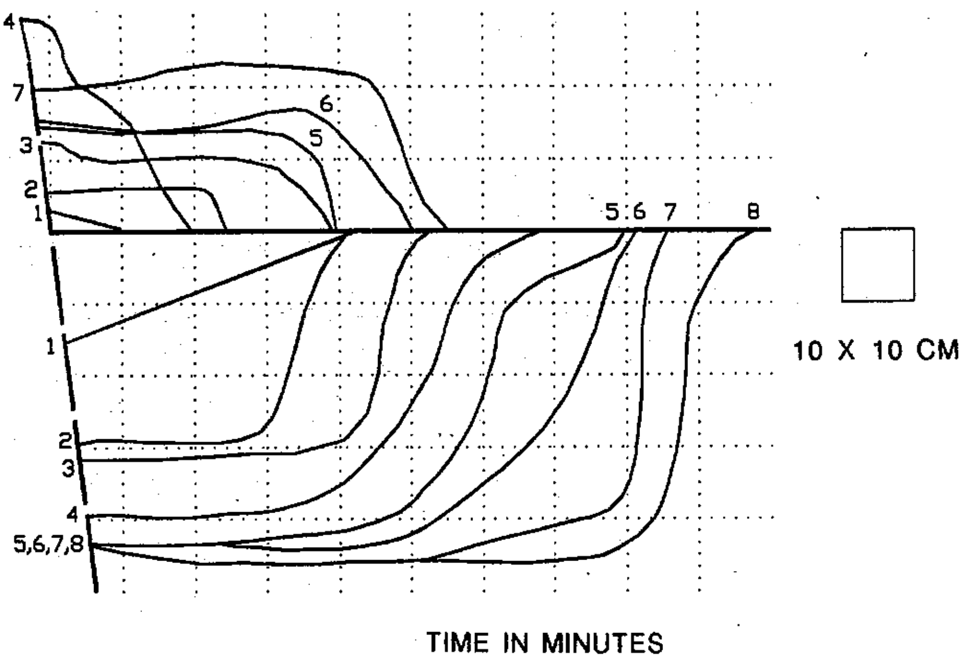
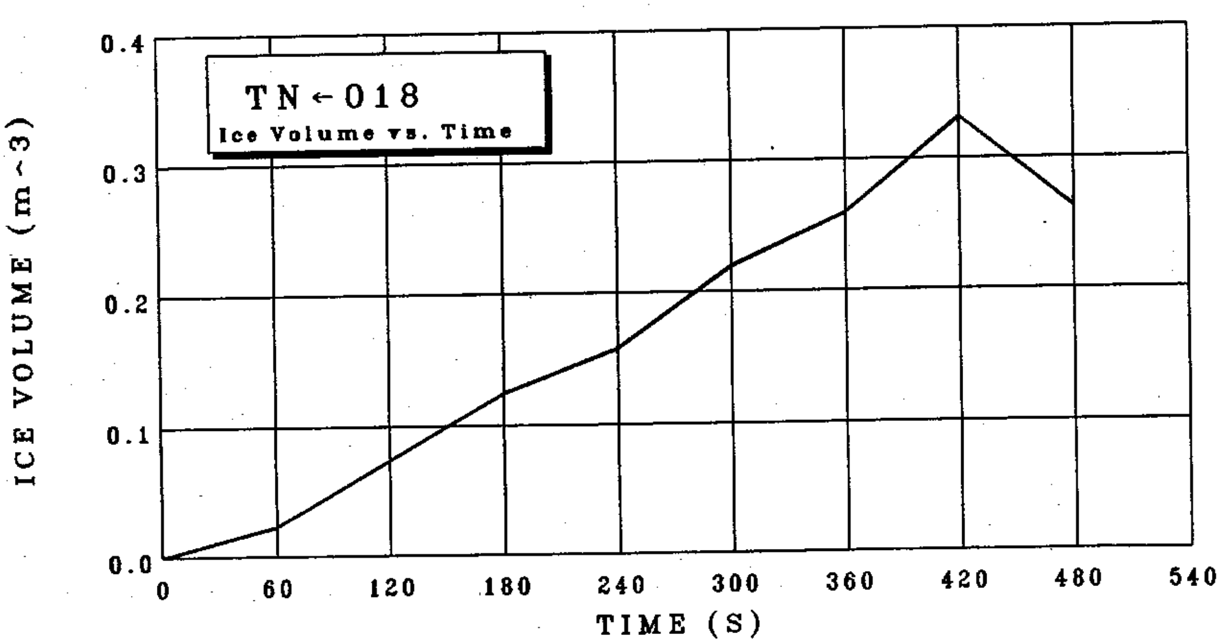
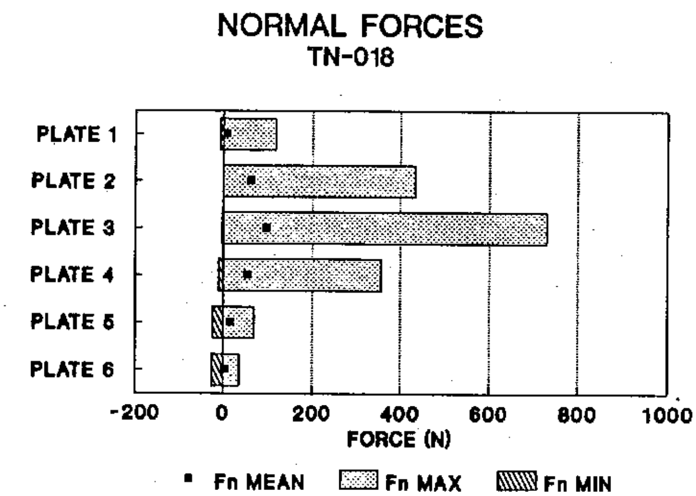
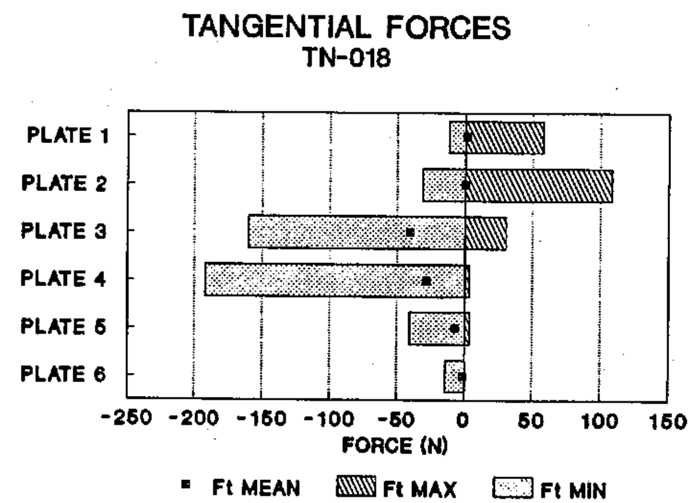
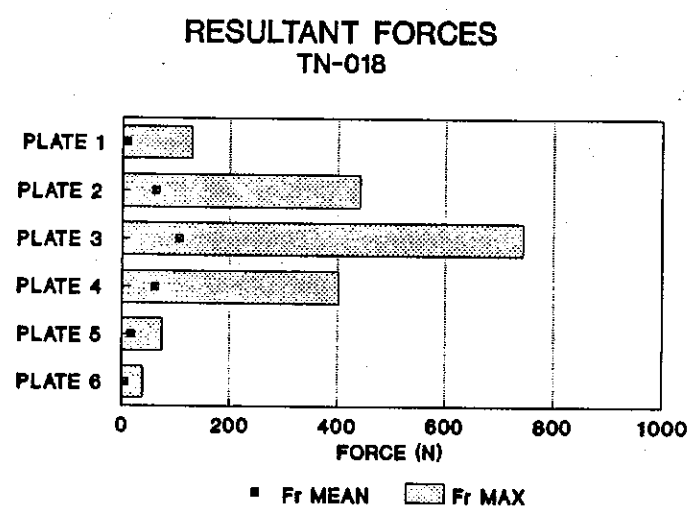
ICE PILEUP STUDY
for CANADIAN COAST GUARD

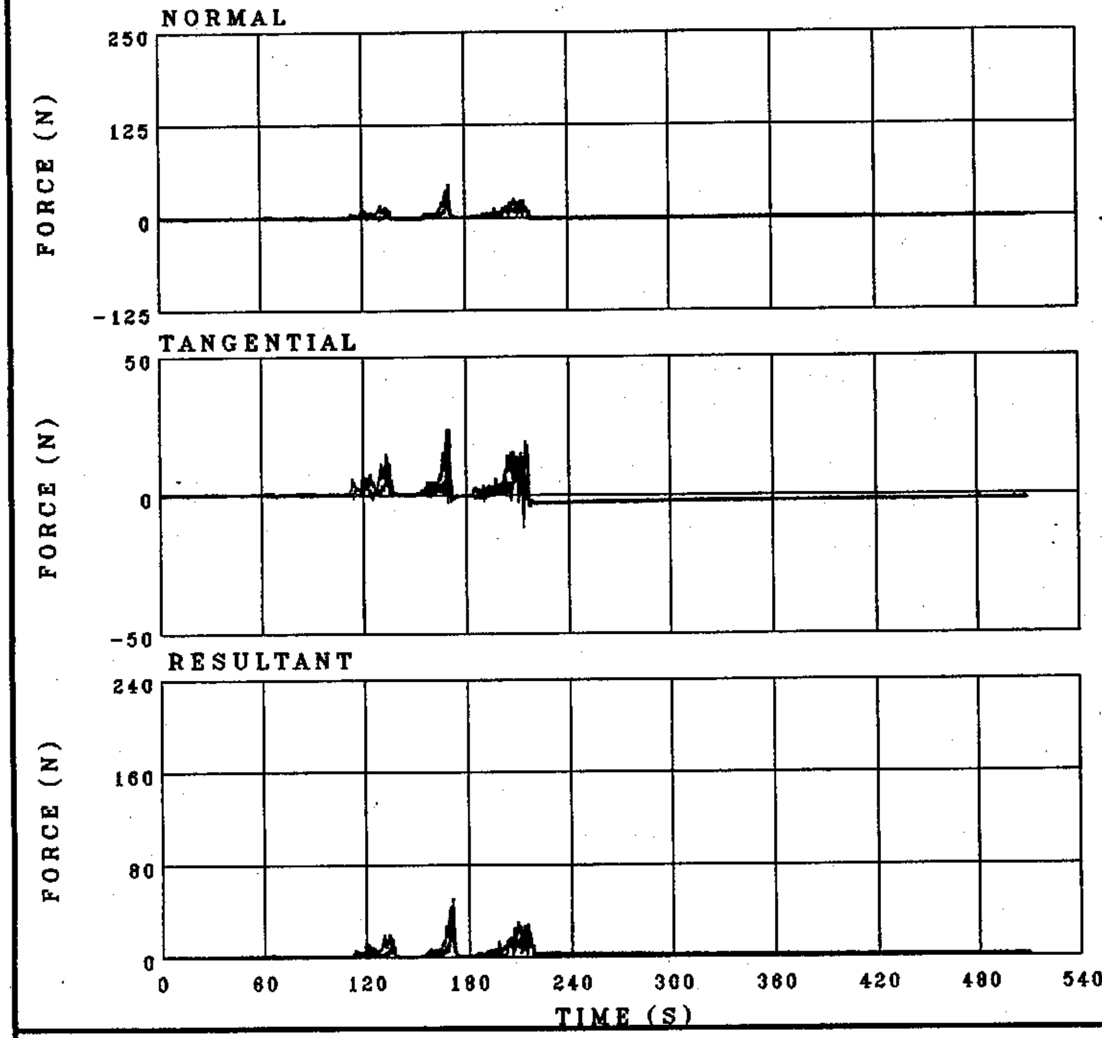

4
7
3
2
1
6
5
5:6 7
8
1
2
3
4
5,6,7,8
10 X 10 CM
TIME IN MINUTES


TN←018
Ice Volume vs. Time
ICE VOLUME (m^3)
0.0
0.1
0.2
0.3
0.4
0
60
120
180
240
300
360
420
480
540
TIME (S)


NORMAL FORCES
TN-018
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-200 0 200 400 600 800 1000
FORCE (N)
Fn MEAN
Fn MAX
Fn MIN


TANGENTIAL FORCES
TN-018
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-250 -200 -150 -100 -50 0 50 100 150
FORCE (N)
Ft MEAN
Ft MAX
Ft MIN


RESULTANT FORCES
TN-018
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
0 200 400 600 800 1000
FORCE (N)
Fr MEAN
Fr MAX



FILE TN-019

PLATE #1

NORMAL

MEAN FORCE = 0.4913 N
MAX FORCE = 31.20 N
MIN FORCE = -1.600 N

TANGENTIAL

MEAN FORCE = -0.6026 N
MAX FORCE = 18.86 N
MIN FORCE = -3.935 N

RESULTANT

MEAN FORCE = 2.457 N
MAX FORCE = 35.84 N
MIN FORCE = 0.04369 N
AVERAGE ANGLE = -46.04 O

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 24.00 kPa
ICE THICKNESS = 2.300 cm
ICE DENSITY = 0.9300 g/cc

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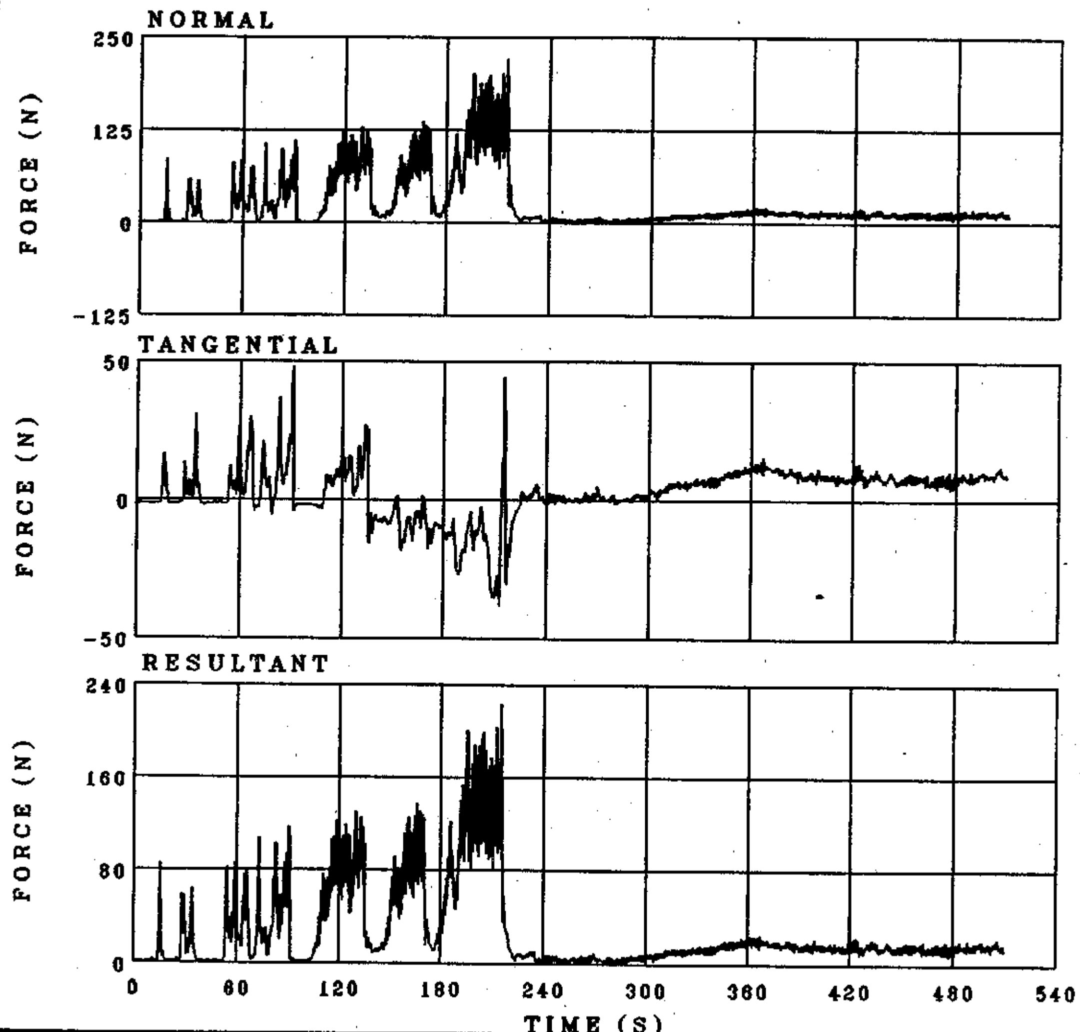
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN-019

PLATE #2

NORMAL

MEAN FORCE = 24.90 N
MAX FORCE = 220.7 N
MIN FORCE = -0.4352 N

TANGENTIAL

MEAN FORCE = 2.666 N
MAX FORCE = 48.26 N
MIN FORCE = -38.30 N

RESULTANT

MEAN FORCE = 26.72 N
MAX FORCE = 223.5 N
MIN FORCE = 0.4612 N
AVERAGE ANGLE = 5.717 O

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 24.00 kPa
ICE THICKNESS = 2.300 cm
ICE DENSITY = 0.9300 g/cc

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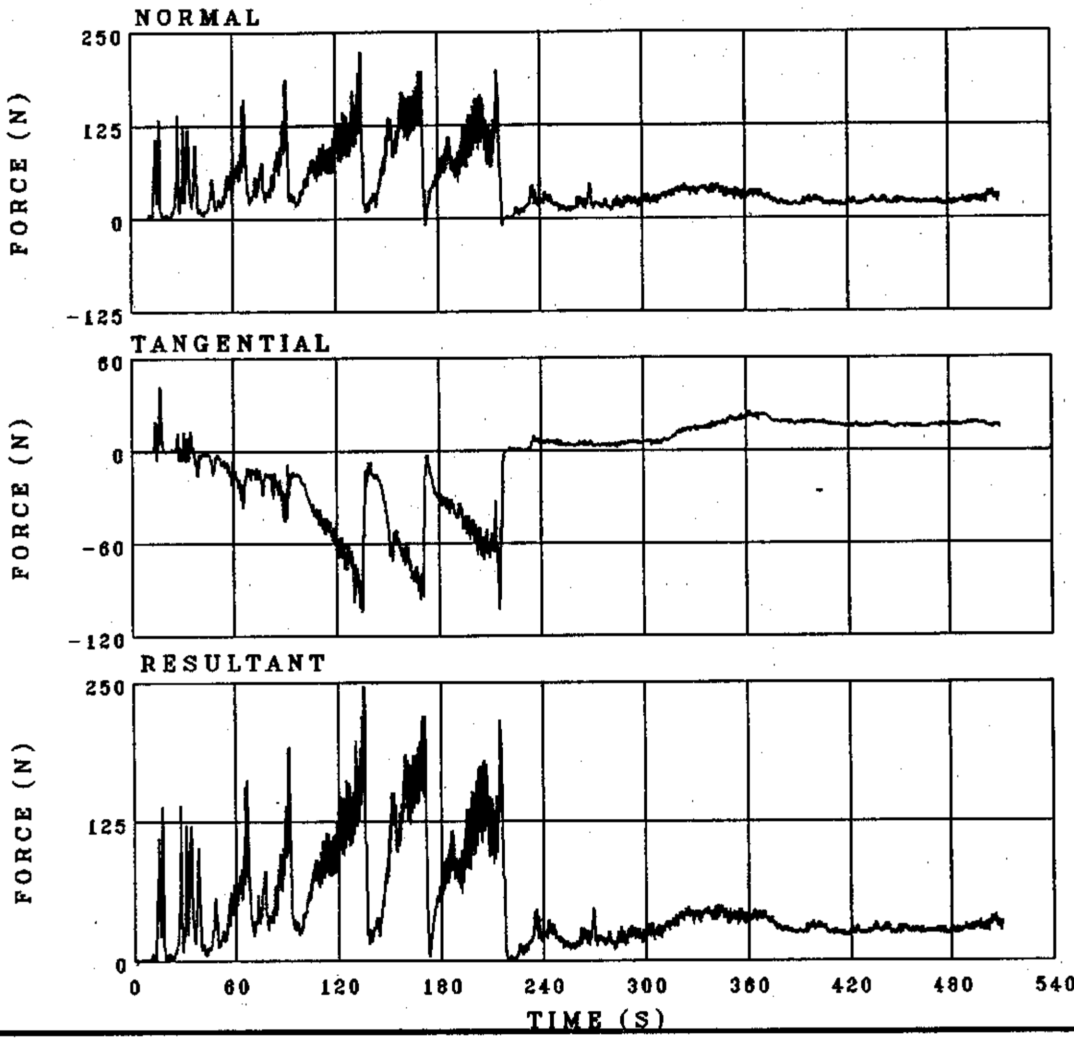
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←019

PLATE #3

NORMAL

MEAN FORCE = 41.83 N
MAX FORCE = 223.9 N
MIN FORCE = -10.56 N

TANGENTIAL

MEAN FORCE = -6.085 N
MAX FORCE = 41.60 N
MIN FORCE = -104.5 N

RESULTANT

MEAN FORCE = 47.44 N
MAX FORCE = 247.0 N
MIN FORCE = 0.05390 N
AVERAGE ANGLE = 5.141 O

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 24.00 kPa
ICE THICKNESS = 2.300 cm
ICE DENSITY = 0.9300 g/cc

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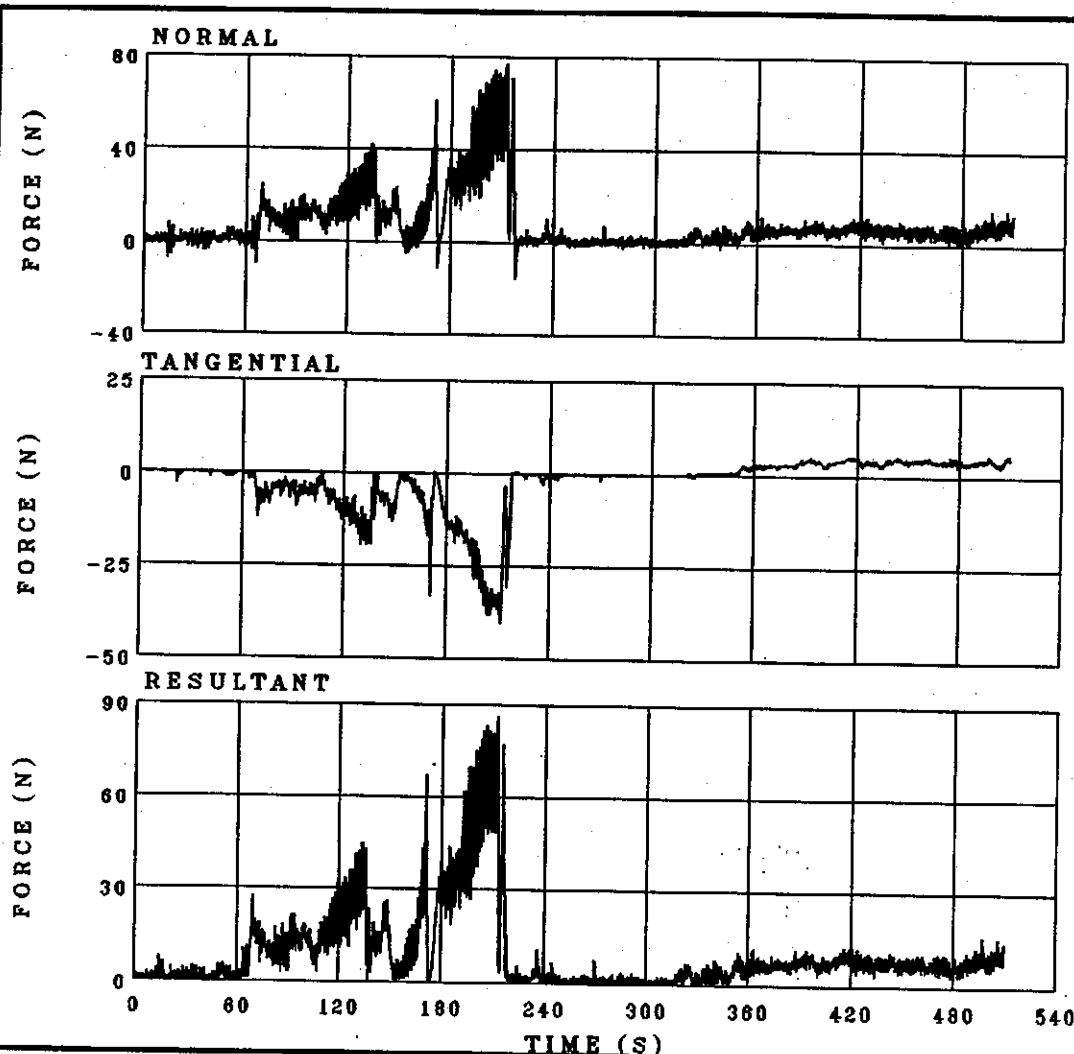
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←019

PLATE #4

NORMAL

MEAN FORCE = 8.428 N
MAX FORCE = 76.89 N
MIN FORCE = −15.76 N

TANGENTIAL

MEAN FORCE = −2.076 N
MAX FORCE = 6.111 N
MIN FORCE = −40.47 N

RESULTANT

MEAN FORCE = 9.893 N
MAX FORCE = 86.46 N
MIN FORCE = 0.04818 N
AVERAGE ANGLE = −5.596 O

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 24.00 kPa
ICE THICKNESS = 2.300 cm
ICE DENSITY = 0.9300 g/cc

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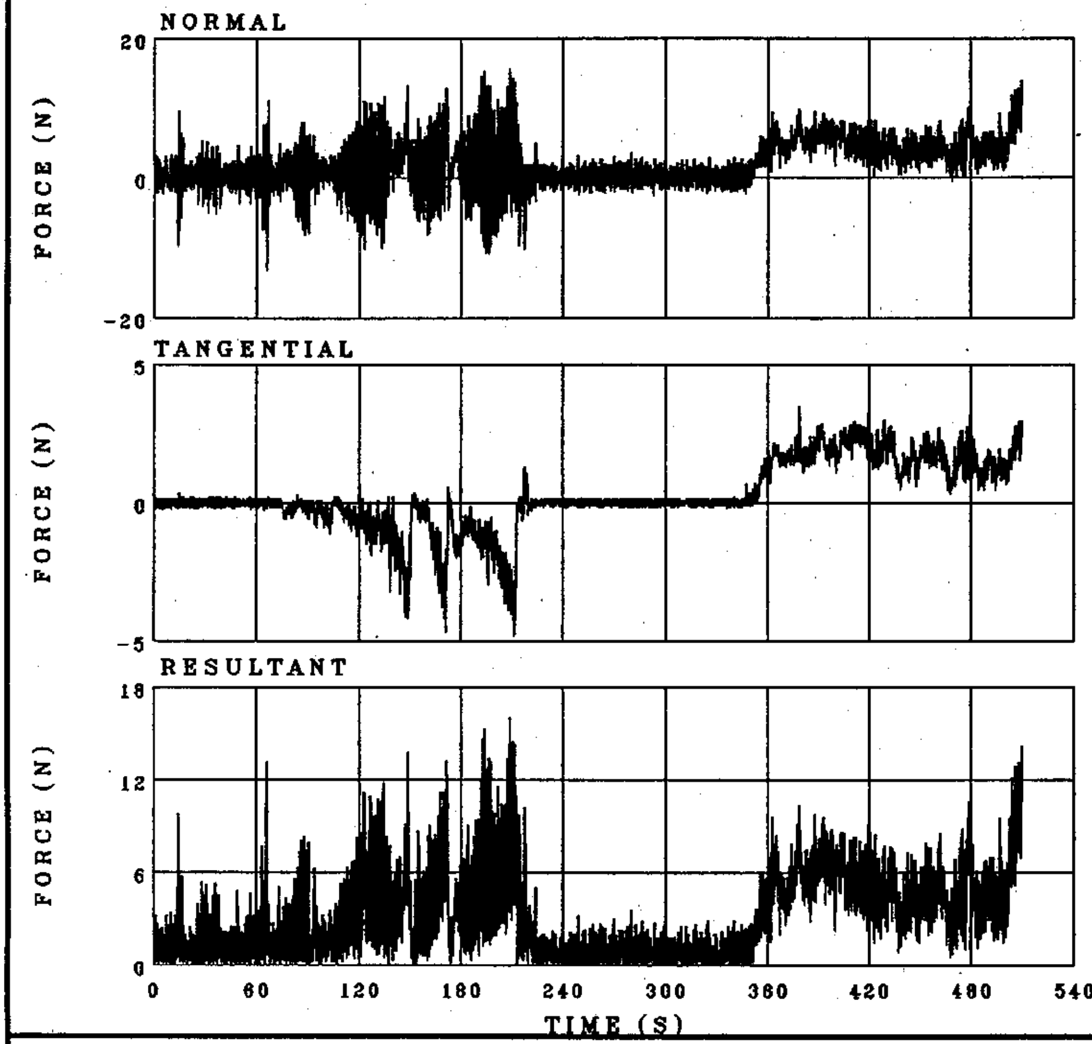
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←019

PLATE #5

NORMAL

MEAN FORCE = 2.083 N
MAX FORCE = 15.66 N
MIN FORCE = −13.18 N

TANGENTIAL

MEAN FORCE = 0.2462 N
MAX FORCE = 3.480 N
MIN FORCE = −4.807 N

RESULTANT

MEAN FORCE = 3.132 N
MAX FORCE = 16.04 N
MIN FORCE = 0.02780 N
AVERAGE ANGLE = −7.952 O

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 24.00 kPa
ICE THICKNESS = 2.300 cm
ICE DENSITY = 0.9300 g/cc

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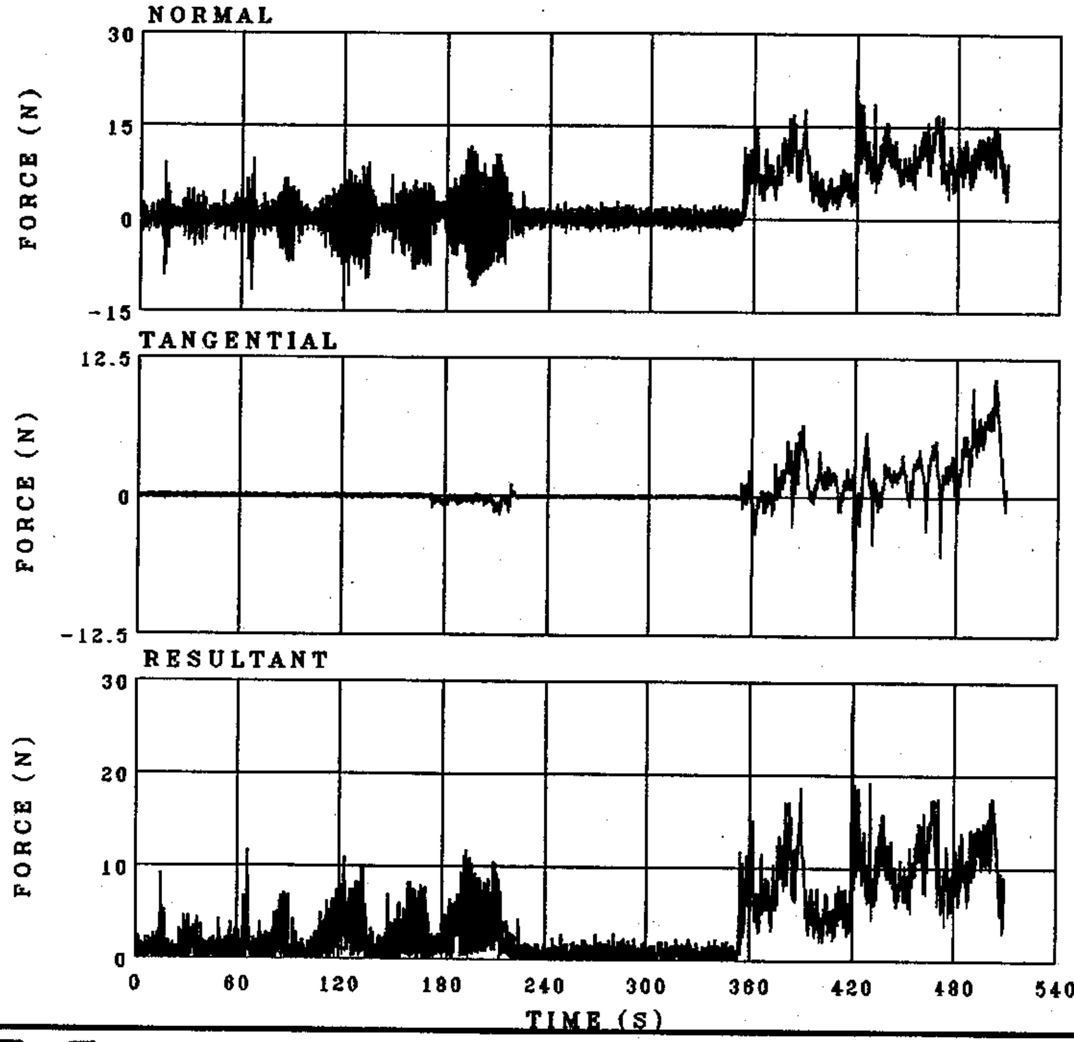
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←019

PLATE #6

NORMAL

MEAN FORCE = 2.763 N
MAX FORCE = 26.38 N
MIN FORCE = -11.74 N

TANGENTIAL

MEAN FORCE = 0.5527 N
MAX FORCE = 10.75 N
MIN FORCE = -10.10 N

RESULTANT

MEAN FORCE = 3.884 N
MAX FORCE = 27.50 N
MIN FORCE = 0.03424 N
AVERAGE ANGLE = -13.91 O

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 24.00 kPa
ICE THICKNESS = 2.300 cm
ICE DENSITY = 0.9300 g/cc

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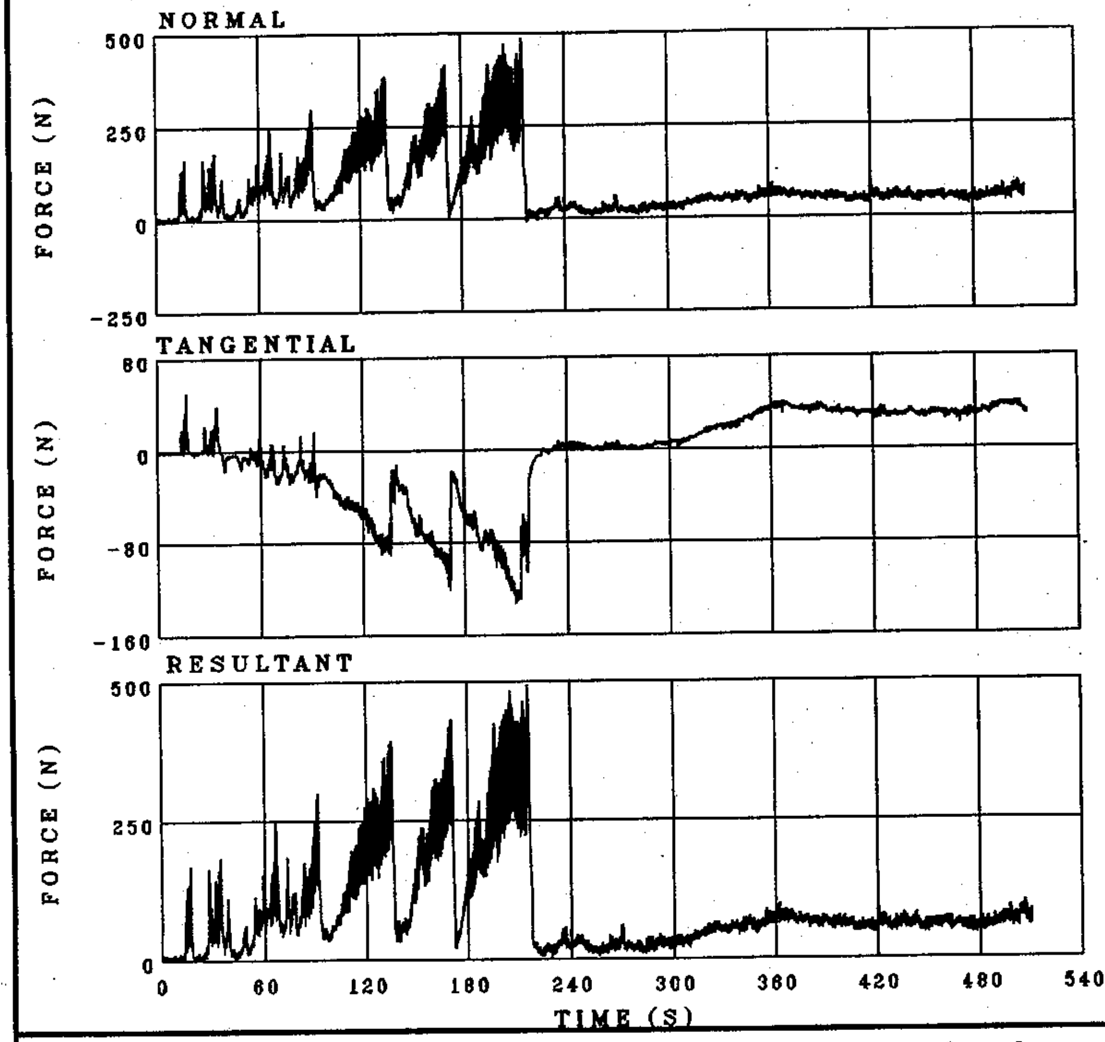
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←019

TOTAL

NORMAL

MEAN FORCE = 80.50 N
MAX FORCE = 486.6 N
MIN FORCE = -11.11 N

TANGENTIAL

MEAN FORCE = -5.300 N
MAX FORCE = 50.87 N
MIN FORCE = -133.3 N

RESULTANT

MEAN FORCE = 88.98 N
MAX FORCE = 494.0 N
MIN FORCE = 0.6401 N
AVERAGE ANGLE = 2.548 O

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 24.00 kPa
ICE THICKNESS = 2.300 cm
ICE DENSITY = 0.9300 g/cc

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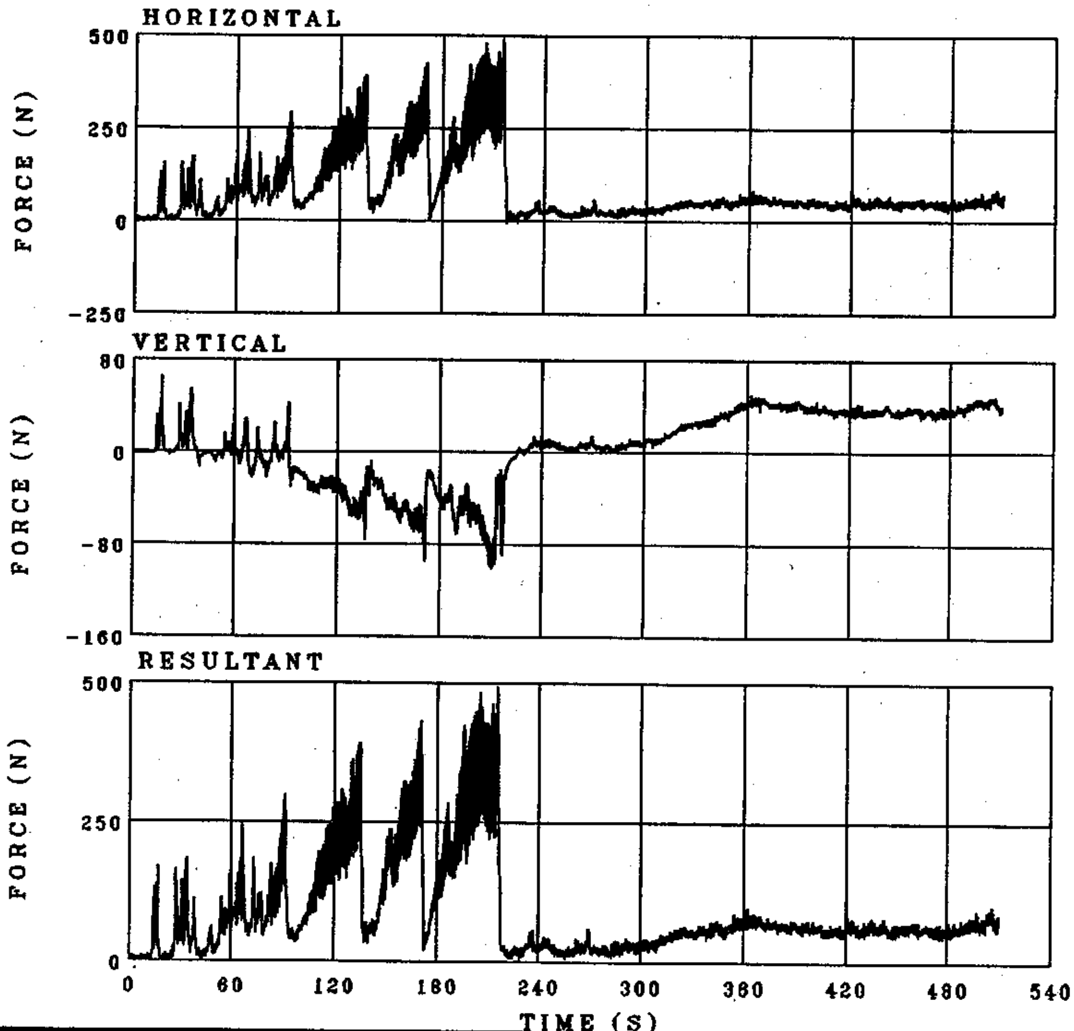
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←019

TOTAL

HORIZONTAL

MEAN FORCE = -5.300 N
MAX FORCE = 50.87 N
MIN FORCE = -133.3 N

VERTICAL

MEAN FORCE = -5.300 N
MAX FORCE = 50.87 N
MIN FORCE = -133.3 N

RESULTANT

MEAN FORCE = -5.300 N
MAX FORCE = 50.87 N
MIN FORCE = -133.3 N
AVERAGE ANGLE = -5.300 D

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 24.00 kPa
ICE THICKNESS = 2.300 cm
ICE DENSITY = 0.9300 g/cc

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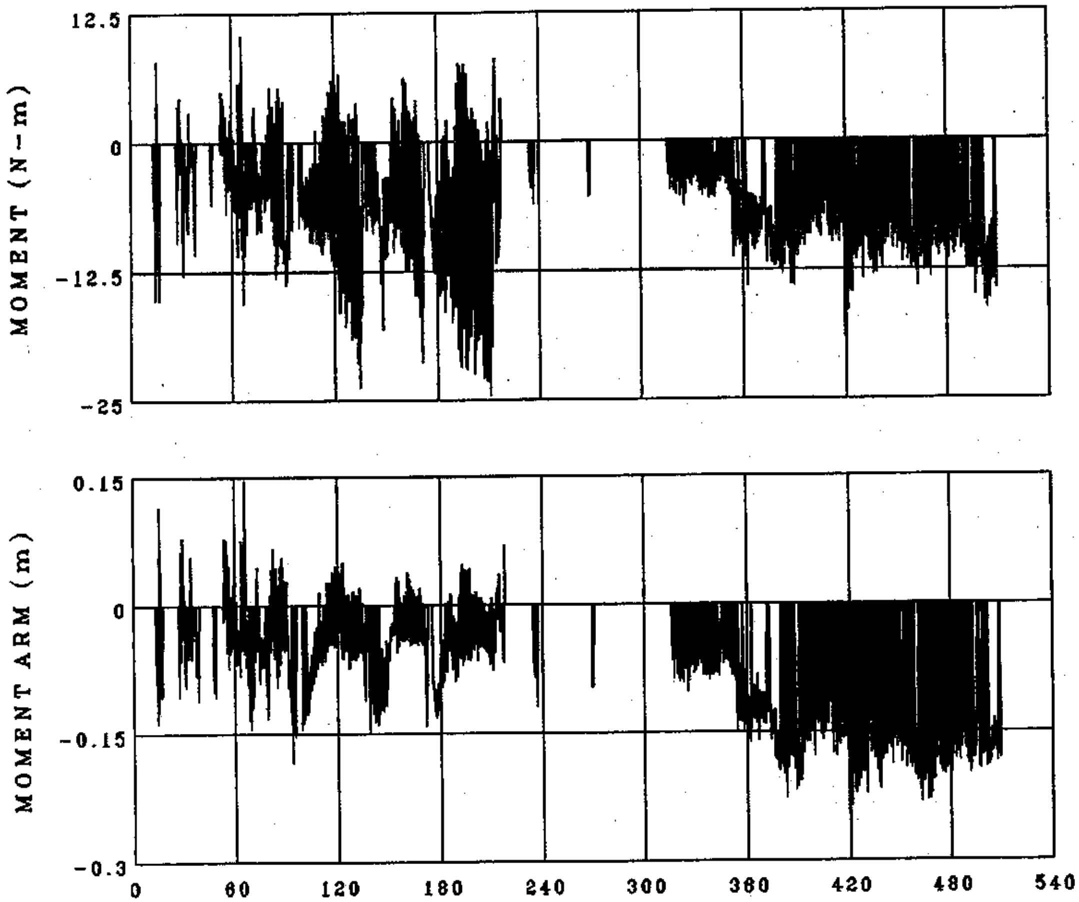
ICE PILEUP STUDY
for CANADIAN COAST GUARD

FILE TN←019

MOMENT



MOMENT

MEAN MOMENT = -4.128 N-m
MAX MOMENT = 10.35 N-m
MIN MOMENT = -24.64 N-m

MOMENT ARM

MEAN ARM = -0.04985 m
MAX ARM = 0.1471 m
MIN ARM = -0.2480 m

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 24.00 kPa
ICE THICKNESS = 2.300 cm
ICE DENSITY = 0.9300 g/cc

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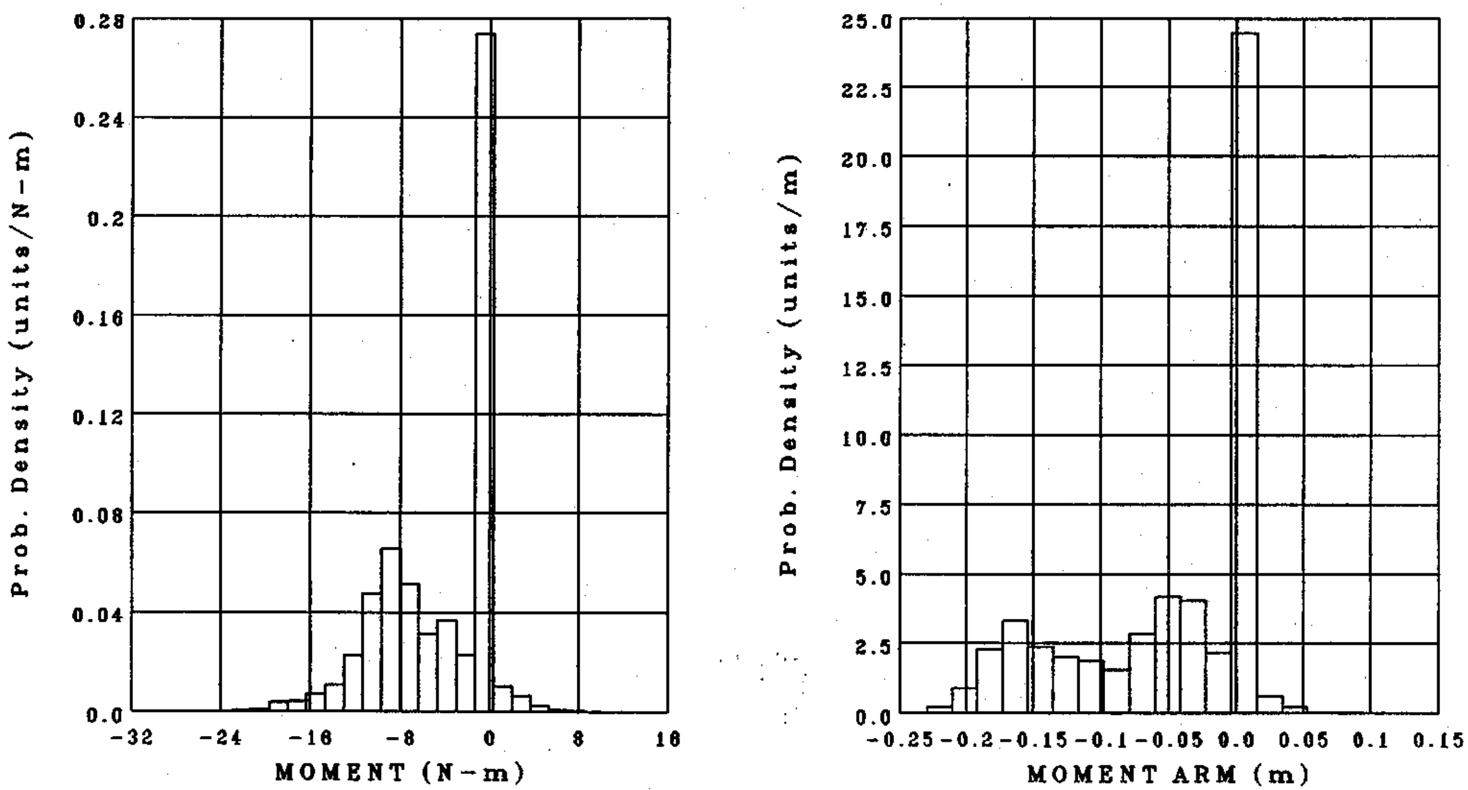
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←019



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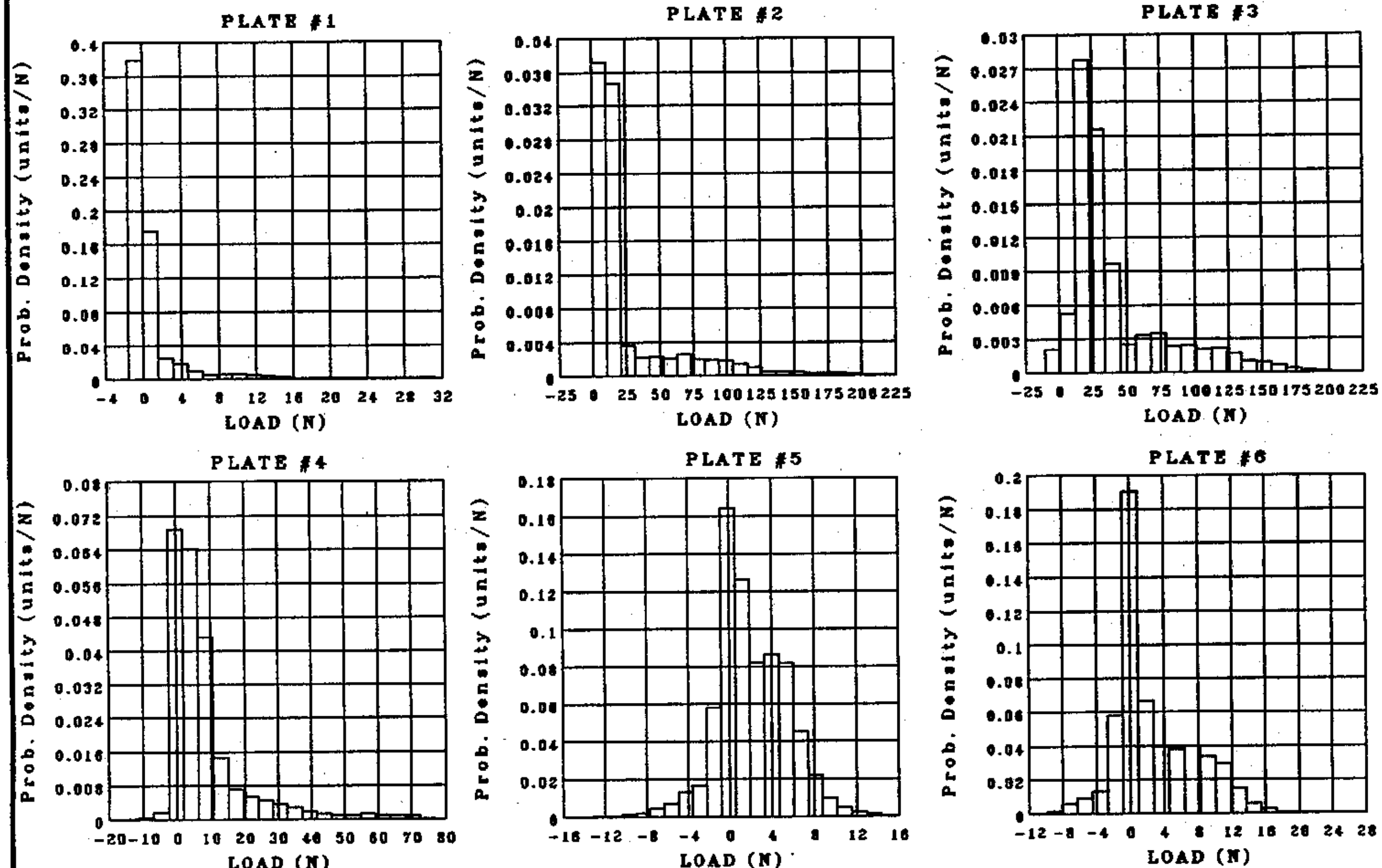
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←019
NORMAL LOAD



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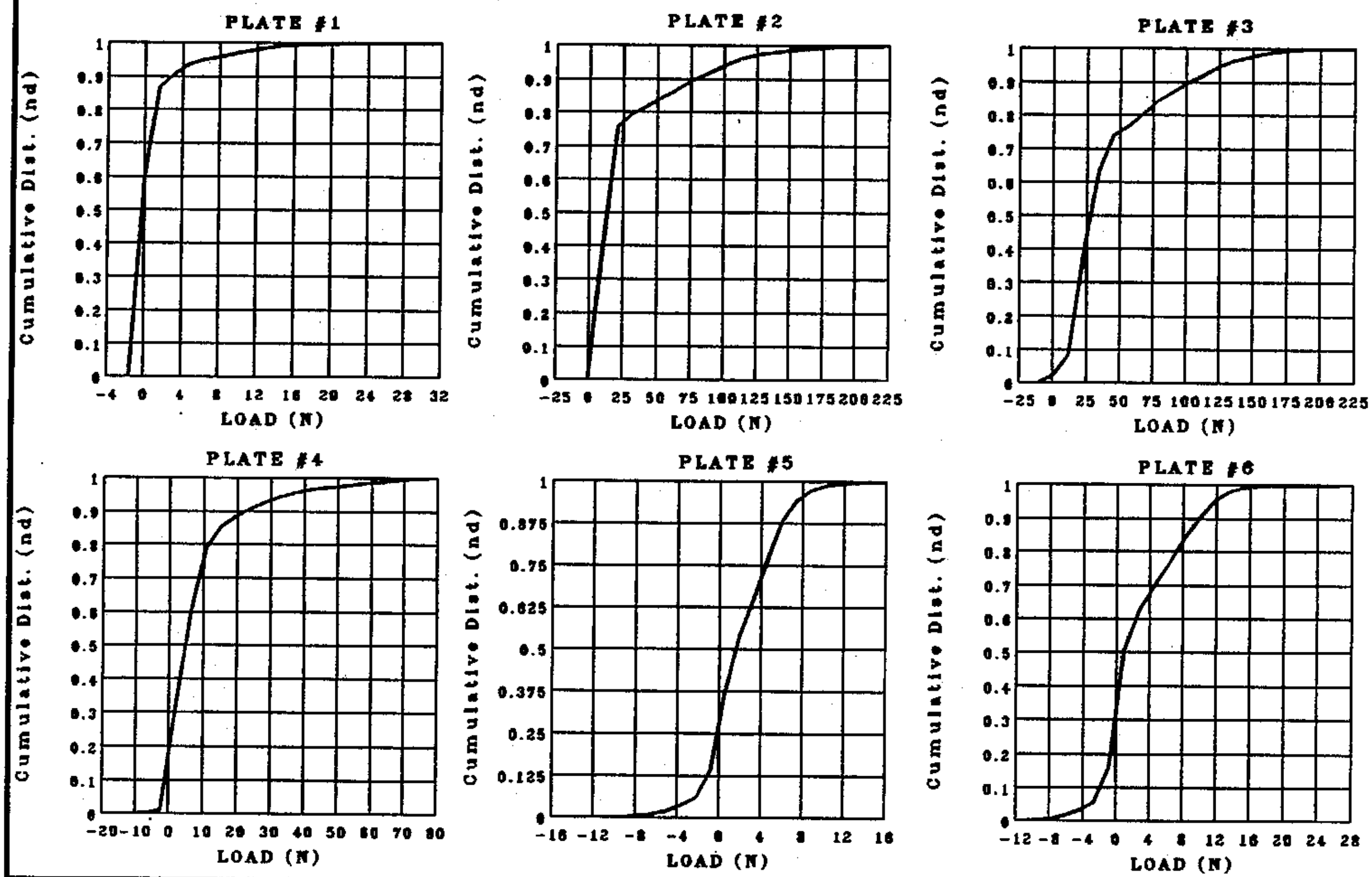
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←019
NORMAL LOAD



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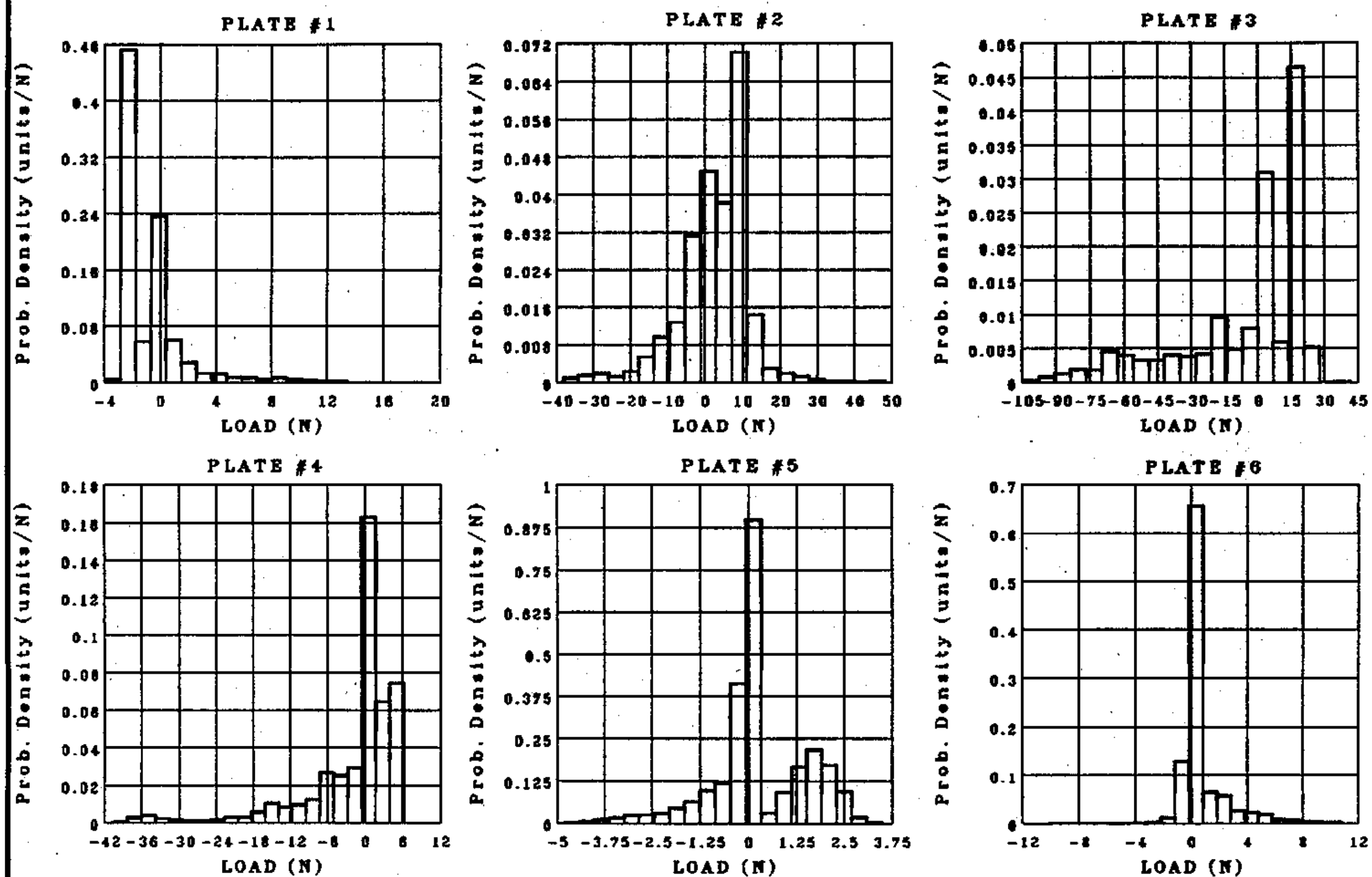
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←019
TANGENTIAL LOAD



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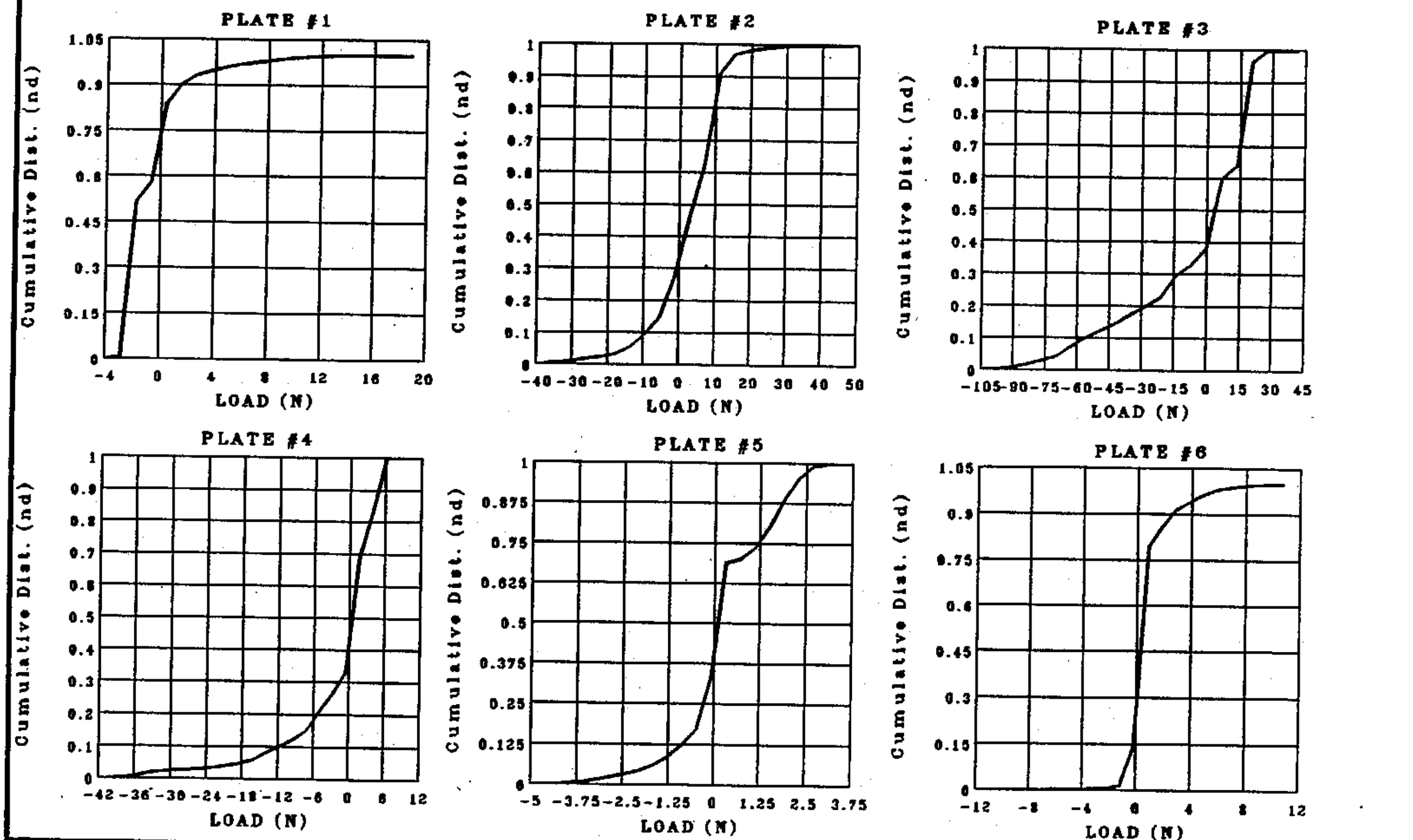
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN ← 019
TANGENTIAL LOAD



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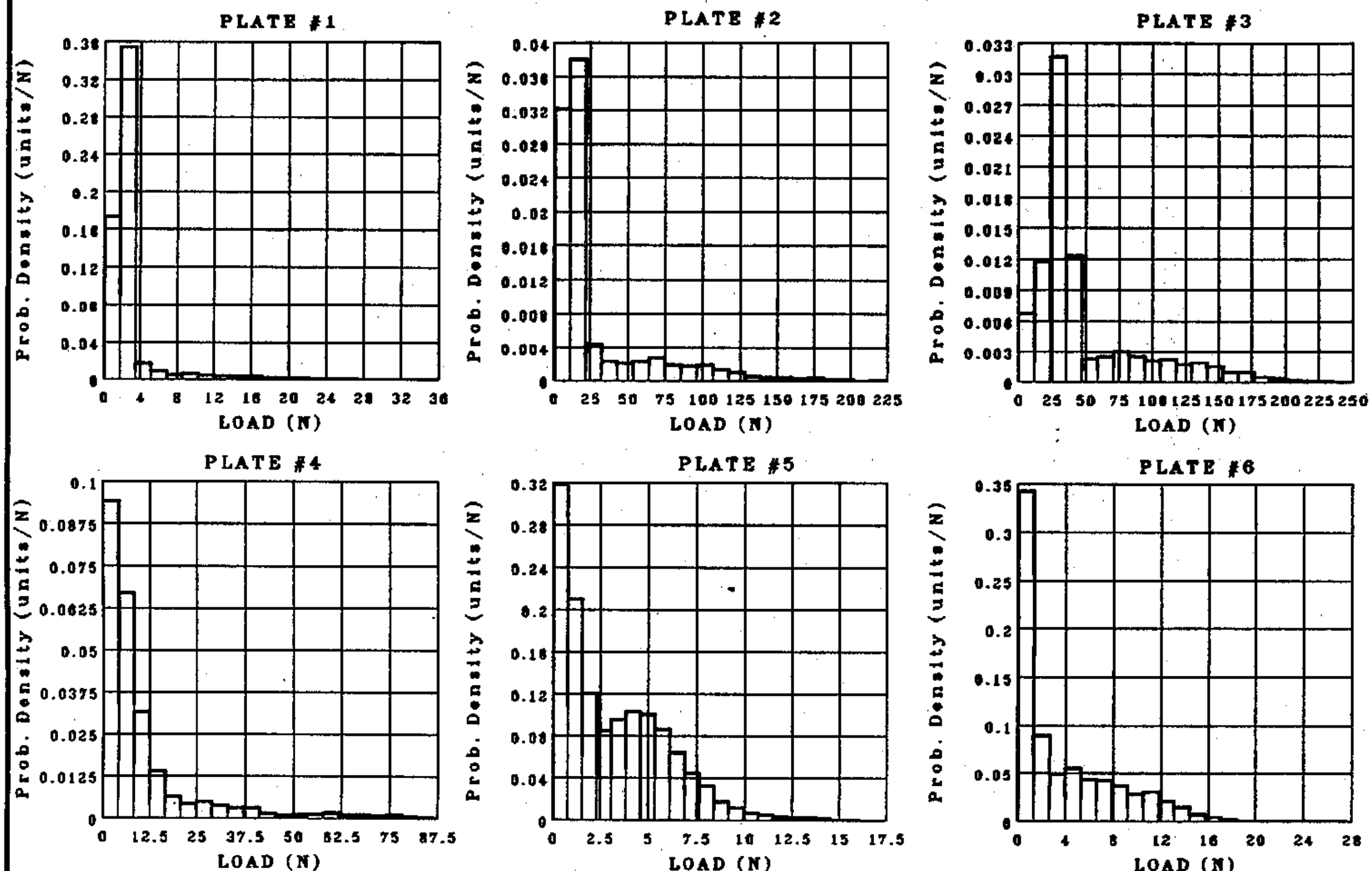
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN ← 019
RESULTANT



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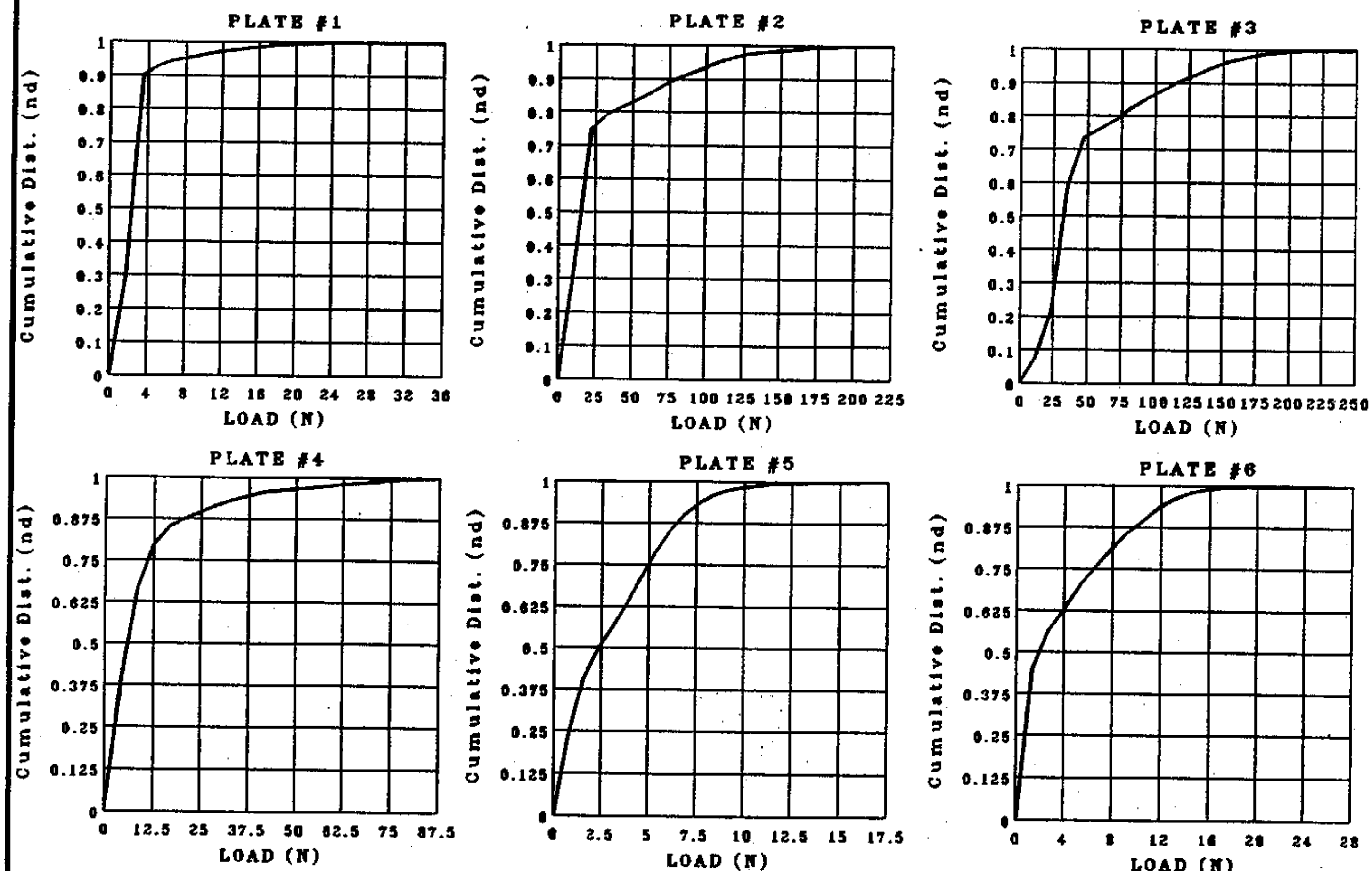
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←019
RESULTANT



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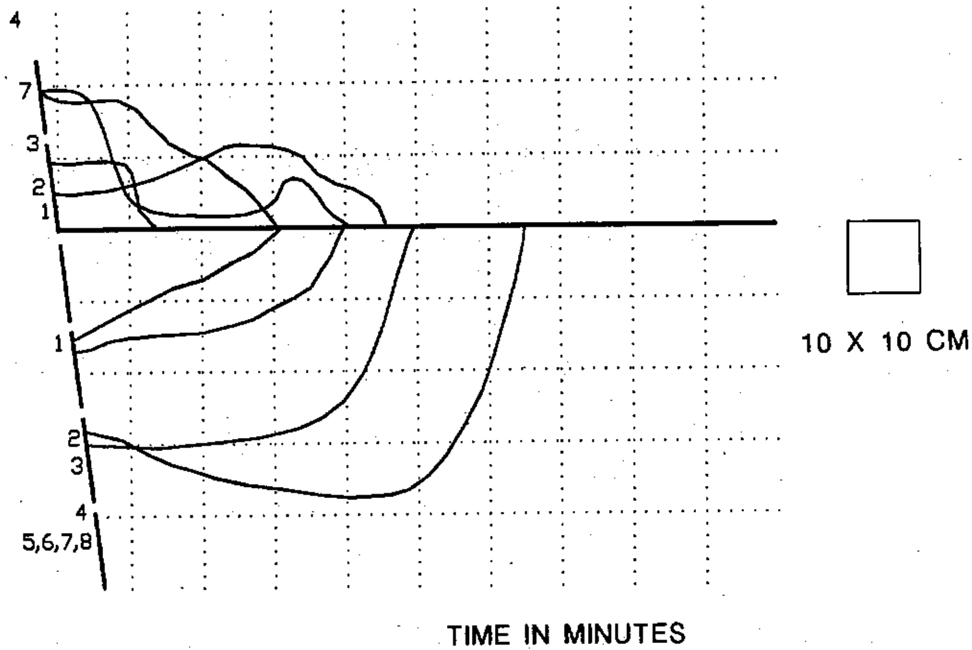
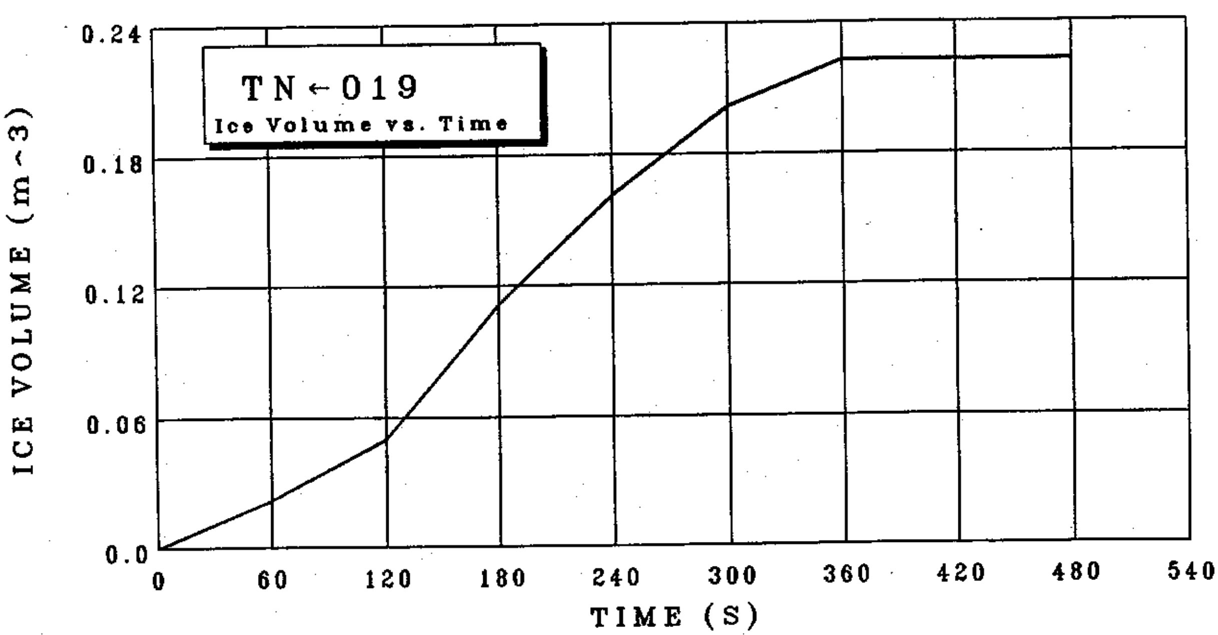
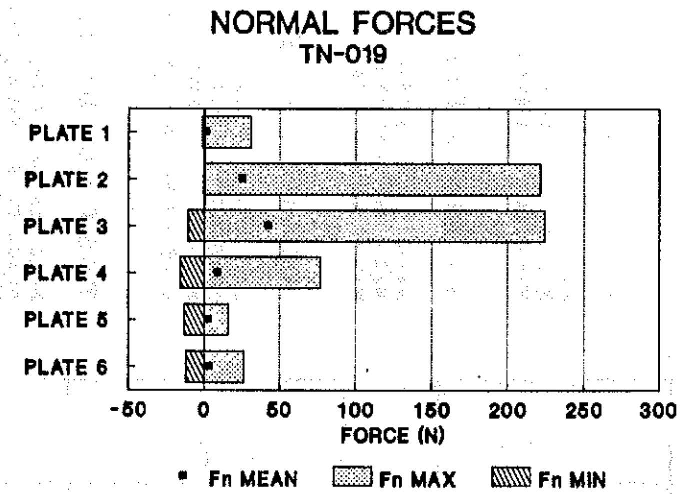
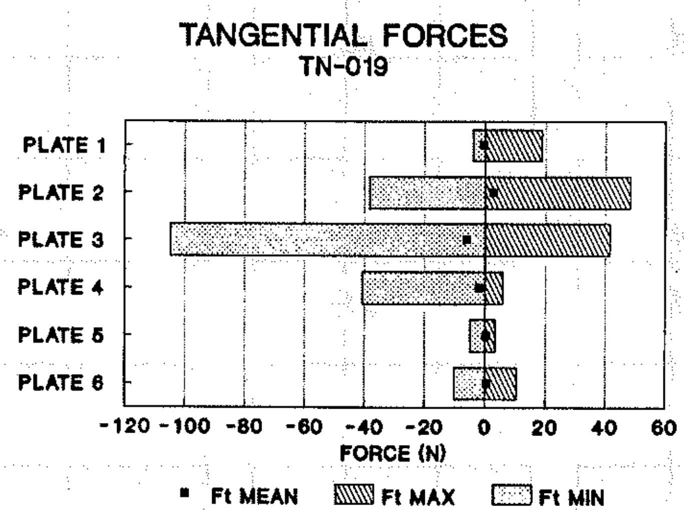
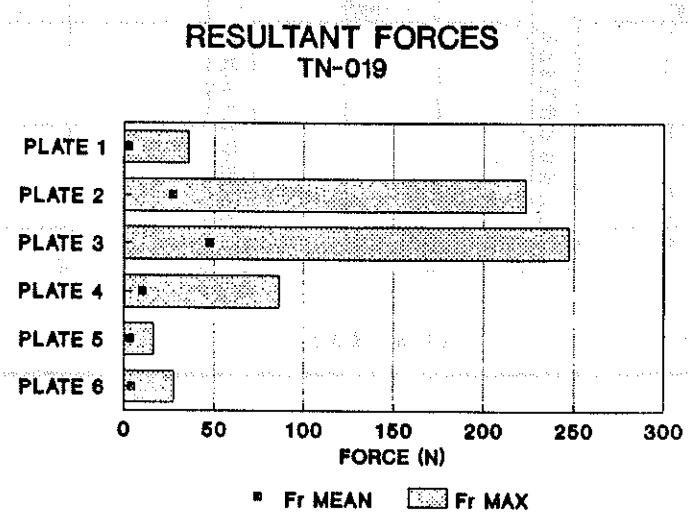
ICE PILEUP STUDY
for CANADIAN COAST GUARD

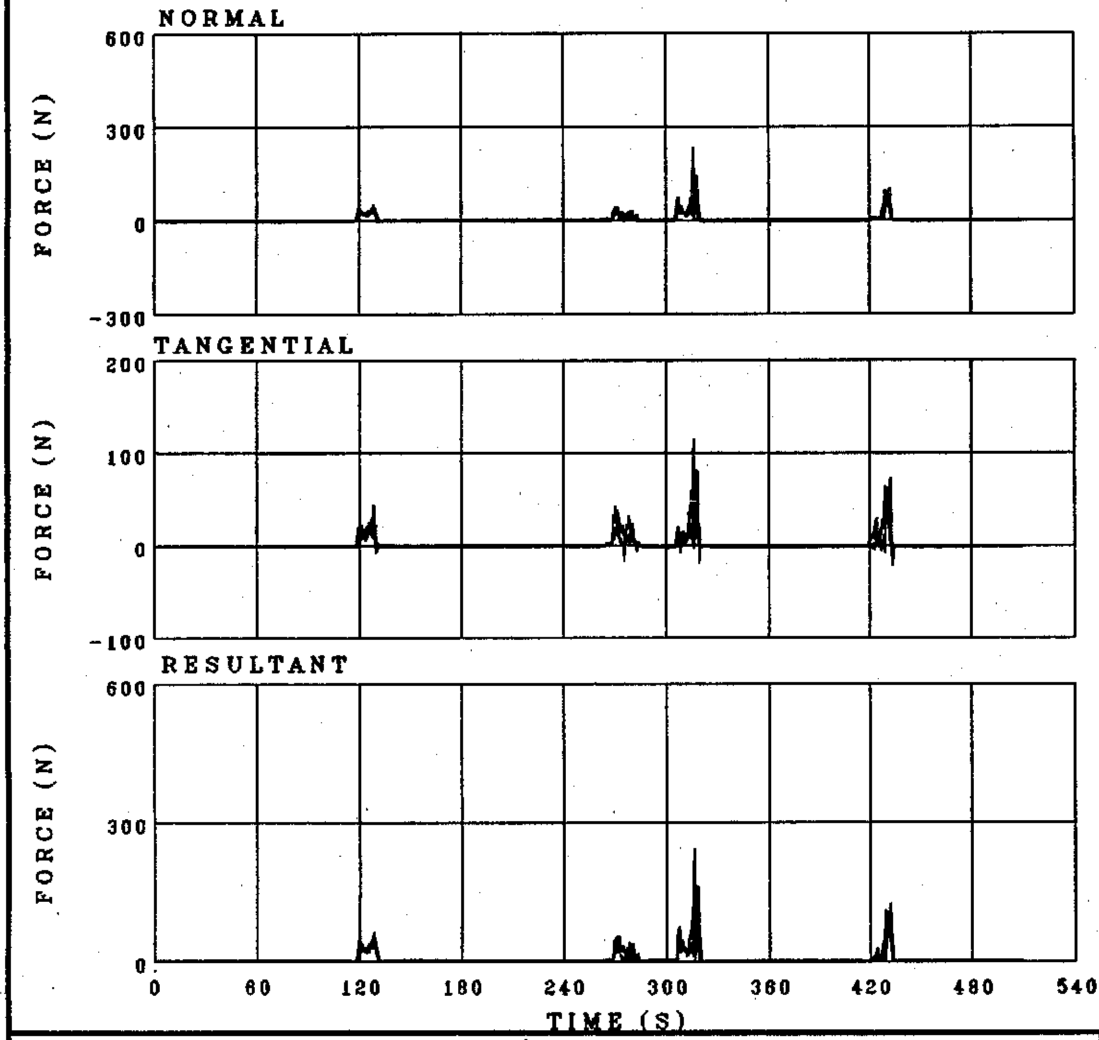

4
7
3
2
1
1
2
3
4
5,6,7,8
10 X 10 CM
TIME IN MINUTES


TN←019
Ice Volume vs. Time
ICE VOLUME (m^3)
0.24
0.18
0.12
0.06
0.0
0
60
120
180
240
300
360
420
480
540
TIME (S)


NORMAL FORCES
TN-019
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-50 0 50 100 150 200 250 300
FORCE (N)
Fn MEAN
Fn MAX
Fn MIN


TANGENTIAL FORCES
TN-019
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-120 -100 -80 -60 -40 -20 0 20 40 60
FORCE (N)
Ft MEAN
Ft MAX
Ft MIN


RESULTANT FORCES
TN-019
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
0 50 100 150 200 250 300
FORCE (N)
Fr MEAN
Fr MAX



FILE TN←020

PLATE #1

NORMAL

MEAN FORCE = 3.485 N
MAX FORCE = 154.6 N
MIN FORCE = -1.026 N

TANGENTIAL

MEAN FORCE = 0.7898 N
MAX FORCE = 80.73 N
MIN FORCE = -11.69 N

RESULTANT

MEAN FORCE = 4.585 N
MAX FORCE = 174.3 N
MIN FORCE = 0.08486 N
AVERAGE ANGLE = -48.89 D

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 15.00 kPa
ICE THICKNESS = 3.620 cm
ICE DENSITY = 0.9300 g/cc

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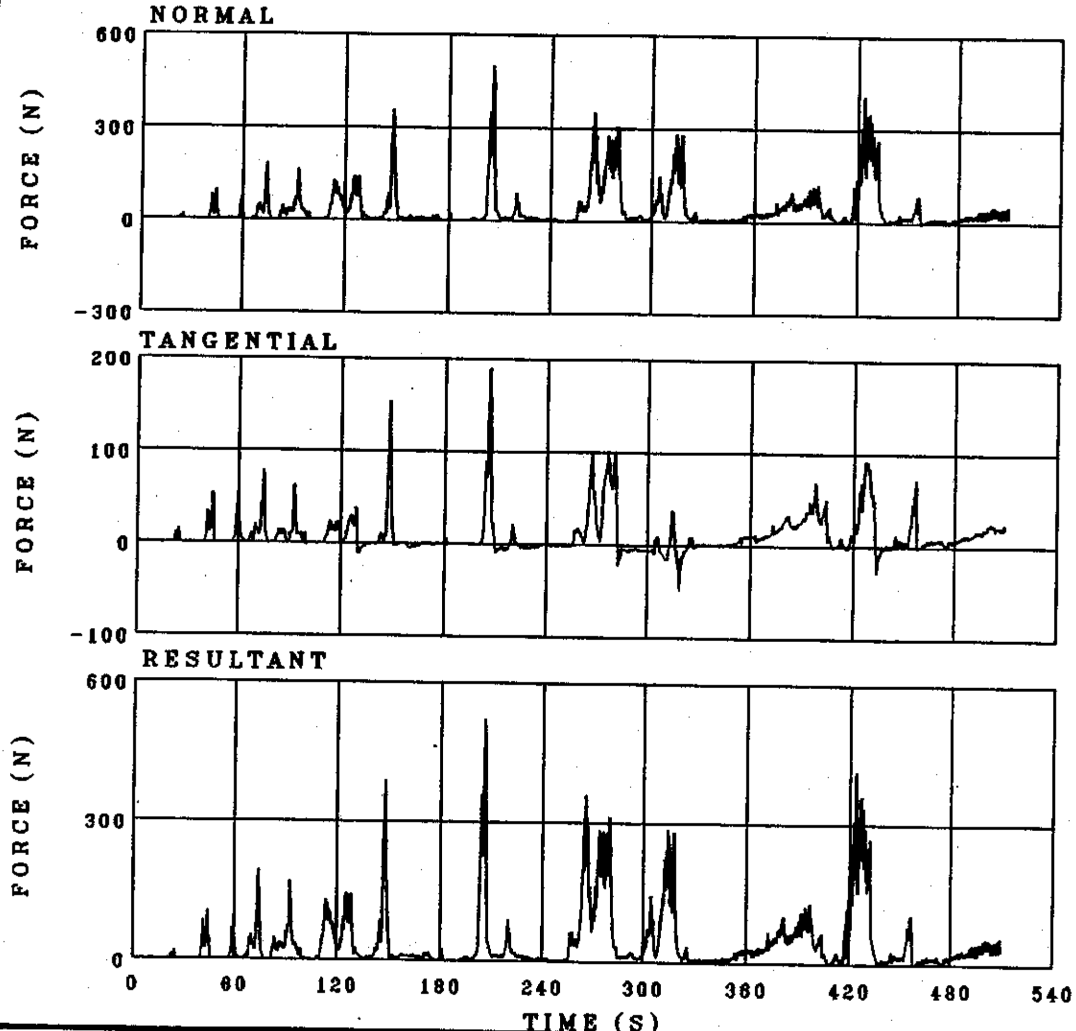
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←020

PLATE #2

NORMAL

MEAN FORCE = 37.16 N
MAX FORCE = 502.4 N
MIN FORCE = -6.799 N

TANGENTIAL

MEAN FORCE = 10.21 N
MAX FORCE = 190.8 N
MIN FORCE = -48.56 N

RESULTANT

MEAN FORCE = 40.04 N
MAX FORCE = 522.9 N
MIN FORCE = 0.03255 N
AVERAGE ANGLE = 14.89 O

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 15.00 kPa
ICE THICKNESS = 3.620 cm
ICE DENSITY = 0.9300 g/cc

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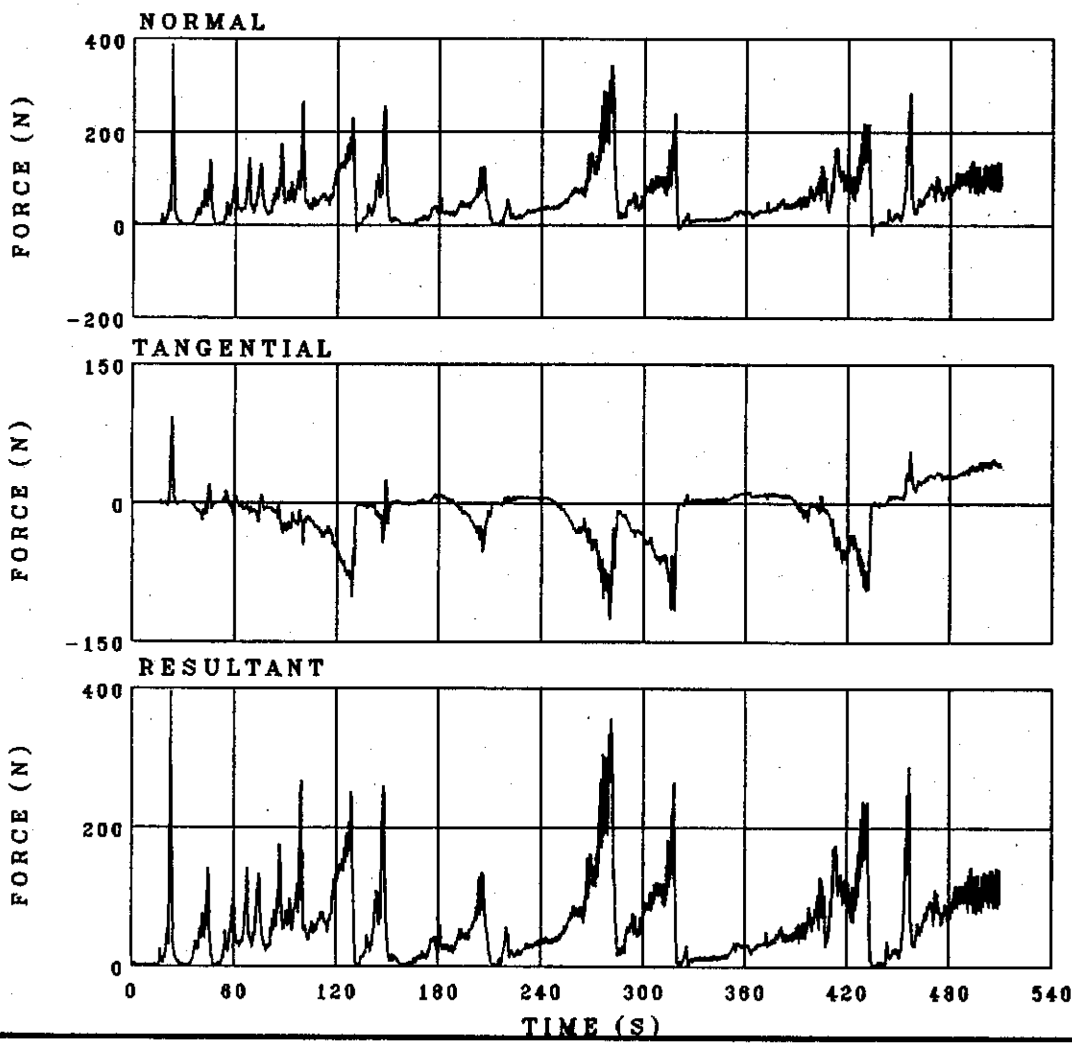
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←020

PLATE #3

NORMAL

MEAN FORCE = 56.34 N
MAX FORCE = 387.3 N
MIN FORCE = -21.86 N

TANGENTIAL

MEAN FORCE = -7.891 N
MAX FORCE = 92.18 N
MIN FORCE = -125.4 N

RESULTANT

MEAN FORCE = 60.37 N
MAX FORCE = 395.7 N
MIN FORCE = 0.03098 N
AVERAGE ANGLE = -3.538 O

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 15.00 kPa
ICE THICKNESS = 3.620 cm
ICE DENSITY = 0.9300 g/cc

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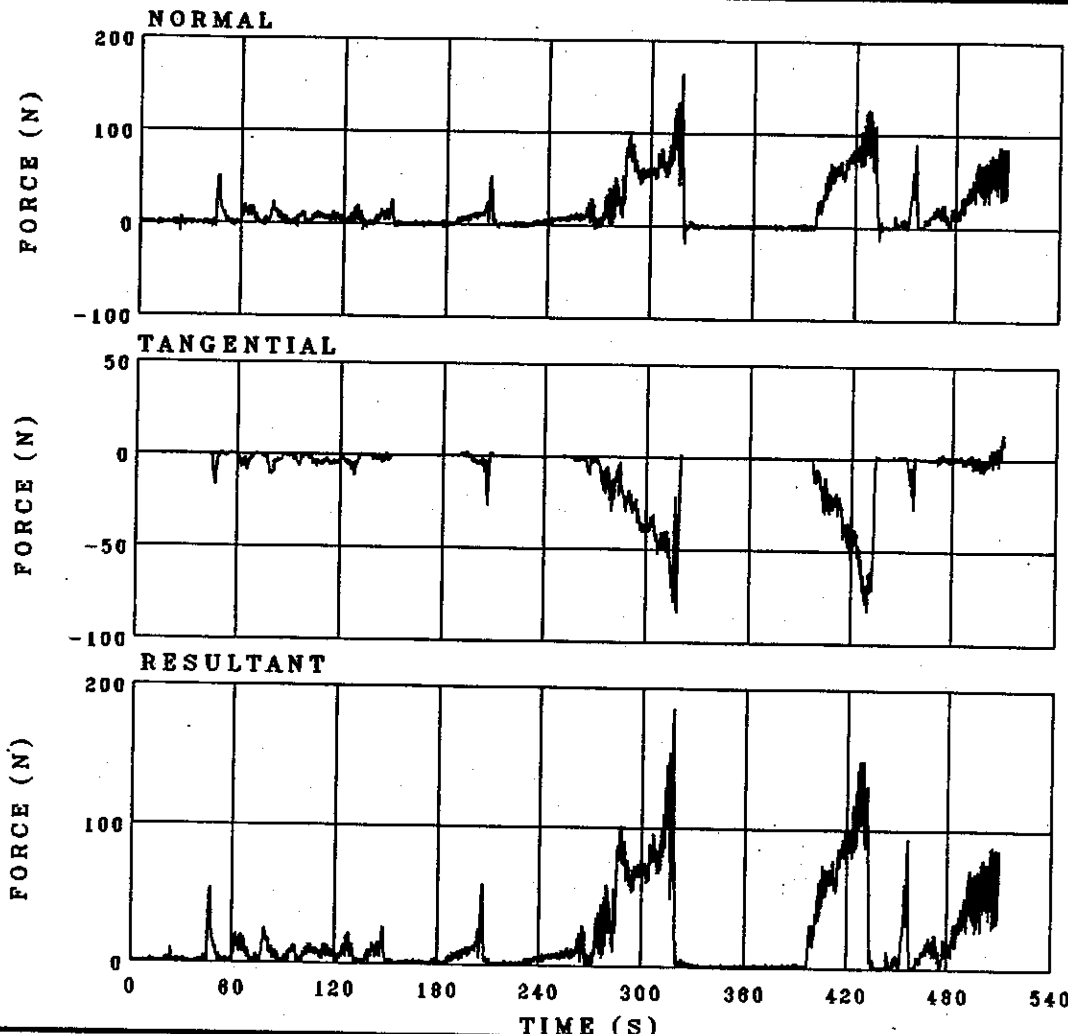
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←020

PLATE #4

NORMAL

MEAN FORCE = 16.36 N
MAX FORCE = 164.7 N
MIN FORCE = −18.72 N

TANGENTIAL

MEAN FORCE = −6.478 N
MAX FORCE = 14.18 N
MIN FORCE = −84.19 N

RESULTANT

MEAN FORCE = 16.58 N
MAX FORCE = 185.0 N
MIN FORCE = 0.01970 N
AVERAGE ANGLE = −20.54 O

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 15.00 kPa
ICE THICKNESS = 3.620 cm
ICE DENSITY = 0.9300 g/cc

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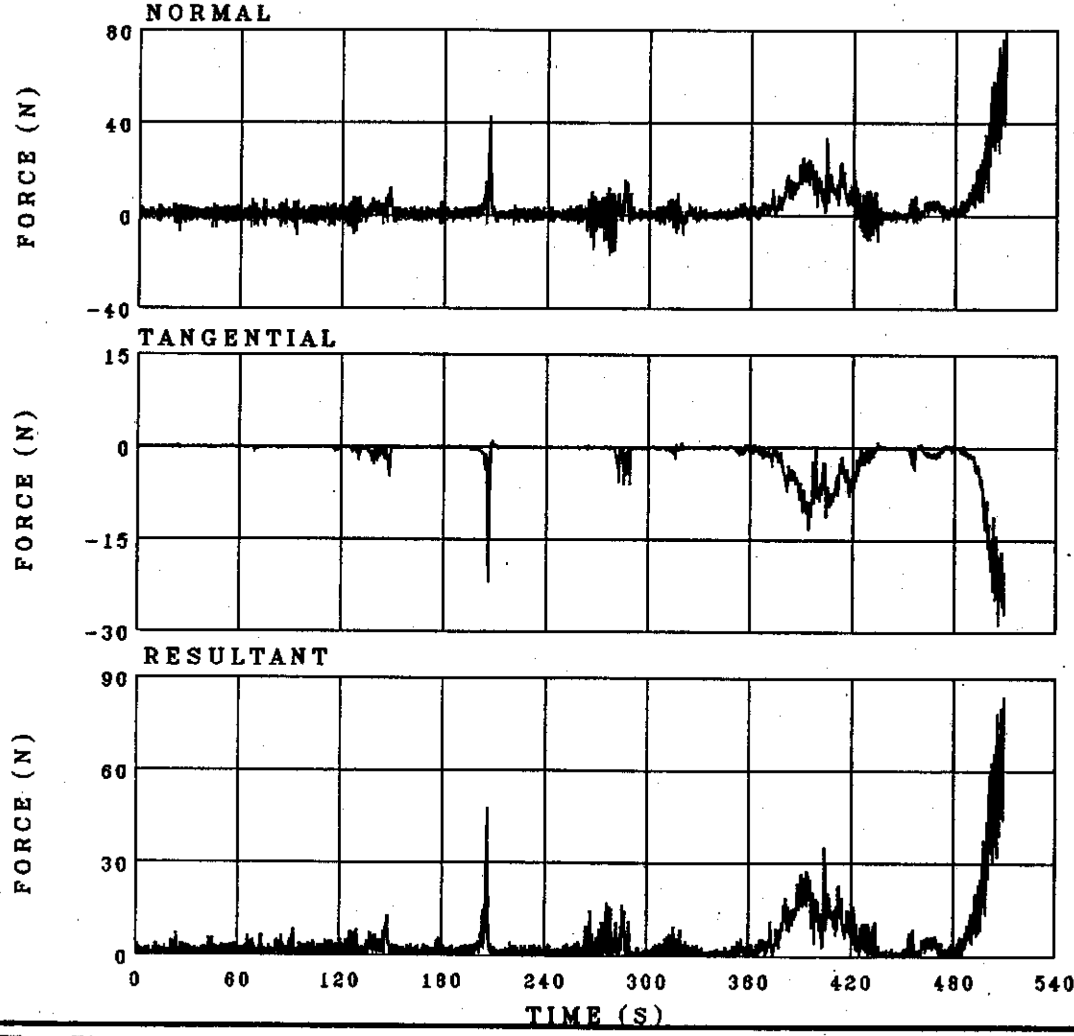
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←020

PLATE #5

NORMAL

MEAN FORCE = 3.291 N
MAX FORCE = 79.59 N
MIN FORCE = -17.26 N

TANGENTIAL

MEAN FORCE = -1.333 N
MAX FORCE = 0.9923 N
MIN FORCE = -28.95 N

RESULTANT

MEAN FORCE = 4.473 N
MAX FORCE = 84.08 N
MIN FORCE = 0.05551 N
AVERAGE ANGLE = -9.608 O

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 15.00 kPa
ICE THICKNESS = 3.620 cm
ICE DENSITY = 0.9300 g/cc

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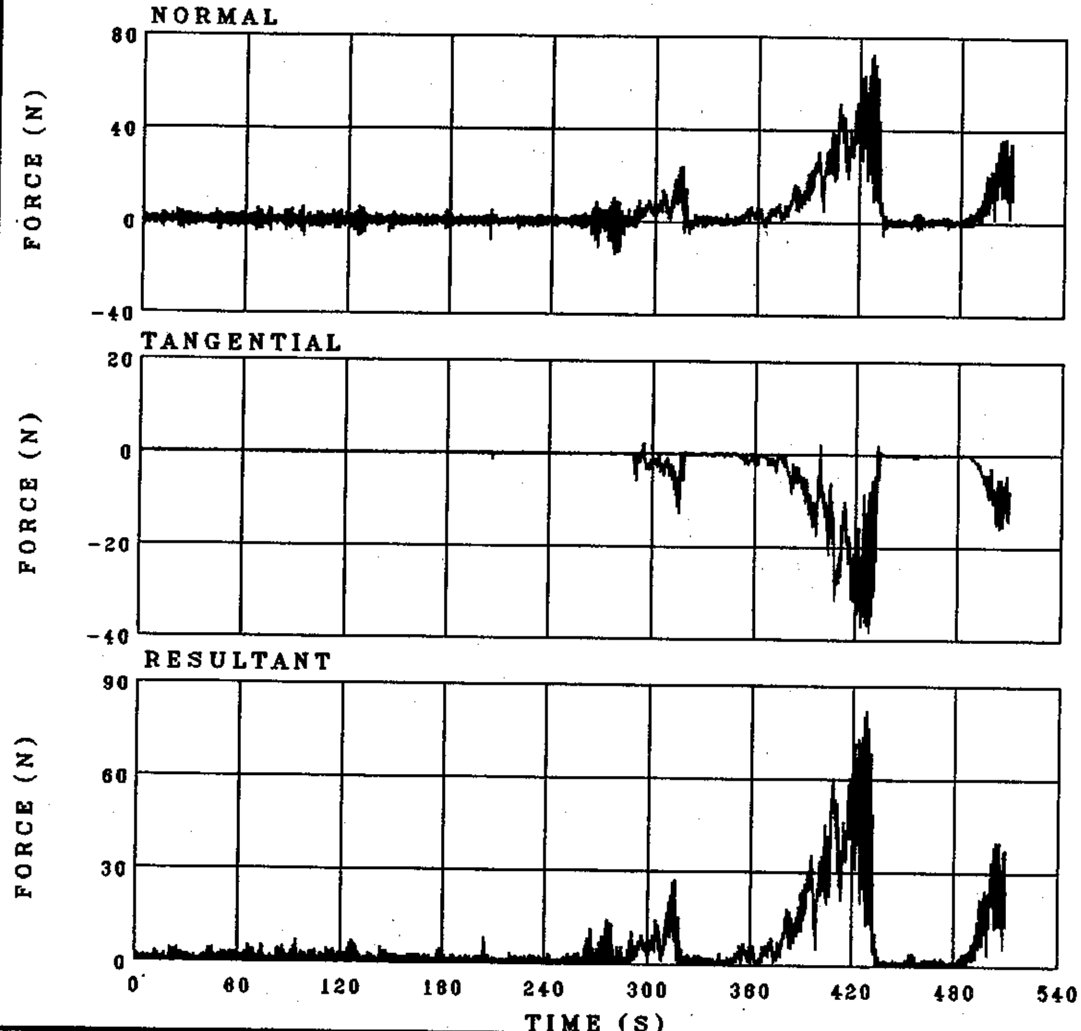
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←020

PLATE #6

NORMAL

MEAN FORCE = 4.304 N
MAX FORCE = 72.71 N
MIN FORCE = -14.37 N

TANGENTIAL

MEAN FORCE = -2.215 N
MAX FORCE = 2.263 N
MIN FORCE = -38.51 N

RESULTANT

MEAN FORCE = 5.652 N
MAX FORCE = 82.28 N
MIN FORCE = 0.06668 N
AVERAGE ANGLE = -36.75 O

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 15.00 kPa
ICE THICKNESS = 3.620 cm
ICE DENSITY = 0.9300 g/cc

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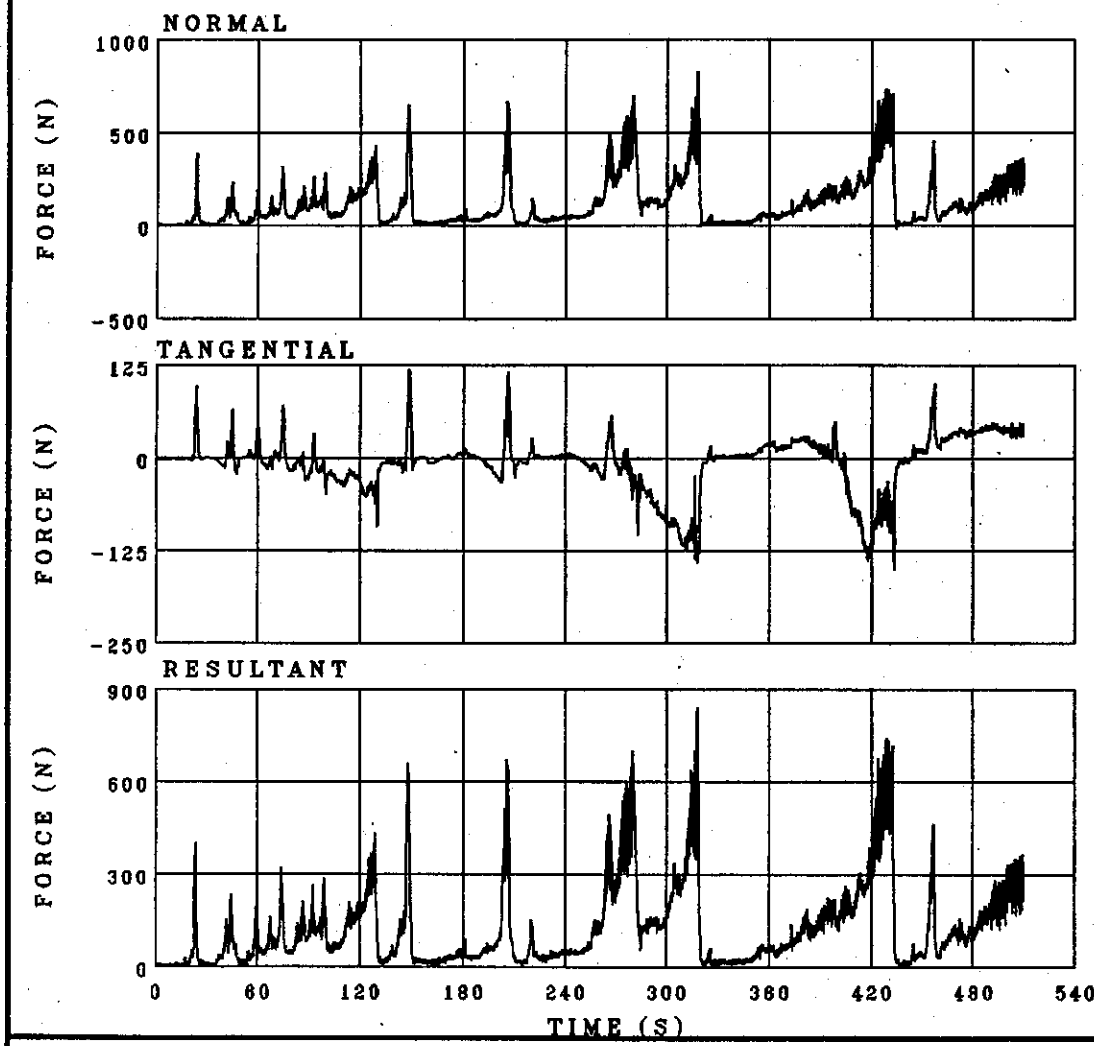
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←020

TOTAL

NORMAL

MEAN FORCE = 120.9 N
MAX FORCE = 832.0 N
MIN FORCE = -20.15 N

TANGENTIAL

MEAN FORCE = -6.913 N
MAX FORCE = 120.2 N
MIN FORCE = -151.2 N

RESULTANT

MEAN FORCE = 124.8 N
MAX FORCE = 843.8 N
MIN FORCE = 0.2290 N
AVERAGE ANGLE = -4.496 O

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 15.00 kPa
ICE THICKNESS = 3.620 cm
ICE DENSITY = 0.9300 g/cc

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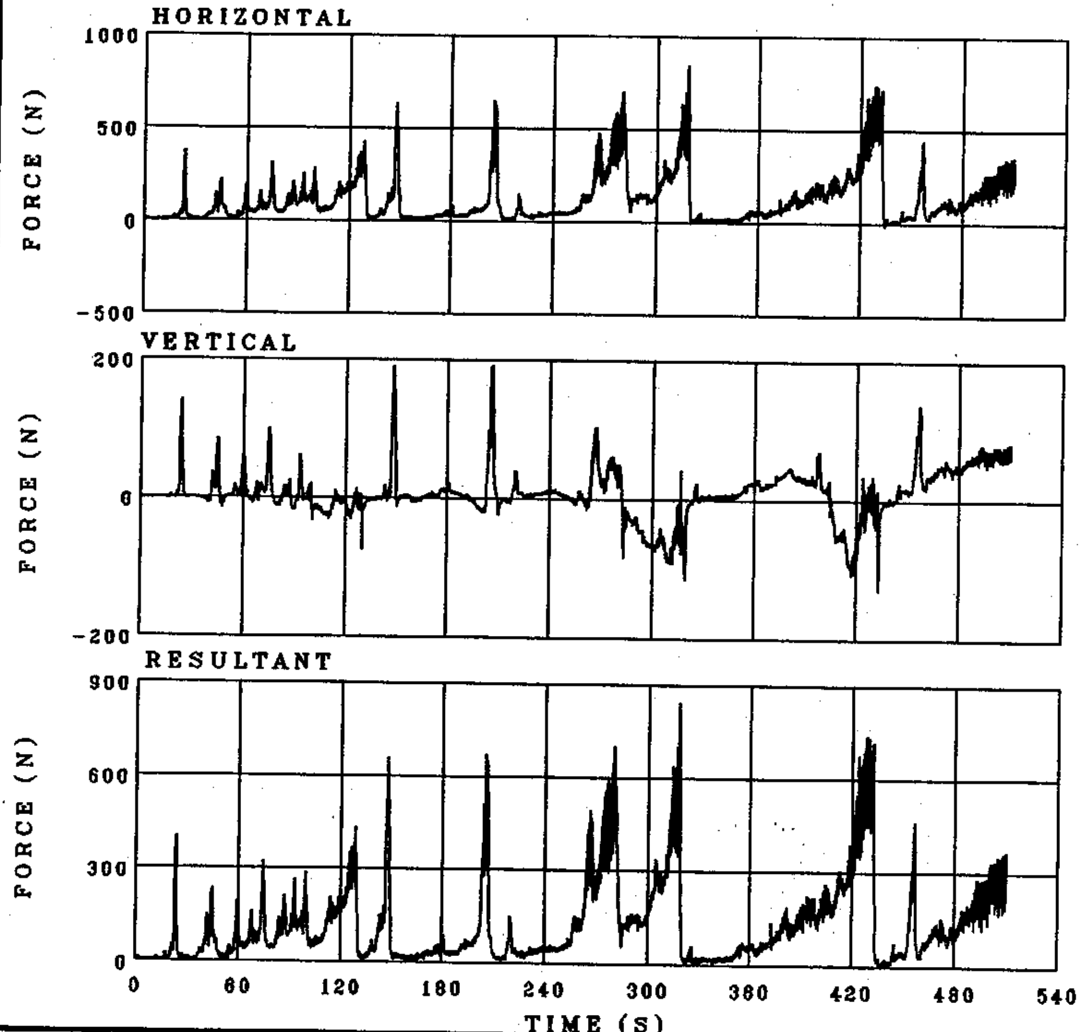
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←020

TOTAL

HORIZONTAL

MEAN FORCE = -6.913 N
MAX FORCE = 120.2 N
MIN FORCE = -151.2 N

VERTICAL

MEAN FORCE = -6.913 N
MAX FORCE = 120.2 N
MIN FORCE = -151.2 N

RESULTANT

MEAN FORCE = -6.913 N
MAX FORCE = 120.2 N
MIN FORCE = -151.2 N
AVERAGE ANGLE = -6.913 O

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 15.00 kPa
ICE THICKNESS = 3.620 cm
ICE DENSITY = 0.9300 g/cc

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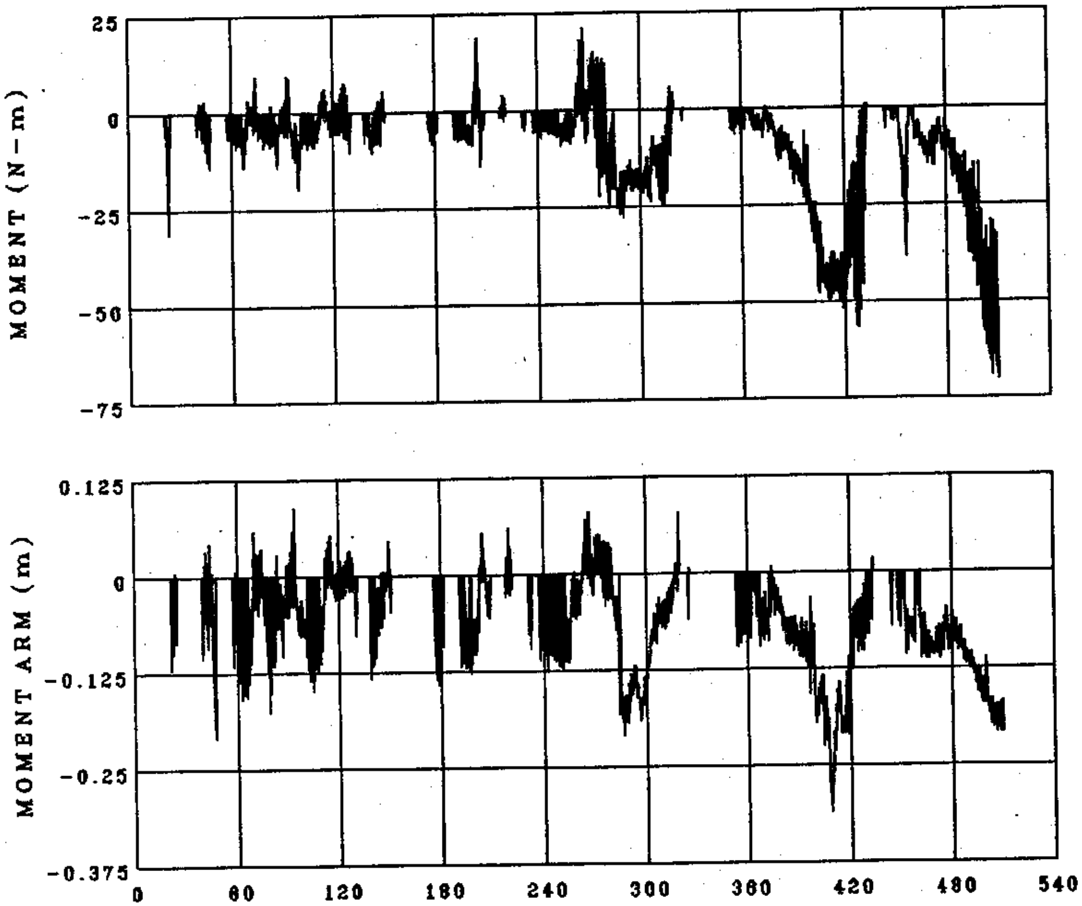
ICE PILEUP STUDY
for CANADIAN COAST GUARD

FILE TN-020

MOMENT



MOMENT

MEAN MOMENT = -7.391 N-m
MAX MOMENT = 21.12 N-m
MIN MOMENT = -70.30 N-m

MOMENT ARM

MEAN ARM = -0.04468 m
MAX ARM = 0.08855 m
MIN ARM = -0.3119 m

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 15.00 kPa
ICE THICKNESS = 3.620 cm
ICE DENSITY = 0.9300 g/cc

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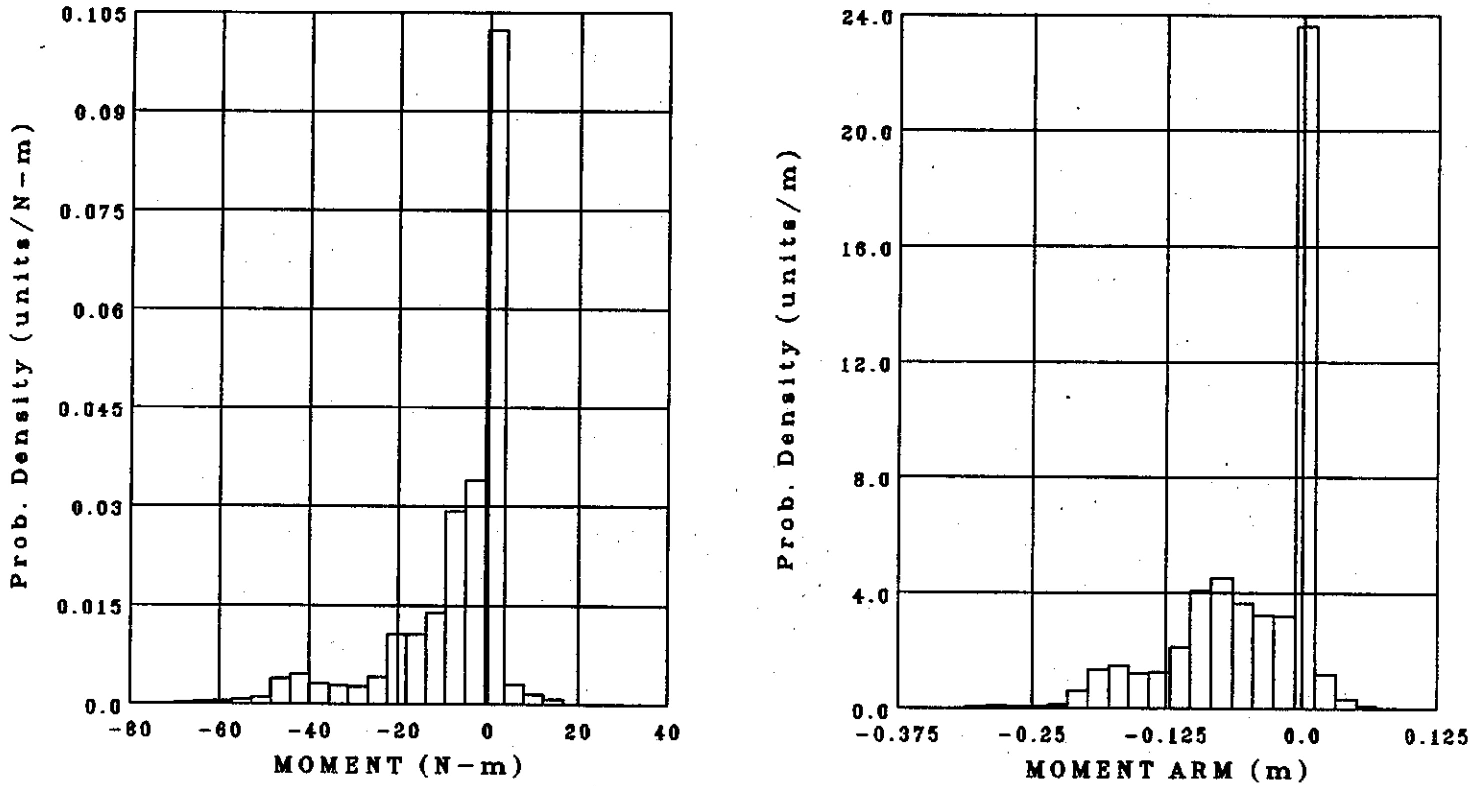
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←020



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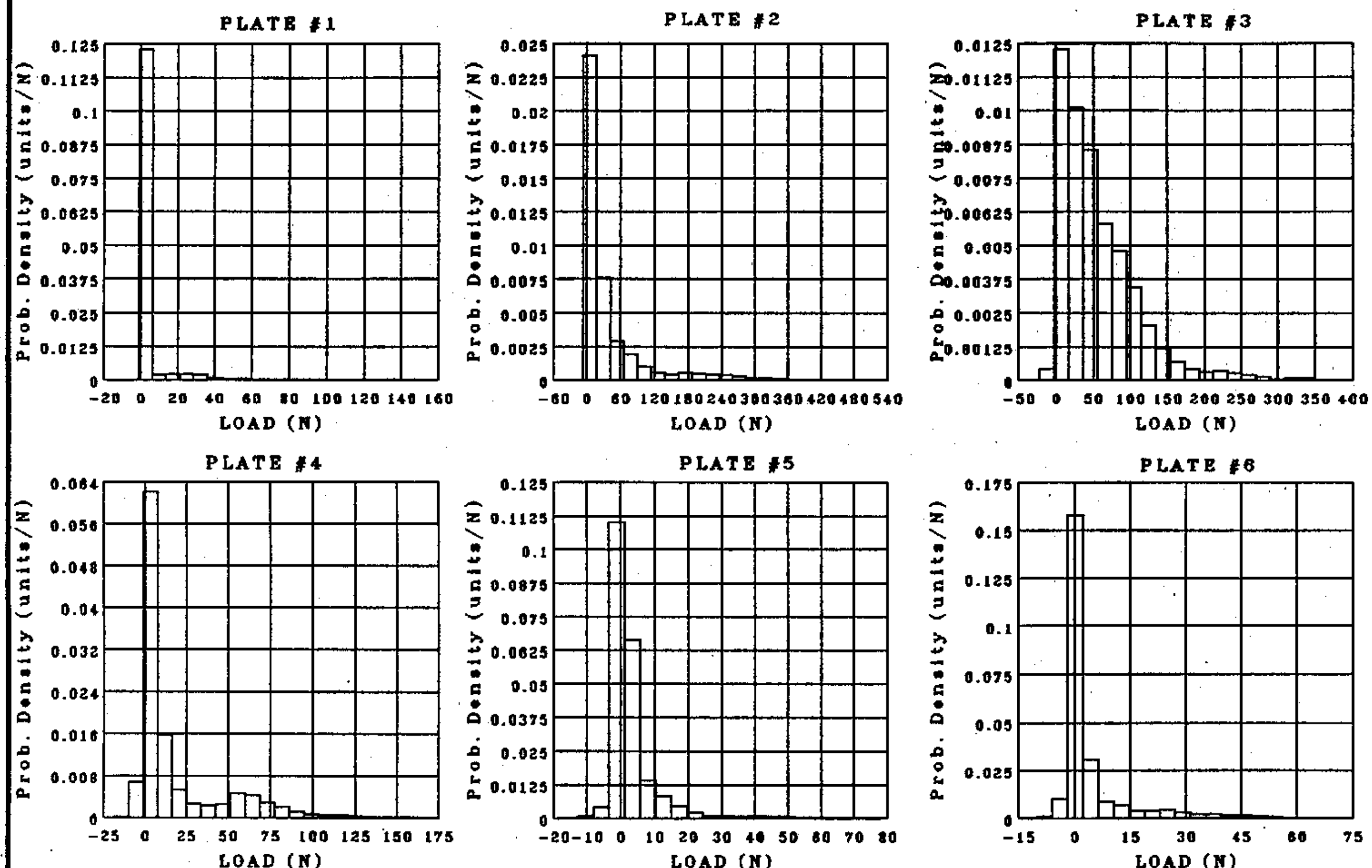
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←020
NORMAL LOAD



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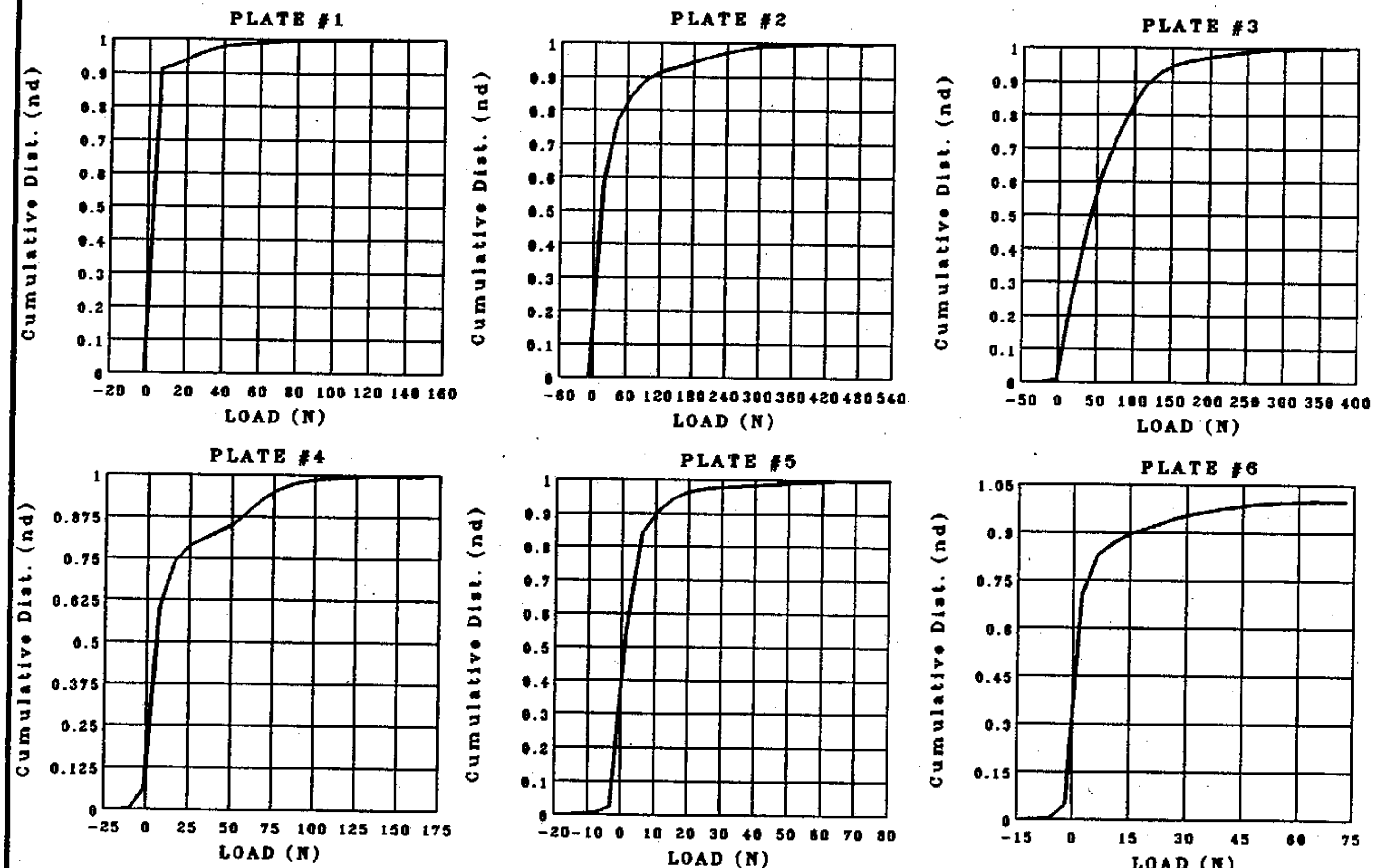
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←020
NORMAL LOAD



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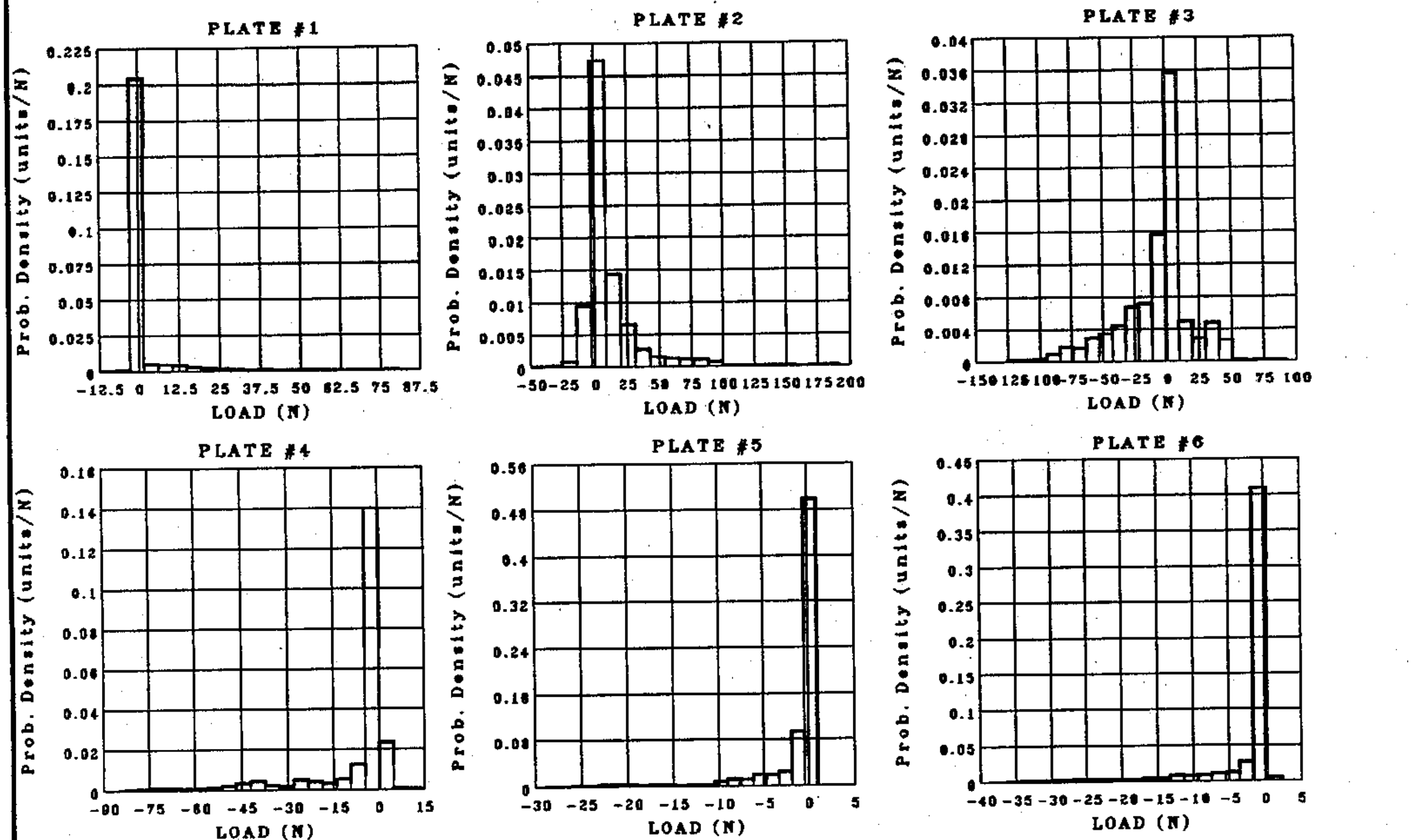
ICE PILEUP STUDY

for CANADIAN COAST GUARD

TN←020
TANGENTIAL LOAD



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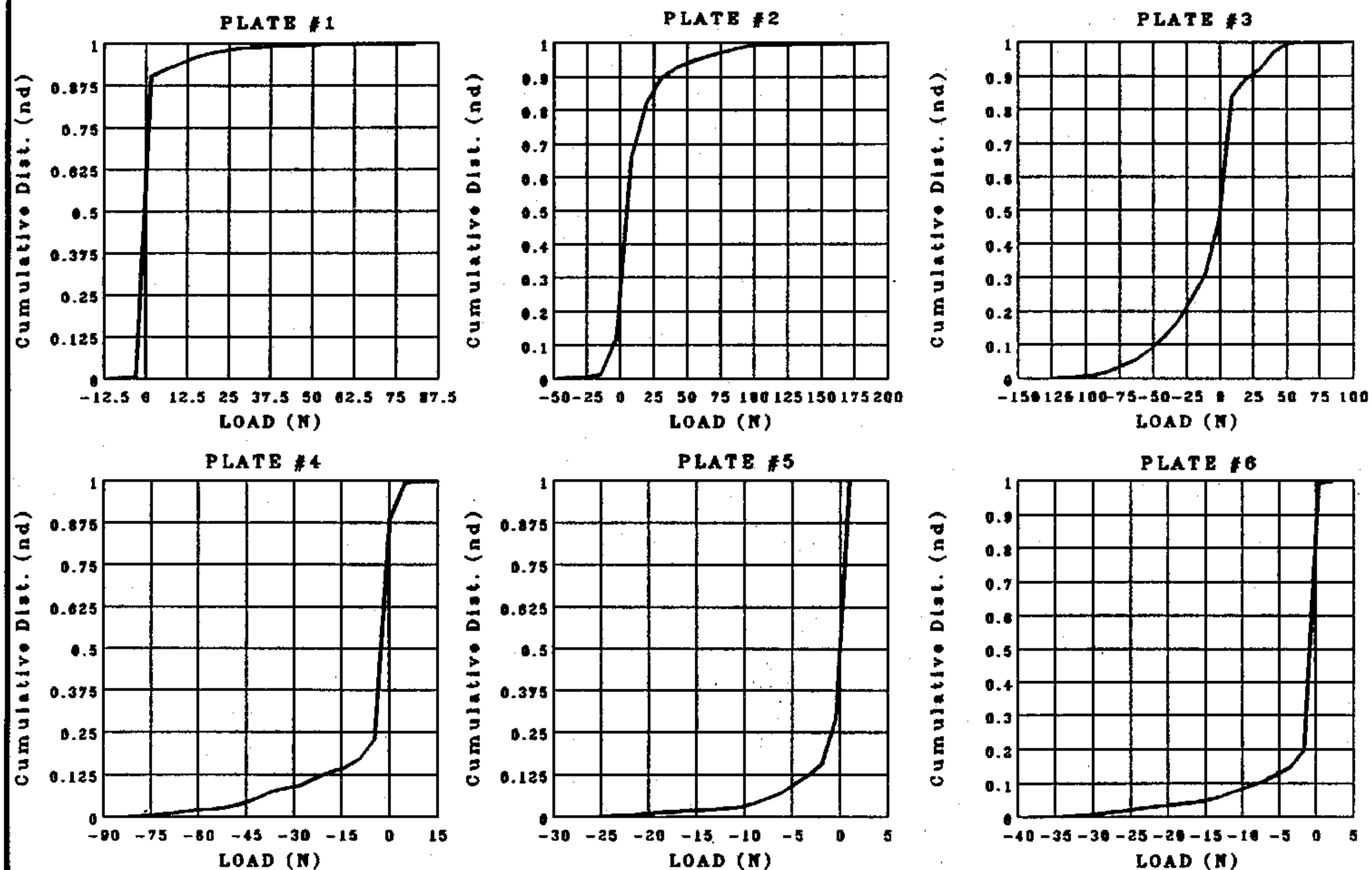
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←020
TANGENTIAL LOAD



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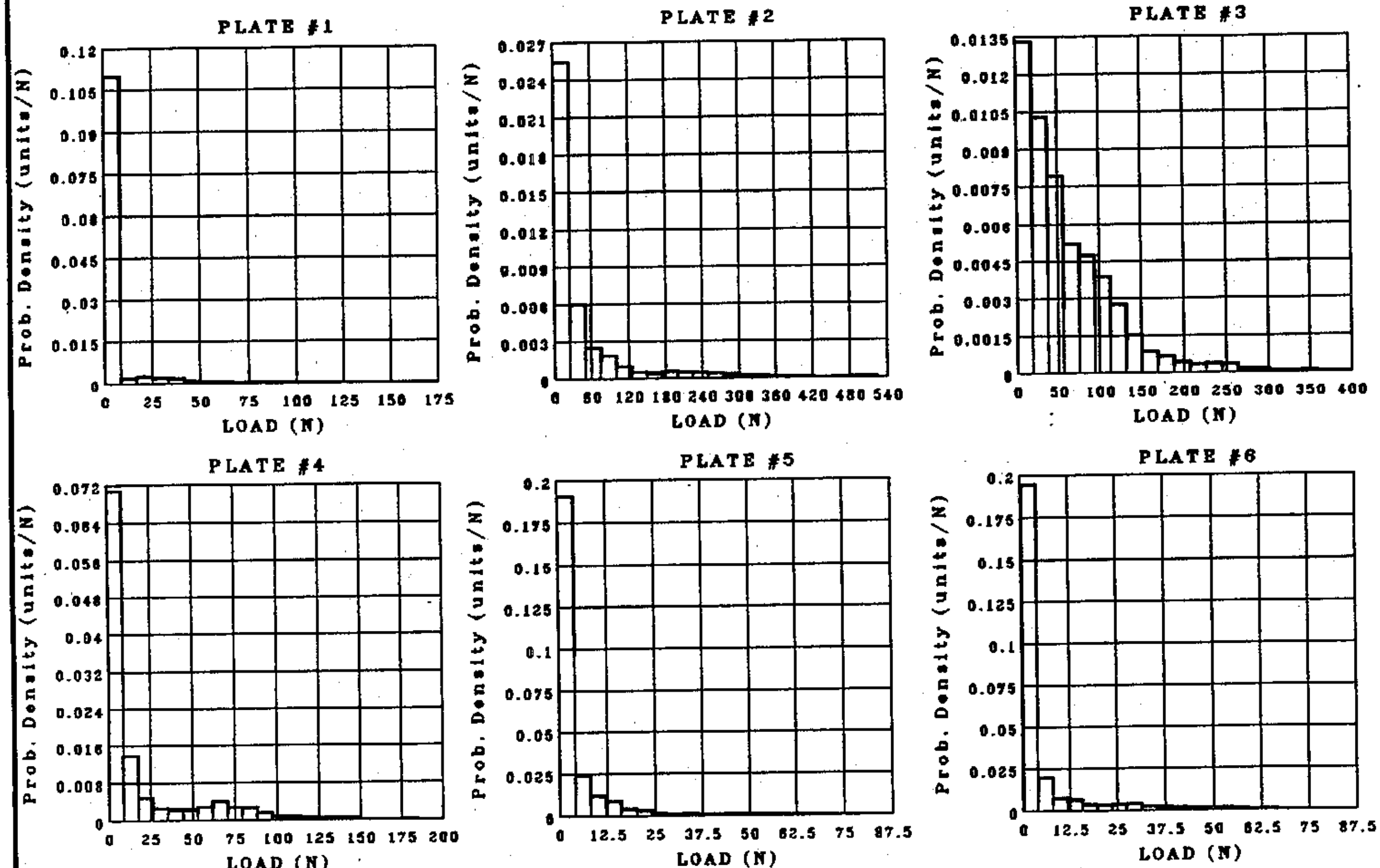
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←020
RESULTANT



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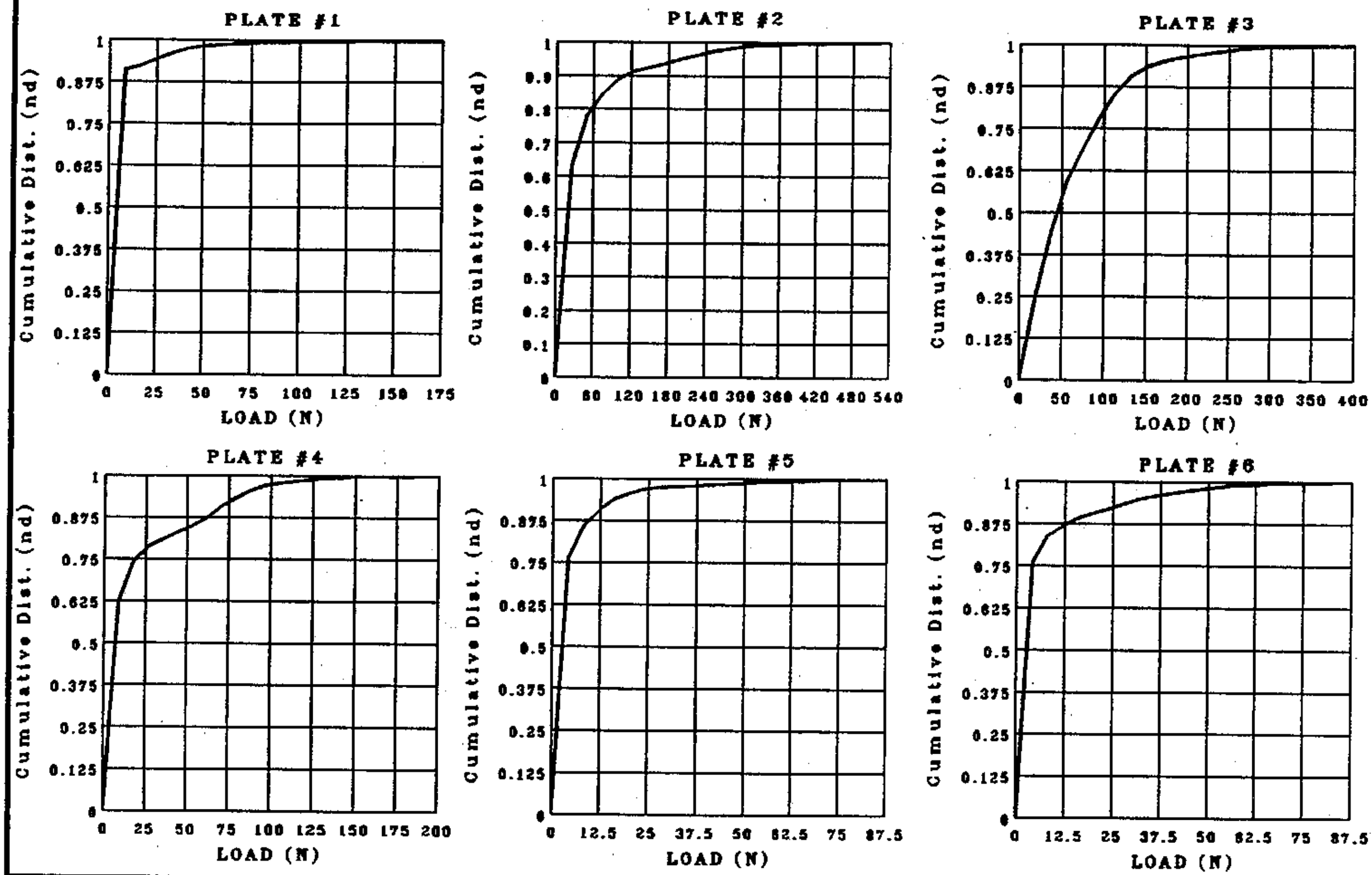
ICE PILEUP STUDY for CANADIAN COAST GUARD

TN←020

RESULTANT



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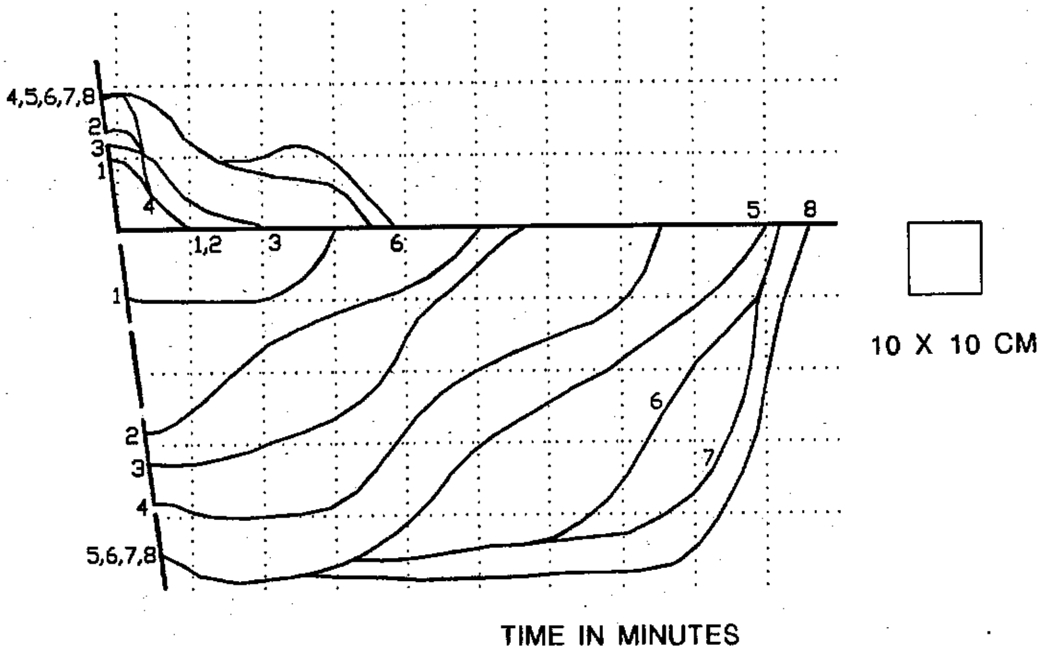
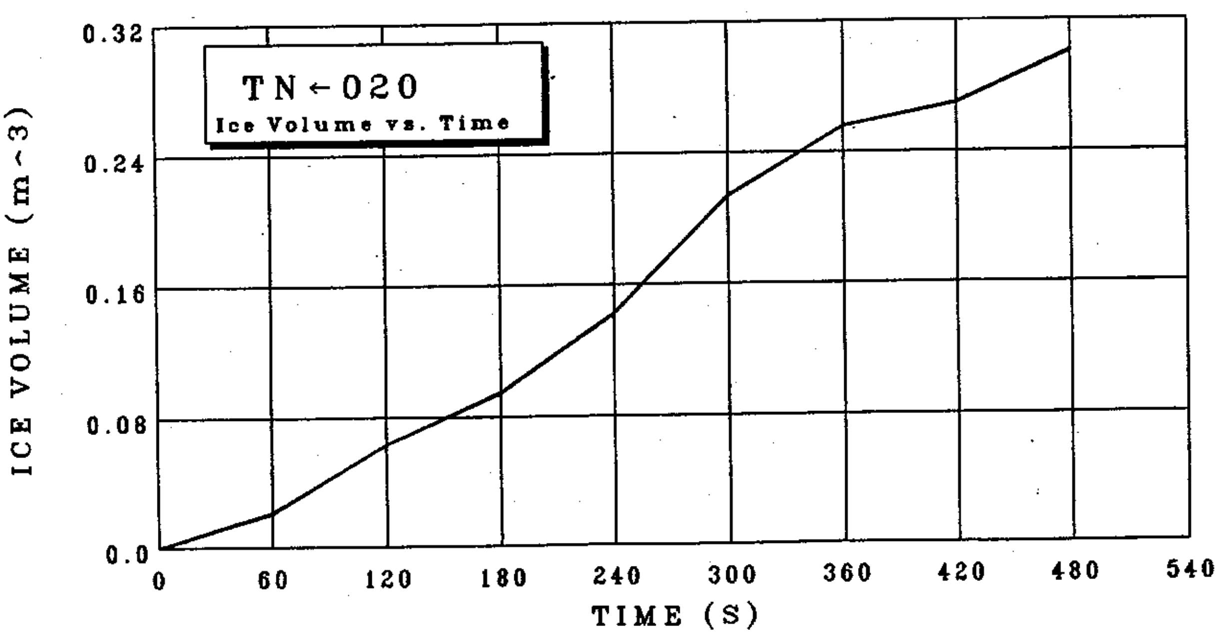
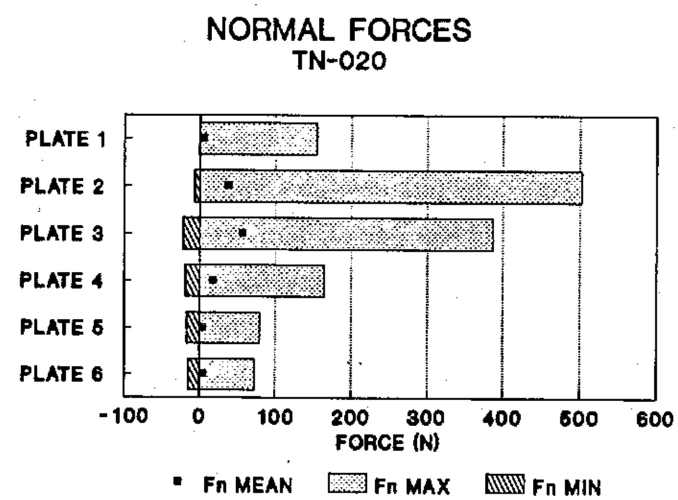
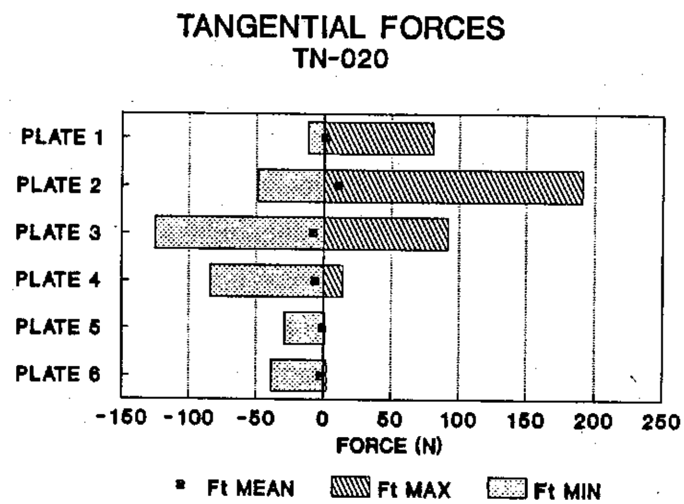
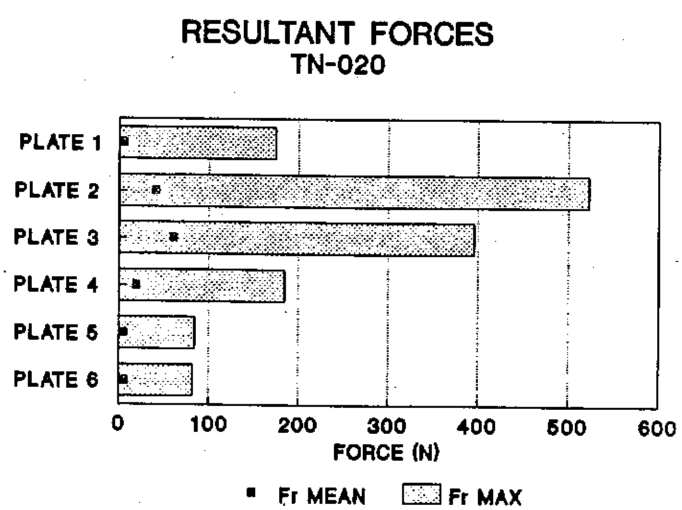
ICE PILEUP STUDY for CANADIAN COAST GUARD

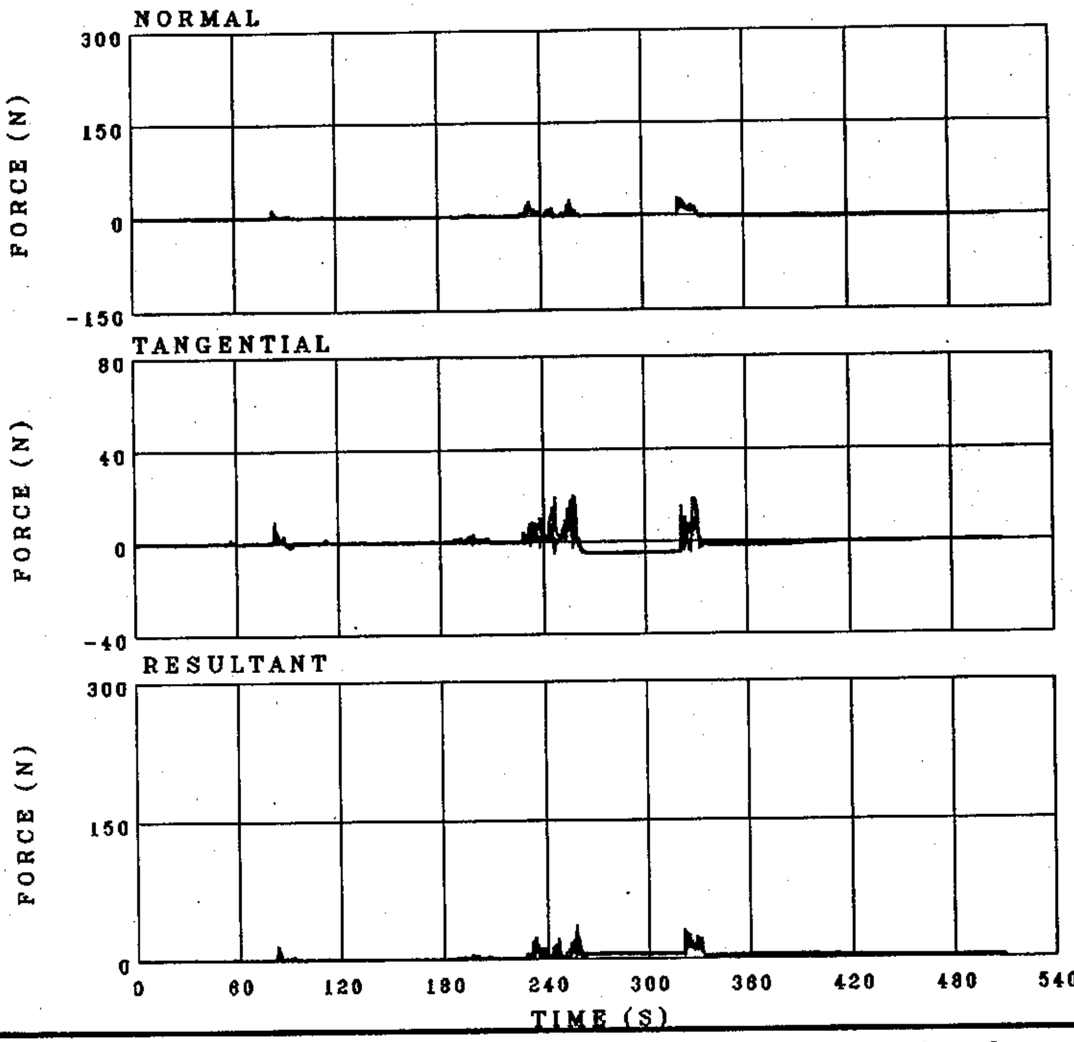

4,5,6,7,8
2
3
1
4
1,2
3
6
5
8
1
2
3
4
5,6,7,8
6
7
10 X 10 CM
TIME IN MINUTES


TN←020
Ice Volume vs. Time
ICE VOLUME (m^3)
0.32
0.24
0.16
0.08
0.0
0
60
120
180
240
300
360
420
480
540
TIME (S)


NORMAL FORCES
TN-020
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-100
0
100
200
300
400
500
600
FORCE (N)
Fn MEAN
Fn MAX
Fn MIN


TANGENTIAL FORCES
TN-020
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-150
-100
-50
0
50
100
150
200
250
FORCE (N)
Ft MEAN
Ft MAX
Ft MIN


RESULTANT FORCES
TN-020
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
0
100
200
300
400
500
600
FORCE (N)
Fr MEAN
Fr MAX



FILE TN←021

PLATE #1

NORMAL

MEAN FORCE = -0.1426 N
MAX FORCE = 24.28 N
MIN FORCE = -3.720 N

TANGENTIAL

MEAN FORCE = -0.4095 N
MAX FORCE = 16.86 N
MIN FORCE = -5.056 N

RESULTANT

MEAN FORCE = 2.409 N
MAX FORCE = 25.43 N
MIN FORCE = 0.08493 N
AVERAGE ANGLE = -26.03 O

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 24.00 kPa
ICE THICKNESS = 2.570 cm
ICE DENSITY = 0.9300 g/cc

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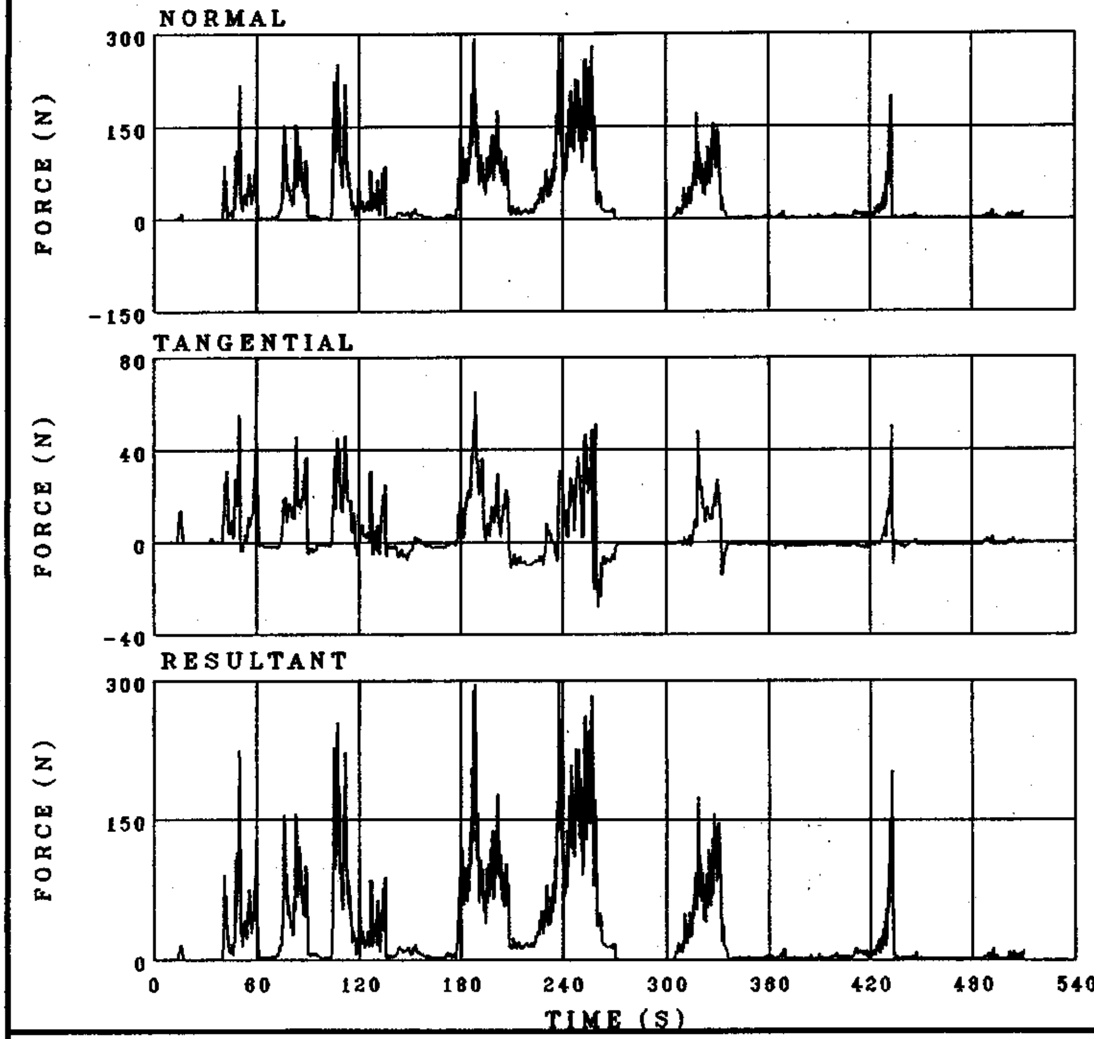
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←021

PLATE #2

NORMAL

MEAN FORCE = 28.11 N
MAX FORCE = 296.5 N
MIN FORCE = -1.328 N

TANGENTIAL

MEAN FORCE = 3.328 N
MAX FORCE = 64.98 N
MIN FORCE = -28.47 N

RESULTANT

MEAN FORCE = 29.25 N
MAX FORCE = 297.8 N
MIN FORCE = 0.04415 N
AVERAGE ANGLE = -13.04 D

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 24.00 kPa
ICE THICKNESS = 2.570 cm
ICE DENSITY = 0.9300 g/cc

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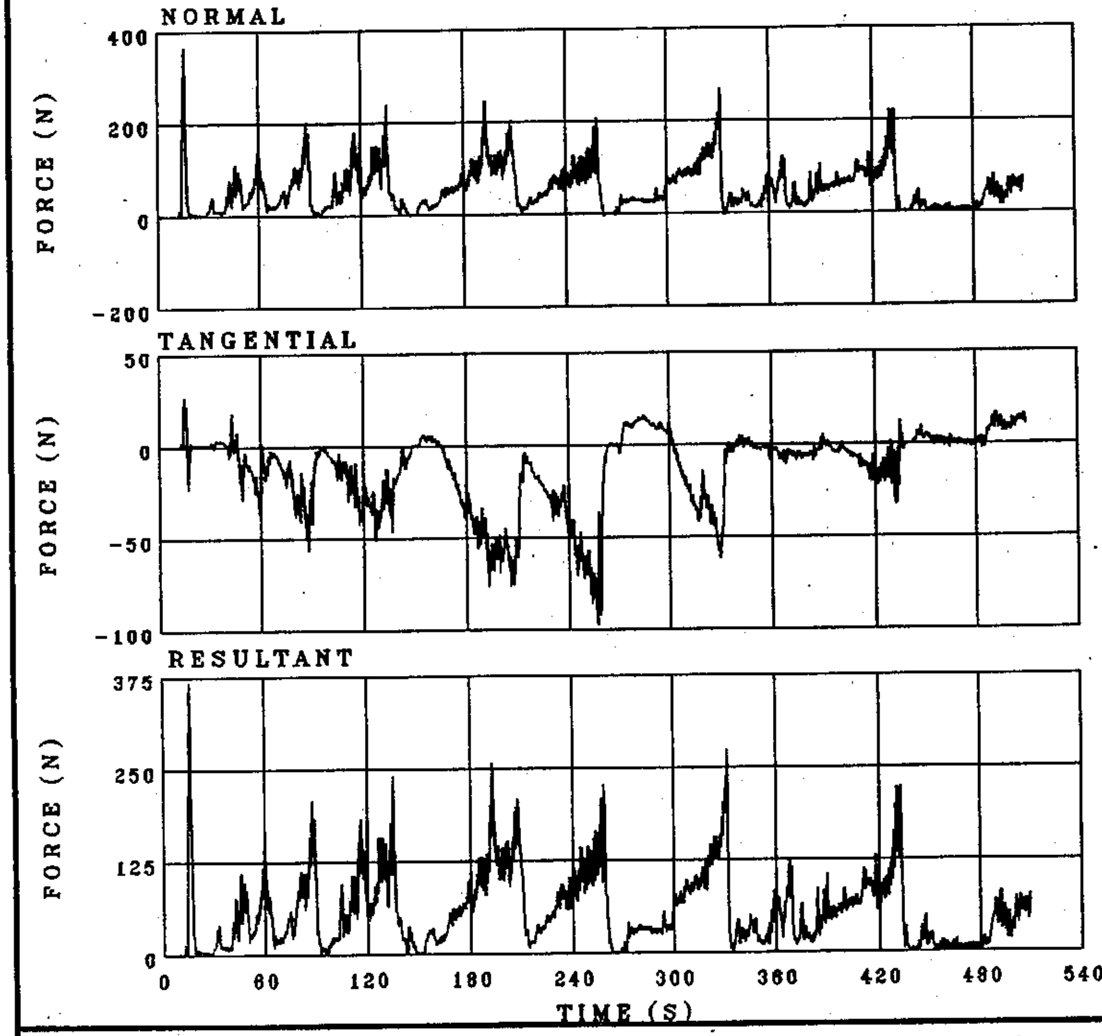
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←021

PLATE #3

NORMAL

MEAN FORCE = 52.77 N
MAX FORCE = 367.1 N
MIN FORCE = -5.659 N

TANGENTIAL

MEAN FORCE = -12.88 N
MAX FORCE = 26.89 N
MIN FORCE = -98.03 N

RESULTANT

MEAN FORCE = 56.05 N
MAX FORCE = 367.8 N
MIN FORCE = 0.03156 N
AVERAGE ANGLE = -7.675 D

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 24.00 kPa
ICE THICKNESS = 2.570 cm
ICE DENSITY = 0.9300 g/cc

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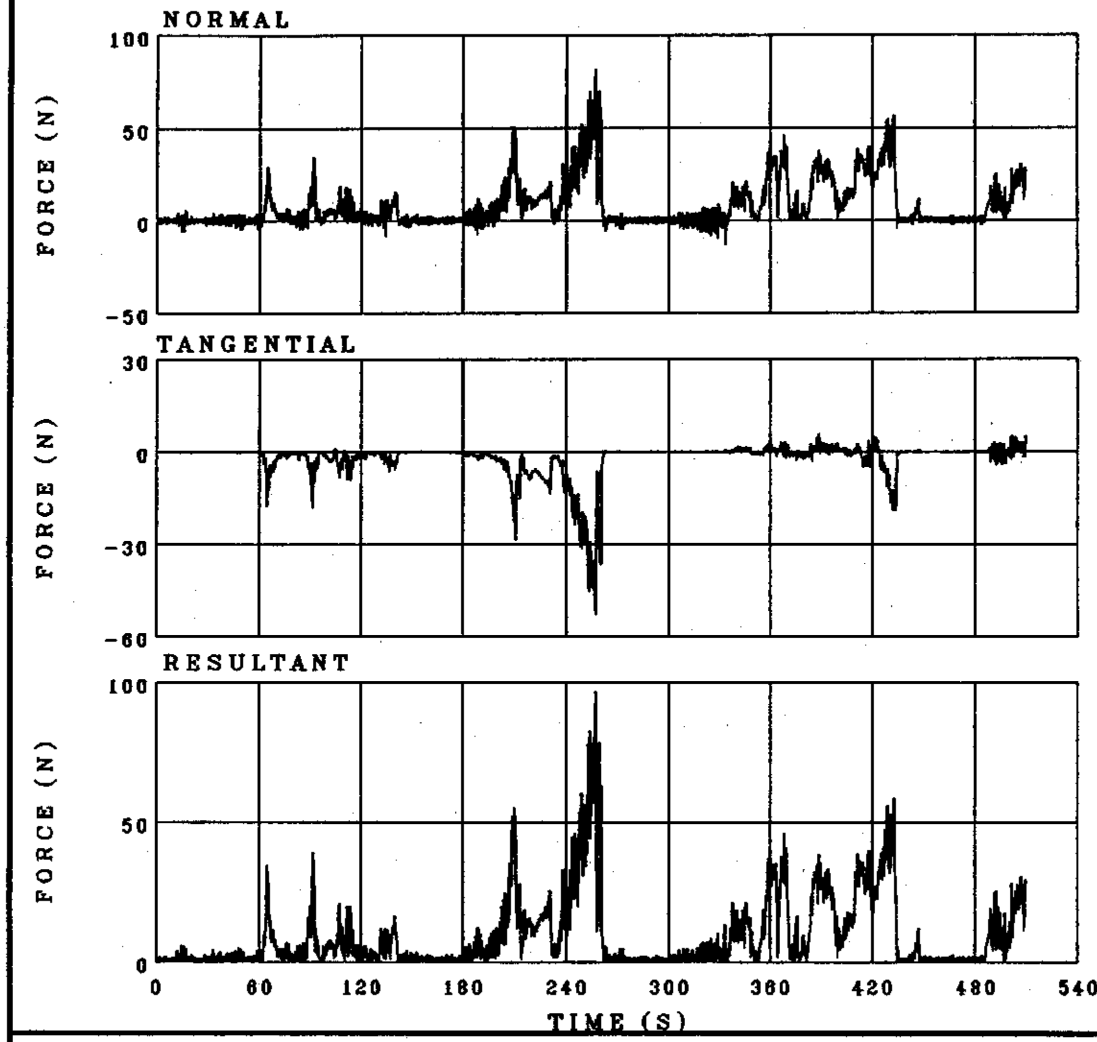
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←021

PLATE #4

NORMAL

MEAN FORCE = 8.137 N
MAX FORCE = 82.00 N
MIN FORCE = -13.41 N

TANGENTIAL

MEAN FORCE = -2.195 N
MAX FORCE = 5.751 N
MIN FORCE = -52.85 N

RESULTANT

MEAN FORCE = 9.381 N
MAX FORCE = 96.82 N
MIN FORCE = 0.05986 N
AVERAGE ANGLE = -9.438 O

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 24.00 kPa
ICE THICKNESS = 2.570 cm
ICE DENSITY = 0.9300 g/cc

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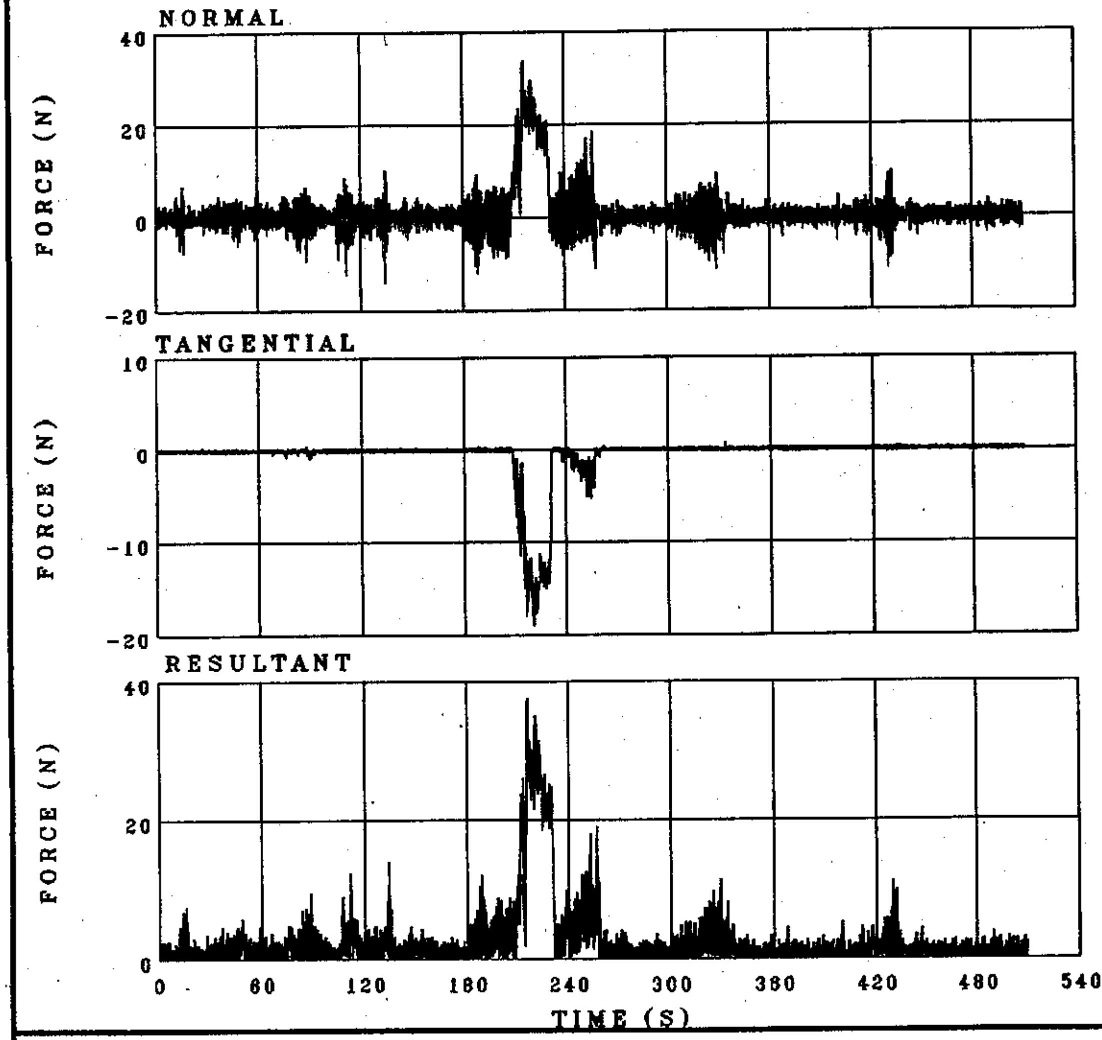
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←021

PLATE #5

NORMAL

MEAN FORCE = 0.8733 N
MAX FORCE = 33.96 N
MIN FORCE = −14.06 N

TANGENTIAL

MEAN FORCE = −0.5877 N
MAX FORCE = 0.6896 N
MIN FORCE = −19.08 N

RESULTANT

MEAN FORCE = 2.464 N
MAX FORCE = 37.63 N
MIN FORCE = 0.003339 N
AVERAGE ANGLE = 16.63 O

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 24.00 kPa
ICE THICKNESS = 2.570 cm
ICE DENSITY = 0.9300 g/cc

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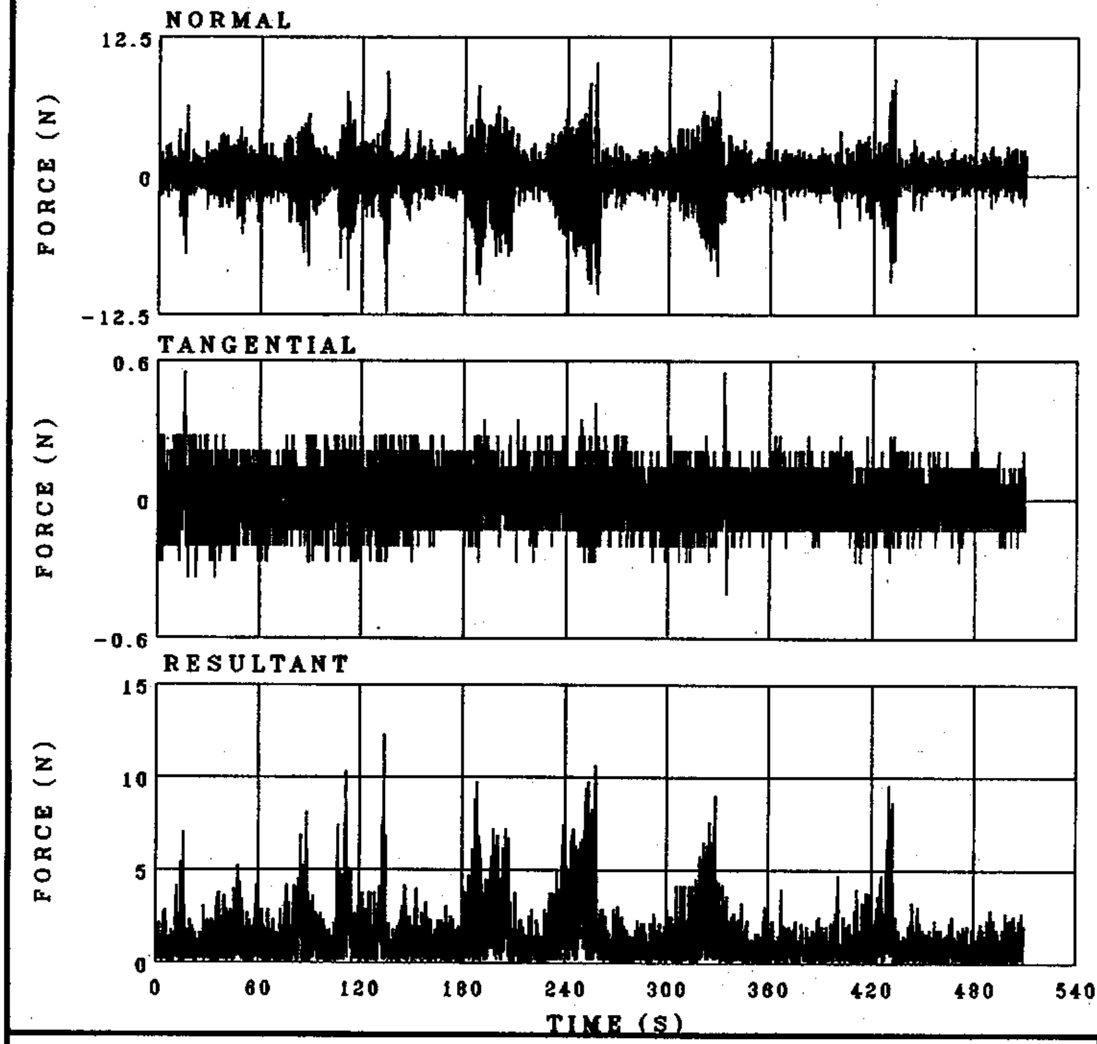
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←021

PLATE #6

NORMAL

MEAN FORCE = 0.05700 N
MAX FORCE = 10.11 N
MIN FORCE = -12.29 N

TANGENTIAL

MEAN FORCE = -0.01013 N
MAX FORCE = 0.5554 N
MIN FORCE = -0.4113 N

RESULTANT

MEAN FORCE = 1.259 N
MAX FORCE = 12.29 N
MIN FORCE = 0.003112 N
AVERAGE ANGLE = 6.114 O

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 24.00 kPa
ICE THICKNESS = 2.570 cm
ICE DENSITY = 0.9300 g/cc

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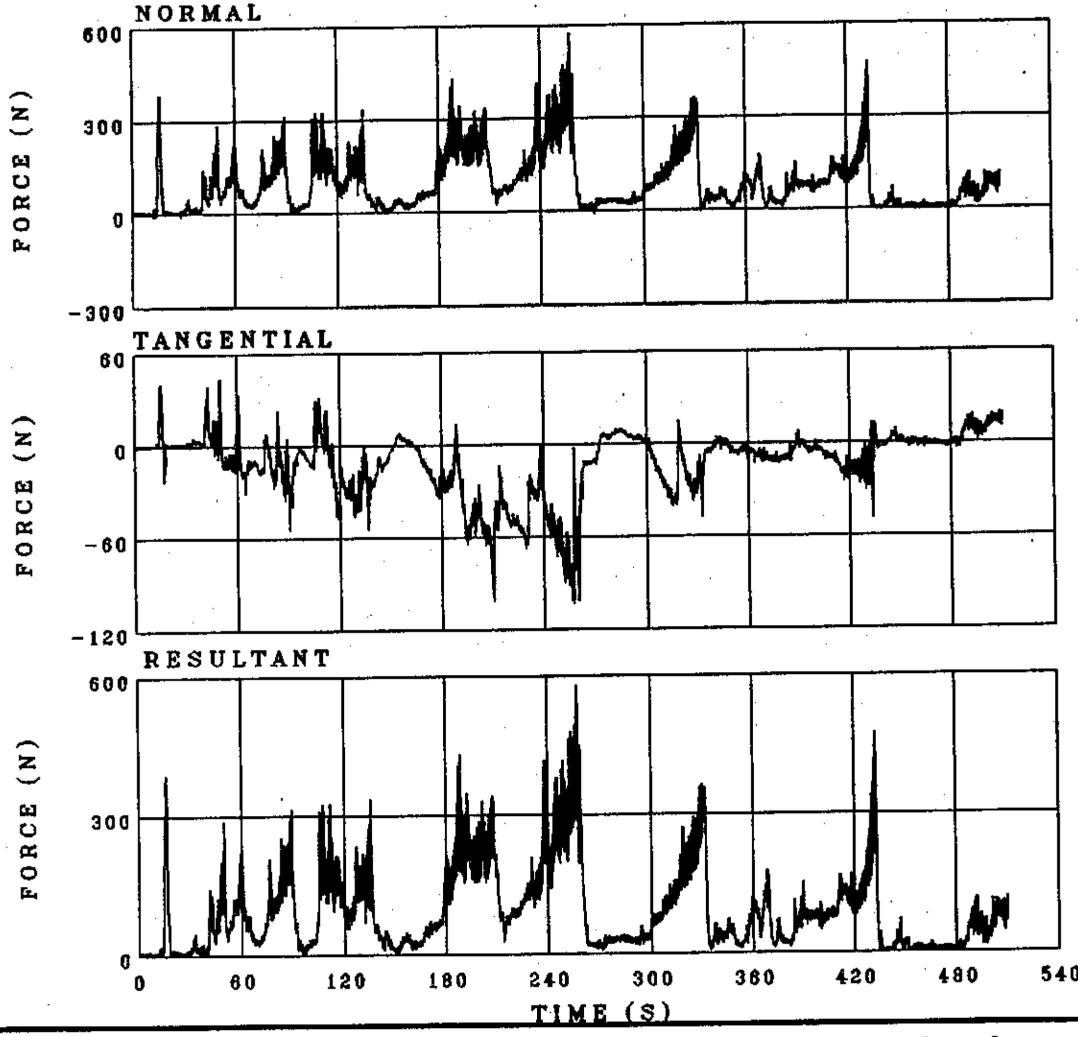
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←021

TOTAL

NORMAL

MEAN FORCE = 89.81 N
MAX FORCE = 574.8 N
MIN FORCE = -12.63 N

TANGENTIAL

MEAN FORCE = -12.76 N
MAX FORCE = 43.69 N
MIN FORCE = -103.7 N

RESULTANT

MEAN FORCE = 92.43 N
MAX FORCE = 581.5 N
MIN FORCE = 0.1699 N
AVERAGE ANGLE = -8.868 O

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 24.00 kPa
ICE THICKNESS = 2.570 cm
ICE DENSITY = 0.9300 g/cc

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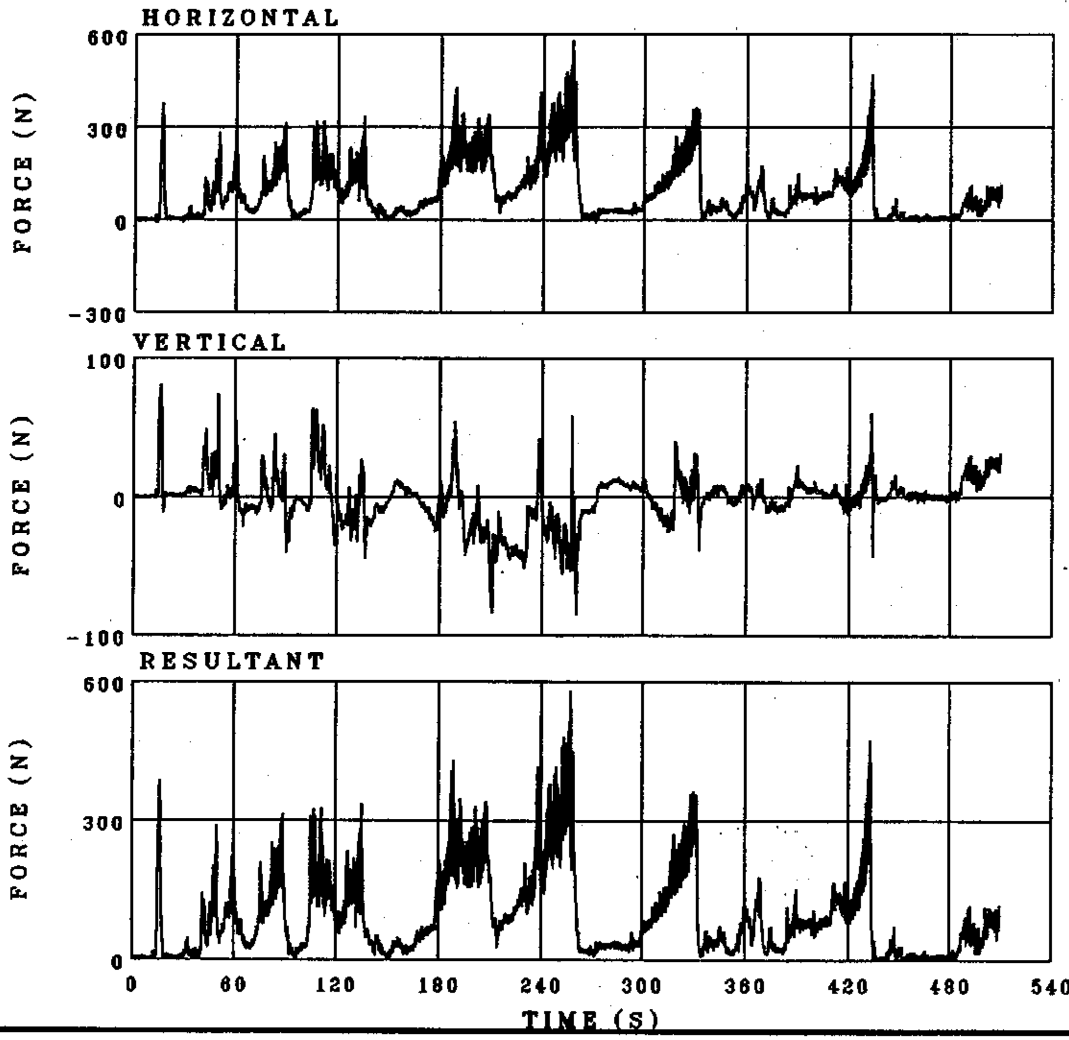
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←021

TOTAL

HORIZONTAL

MEAN FORCE = -12.76 N
MAX FORCE = 43.69 N
MIN FORCE = -103.7 N

VERTICAL

MEAN FORCE = -12.76 N
MAX FORCE = 43.69 N
MIN FORCE = -103.7 N

RESULTANT

MEAN FORCE = -12.76 N
MAX FORCE = 43.69 N
MIN FORCE = -103.7 N
AVERAGE ANGLE = -12.76 O

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 24.00 kPa
ICE THICKNESS = 2.570 cm
ICE DENSITY = 0.9300 g/cc

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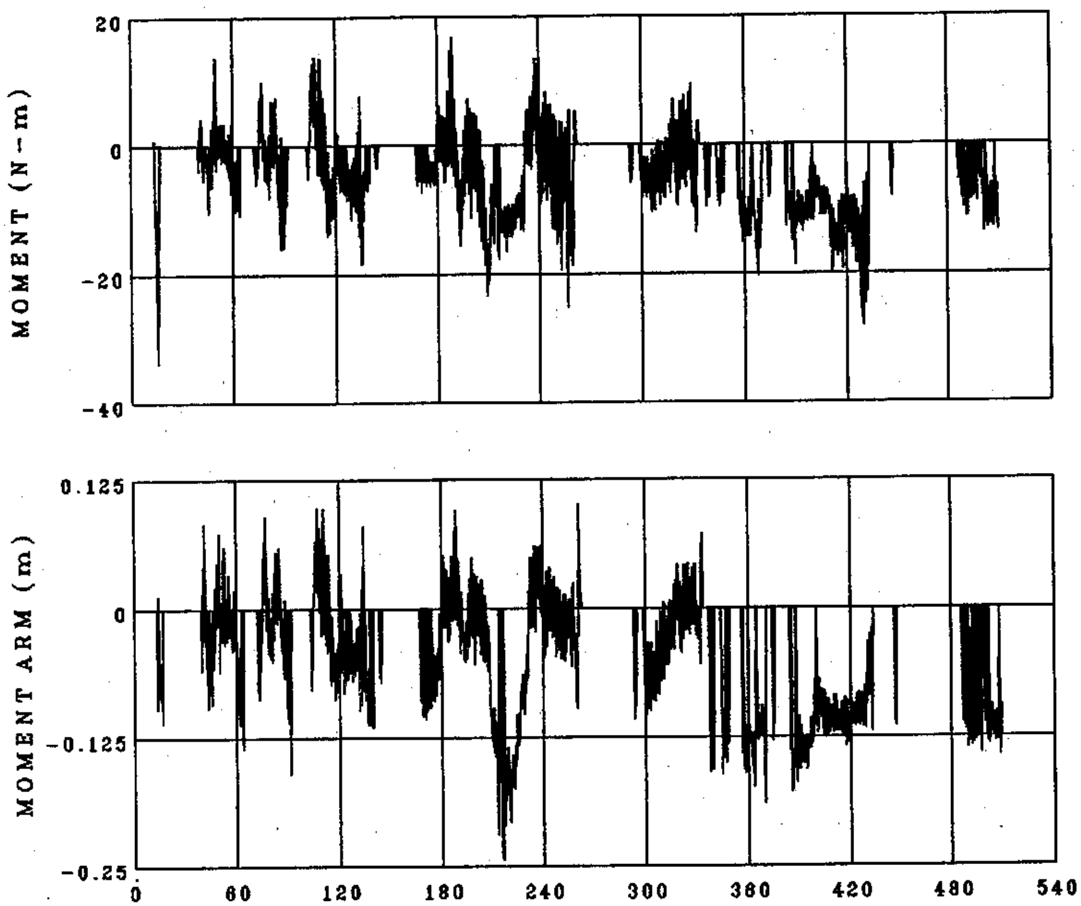
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←021

MOMENT

MOMENT

MEAN MOMENT = -3.380 N-m
MAX MOMENT = 16.88 N-m
MIN MOMENT = -33.95 N-m

MOMENT ARM

MEAN ARM = -0.03240 m
MAX ARM = 0.1012 m
MIN ARM = -0.2448 m

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 24.00 kPa
ICE THICKNESS = 2.570 cm
ICE DENSITY = 0.9300 g/cc

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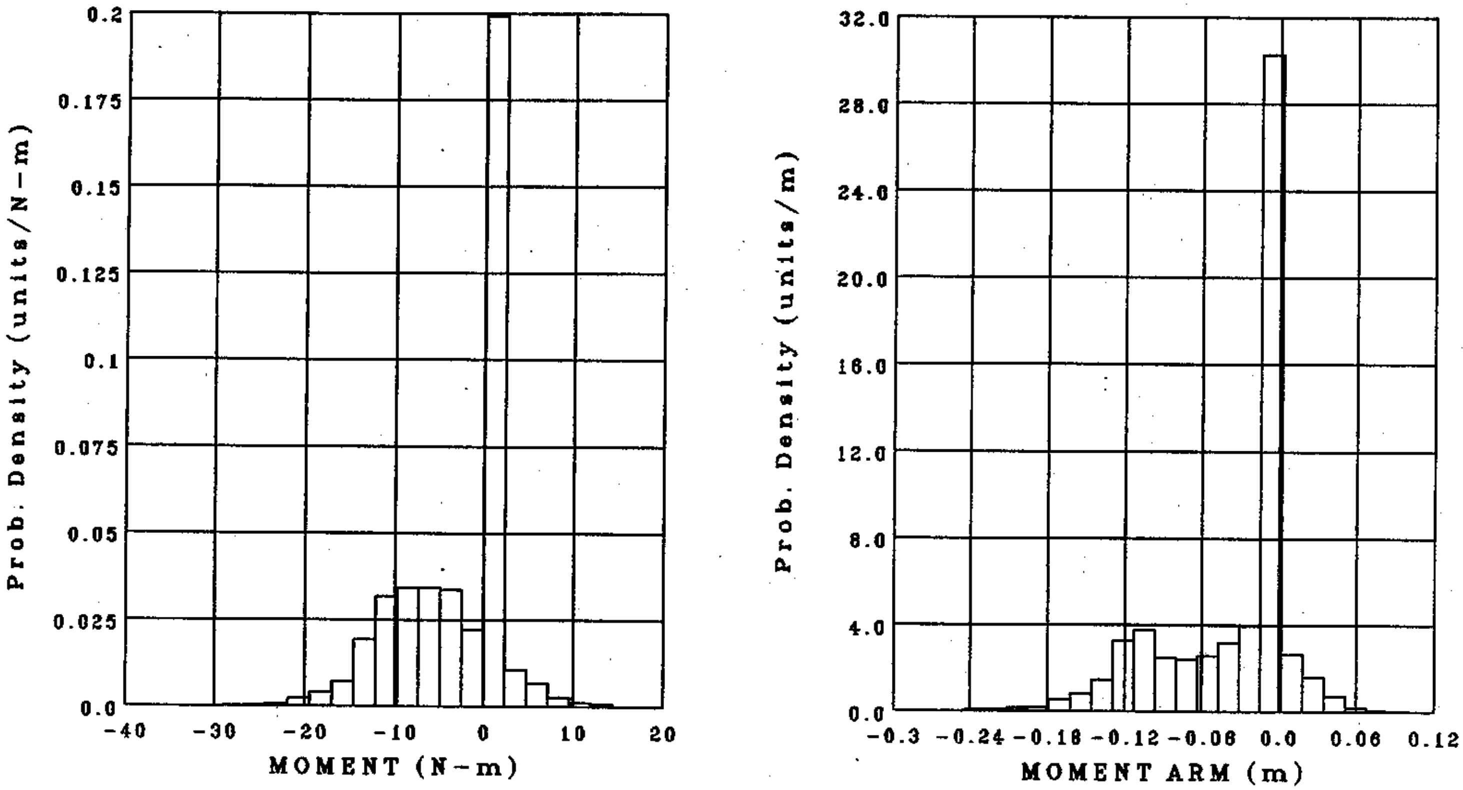
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←021



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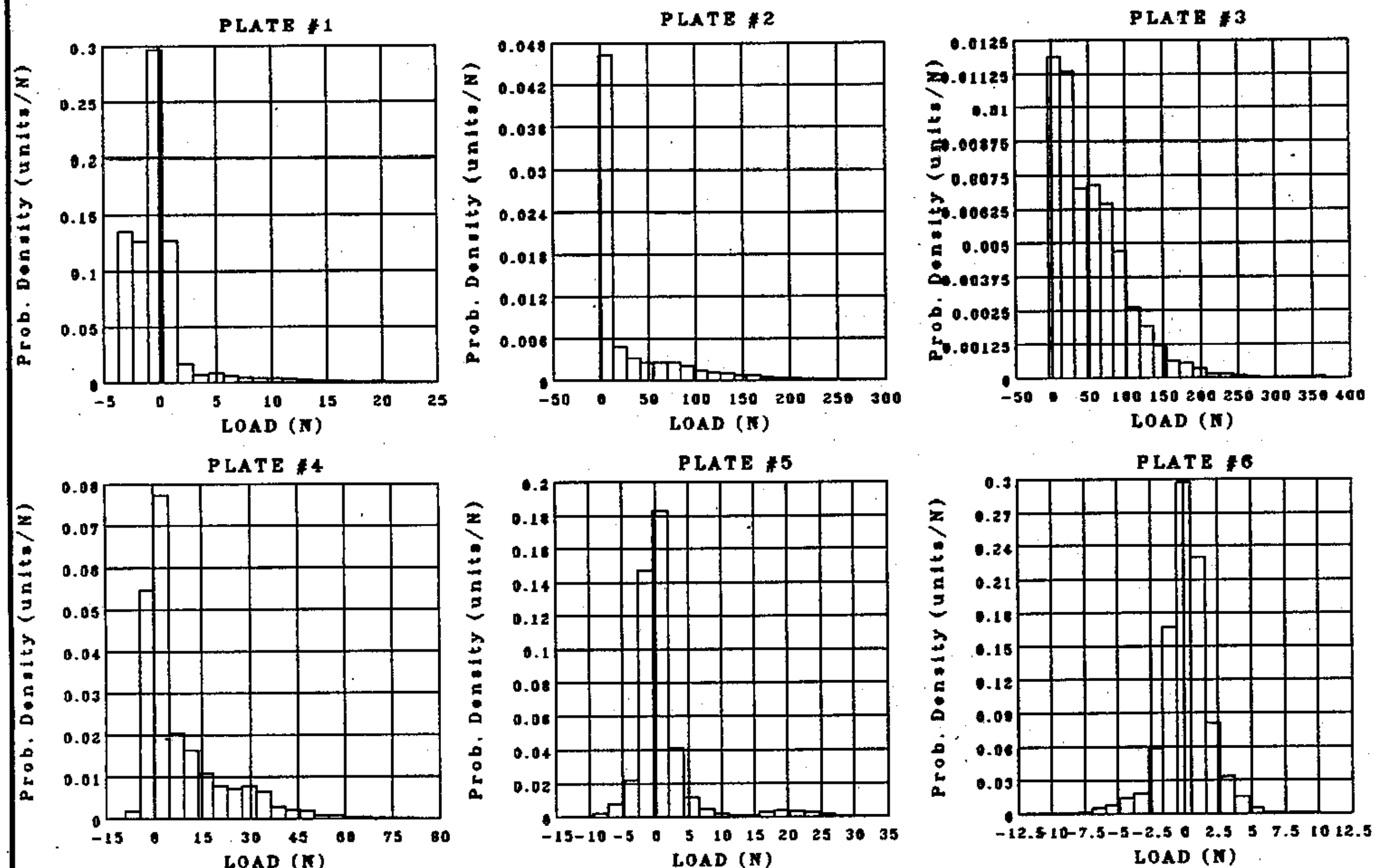
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←021
NORMAL LOAD



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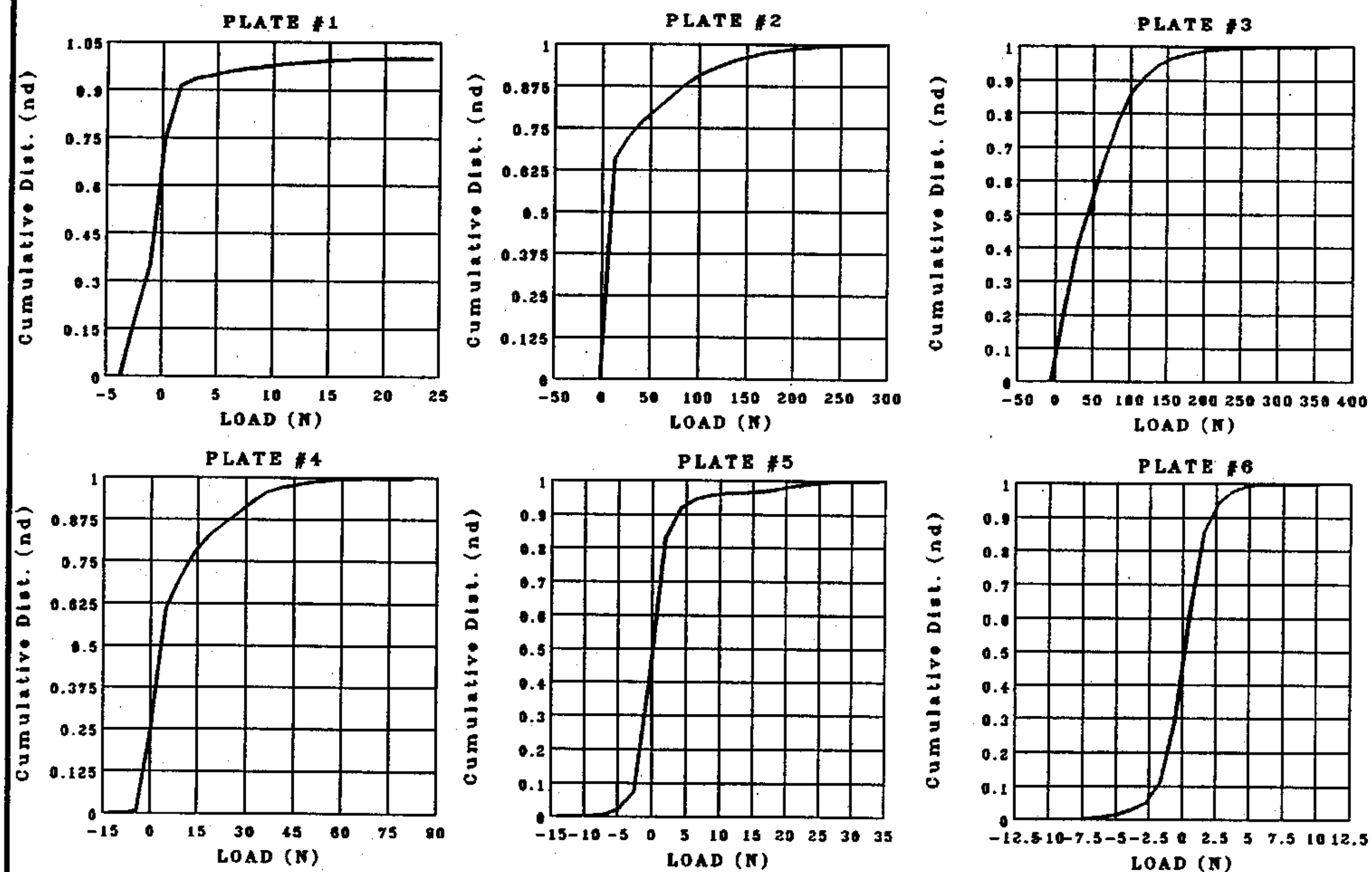
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←021
NORMAL LOAD



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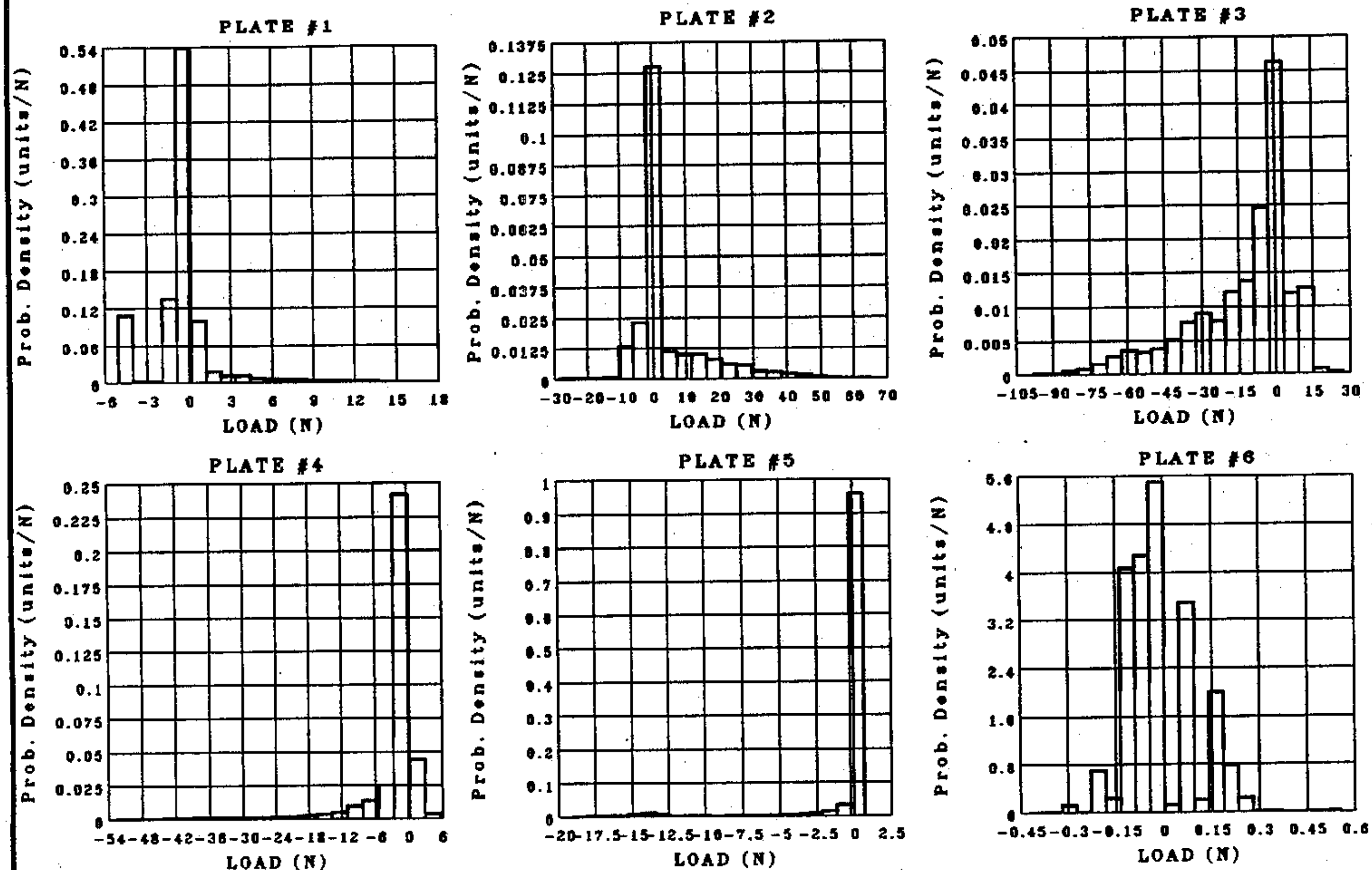
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←021

TANGENTIAL LOAD



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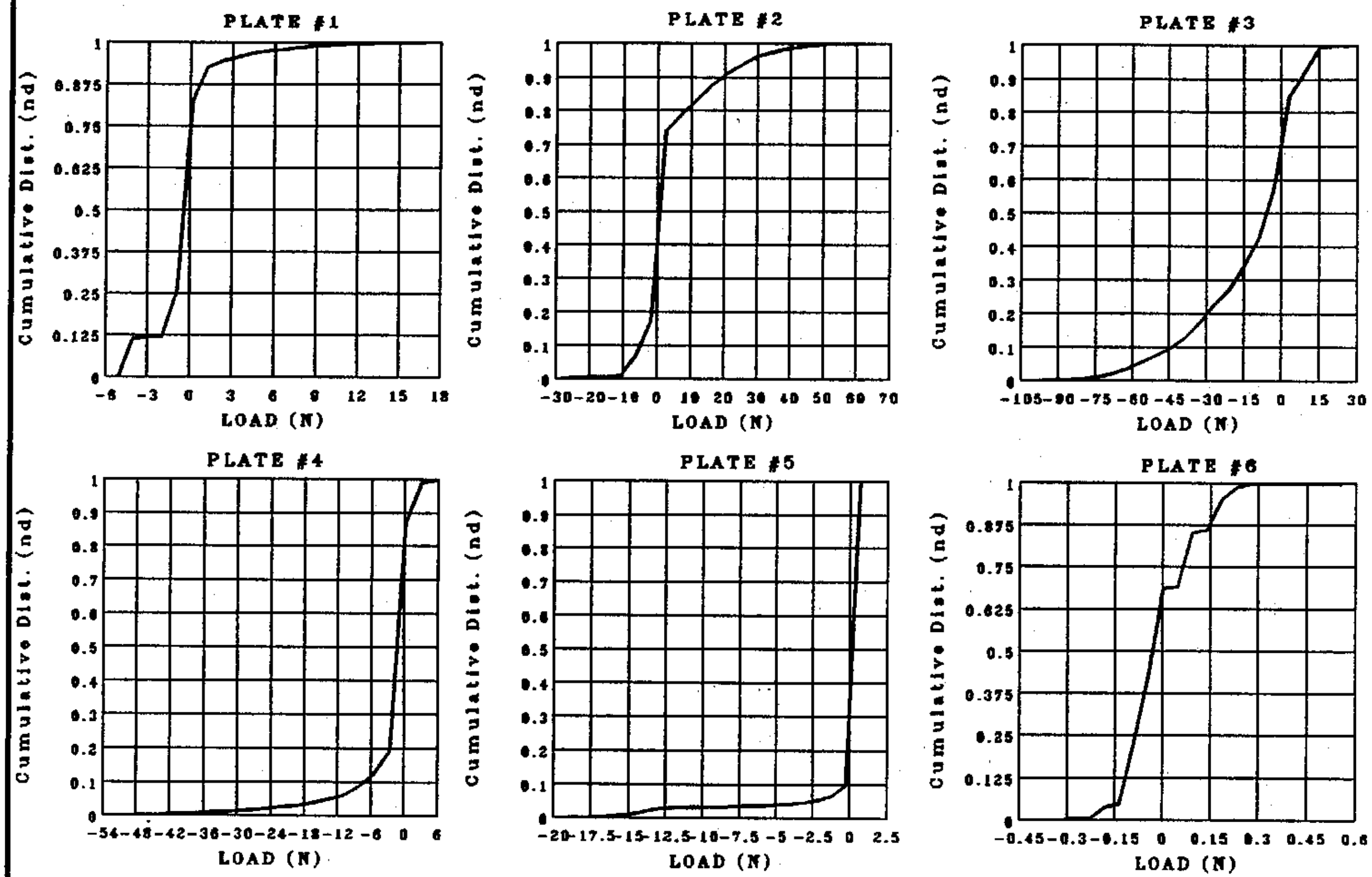
TN←021
TANGENTIAL LOAD



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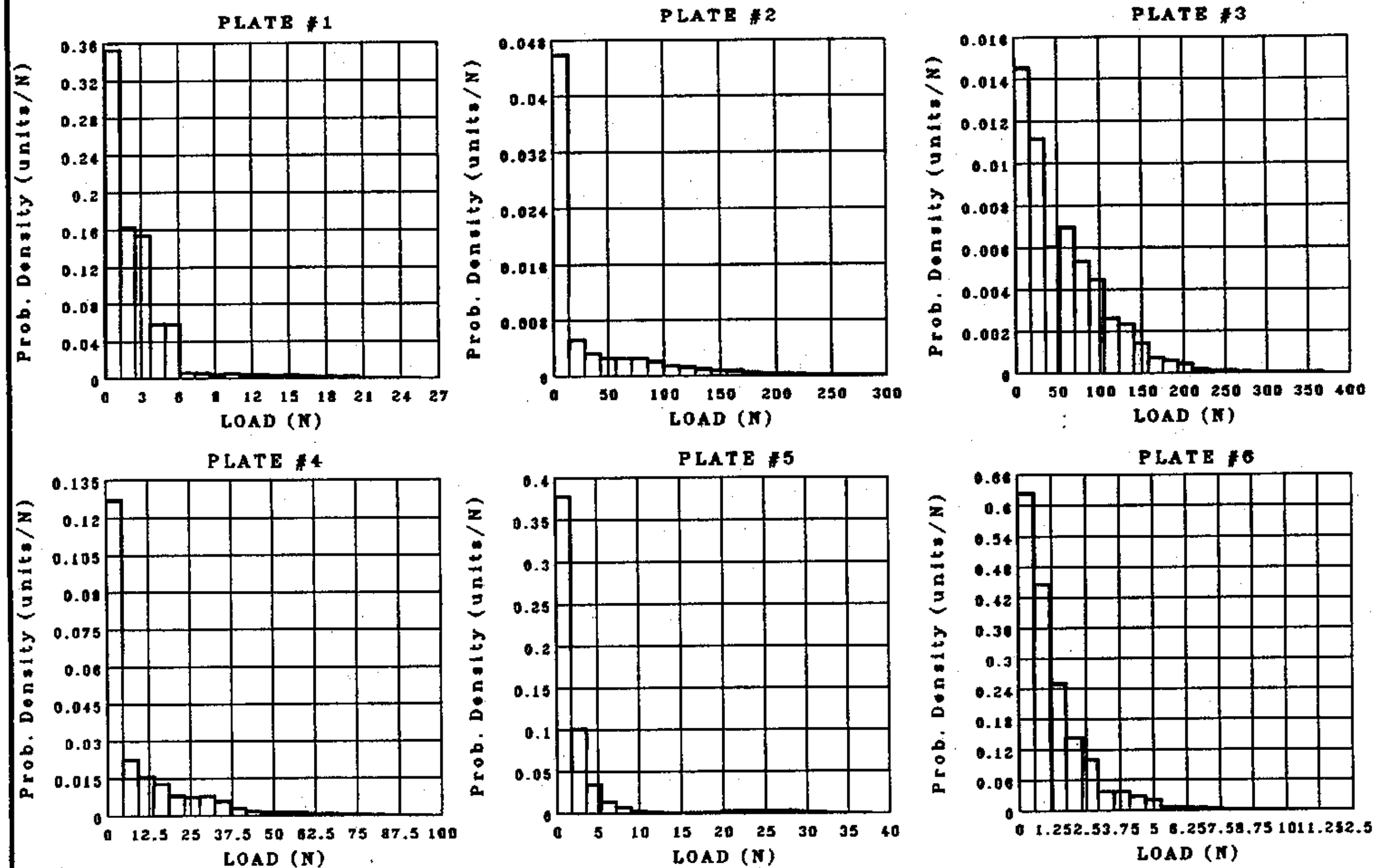
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←021
RESULTANT



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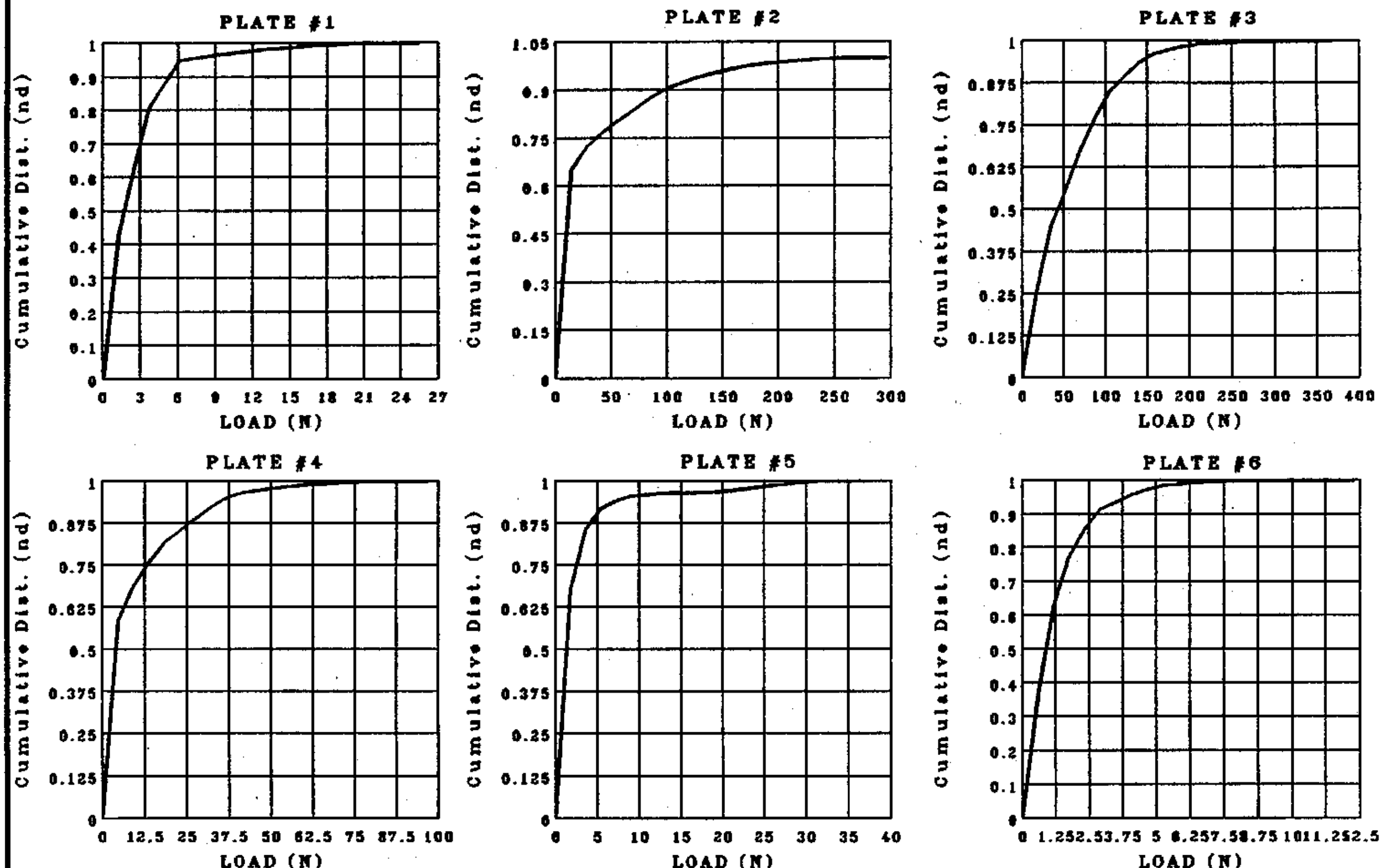
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←021
RESULTANT



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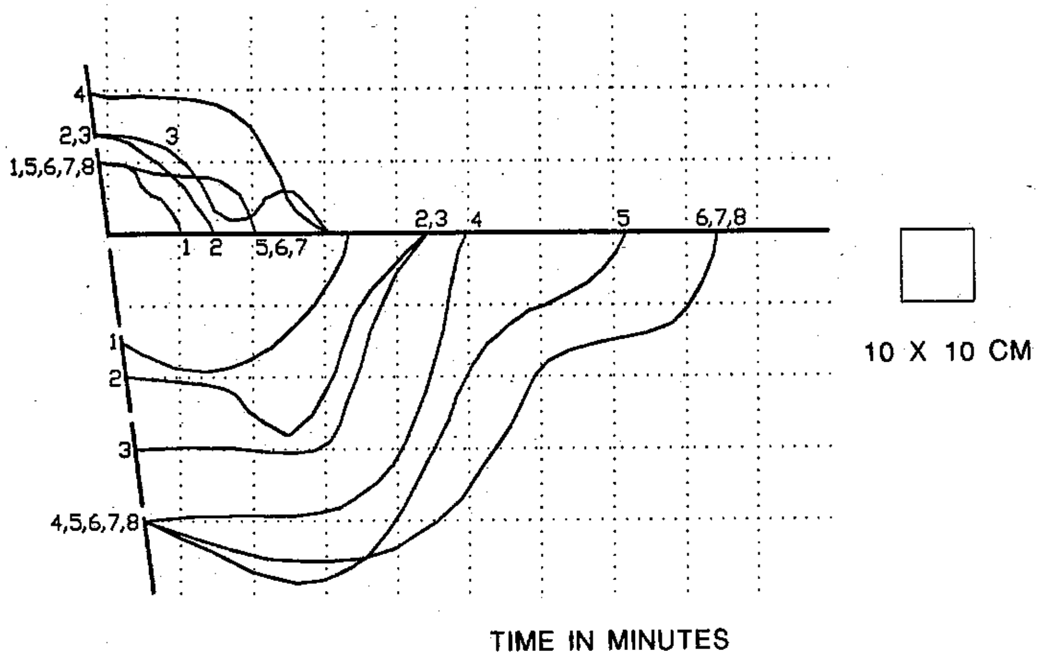
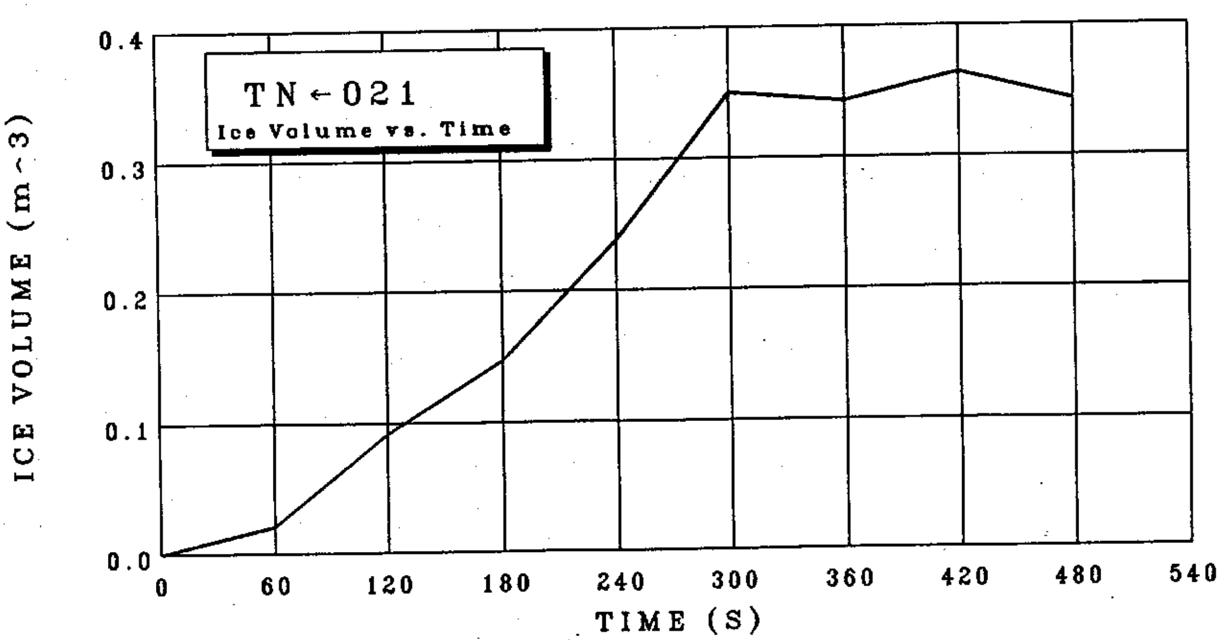
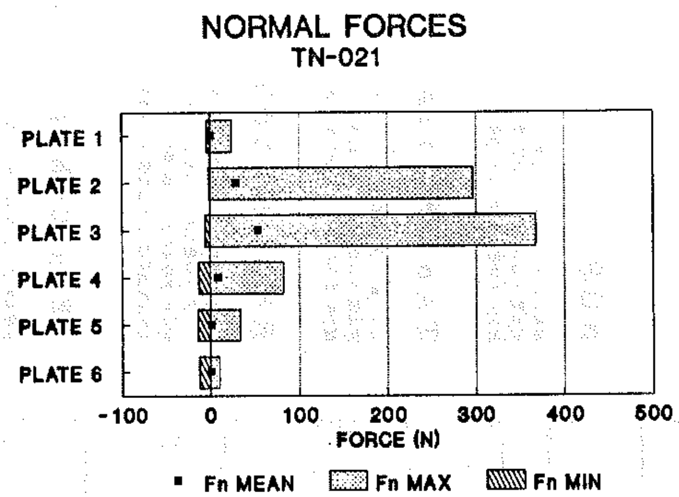
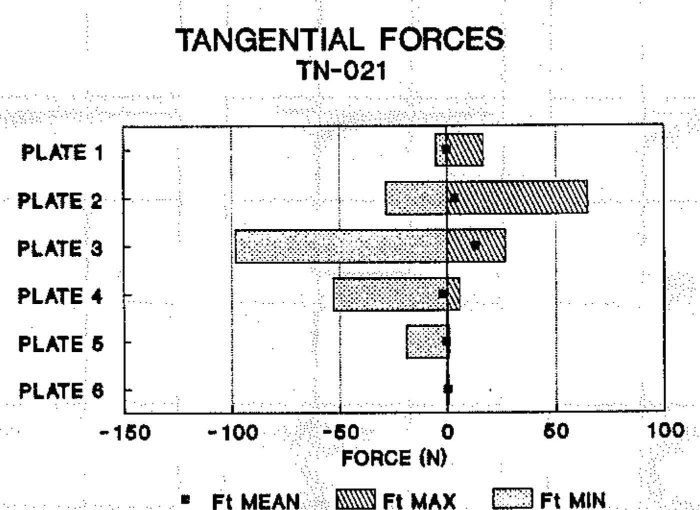
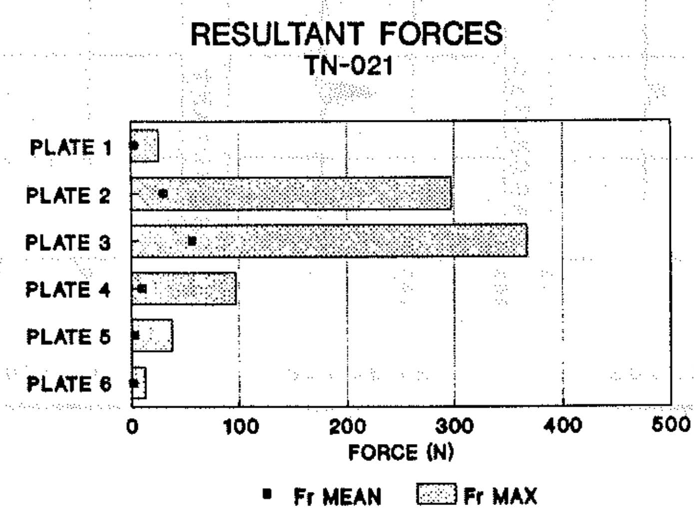
ICE PILEUP STUDY
for CANADIAN COAST GUARD

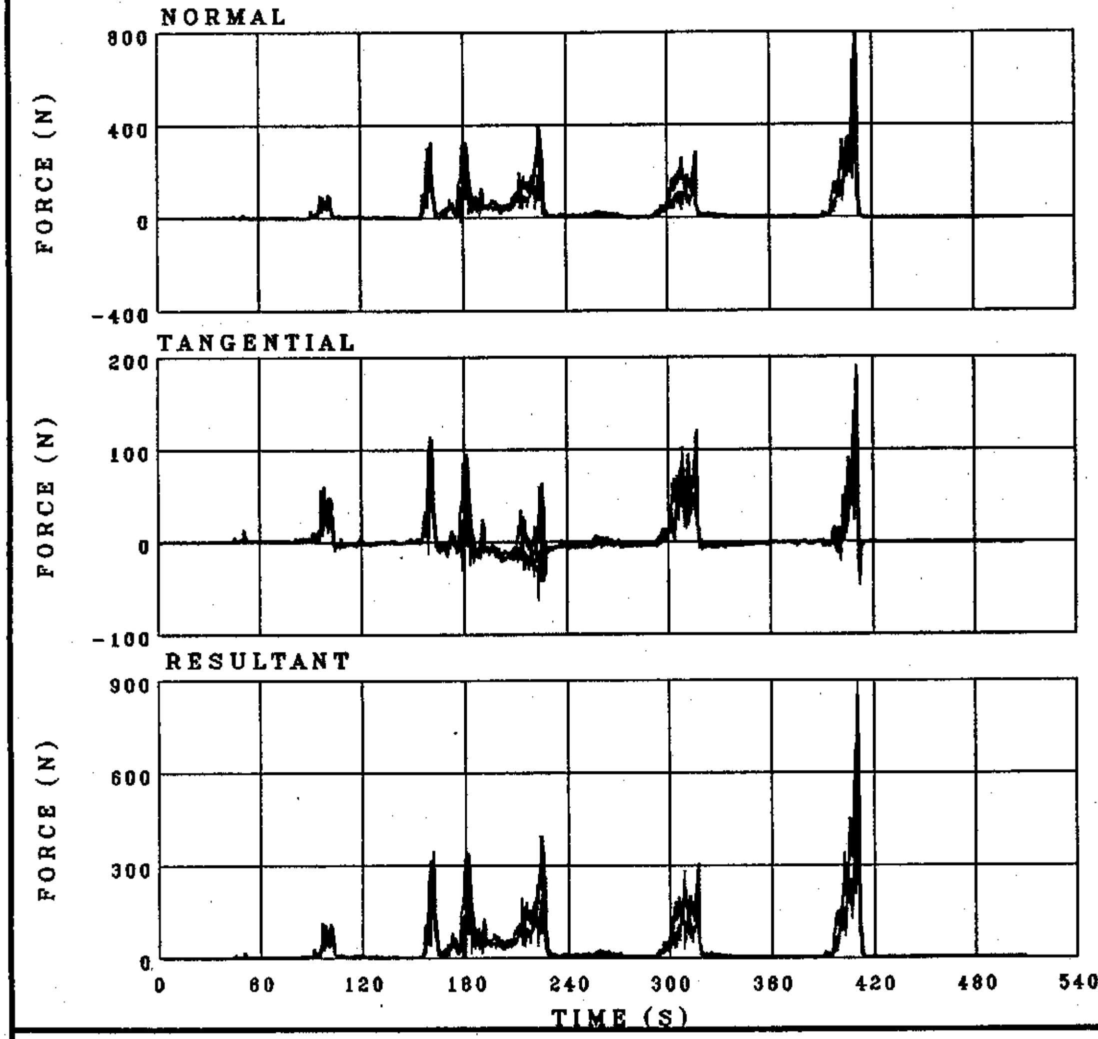

4
2,3
3
1,5,6,7,8
1
2
5,6,7
2,3
4
5
6,7,8
1
2
3
4,5,6,7,8
10 X 10 CM
TIME IN MINUTES


TN←021
Ice Volume vs. Time
ICE VOLUME (m^3)
0.0
0.1
0.2
0.3
0.4
0
60
120
180
240
300
360
420
480
540
TIME (S)


NORMAL FORCES
TN-021
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-100
0
100
200
300
400
500
FORCE (N)
Fn MEAN
Fn MAX
Fn MIN


TANGENTIAL FORCES
TN-021
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-150
-100
-50
0
50
100
FORCE (N)
Ft MEAN
Ft MAX
Ft MIN


RESULTANT FORCES
TN-021
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
0
100
200
300
400
500
FORCE (N)
Fr MEAN
Fr MAX



FILE TN←022

PLATE #1

NORMAL

MEAN FORCE = 26.06 N
MAX FORCE = 783.8 N
MIN FORCE = -4.064 N

TANGENTIAL

MEAN FORCE = 2.739 N
MAX FORCE = 171.4 N
MIN FORCE = -37.67 N

RESULTANT

MEAN FORCE = 29.27 N
MAX FORCE = 802.0 N
MIN FORCE = 0.06090 N
AVERAGE ANGLE = -35.75 O

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 21.00 kPa
ICE THICKNESS = 3.790 cm
ICE DENSITY = 0.7900 g/cc

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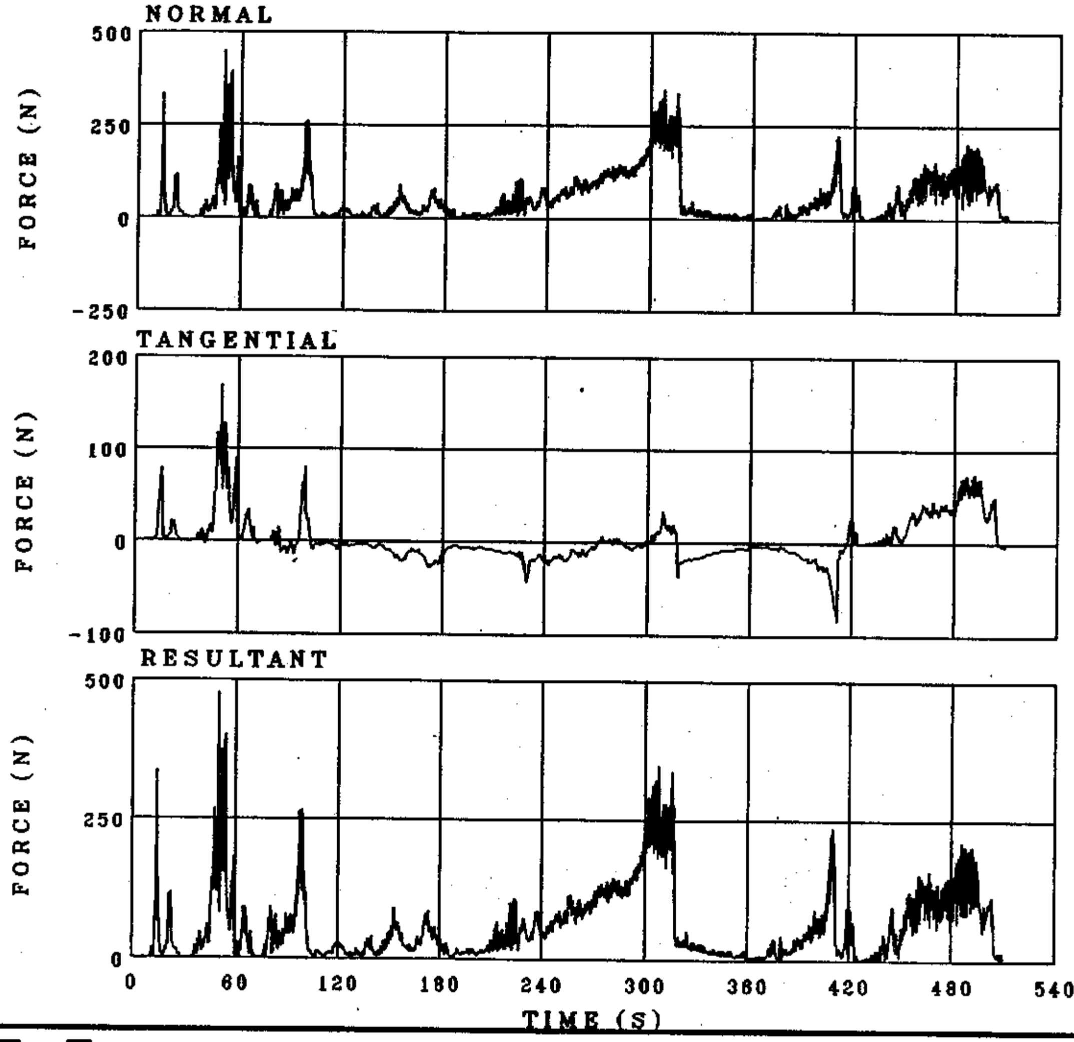
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←022

PLATE #2

NORMAL

MEAN FORCE = 53.51 N
MAX FORCE = 447.6 N
MIN FORCE = -2.064 N

TANGENTIAL

MEAN FORCE = 1.556 N
MAX FORCE = 169.7 N
MIN FORCE = -83.76 N

RESULTANT

MEAN FORCE = 57.00 N
MAX FORCE = 477.4 N
MIN FORCE = 0.01868 N
AVERAGE ANGLE = -11.09 O

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 21.00 kPa
ICE THICKNESS = 3.790 cm
ICE DENSITY = 0.7900 g/cc

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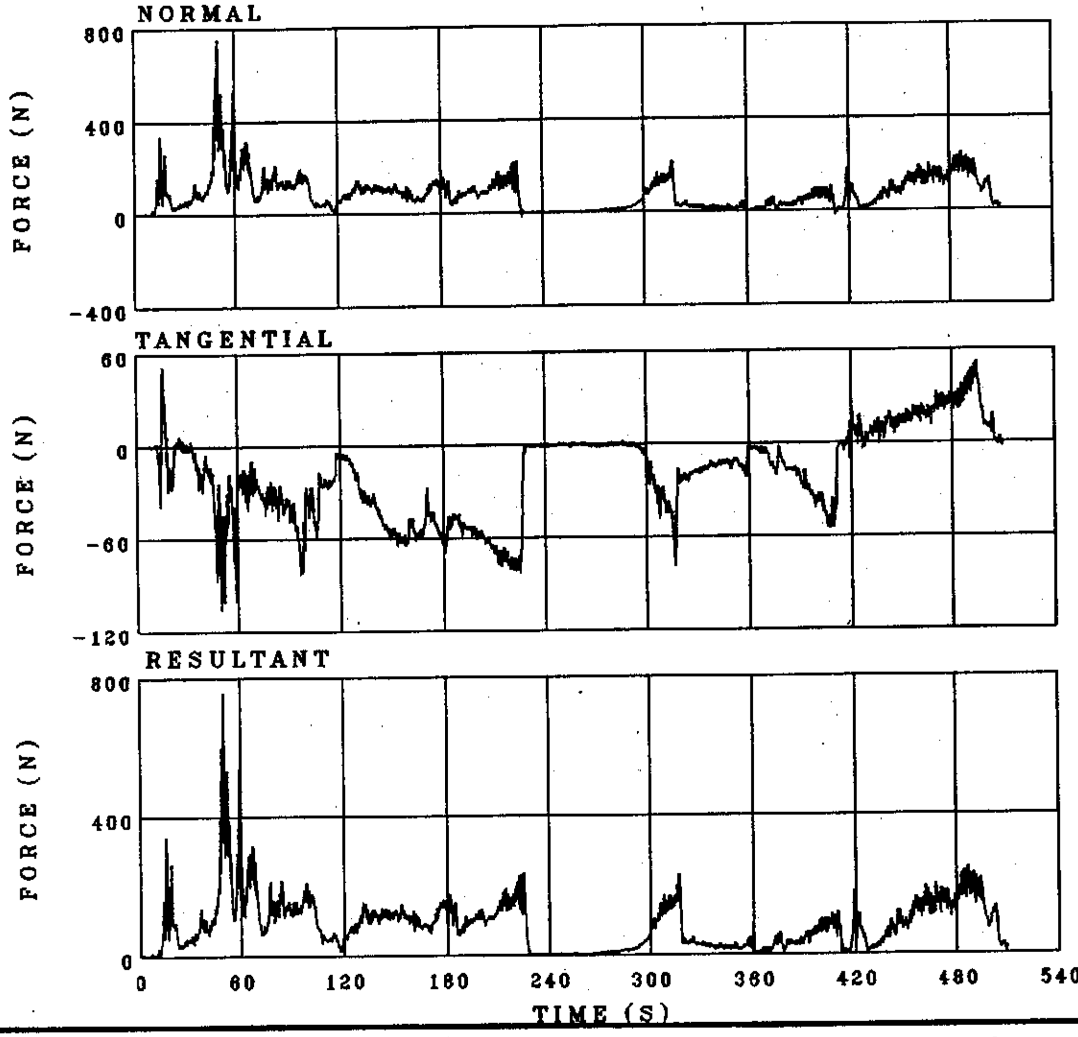
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←022

PLATE #3

NORMAL

MEAN FORCE = 77.99 N
MAX FORCE = 751.5 N
MIN FORCE = -23.99 N

TANGENTIAL

MEAN FORCE = -18.44 N
MAX FORCE = 52.52 N
MIN FORCE = -106.5 N

RESULTANT

MEAN FORCE = 83.69 N
MAX FORCE = 758.6 N
MIN FORCE = 0.1151 N
AVERAGE ANGLE = -14.03 D

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 21.00 kPa
ICE THICKNESS = 3.790 cm
ICE DENSITY = 0.7900 g/cc

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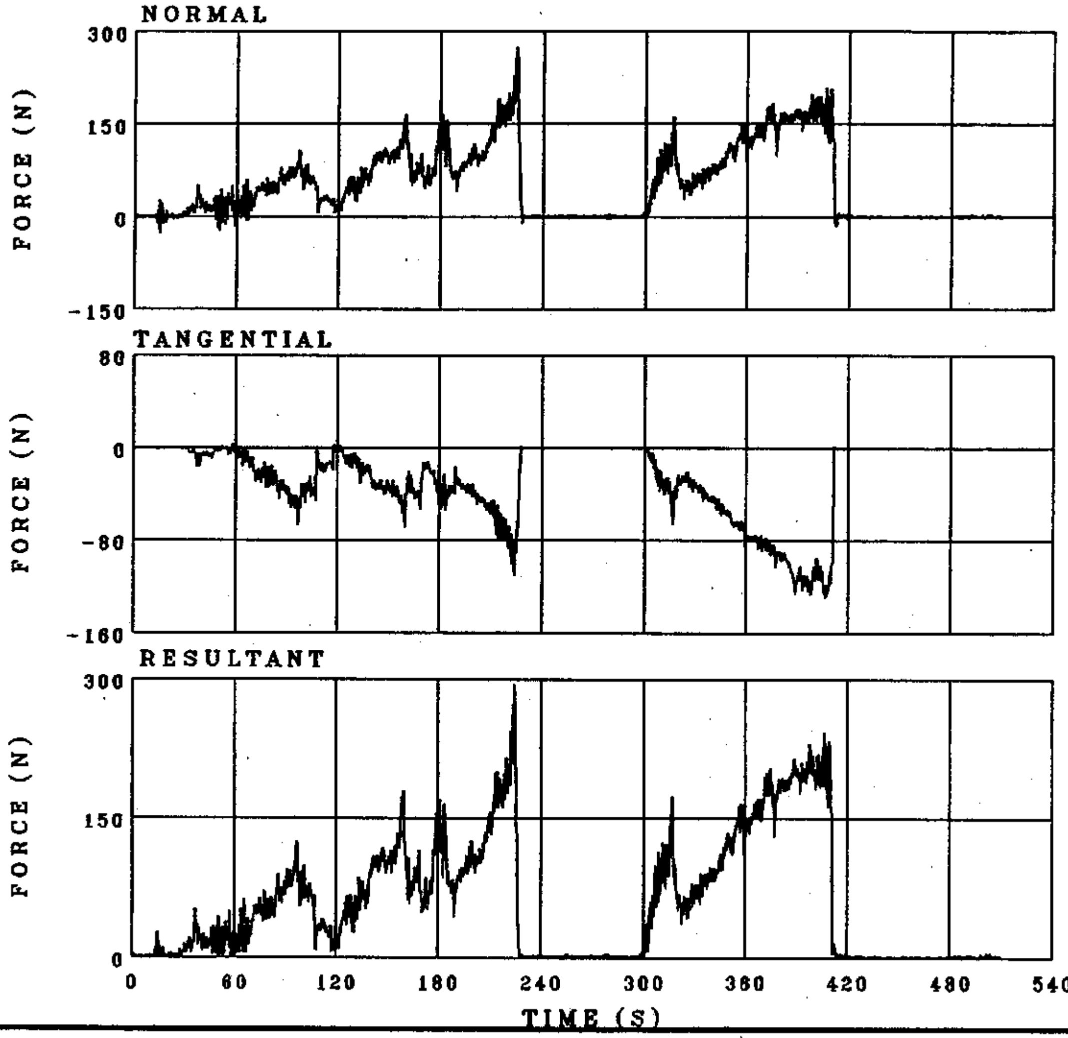
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←022

PLATE #4

NORMAL

MEAN FORCE = 51.59 N
MAX FORCE = 274.7 N
MIN FORCE = -27.86 N

TANGENTIAL

MEAN FORCE = -25.58 N
MAX FORCE = 3.223 N
MIN FORCE = -129.3 N

RESULTANT

MEAN FORCE = 58.55 N
MAX FORCE = 294.3 N
MIN FORCE = 0.06712 N
AVERAGE ANGLE = -16.73 O

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 21.00 kPa
ICE THICKNESS = 3.790 cm
ICE DENSITY = 0.7900 g/cc

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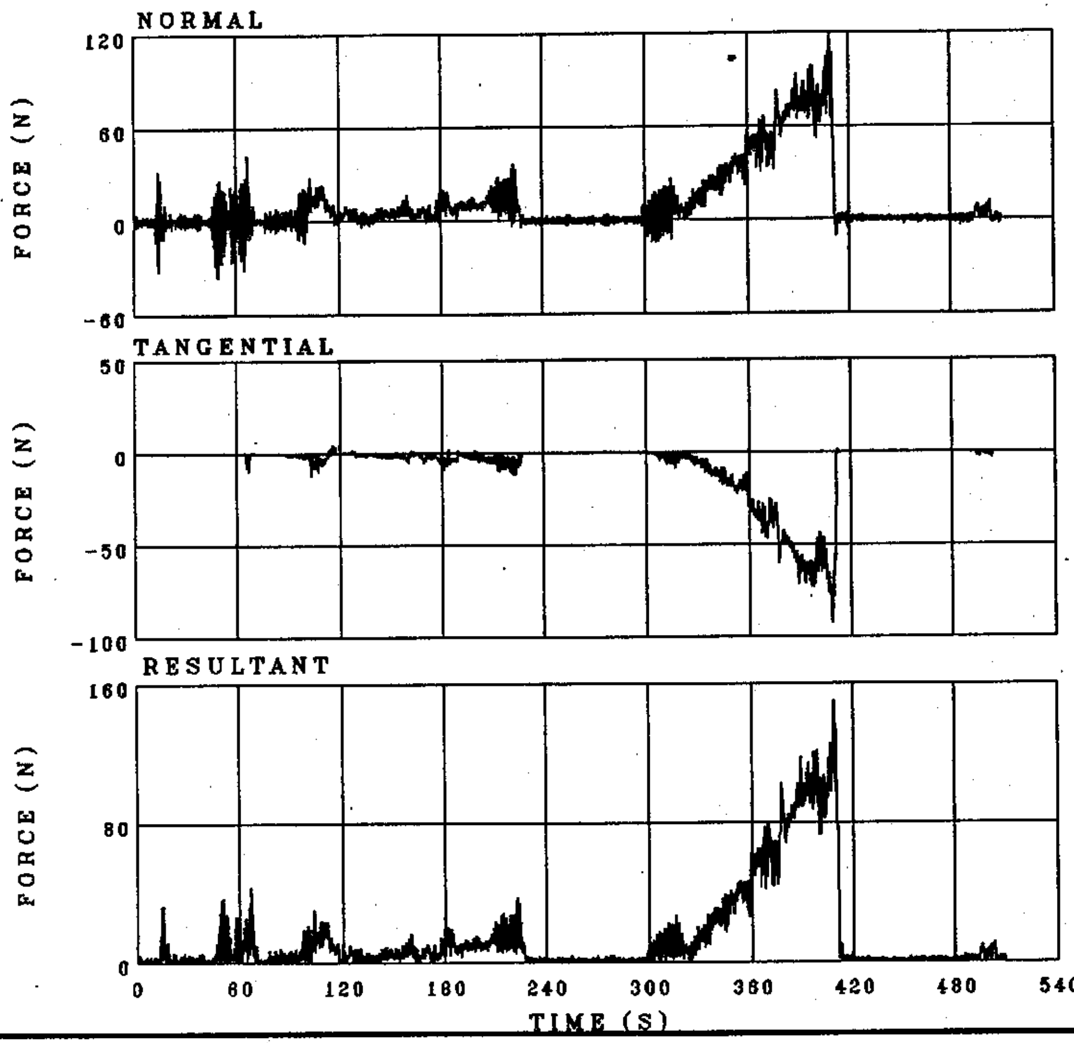
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←022

PLATE #5

NORMAL

MEAN FORCE = 10.75 N
MAX FORCE = 119.5 N
MIN FORCE = -36.86 N

TANGENTIAL

MEAN FORCE = -6.787 N
MAX FORCE = 4.499 N
MIN FORCE = -92.76 N

RESULTANT

MEAN FORCE = 14.27 N
MAX FORCE = 150.7 N
MIN FORCE = 0.03931 N
AVERAGE ANGLE = -6.289 D

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 21.00 kPa
ICE THICKNESS = 3.790 cm
ICE DENSITY = 0.7900 g/cc

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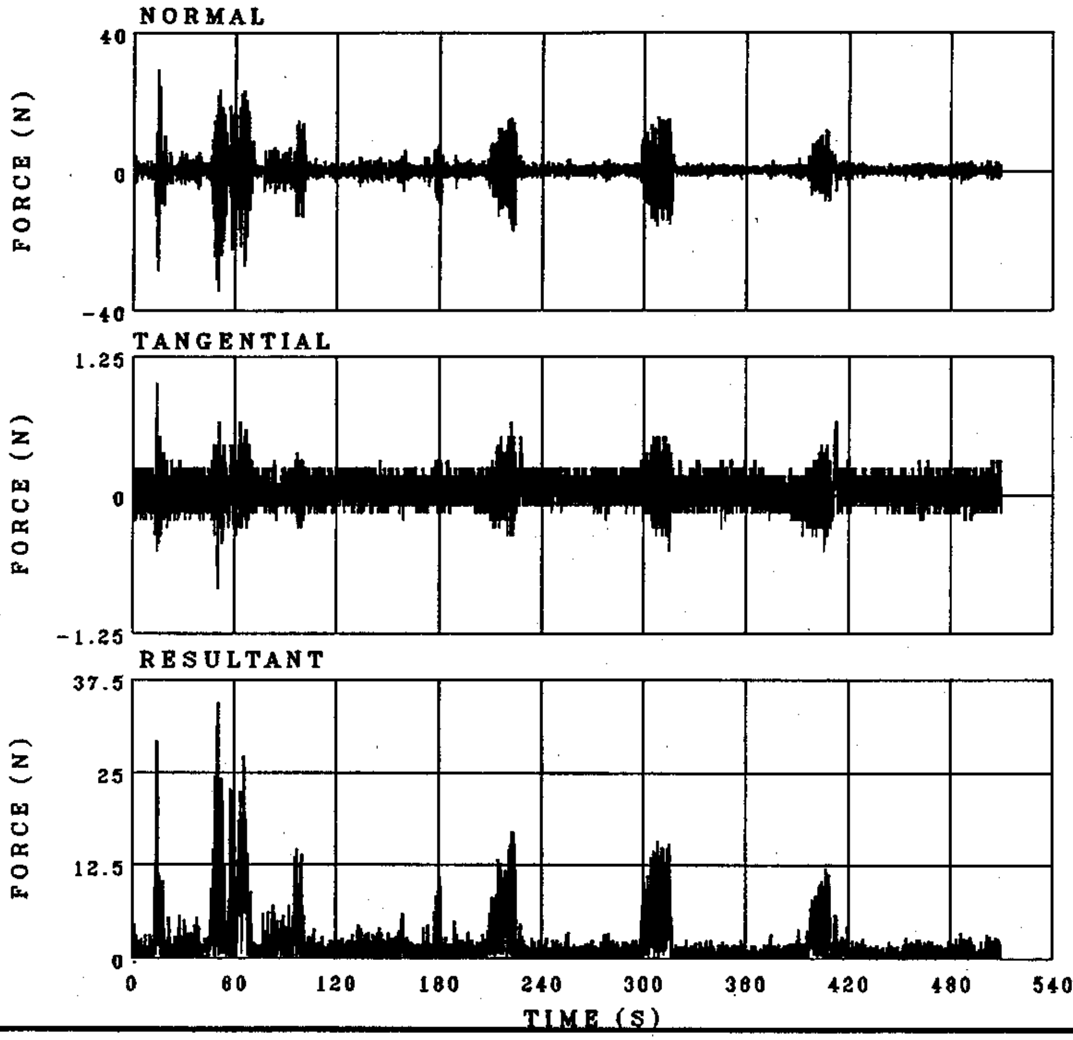
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←022

PLATE #6

NORMAL

MEAN FORCE = 0.1606 N
MAX FORCE = 29.37 N
MIN FORCE = -34.43 N

TANGENTIAL

MEAN FORCE = 0.02913 N
MAX FORCE = 1.012 N
MIN FORCE = -0.8529 N

RESULTANT

MEAN FORCE = 1.912 N
MAX FORCE = 34.44 N
MIN FORCE = 0.08471 N
AVERAGE ANGLE = -16.16 D

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 21.00 kPa
ICE THICKNESS = 3.790 cm
ICE DENSITY = 0.7900 g/cc

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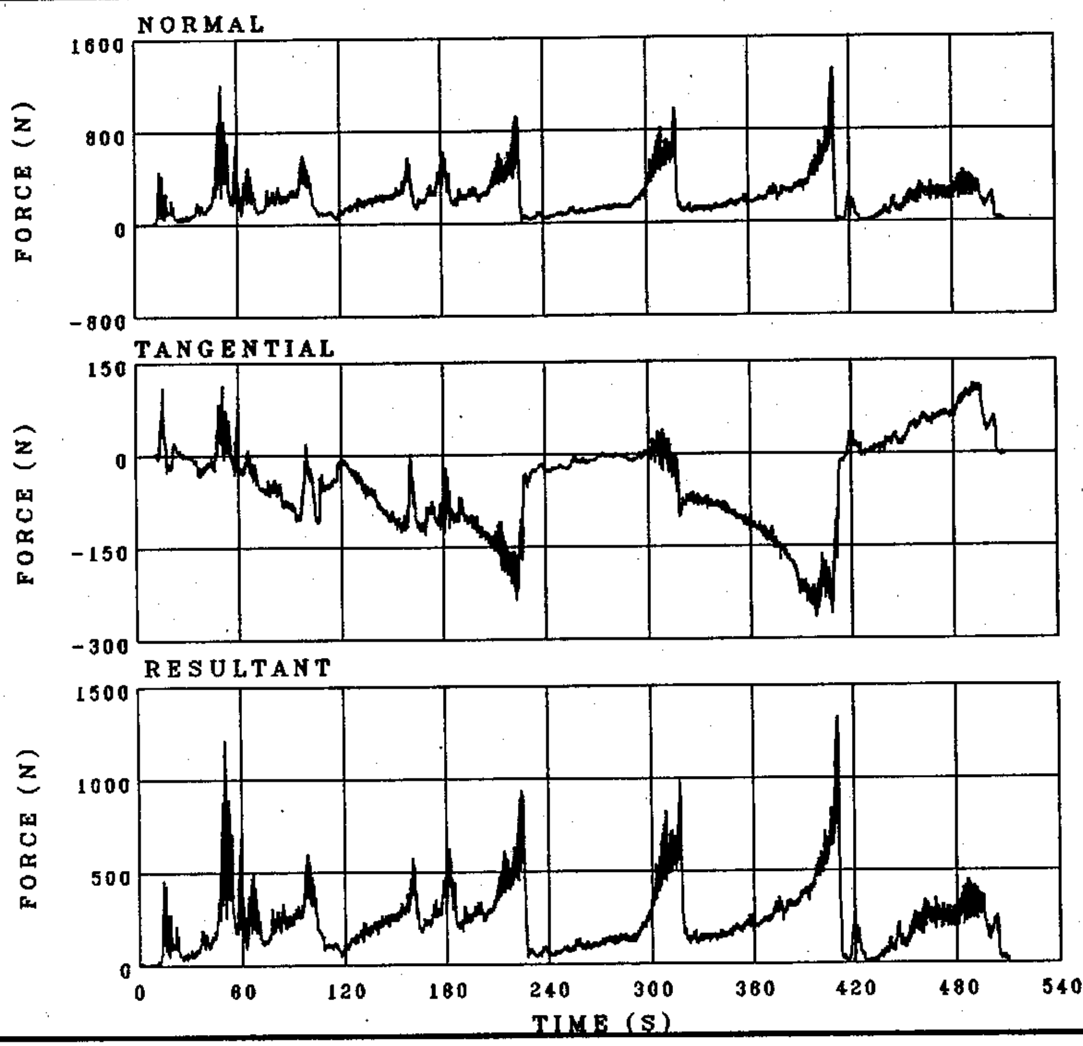
ICE PILEUP STUDY
for CANADIAN COAST GUARD



FILE TN←022

TOTAL

NORMAL

MEAN FORCE = 220.1 N
MAX FORCE = 1327.0 N
MIN FORCE = -10.95 N

TANGENTIAL

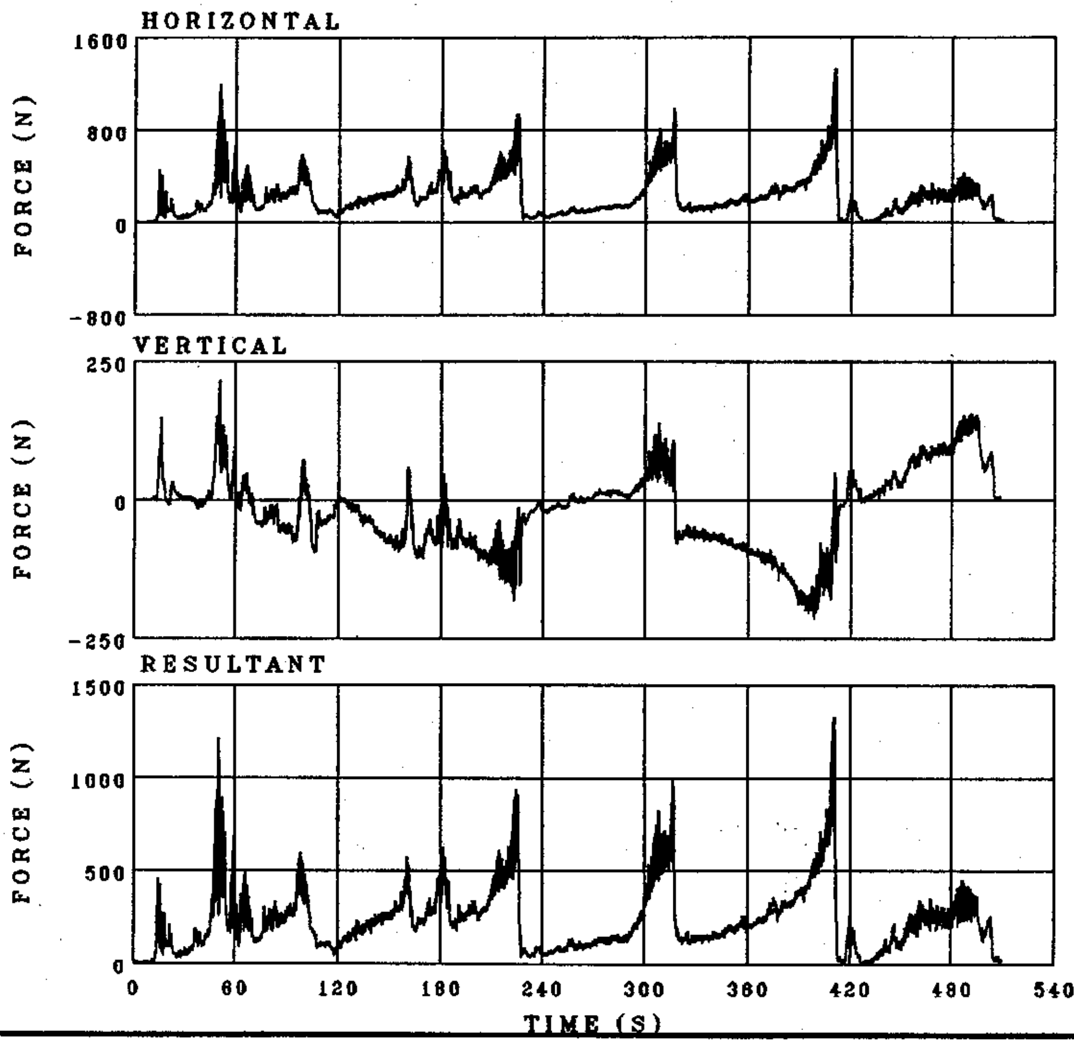
MEAN FORCE = -46.49 N
MAX FORCE = 113.6 N
MIN FORCE = -266.6 N

RESULTANT

MEAN FORCE = 233.7 N
MAX FORCE = 1332.0 N
MIN FORCE = 0.1078 N
AVERAGE ANGLE = -10.81 O

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 21.00 kPa
ICE THICKNESS = 3.790 cm
ICE DENSITY = 0.7900 g/cc



FILE TN←022

TOTAL

HORIZONTAL

MEAN FORCE = -46.49 N
MAX FORCE = 113.6 N
MIN FORCE = -266.6 N

VERTICAL

MEAN FORCE = -46.49 N
MAX FORCE = 113.6 N
MIN FORCE = -266.6 N

RESULTANT

MEAN FORCE = -46.49 N
MAX FORCE = 113.6 N
MIN FORCE = -266.6 N
AVERAGE ANGLE = -46.49 O

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 21.00 kPa
ICE THICKNESS = 3.790 cm
ICE DENSITY = 0.7900 g/cc

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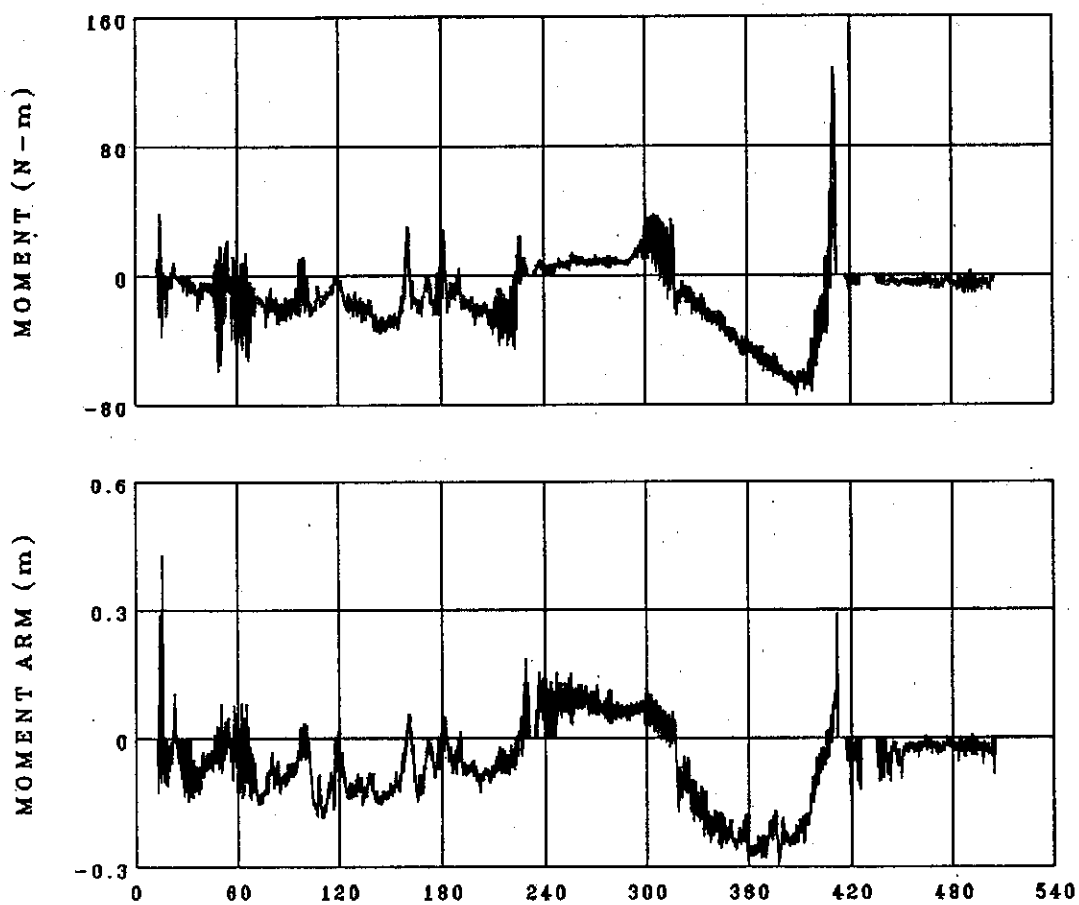
ICE PILEUP STUDY
for CANADIAN COAST GUARD

FILE TN←022

MOMENT



MOMENT

MEAN MOMENT = -11.69 N-m
MAX MOMENT = 128.2 N-m
MIN MOMENT = -75.13 N-m

MOMENT ARM

MEAN ARM = -0.05568 m
MAX ARM = 0.4296 m
MIN ARM = -0.2965 m

TEST CONDITIONS

BOARD ANGLE = 7.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 21.00 kPa
ICE THICKNESS = 3.790 cm
ICE DENSITY = 0.7900 g/cc

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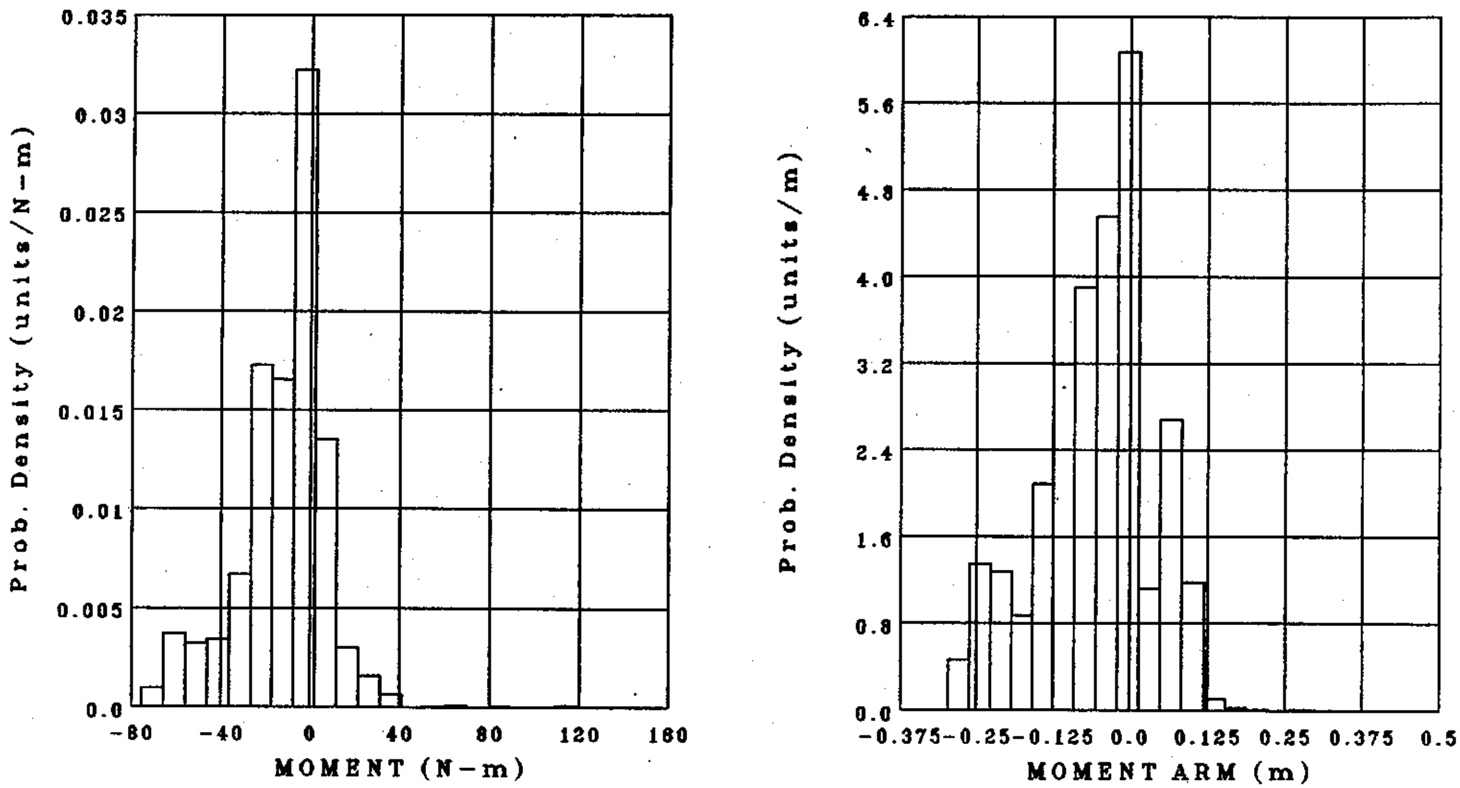
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←022



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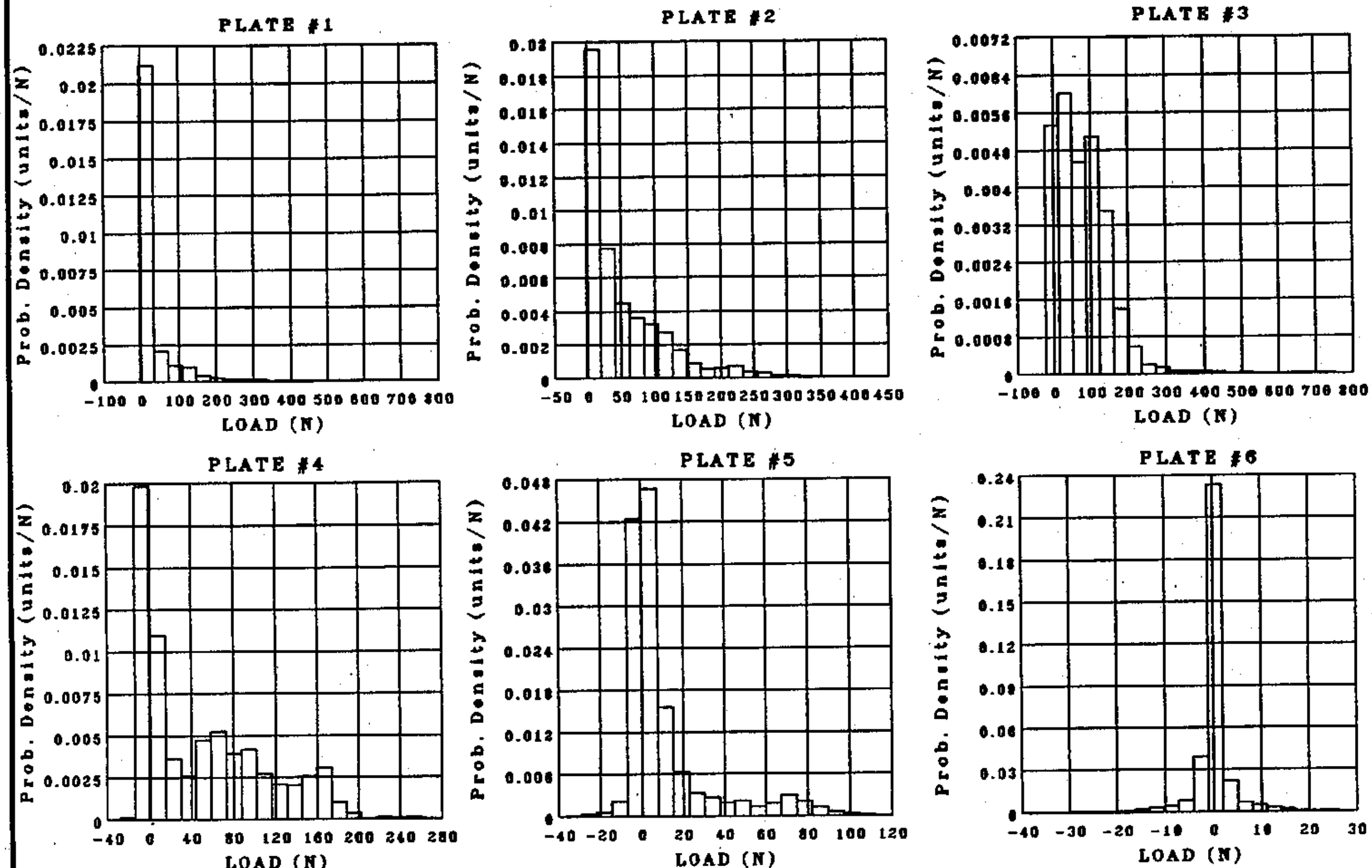
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←022

NORMAL LOAD



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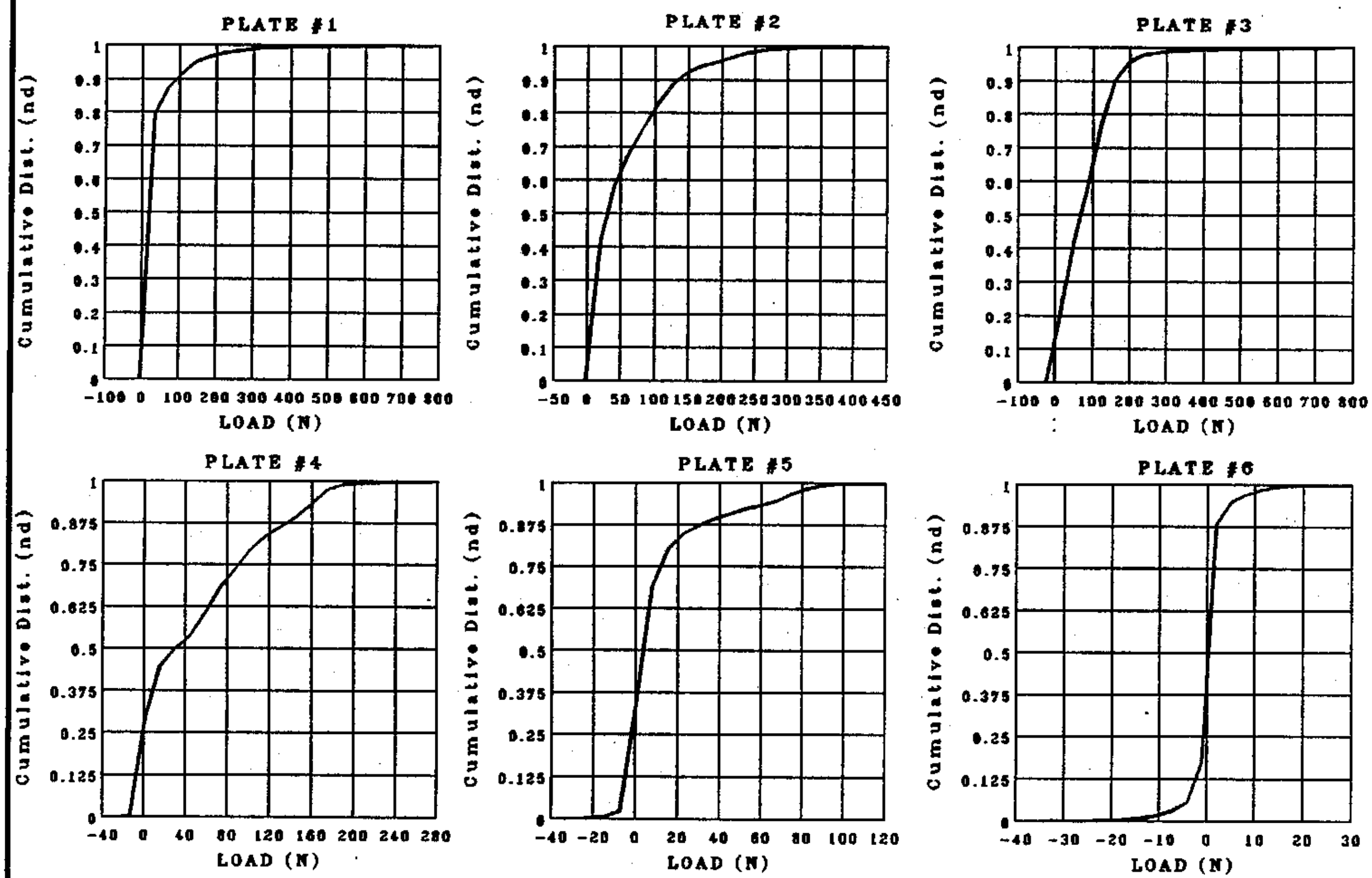
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←022
NORMAL LOAD



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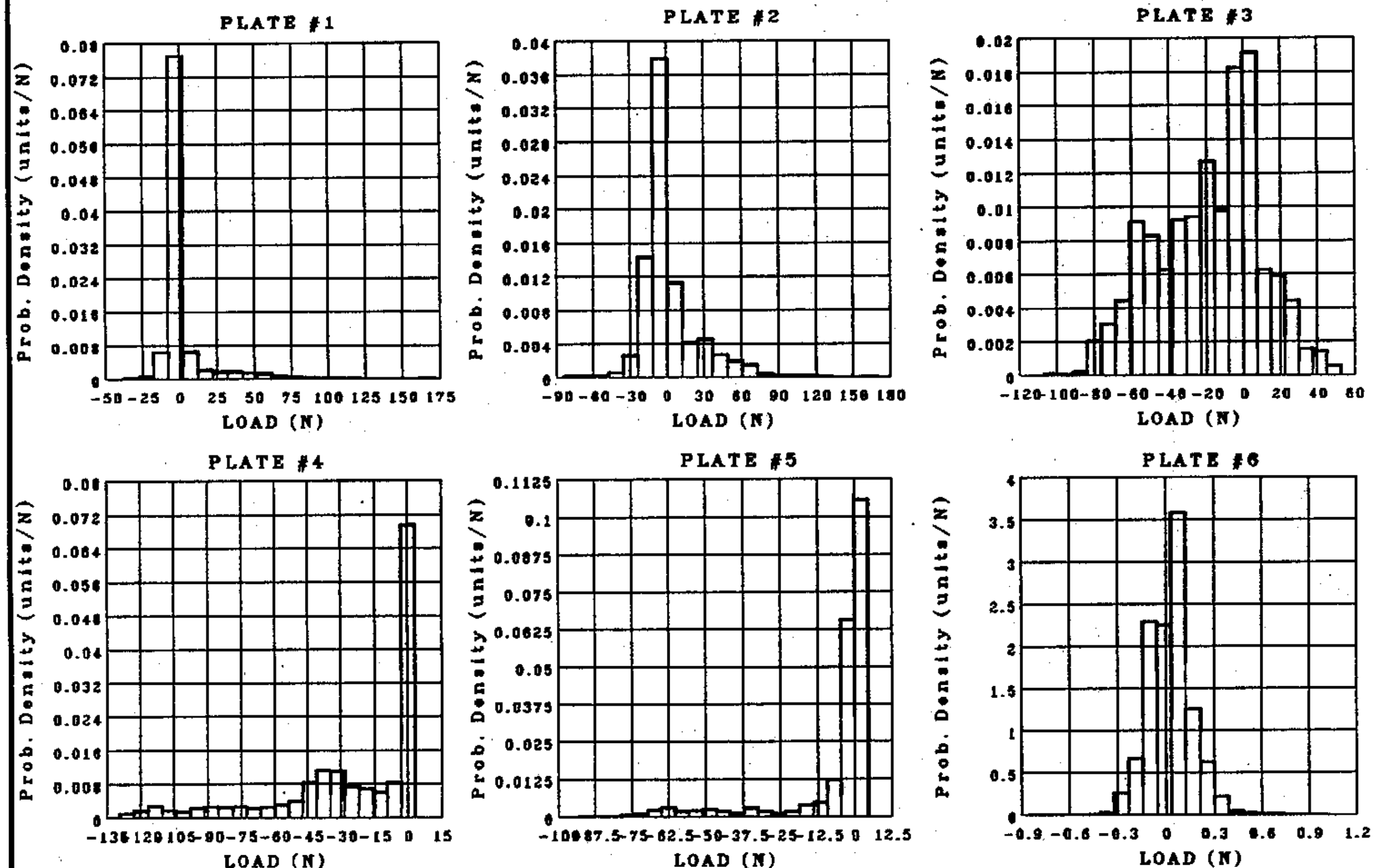
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←022

TANGENTIAL LOAD



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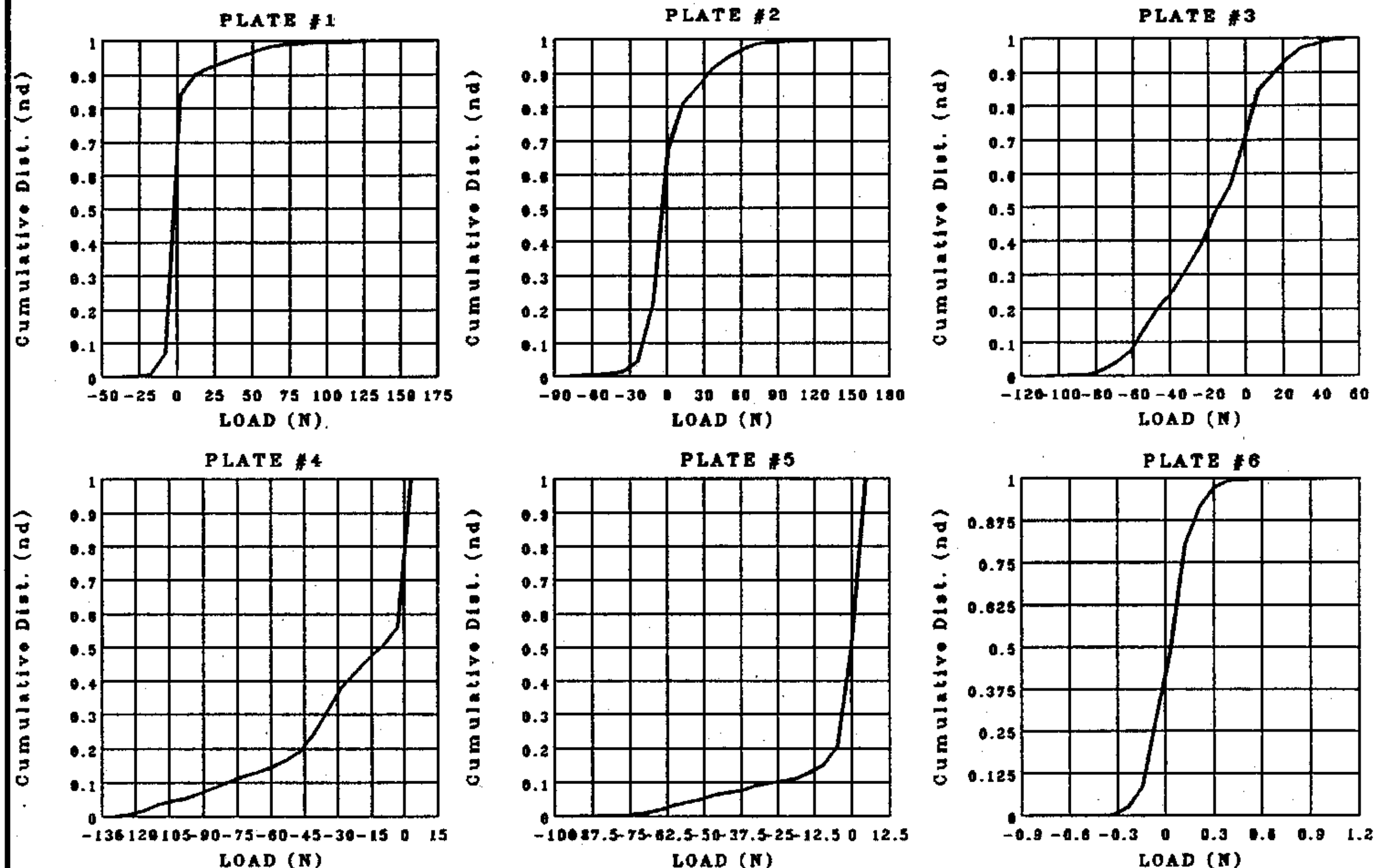
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←022
TANGENTIAL LOAD



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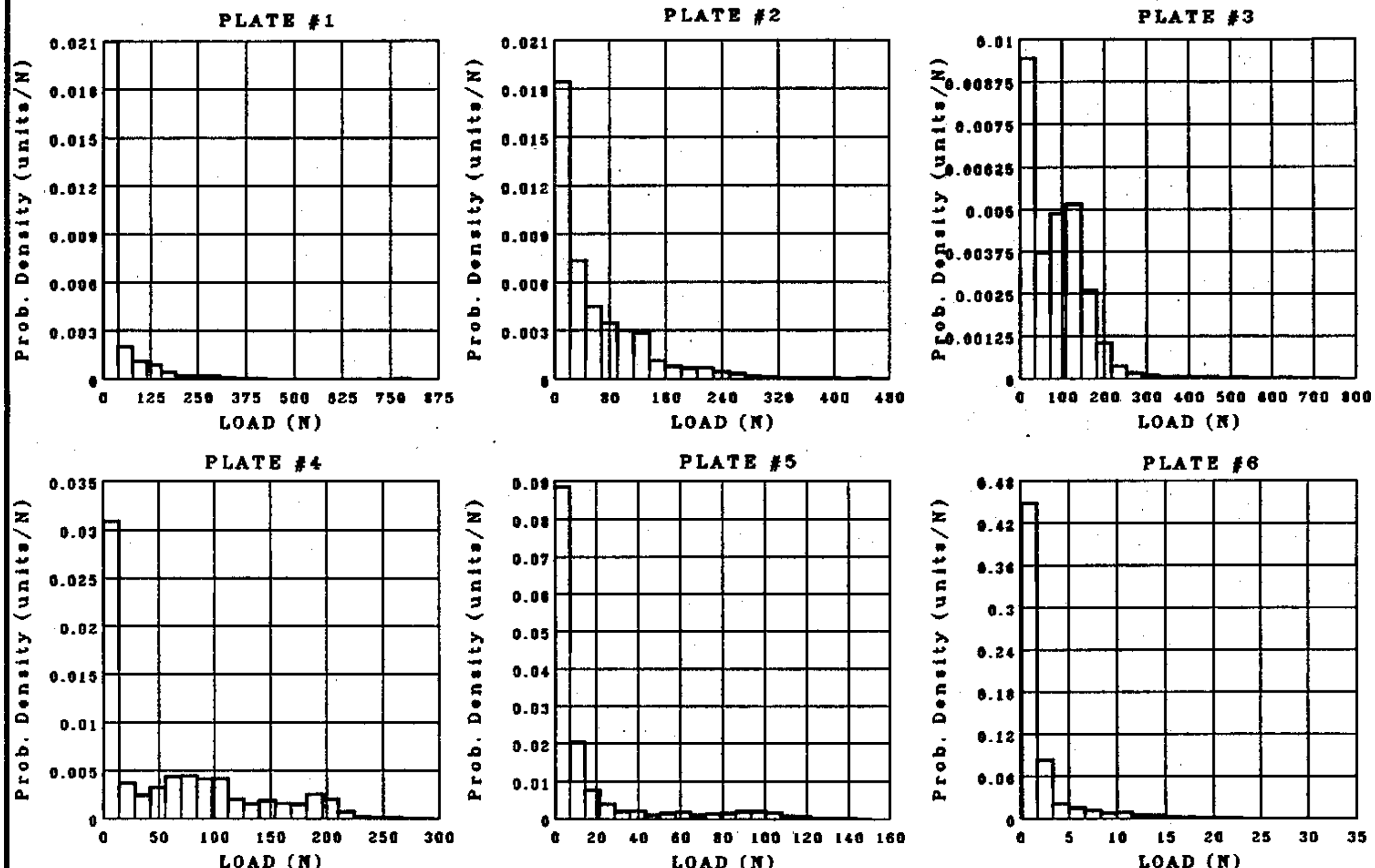
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←022
RESULTANT



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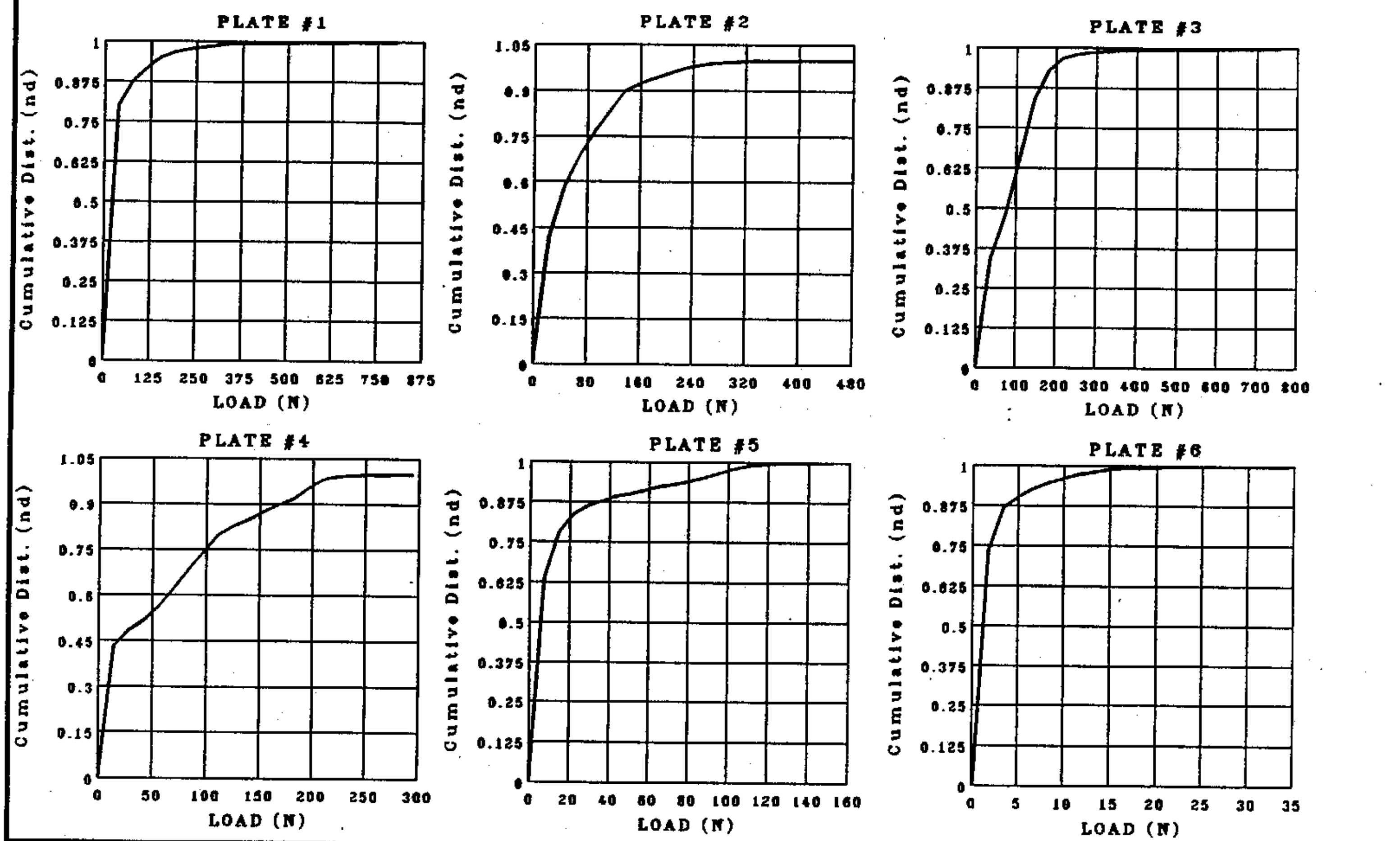
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←022
RESULTANT



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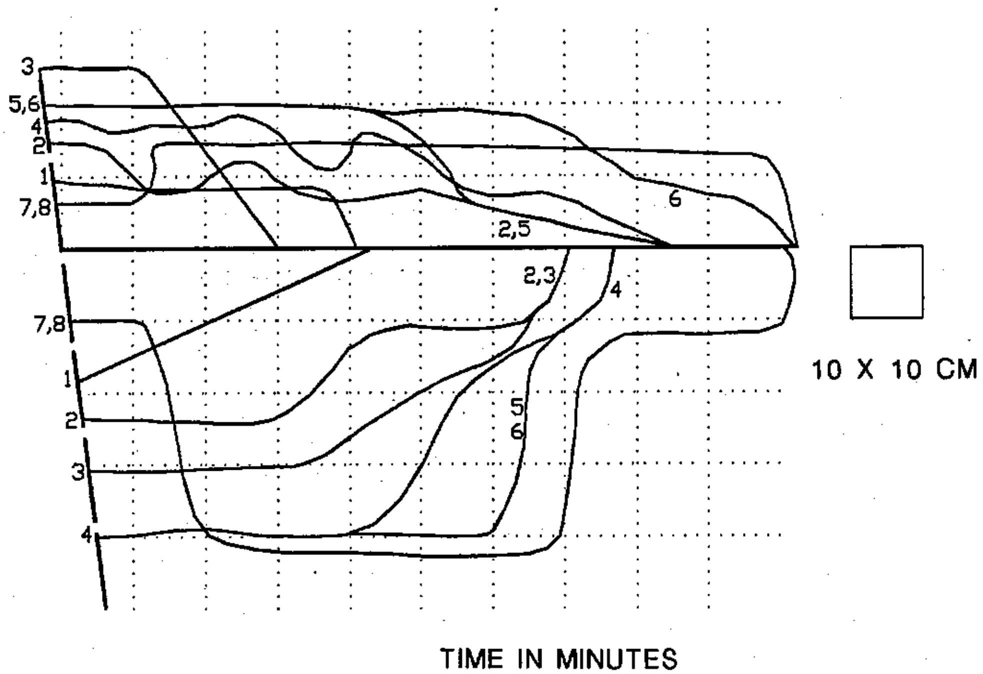
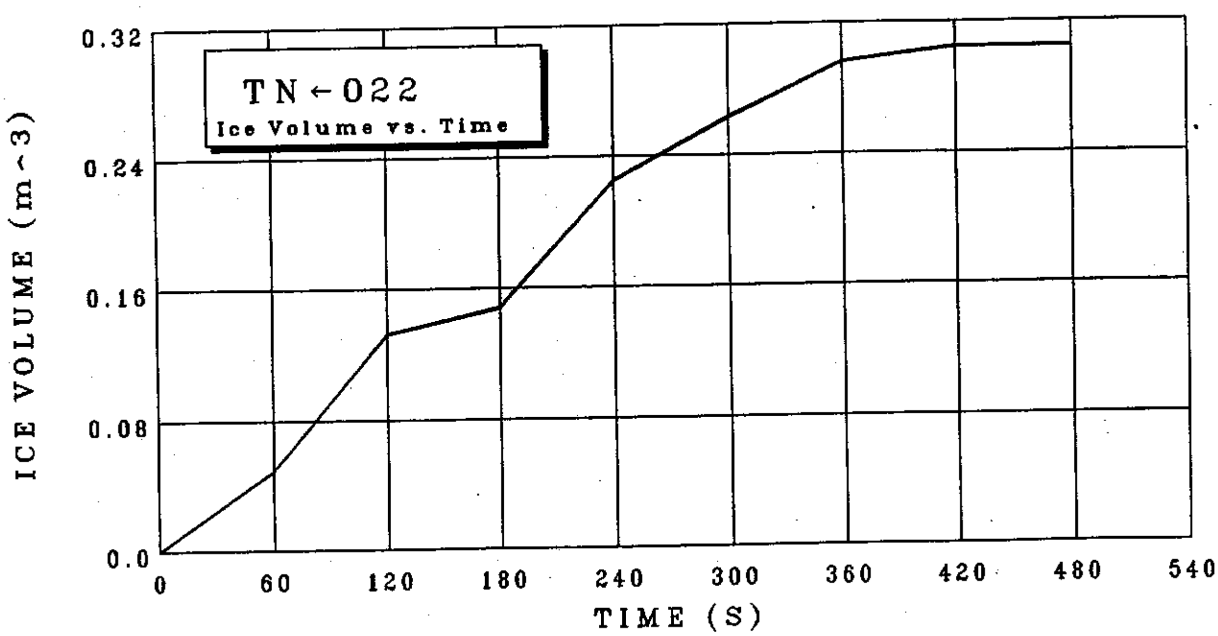
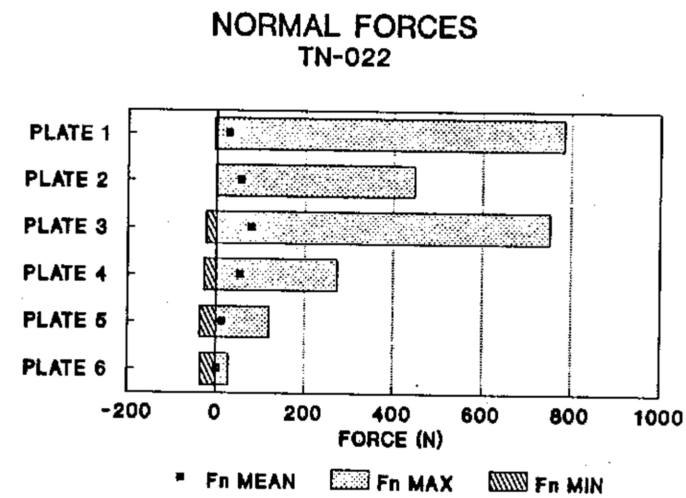
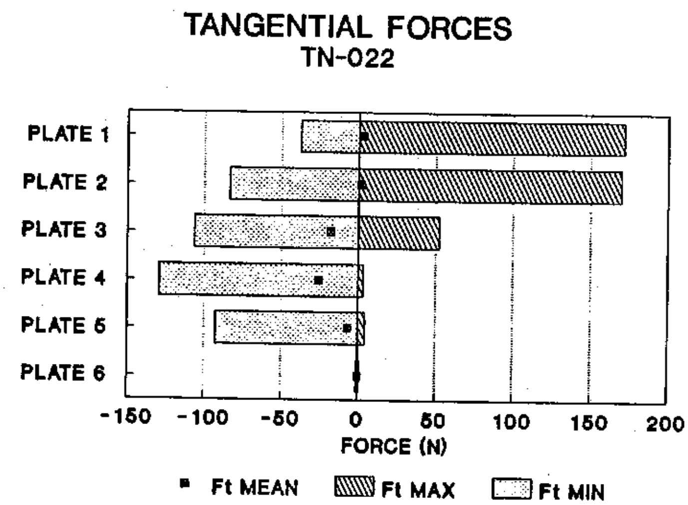
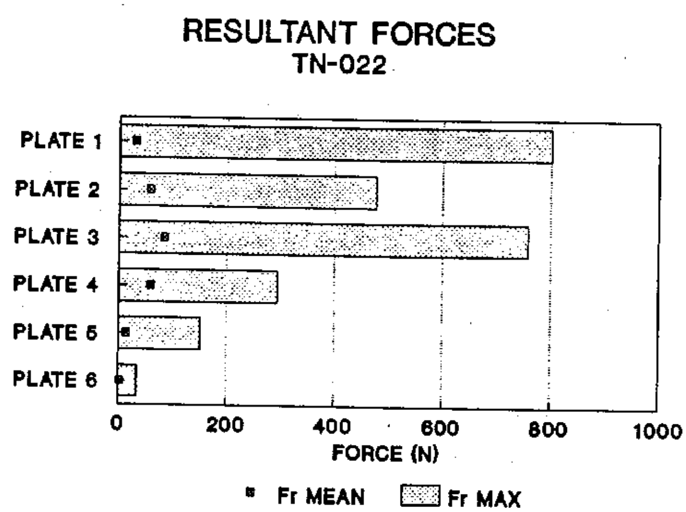
ICE PILEUP STUDY
for CANADIAN COAST GUARD


3
5,6
4
2
1
7,8
6
2,5
2,3
4
7,8
1
2
5
6
3
4
10 X 10 CM
TIME IN MINUTES


TN←022
Ice Volume vs. Time
ICE VOLUME (m^3)
0.32
0.24
0.16
0.08
0.0
0
60
120
180
240
300
360
420
480
540
TIME (S)


NORMAL FORCES
TN-022
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-200
0
200
400
600
800
1000
FORCE (N)
Fn MEAN
Fn MAX
Fn MIN

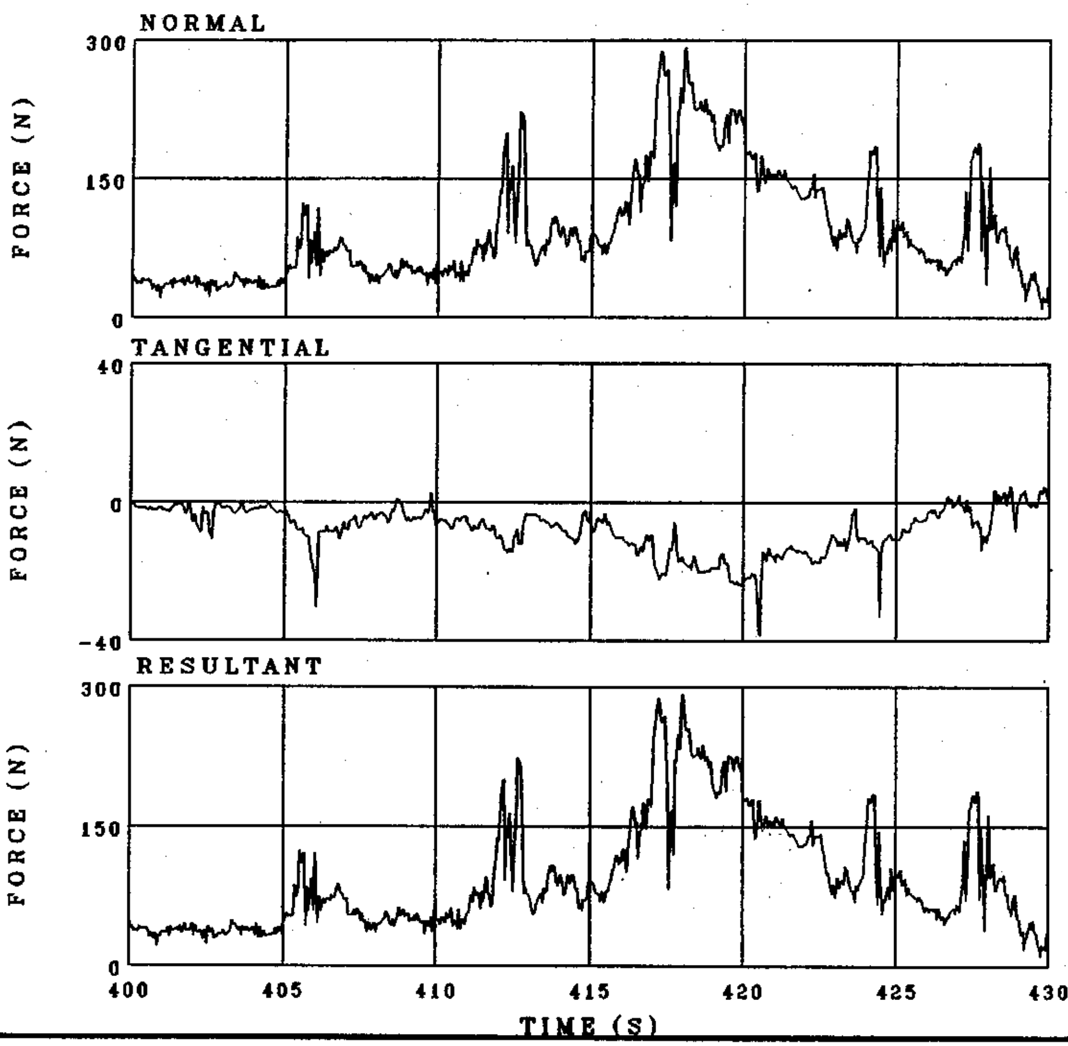

TANGENTIAL FORCES
TN-022
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
-150
-100
-50
0
50
100
150
200
FORCE (N)
Ft MEAN
Ft MAX
Ft MIN


RESULTANT FORCES
TN-022
PLATE 1
PLATE 2
PLATE 3
PLATE 4
PLATE 5
PLATE 6
0
200
400
600
800
1000
FORCE (N)
Fr MEAN
Fr MAX

APPENDIX B

Selected Analysis of 13 Events

FILE NAME	SAMPLING TIME (s)	NUMBER OF SAMPLES	TIME INTERVAL (s)
TN_001	400 – 430	6	5
TN_002	348 – 360	6	2
TN_003	345 – 355	5	2
TN_004	375 – 395	4	5
TN_005	358 – 382	5	5
TN_006	335 – 360	5	5
TN_007	330 – 380	10	5
TN_008	410 – 450	8	5
TN_009	285 – 355	14	5
TN_010	285 – 340	11	5
TN_011	310 – 350	8	5
TN_012	260 – 320	12	5
TN_013	330 – 360	6	5



FILE TN←001

TOTAL

NORMAL

MEAN FORCE = 94.09 N
MAX FORCE = 292.5 N
MIN FORCE = 9.686 N

TANGENTIAL

MEAN FORCE = -7.938 N
MAX FORCE = 4.832 N
MIN FORCE = -38.58 N

RESULTANT

MEAN FORCE = 94.52 N
MAX FORCE = 293.0 N
MIN FORCE = 10.37 N

TEST CONDITIONS

BOARD ANGLE = -23.00 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 106.0 kPa
ICE THICKNESS = 3.100 cm
ICE DENSITY = 0.9300 g/cc

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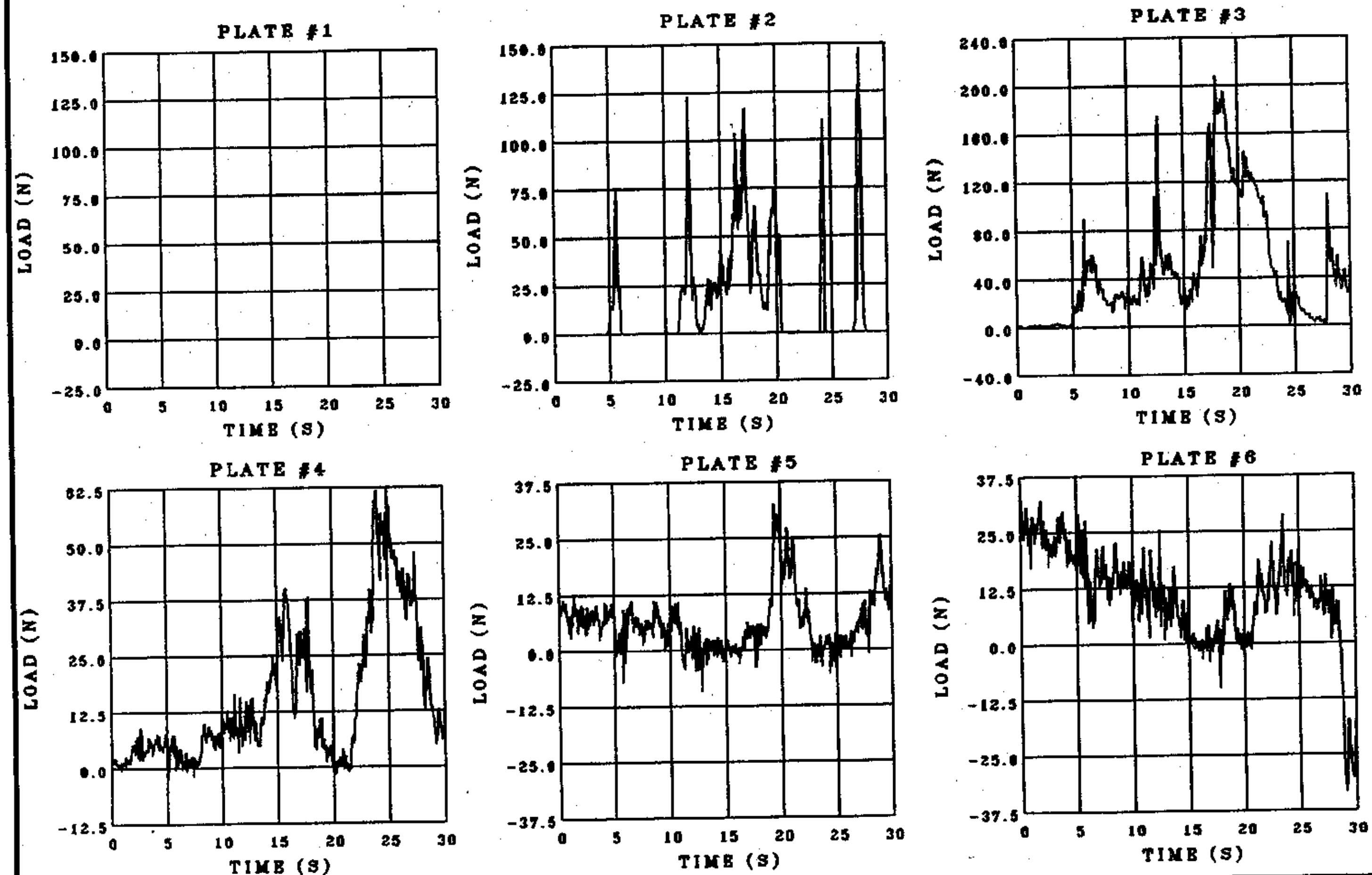
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←001

NORMAL LOAD



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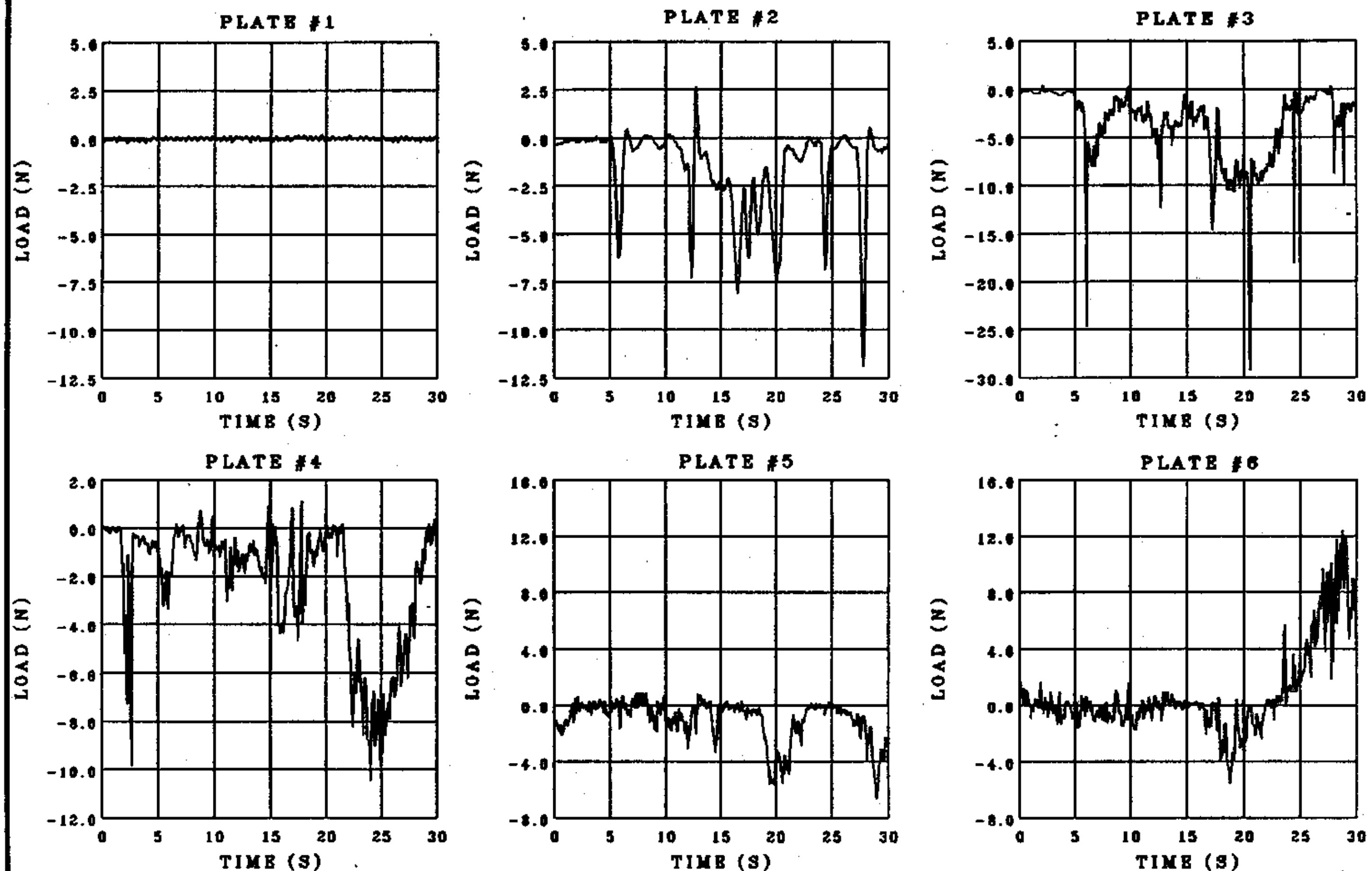
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←001
TANGENTIAL LOAD



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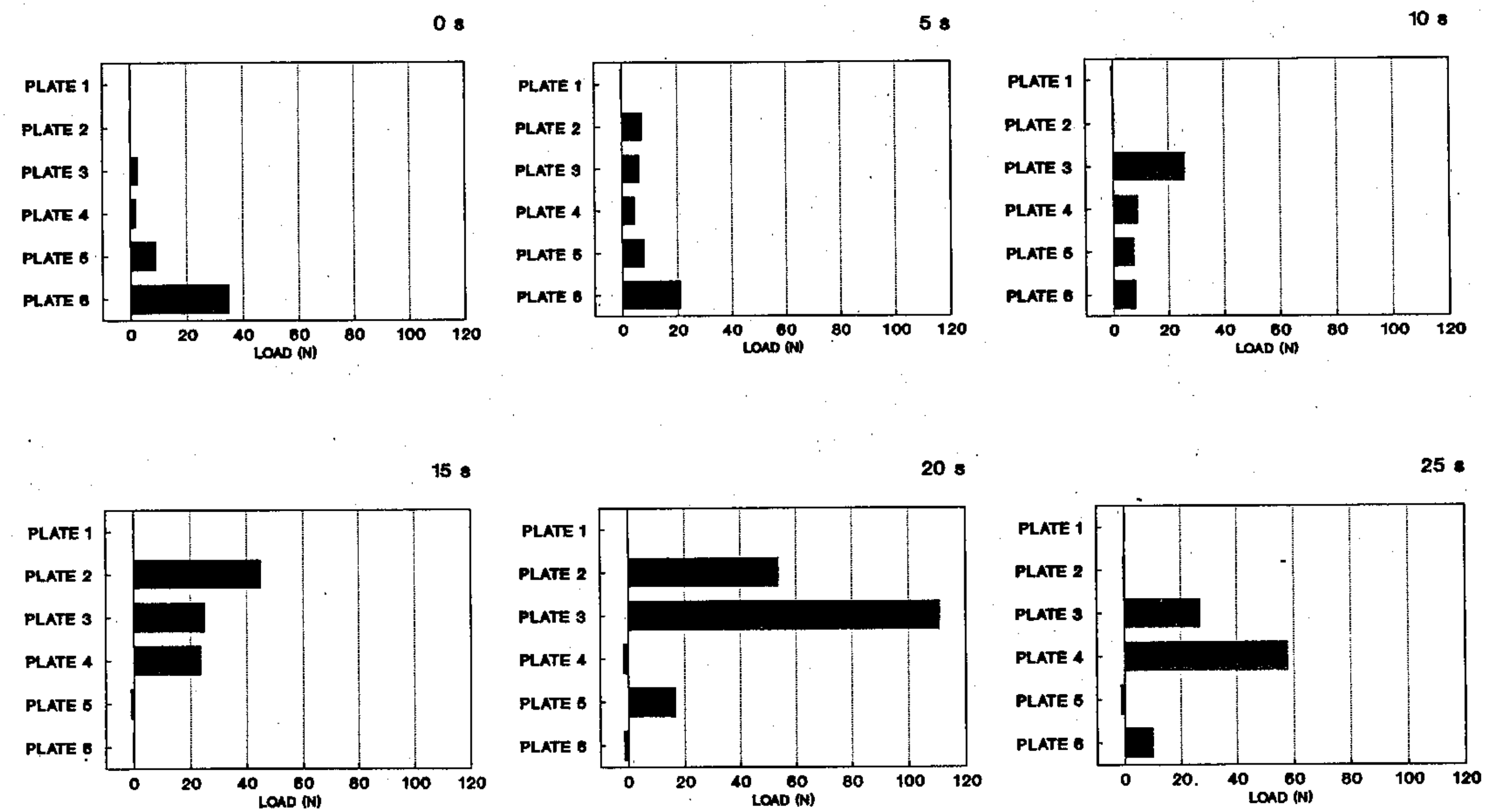
ICE PILEUP STUDY
for CANADIAN COAST GUARD

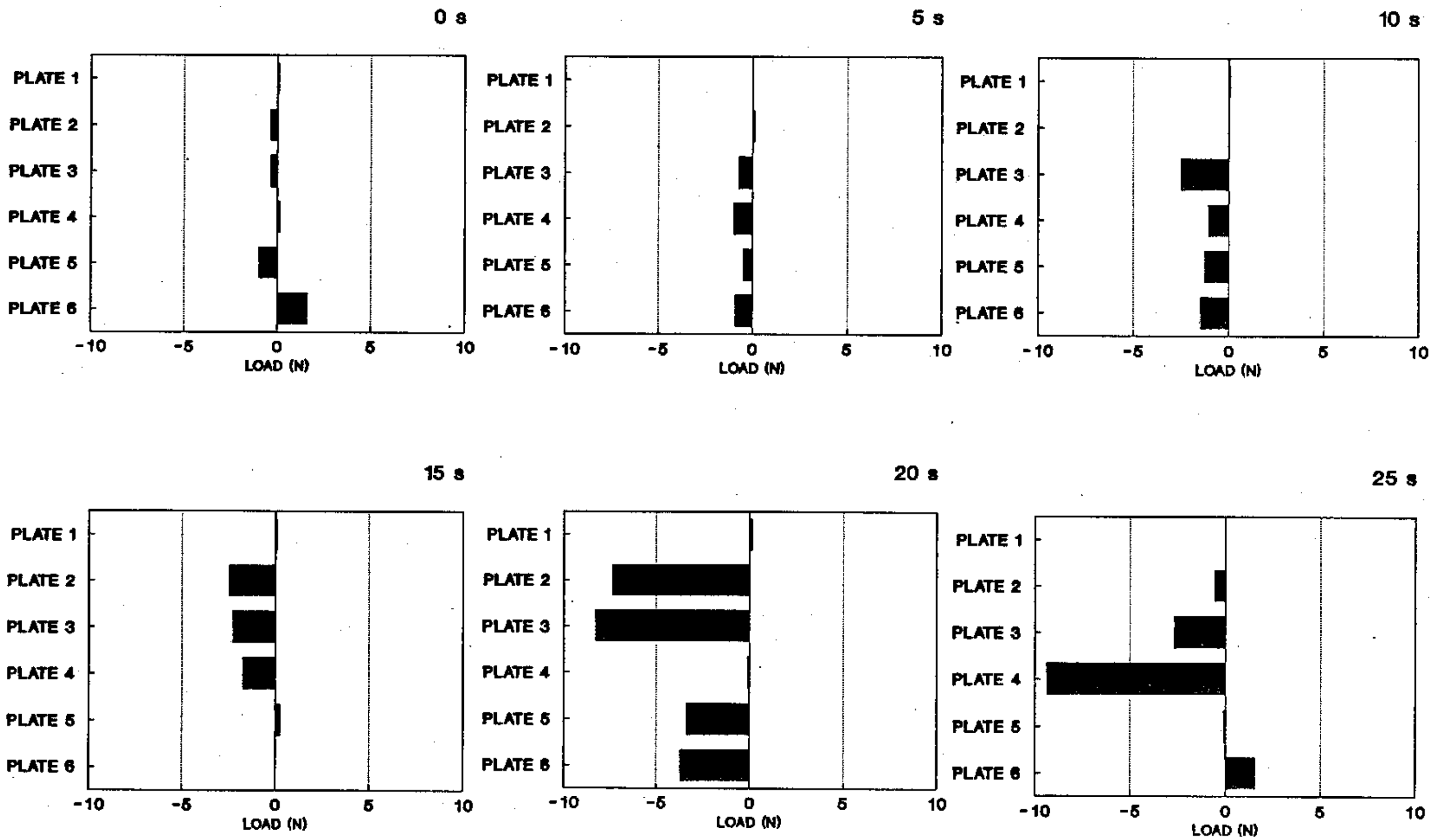
TIME SEQUENCE : NORMAL LOADS

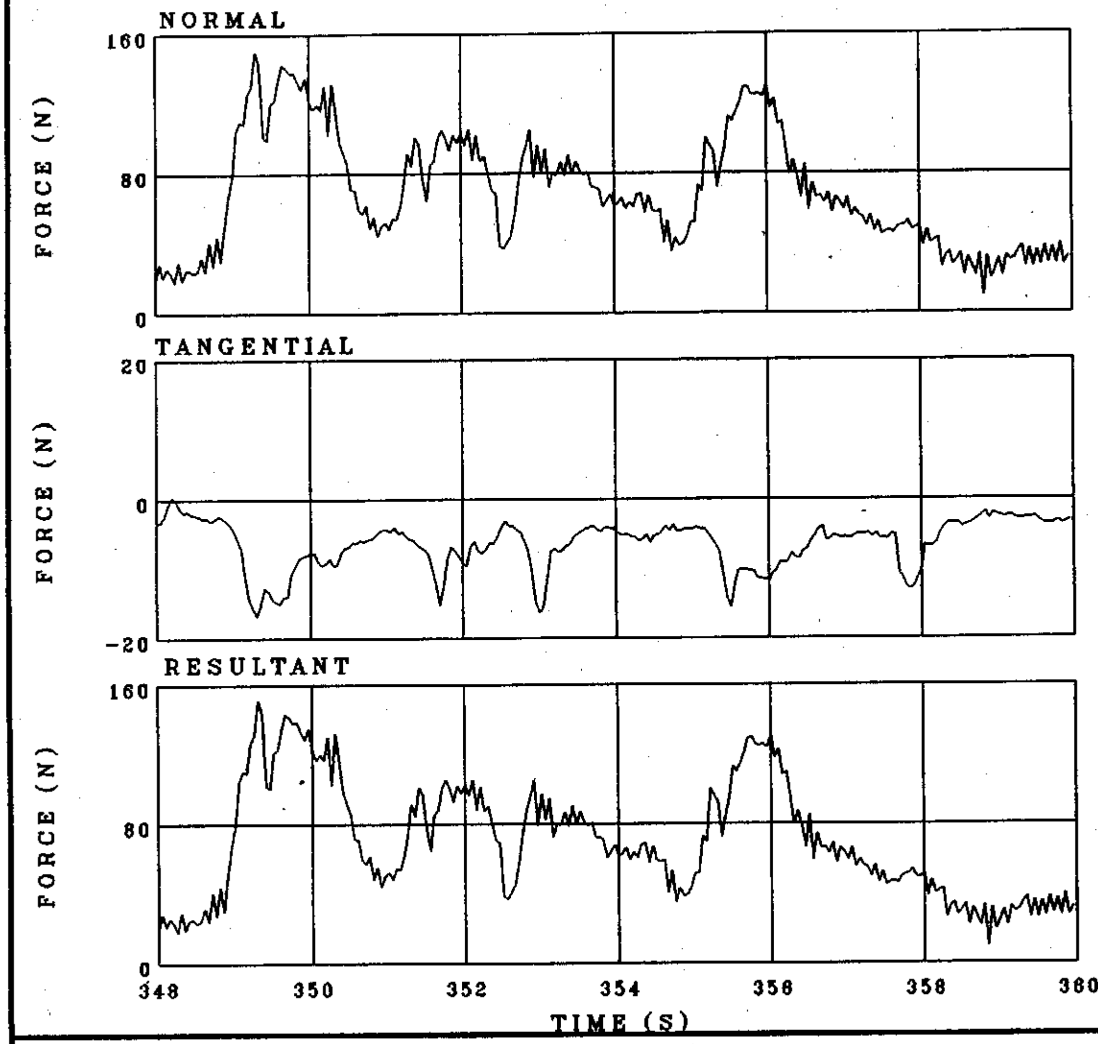
TN_001



TIME SEQUENCE : TANGENTIAL LOADS

TN_001





FILE TN←002

TOTAL

NORMAL

MEAN FORCE = 69.10 N
MAX FORCE = 150.4 N
MIN FORCE = 8.980 N

TANGENTIAL

MEAN FORCE = −6.498 N
MAX FORCE = 0.4066 N
MIN FORCE = −16.88 N

RESULTANT

MEAN FORCE = 69.44 N
MAX FORCE = 151.4 N
MIN FORCE = 9.154 N

TEST CONDITIONS

BOARD ANGLE = −23.00 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 44.00 kPa
ICE THICKNESS = 3.600 cm
ICE DENSITY = 0.9300 g/cc

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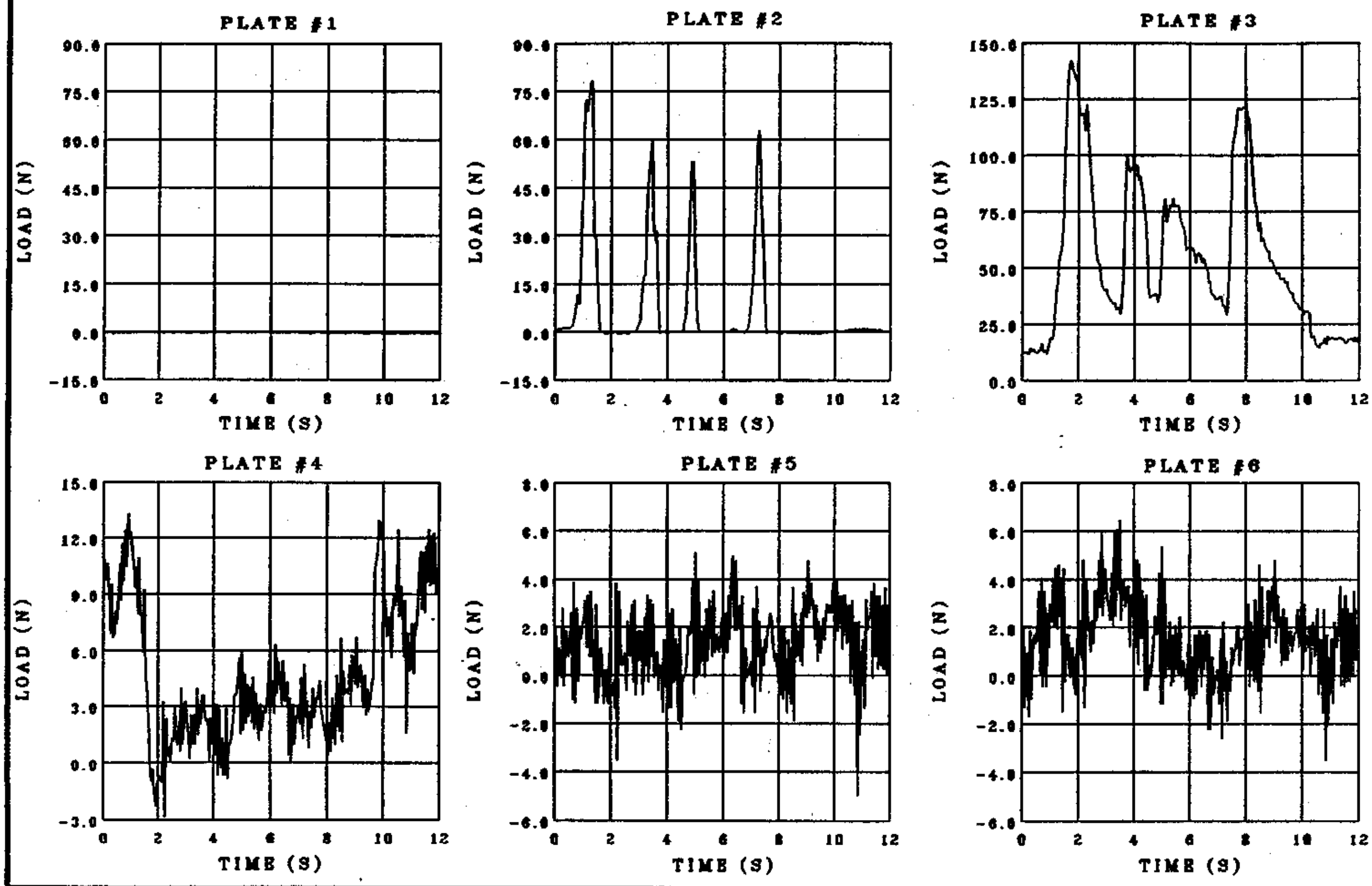
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←002
NORMAL LOAD



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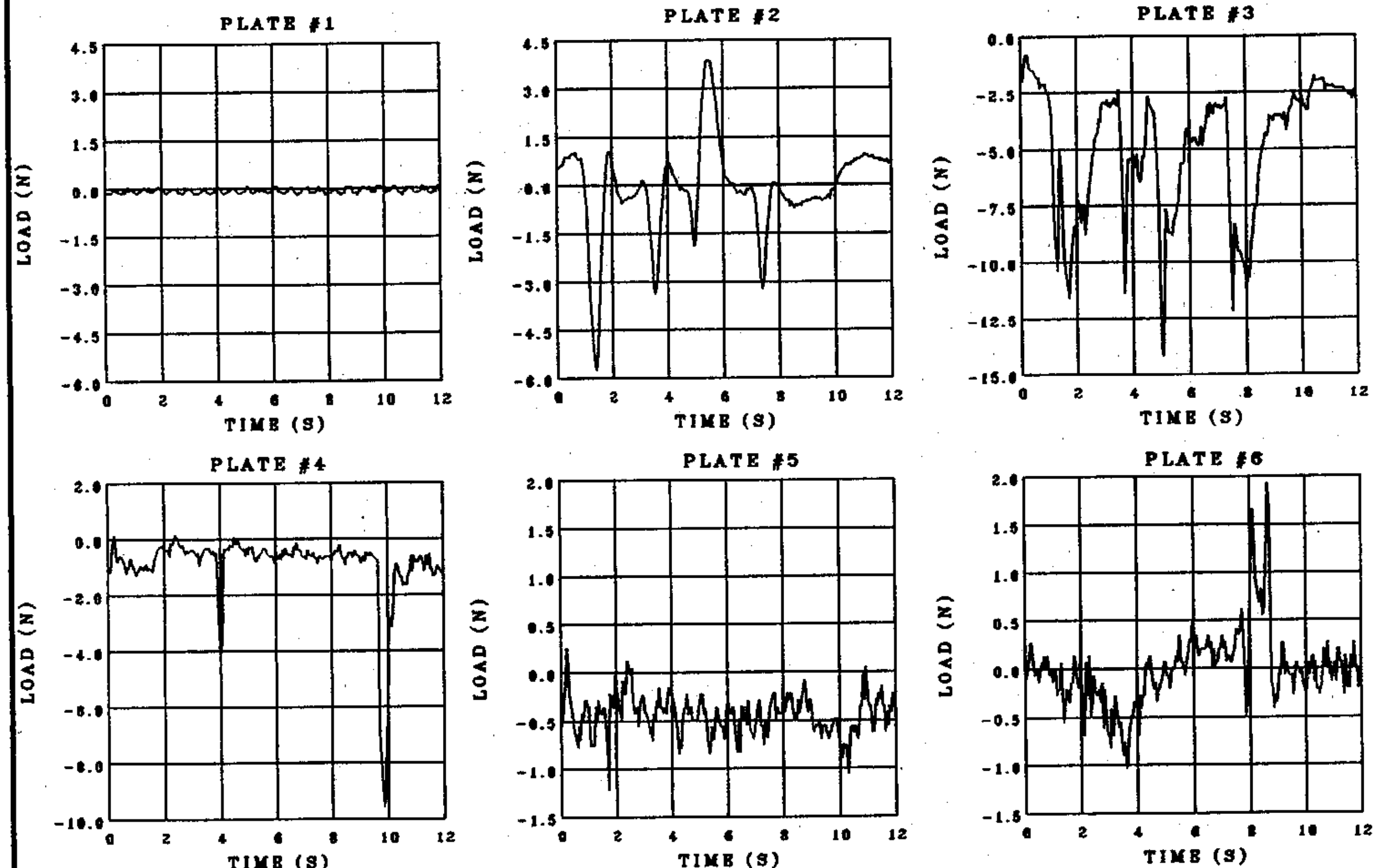
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←002
TANGENTIAL LOAD



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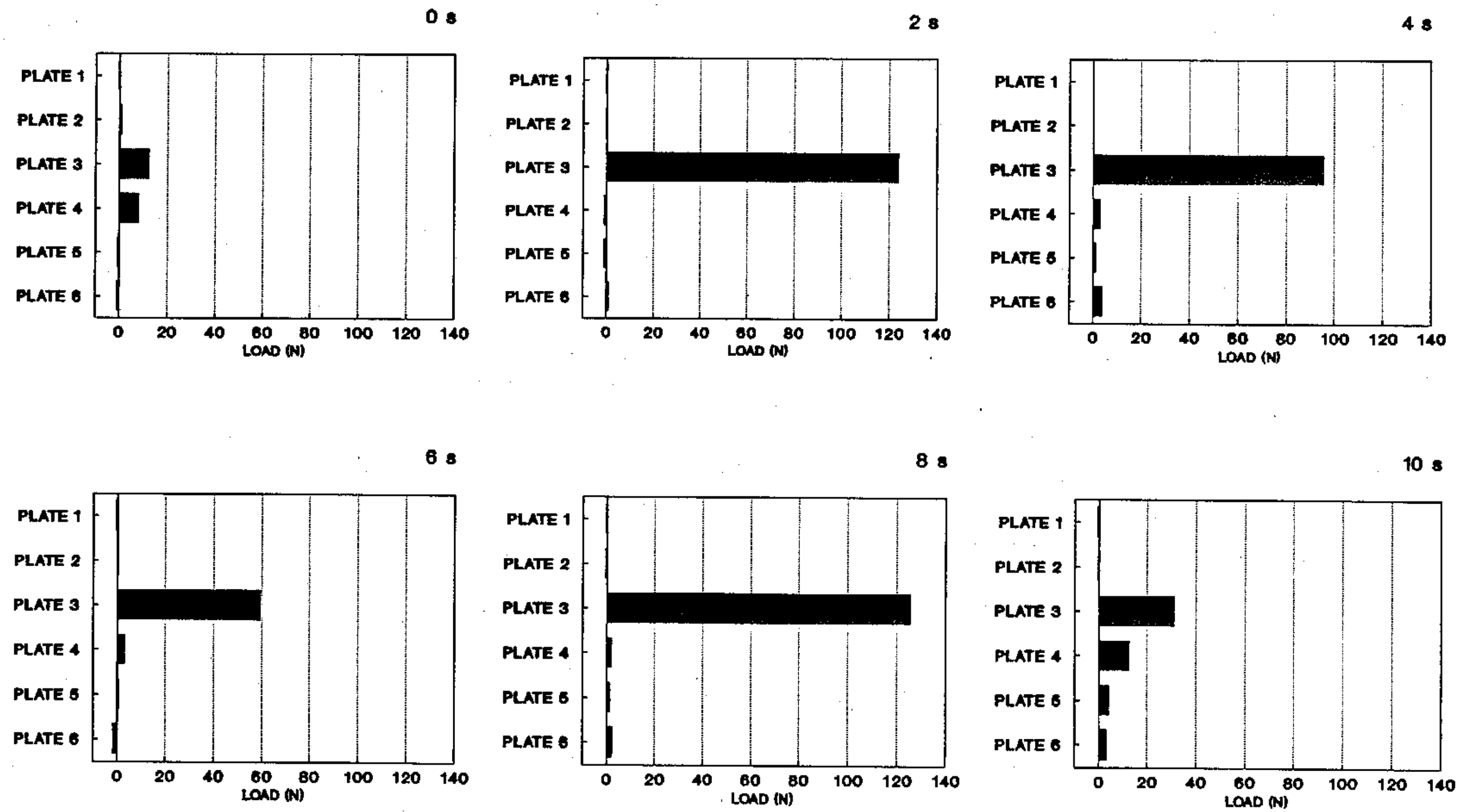
ICE PILEUP STUDY
for CANADIAN COAST GUARD

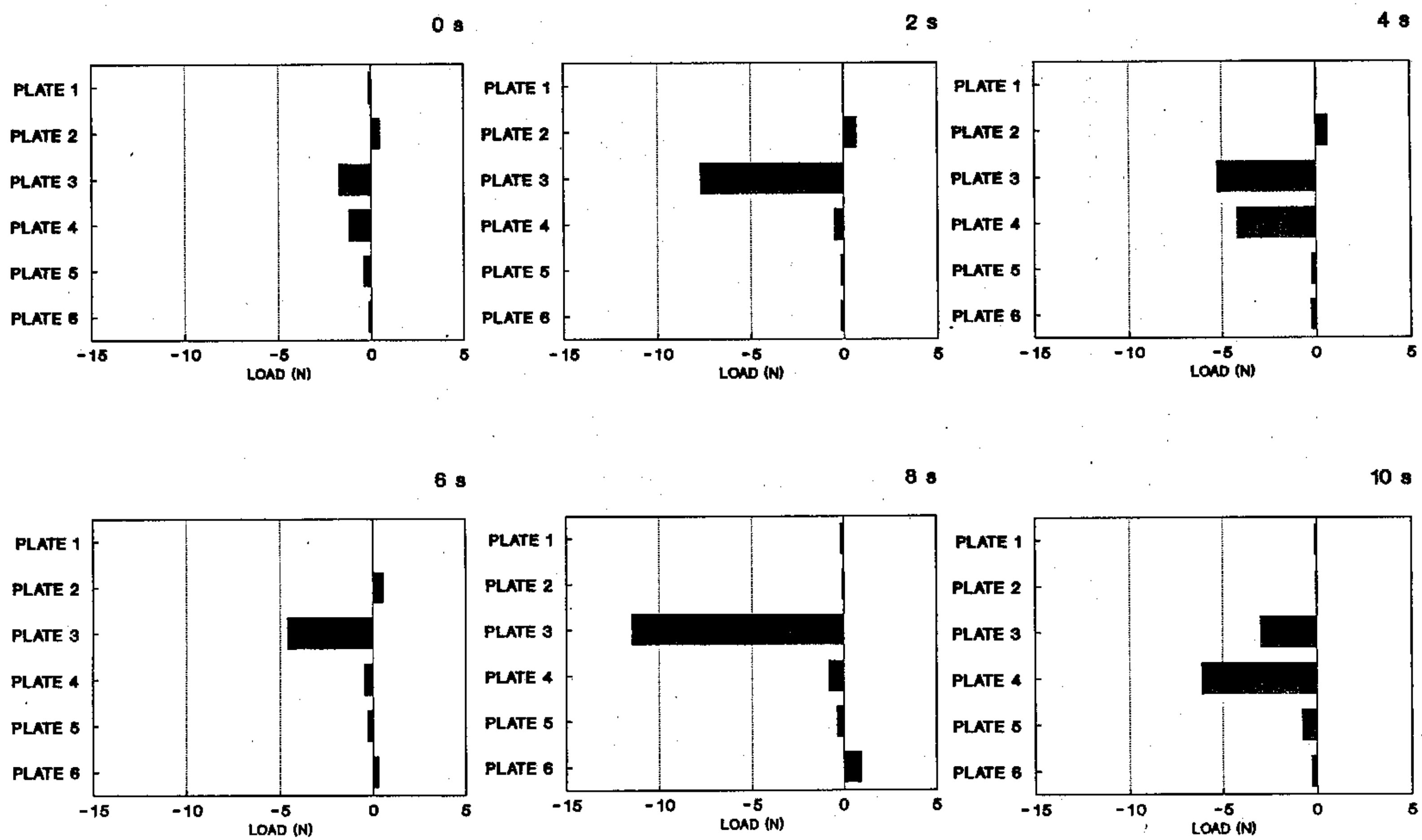
TIME SEQUENCE : NORMAL LOADS

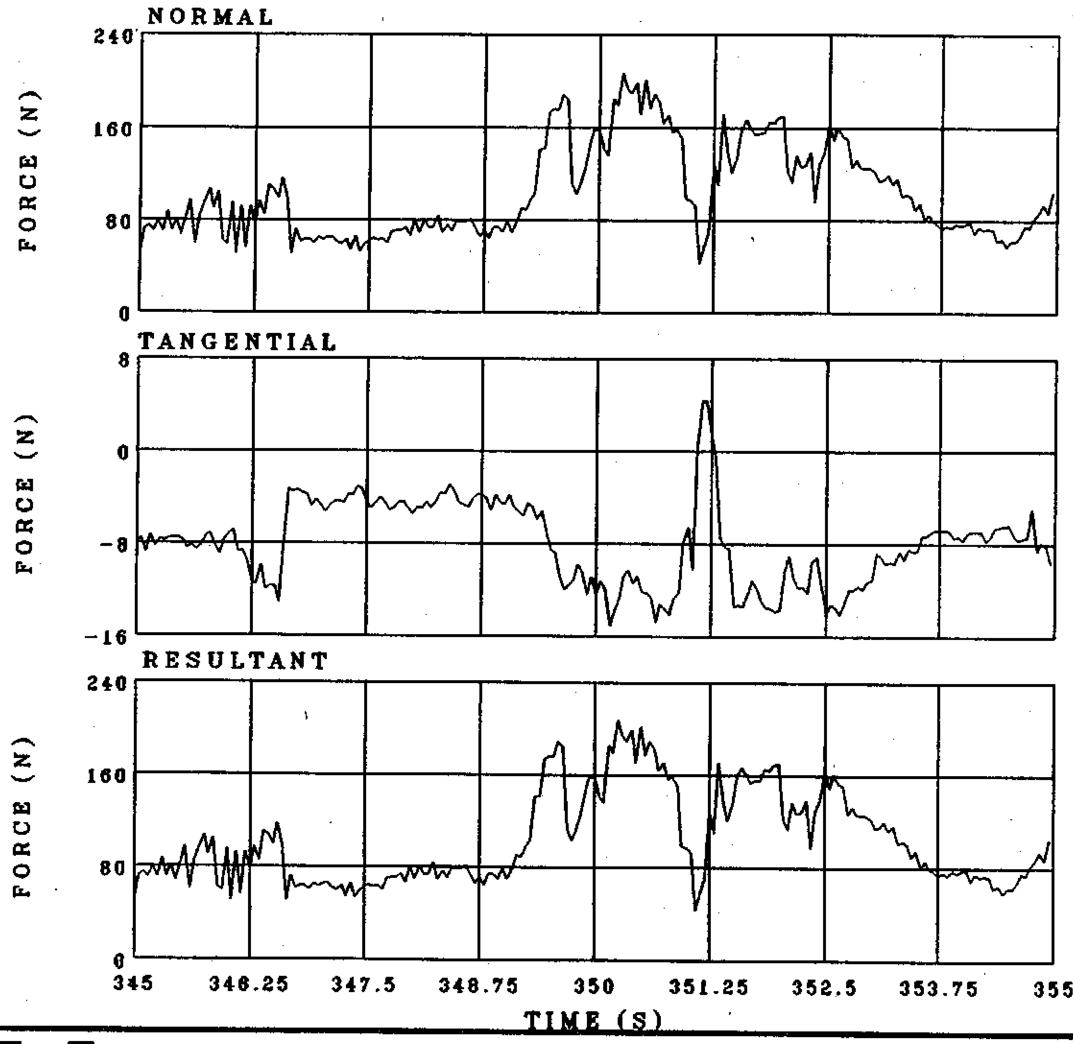
TN_002



TIME SEQUENCE : TANGENTIAL LOADS

TN_002





FILE TN←003

TOTAL

NORMAL

MEAN FORCE = 102.9 N
MAX FORCE = 207.4 N
MIN FORCE = 43.01 N

TANGENTIAL

MEAN FORCE = -7.996 N
MAX FORCE = 4.447 N
MIN FORCE = -15.11 N

RESULTANT

MEAN FORCE = 103.2 N
MAX FORCE = 207.8 N
MIN FORCE = 43.01 N

TEST CONDITIONS

BOARD ANGLE = -23.00 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 83.00 kPa
ICE THICKNESS = 2.800 cm
ICE DENSITY = 0.9300 g/cc

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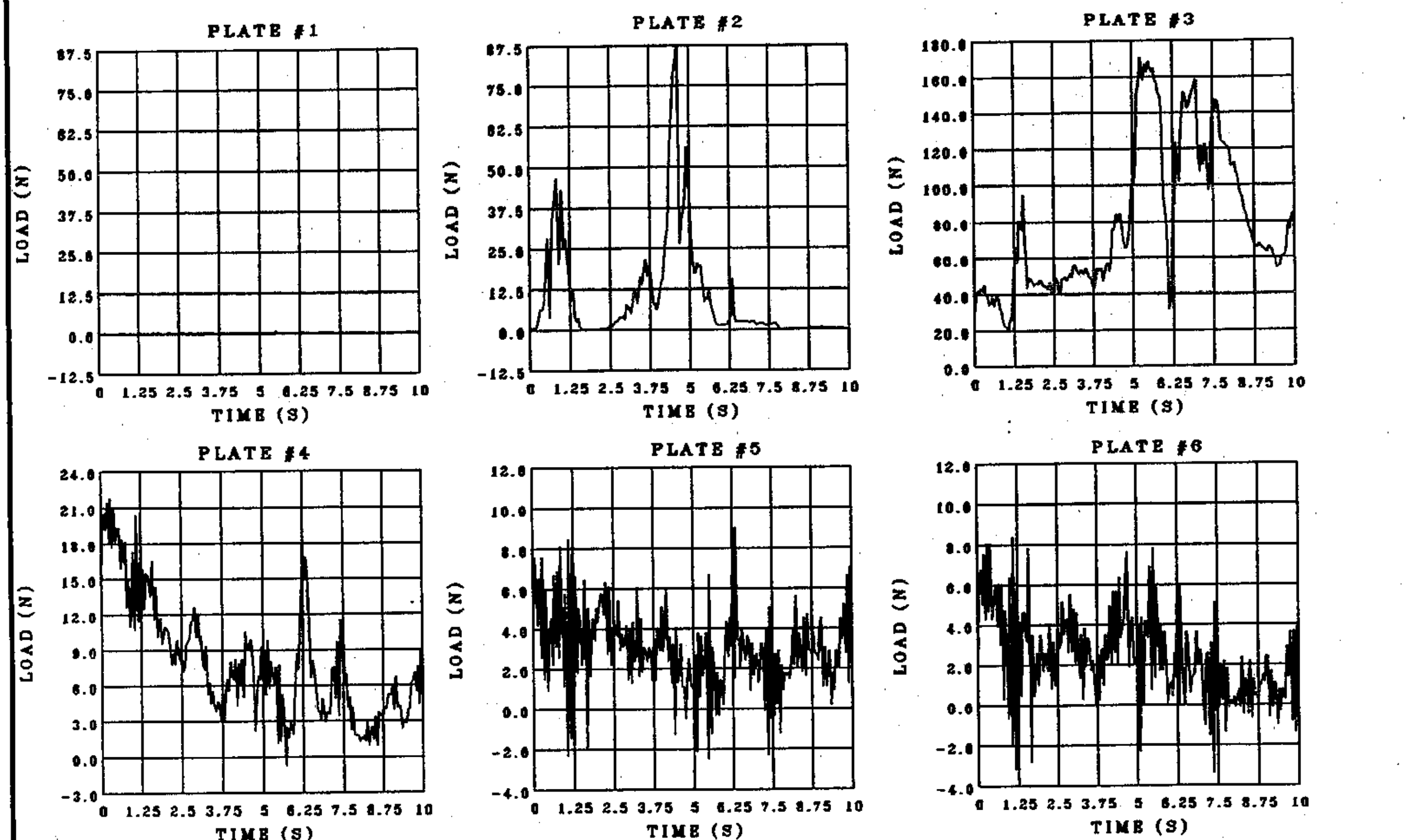
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←003
NORMAL LOAD



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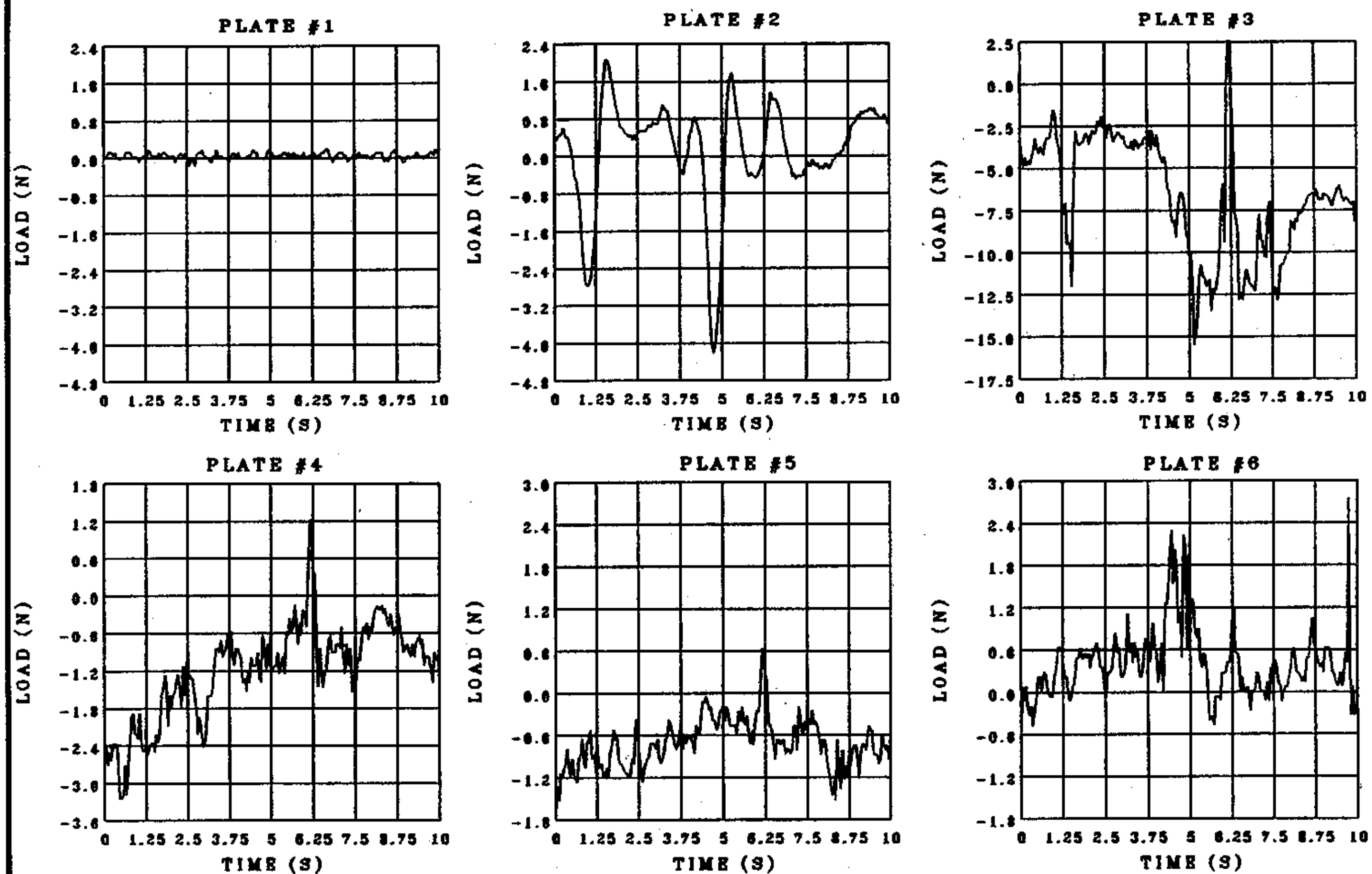
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN ← 003
TANGENTIAL LOAD



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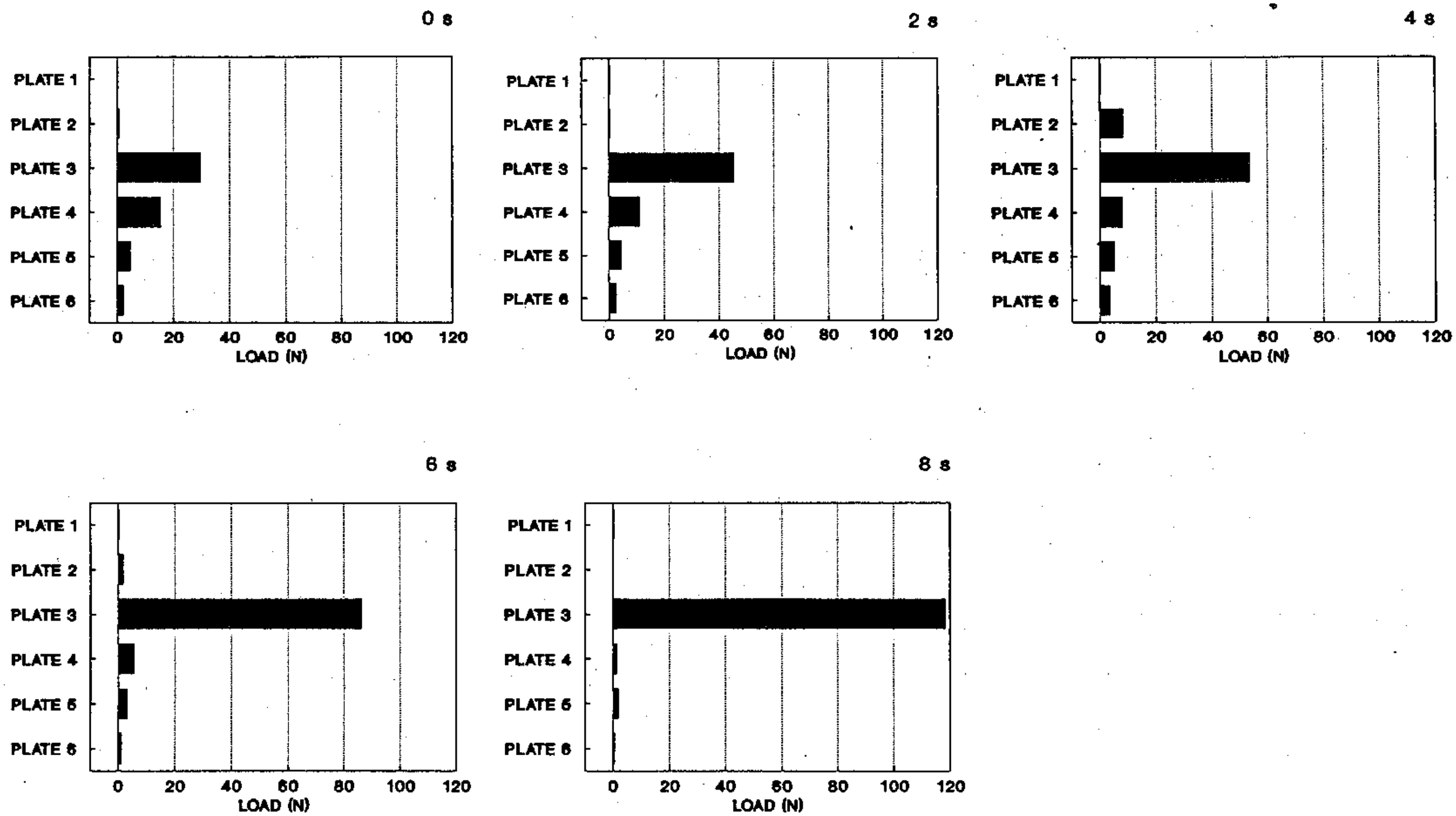
ICE PILEUP STUDY
for CANADIAN COAST GUARD

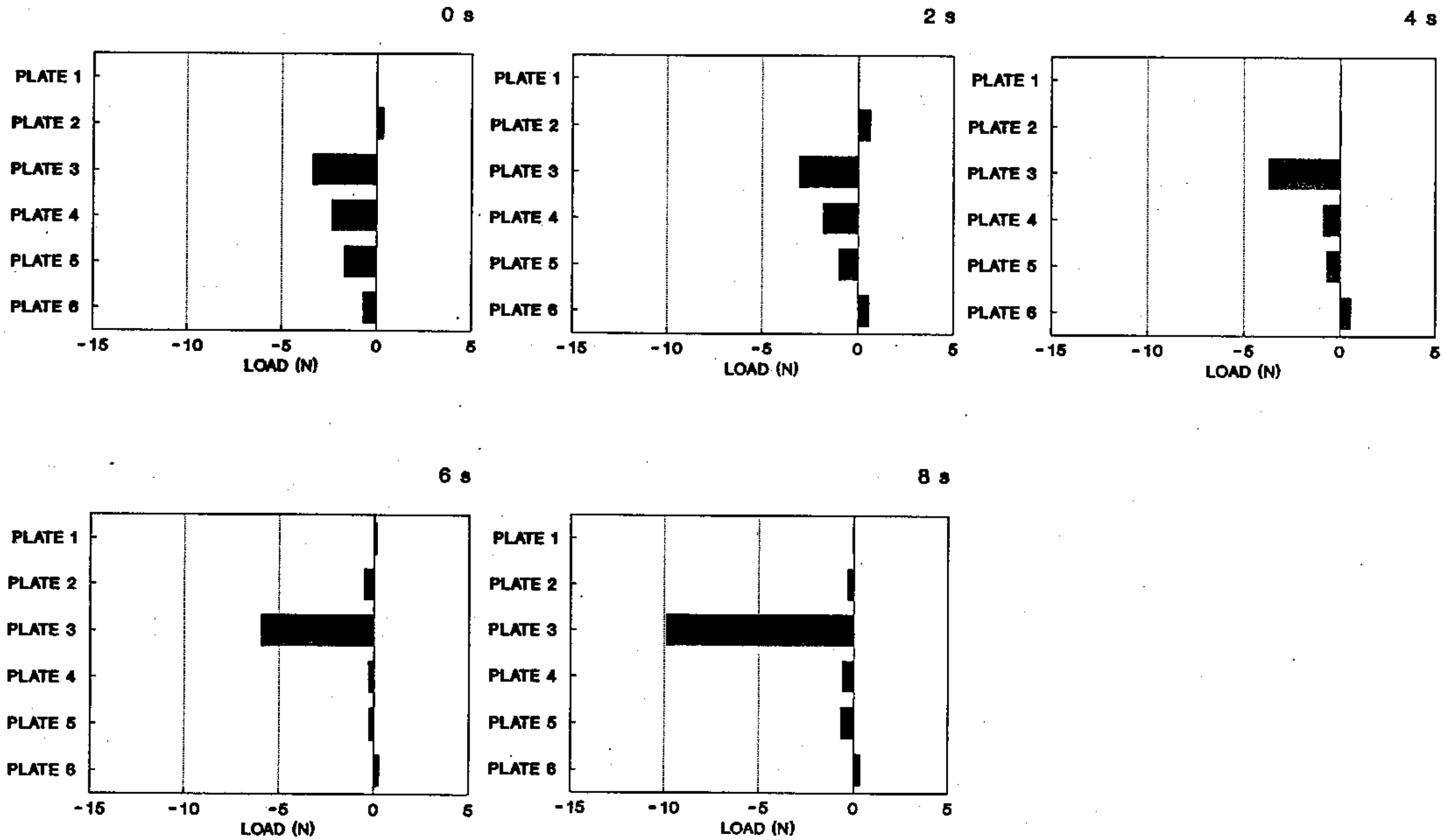
TIME SEQUENCE : NORMAL LOADS

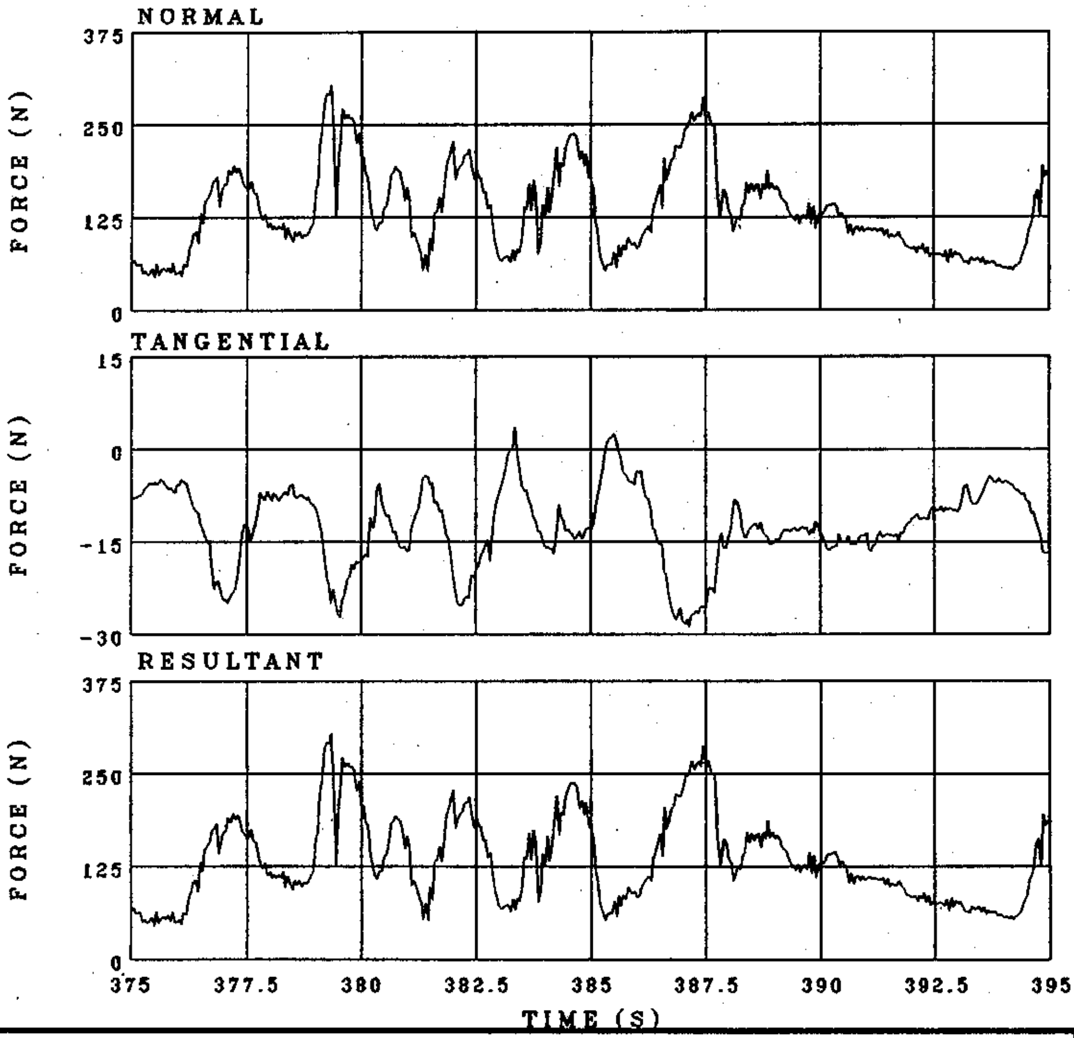
TN_003



TIME SEQUENCE : TANGENTIAL LOADS

TN_003





FILE TN←004

TOTAL

NORMAL

MEAN FORCE = 132.6 N
MAX FORCE = 303.0 N
MIN FORCE = 43.93 N

TANGENTIAL

MEAN FORCE = -12.43 N
MAX FORCE = 3.612 N
MIN FORCE = -28.74 N

RESULTANT

MEAN FORCE = 133.2 N
MAX FORCE = 304.0 N
MIN FORCE = 44.23 N

TEST CONDITIONS

BOARD ANGLE = -15.00 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 70.00 kPa
ICE THICKNESS = 3.500 cm
ICE DENSITY = 0.9300 g/cc

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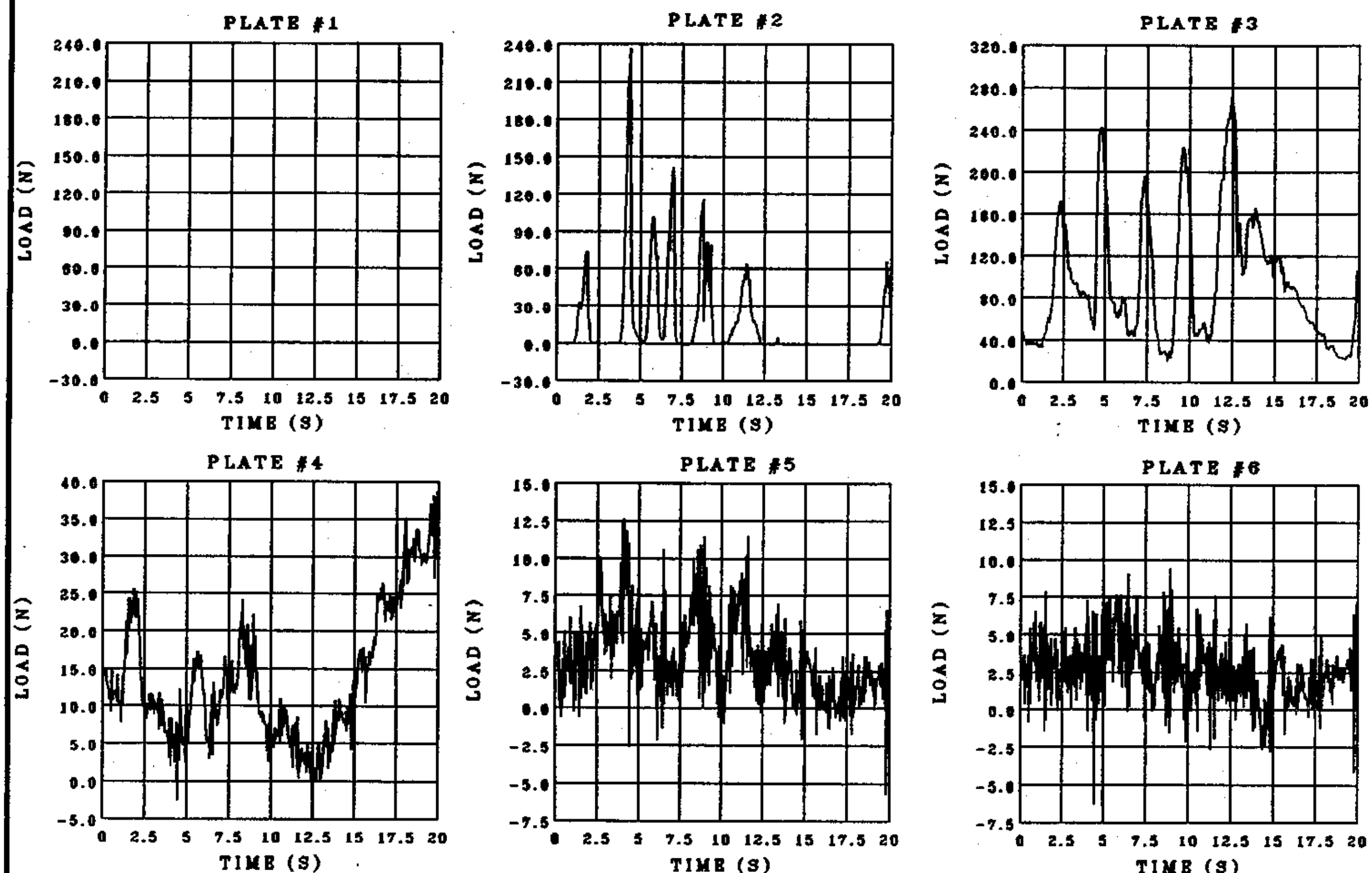
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←004
NORMAL LOAD



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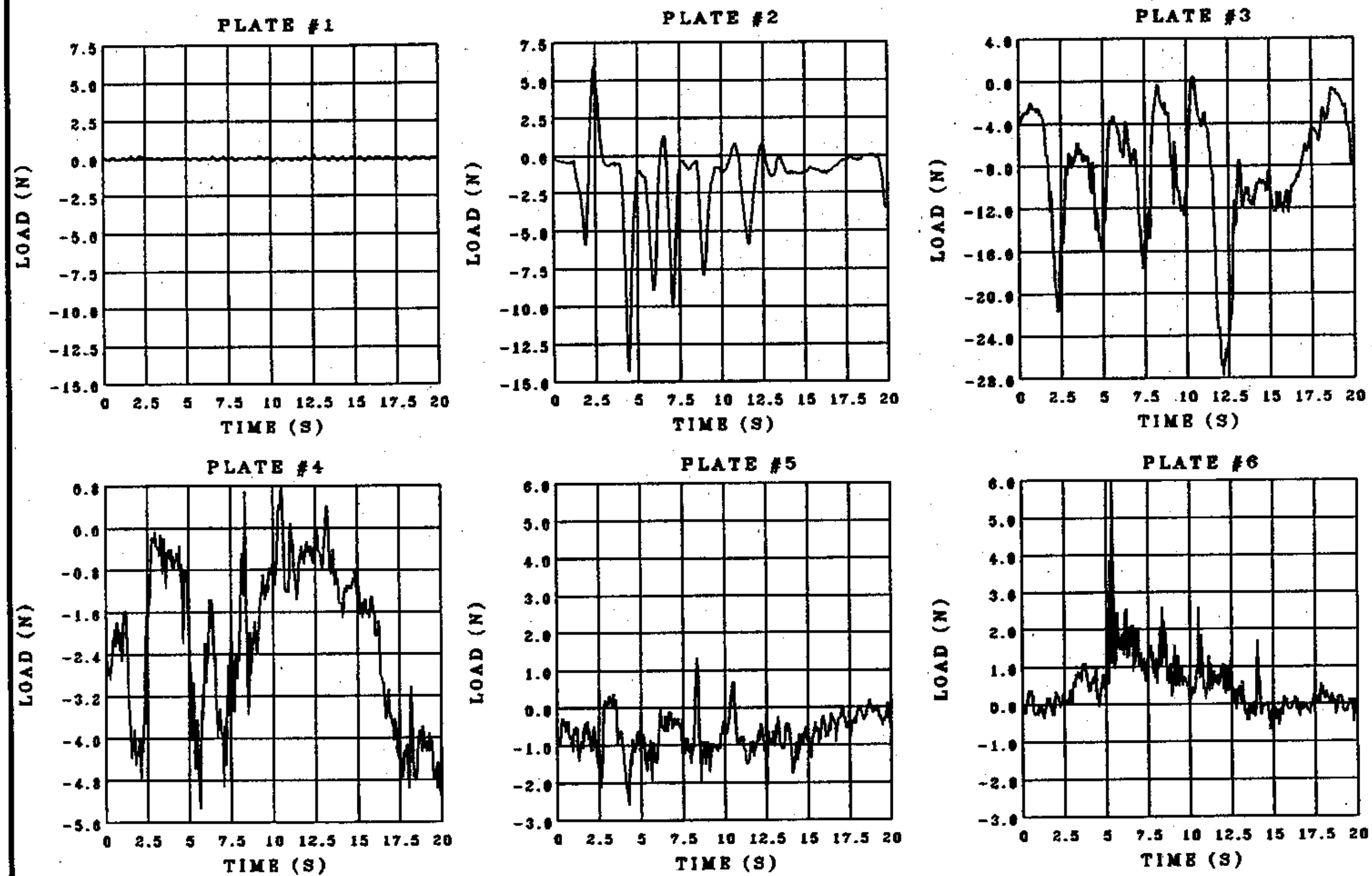
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←004

TANGENTIAL LOAD



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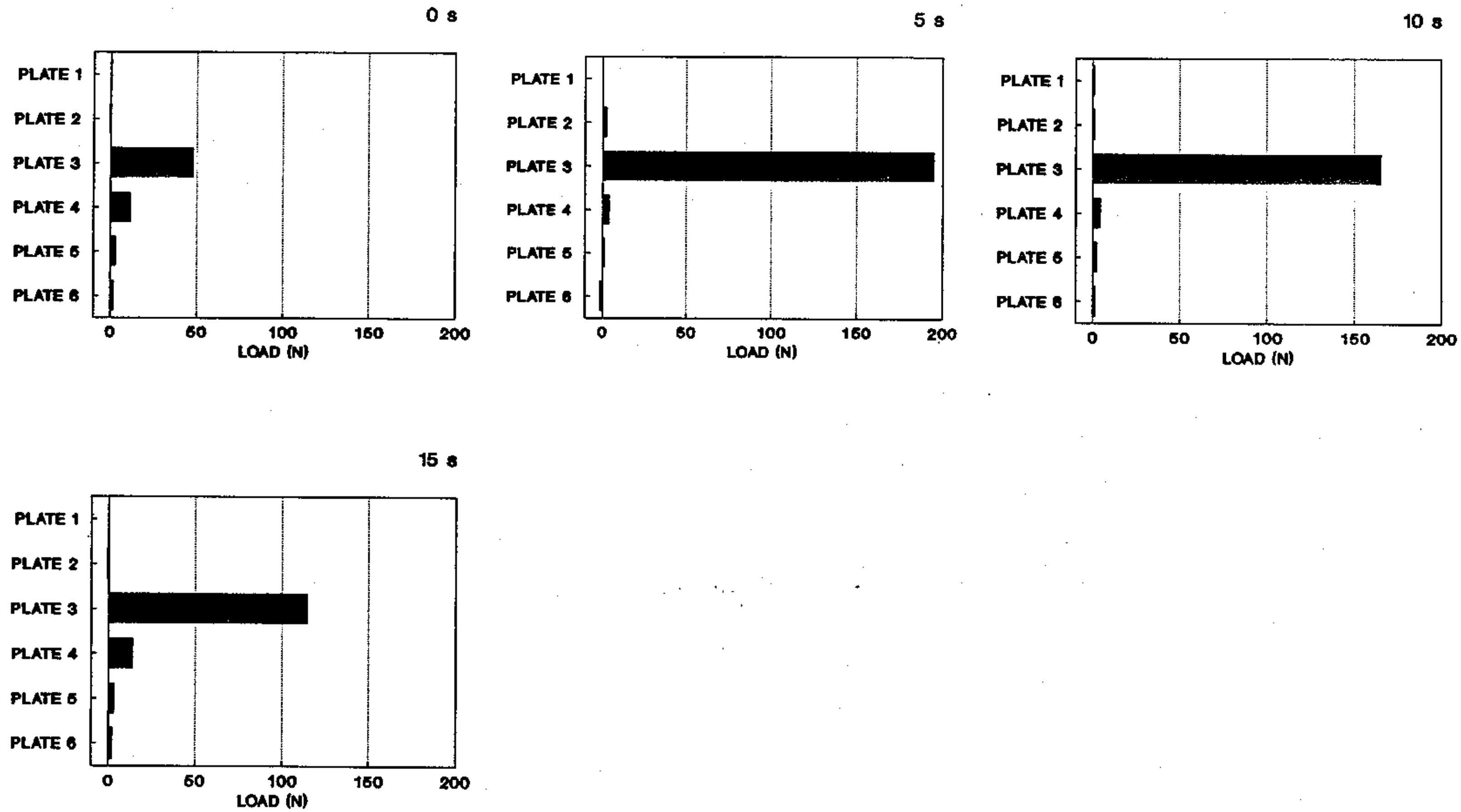
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TIME SEQUENCE : NORMAL LOADS

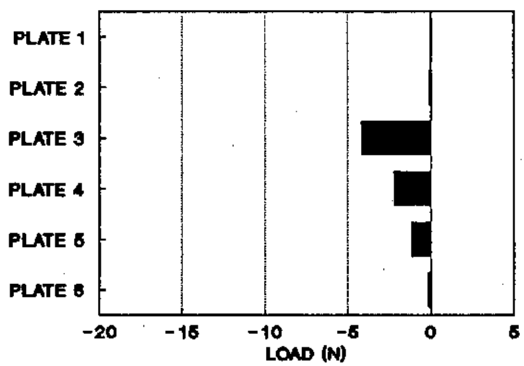
TN_004



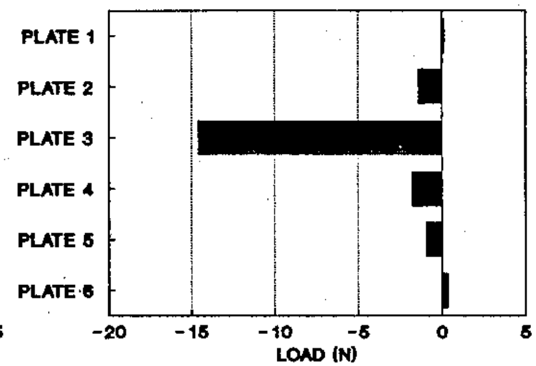
TIME SEQUENCE : TANGENTIAL LOADS

TN_004

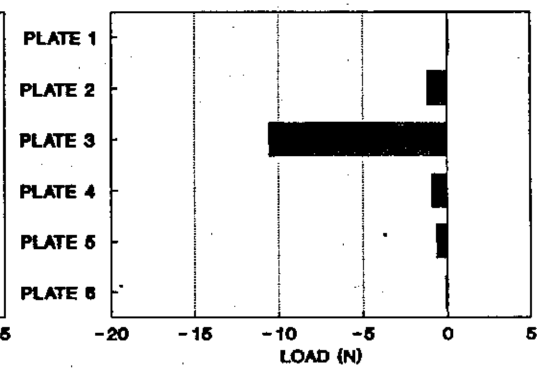
0 s



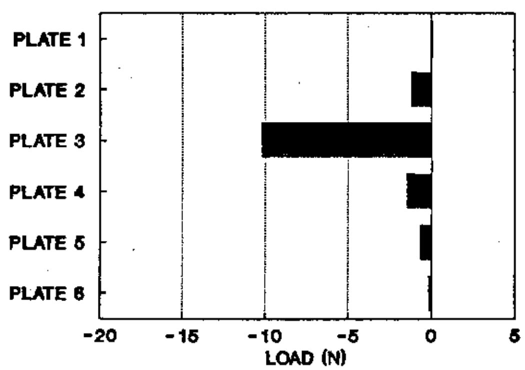
5 s

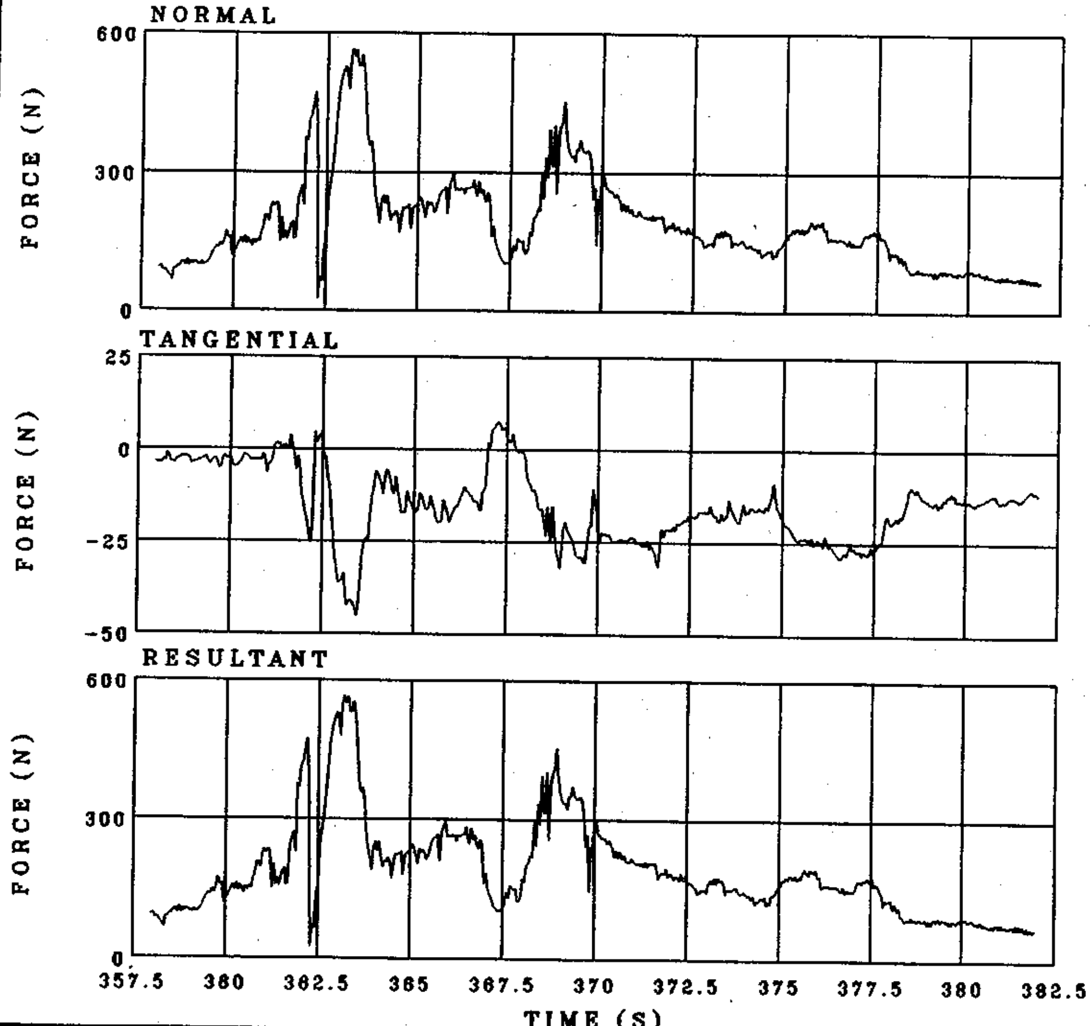


10 s



15 s





FILE TN←005

TOTAL

NORMAL

MEAN FORCE = 188.9 N
MAX FORCE = 565.4 N
MIN FORCE = 24.71 N

TANGENTIAL

MEAN FORCE = -15.05 N
MAX FORCE = 7.753 N
MIN FORCE = -45.33 N

RESULTANT

MEAN FORCE = 189.7 N
MAX FORCE = 567.0 N
MIN FORCE = 25.17 N

TEST CONDITIONS

BOARD ANGLE = -5.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 86.00 kPa
ICE THICKNESS = 3.300 cm
ICE DENSITY = 0.9300 g/cc

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ICE PILEUP STUDY
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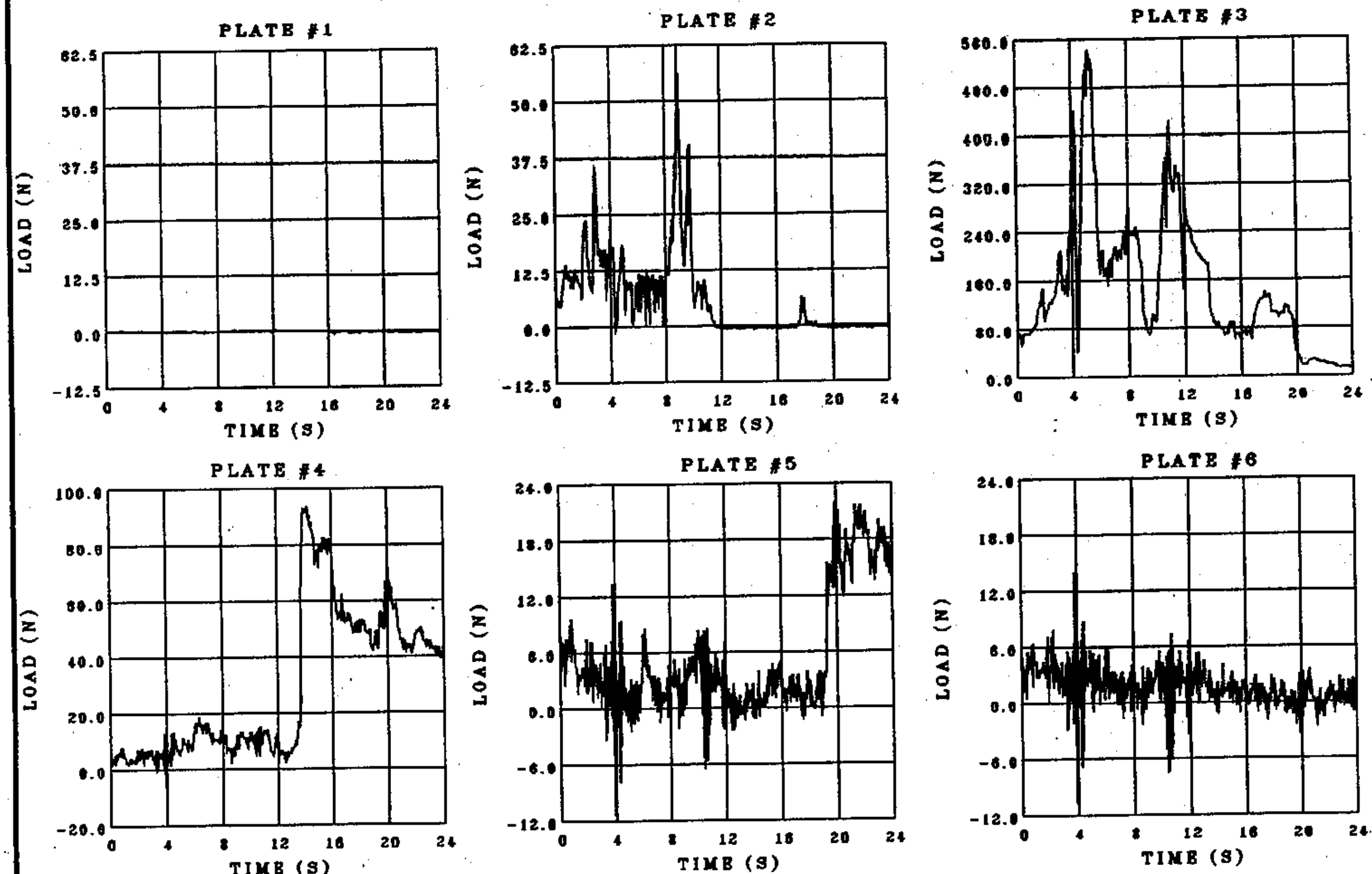
TN ← 005
NORMAL LOAD



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ICE PILEUP STUDY
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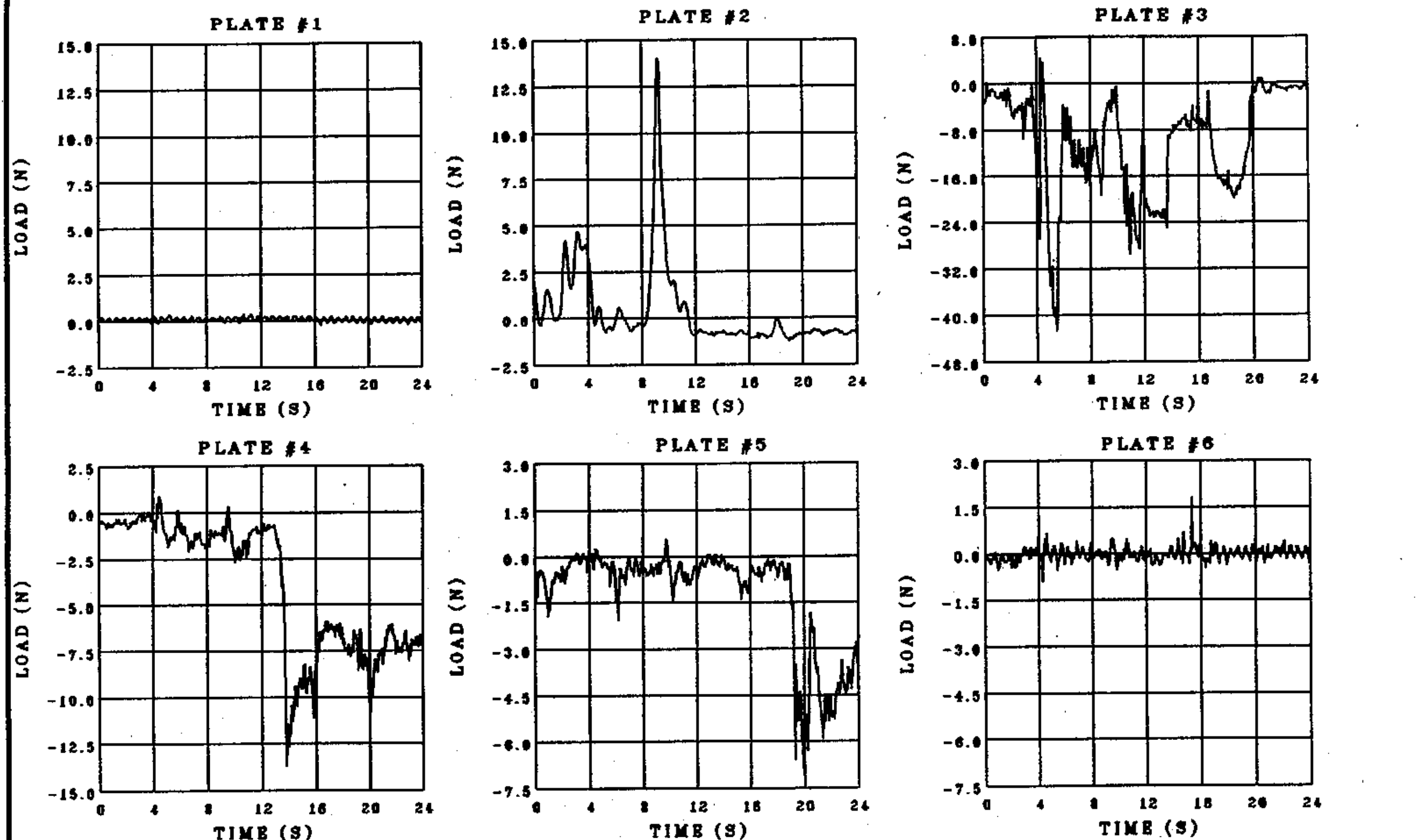
TN←005

TANGENTIAL LOAD



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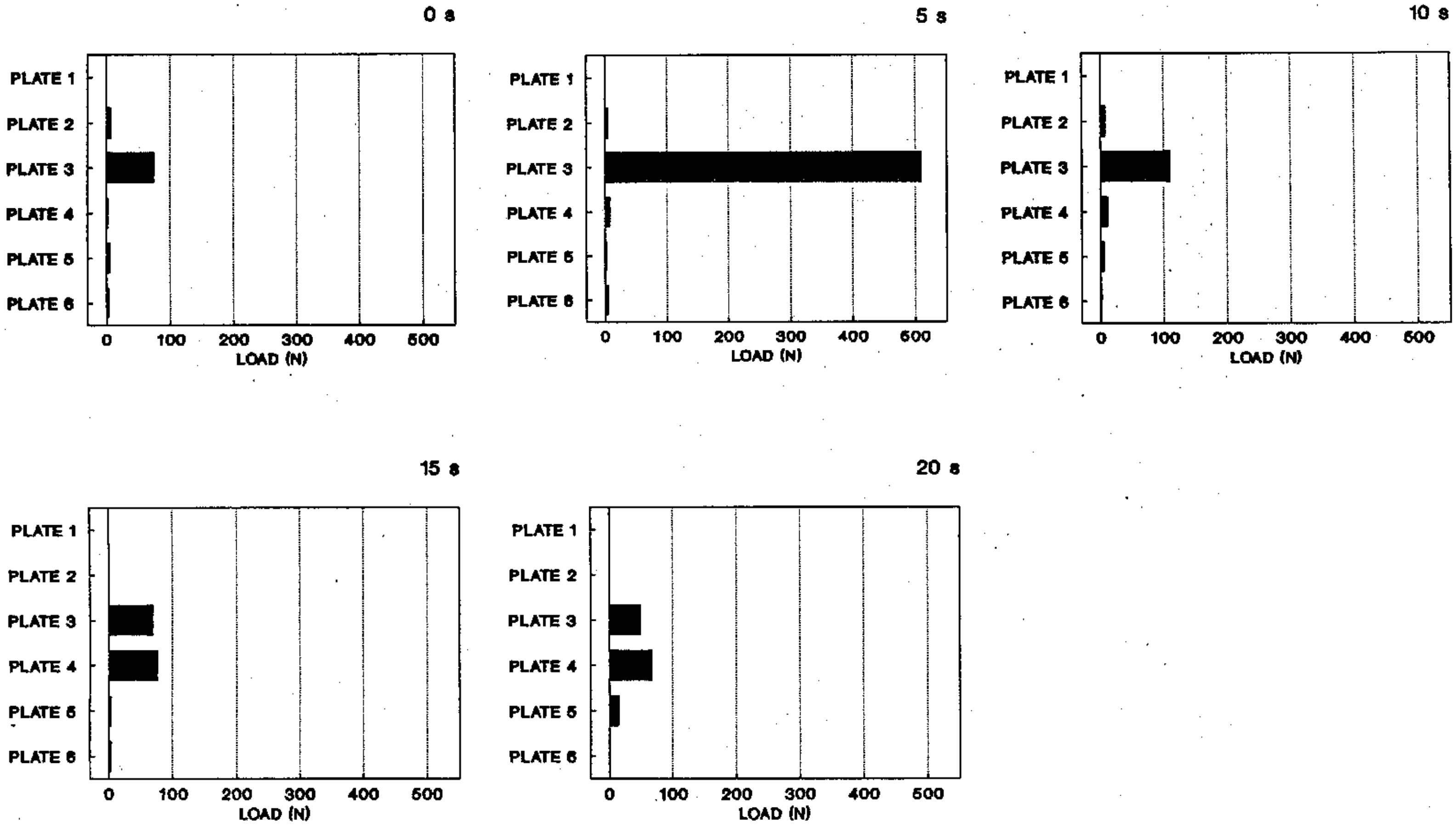
ICE PILEUP STUDY for CANADIAN COAST GUARD

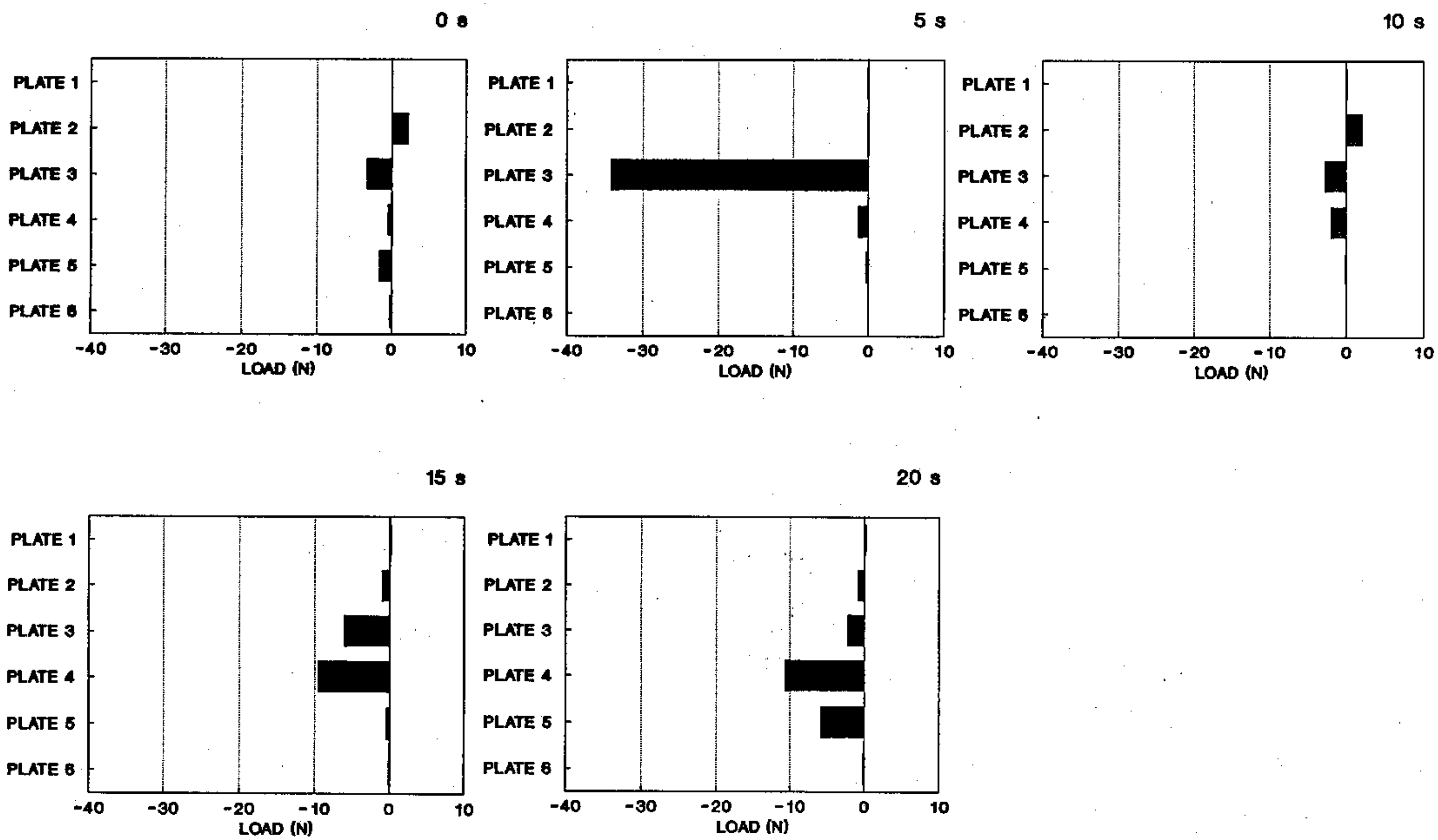
TIME SEQUENCE : NORMAL LOADS

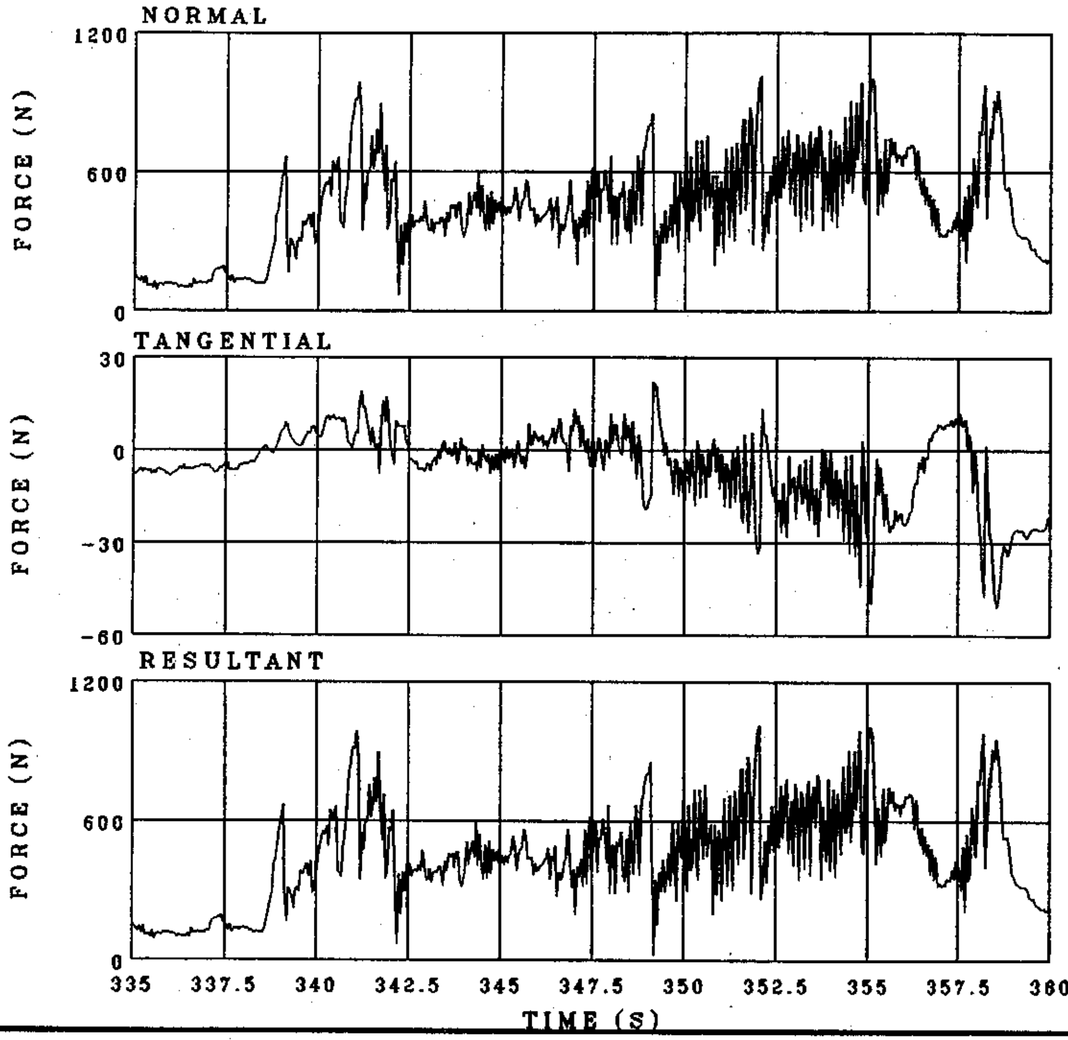
TN_005



TIME SEQUENCE : TANGENTIAL LOADS

TN_005





FILE TN←006

TOTAL

NORMAL

MEAN FORCE = 446.9 N
MAX FORCE = 1015.0 N
MIN FORCE = 2.786 N

TANGENTIAL

MEAN FORCE = -5.582 N
MAX FORCE = 22.15 N
MIN FORCE = -50.98 N

RESULTANT

MEAN FORCE = 447.1 N
MAX FORCE = 1016.0 N
MIN FORCE = 21.32 N

TEST CONDITIONS

BOARD ANGLE = 0.0 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 64.00 kPa
ICE THICKNESS = 3.200 cm
ICE DENSITY = 0.9300 g/cc

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ICE PILEUP STUDY
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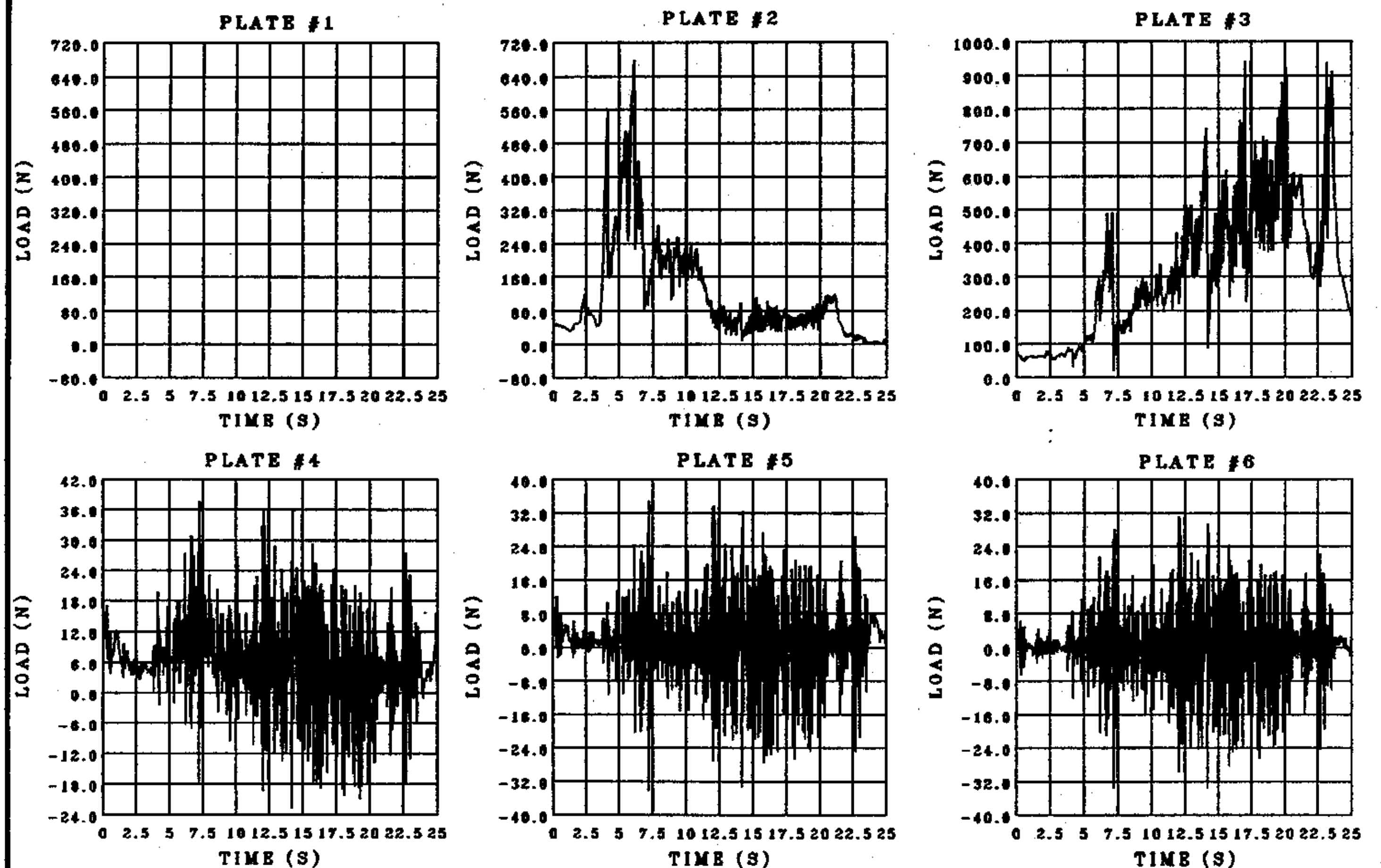
TN←006
NORMAL LOAD



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ICE PILEUP STUDY
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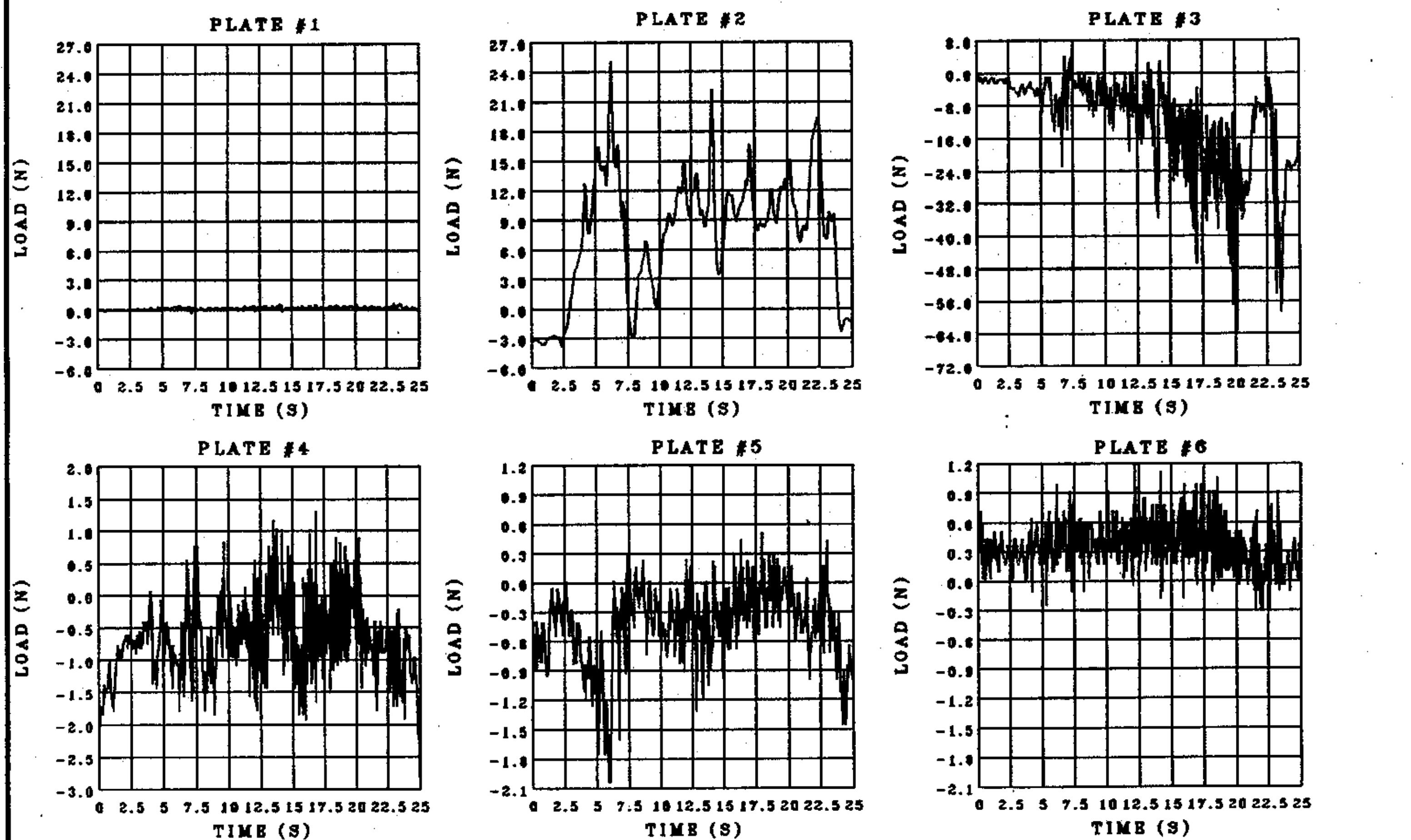
TN←006
TANGENTIAL LOAD



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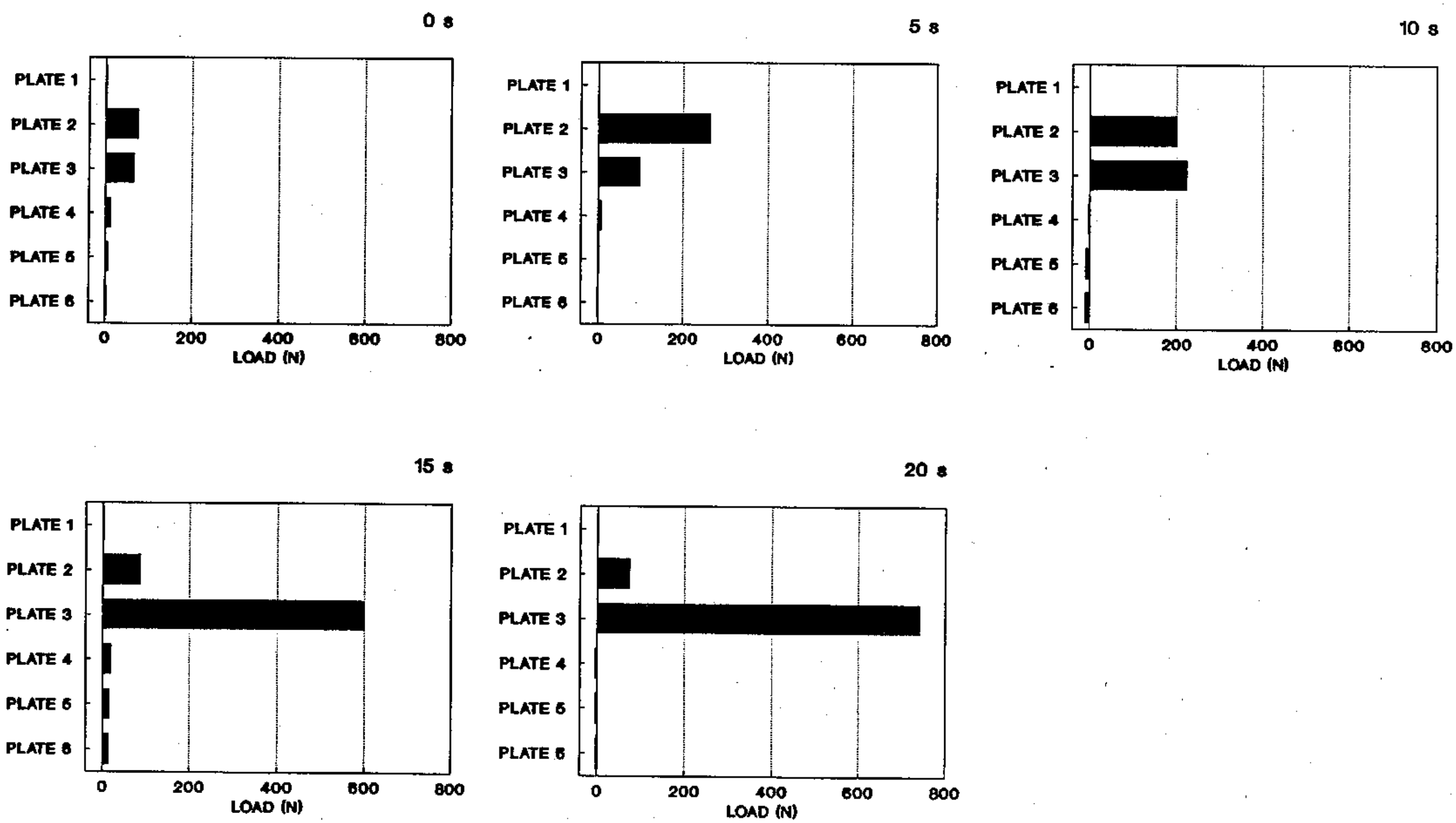
ICE PILEUP STUDY
for CANADIAN COAST GUARD

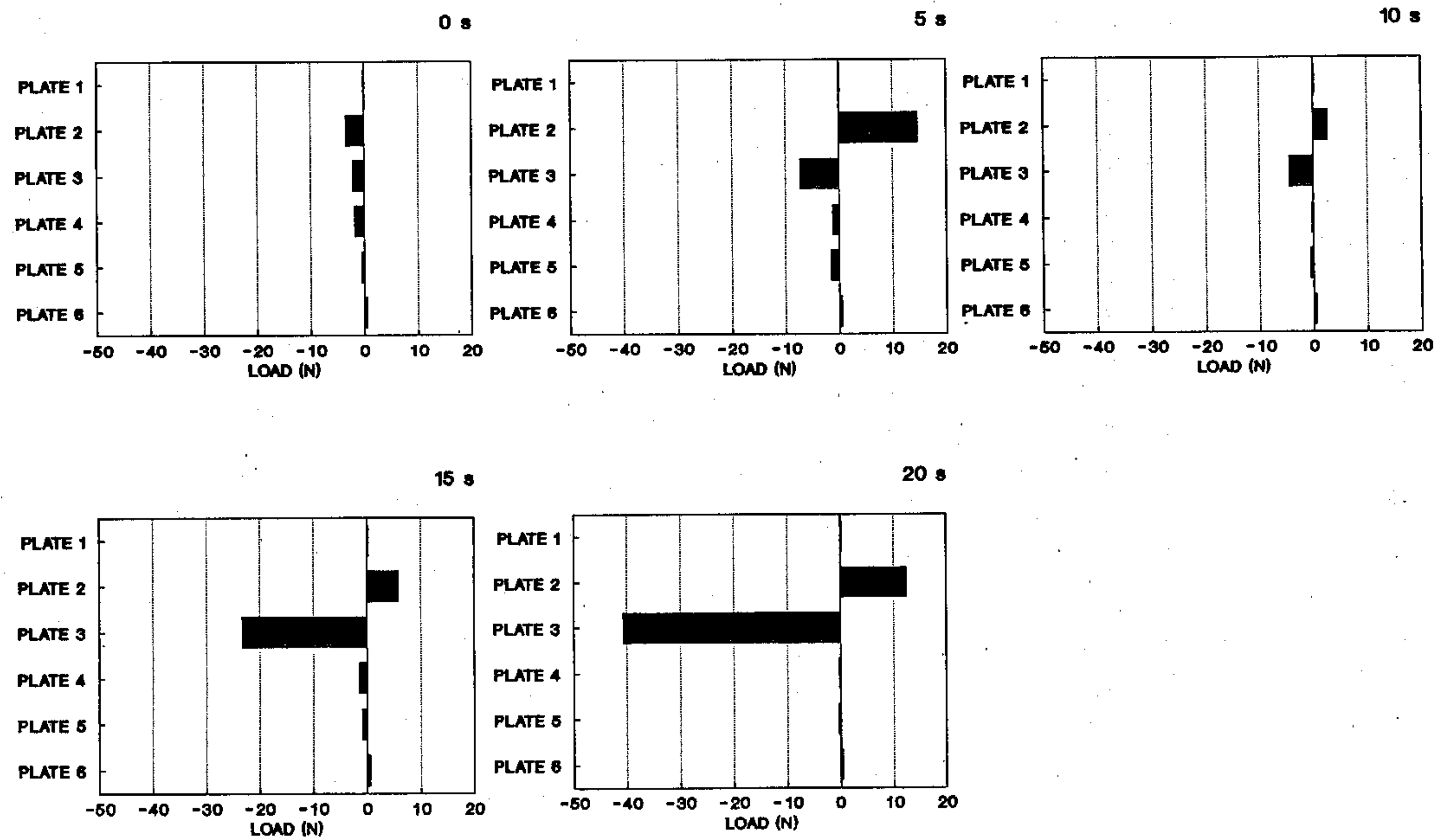
TIME SEQUENCE : NORMAL LOADS

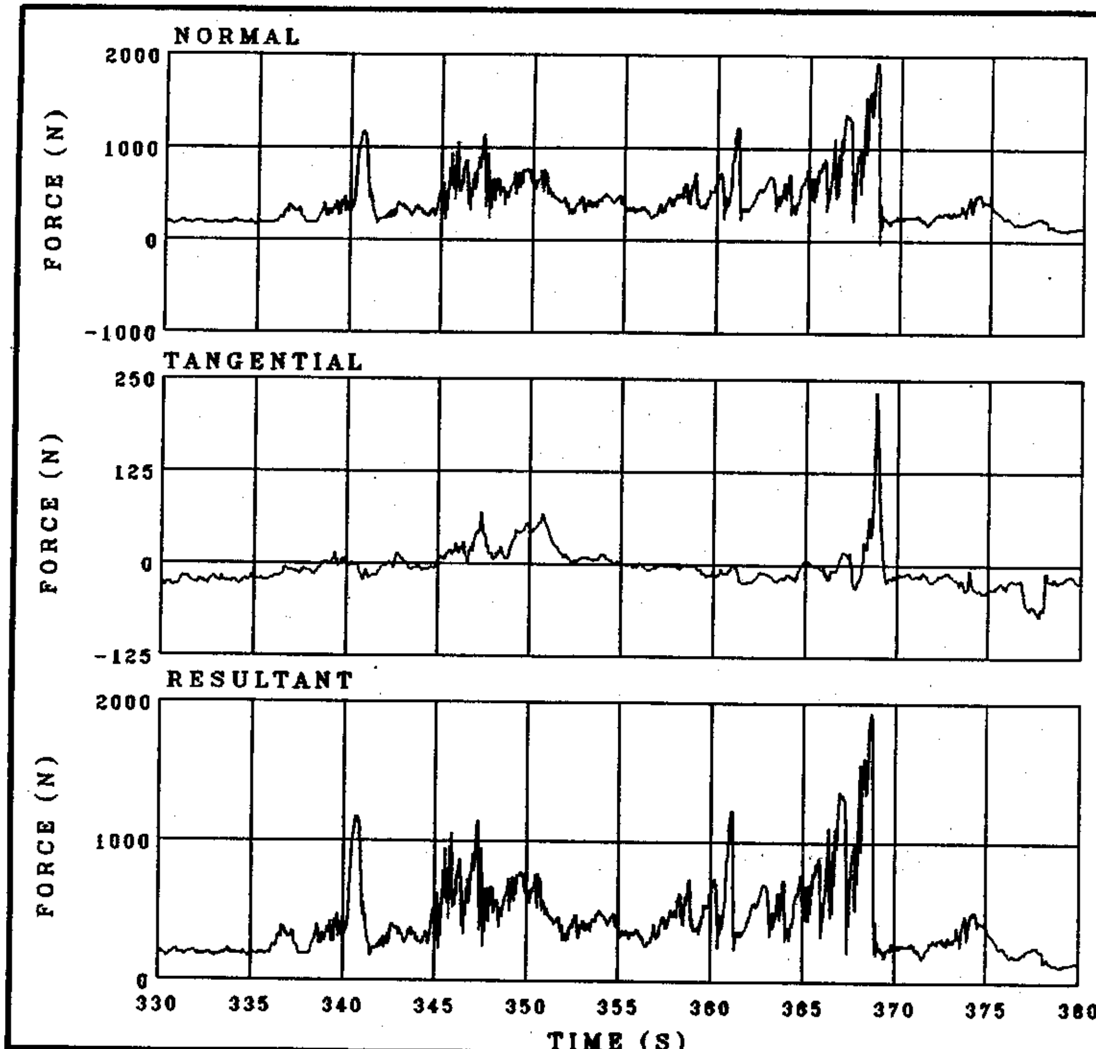
TN_006



TIME SEQUENCE : TANGENTIAL LOADS

TN_006





FILE TN←007

TOTAL

NORMAL

MEAN FORCE = 424.1 N
MAX FORCE = 1933.0 N
MIN FORCE = -41.64 N

TANGENTIAL

MEAN FORCE = -5.148 N
MAX FORCE = 233.6 N
MIN FORCE = -68.57 N

RESULTANT

MEAN FORCE = 425.3 N
MAX FORCE = 1935.0 N
MIN FORCE = 116.3 N

TEST CONDITIONS

BOARD ANGLE = 8.000 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 101.0 kPa
ICE THICKNESS = 3.500 cm
ICE DENSITY = 0.9300 g/cc

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ICE PILEUP STUDY
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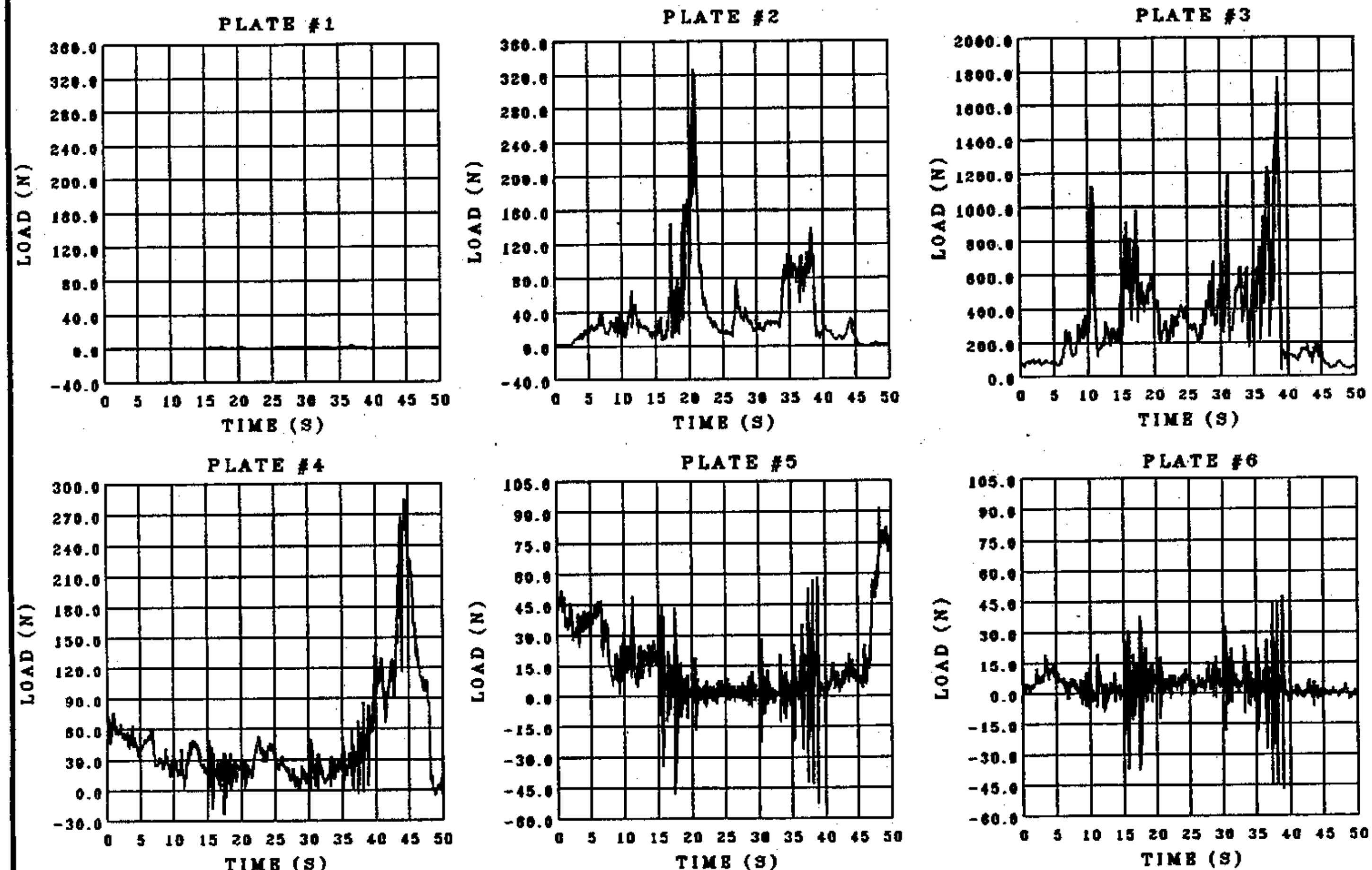
TN←007
NORMAL LOAD



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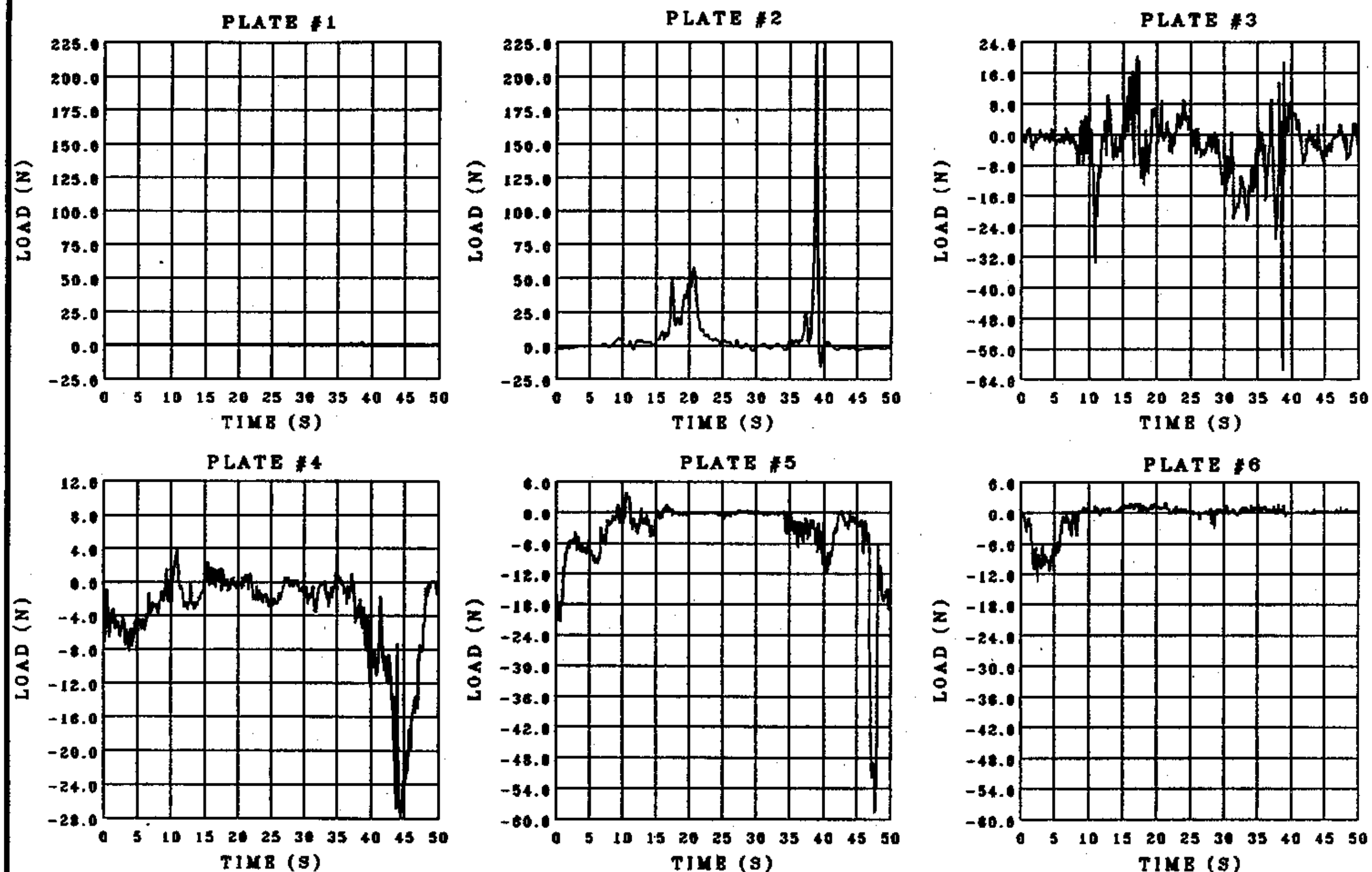
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN ← 007
TANGENTIAL LOAD



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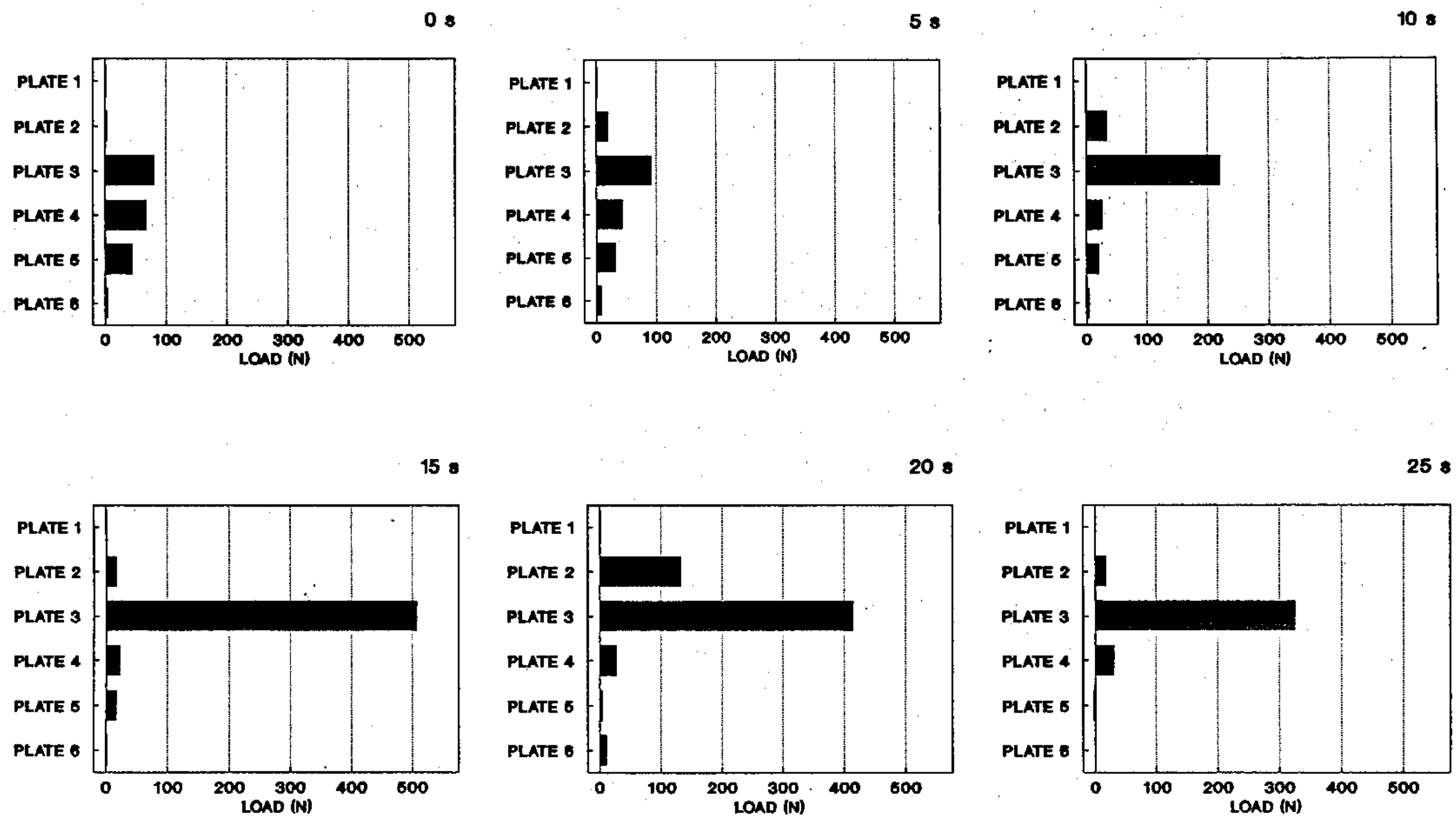
ICE PILEUP STUDY
for CANADIAN COAST GUARD

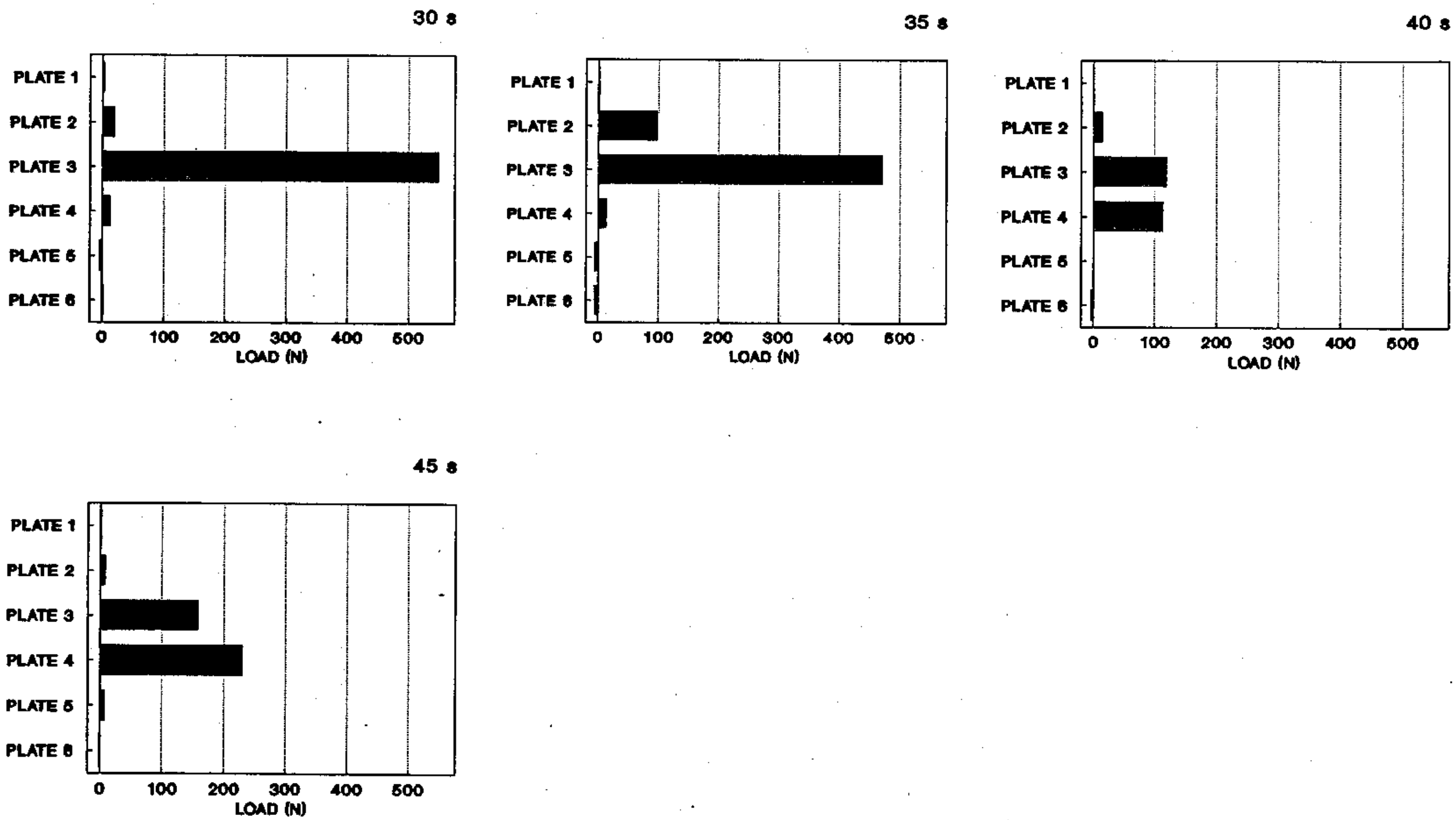
TIME SEQUENCE : NORMAL LOADS

TN_007



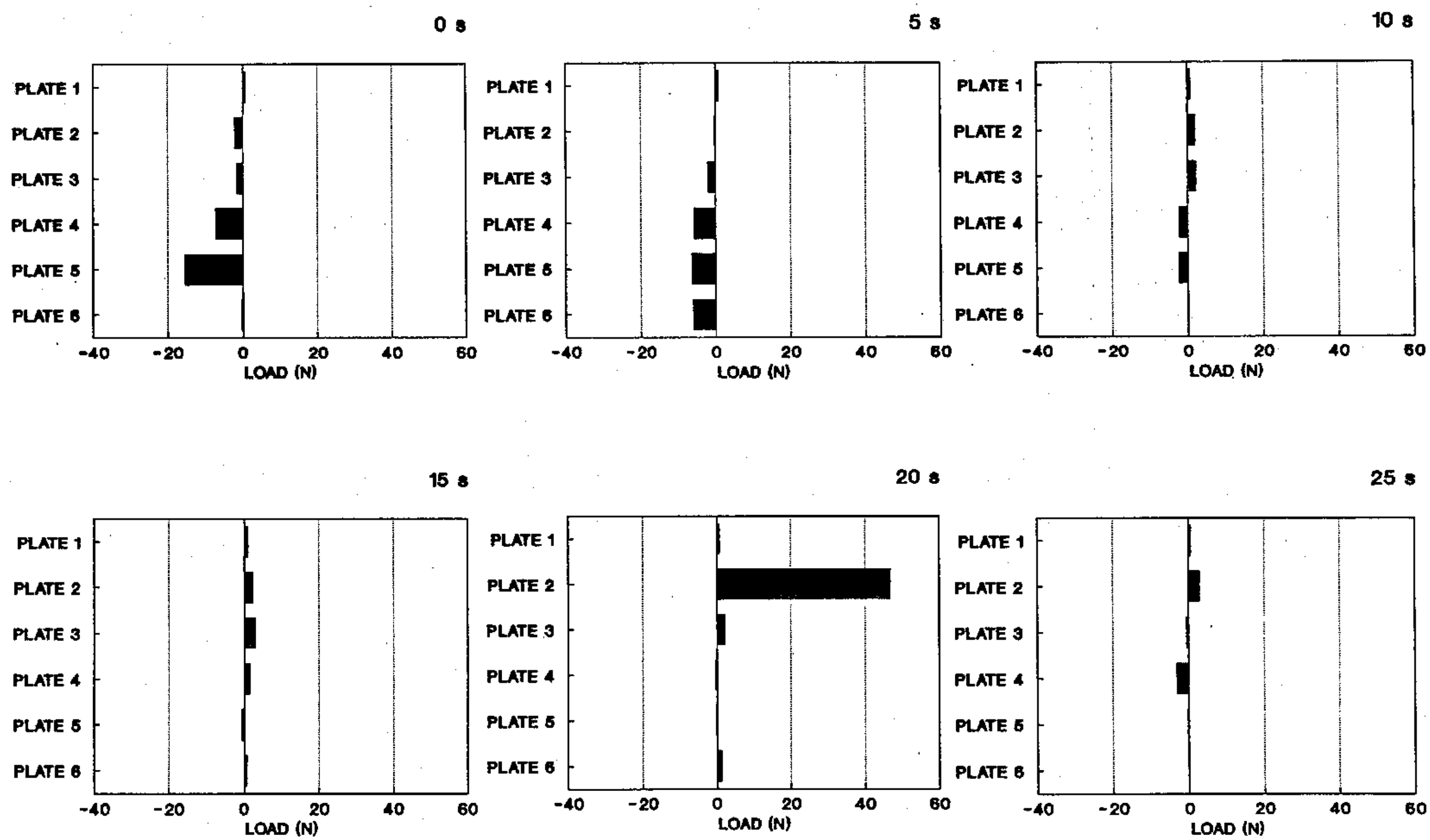
TIME SEQUENCE : NORMAL LOADS

TN_007



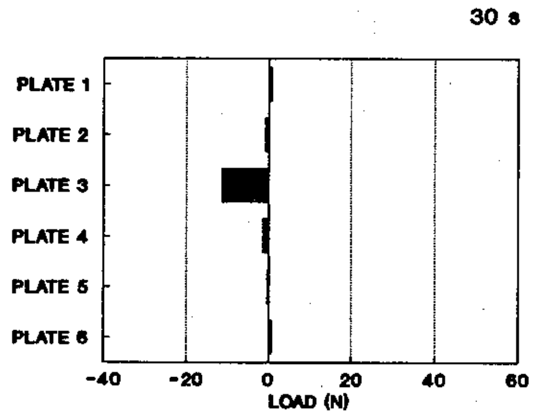
TIME SEQUENCE : TANGENTIAL LOADS

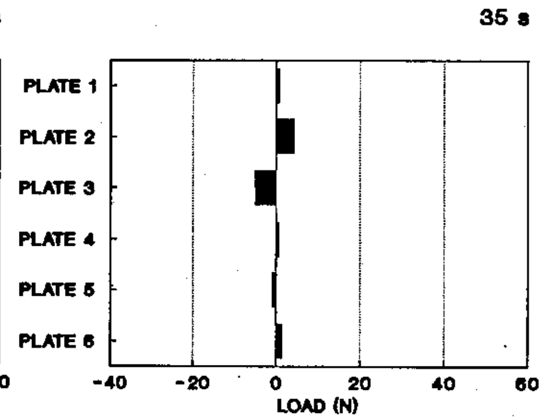
TN_007

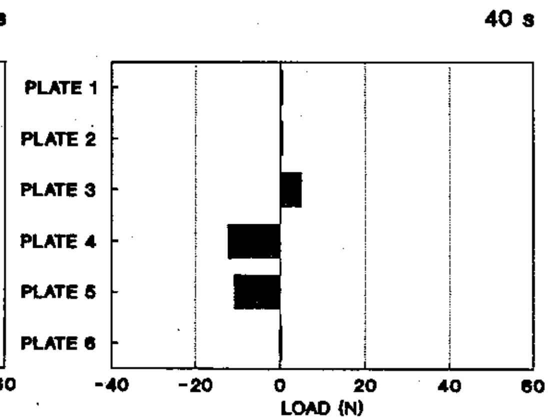


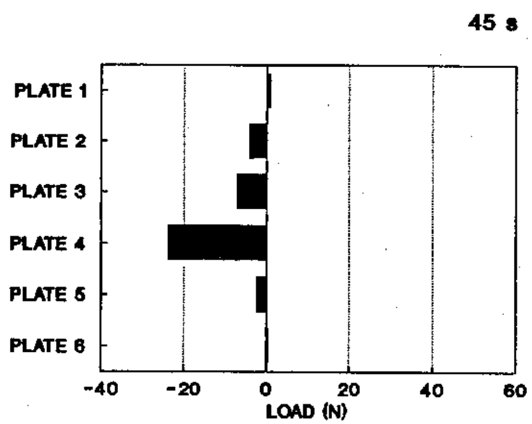
TIME SEQUENCE : TANGENTIAL LOADS

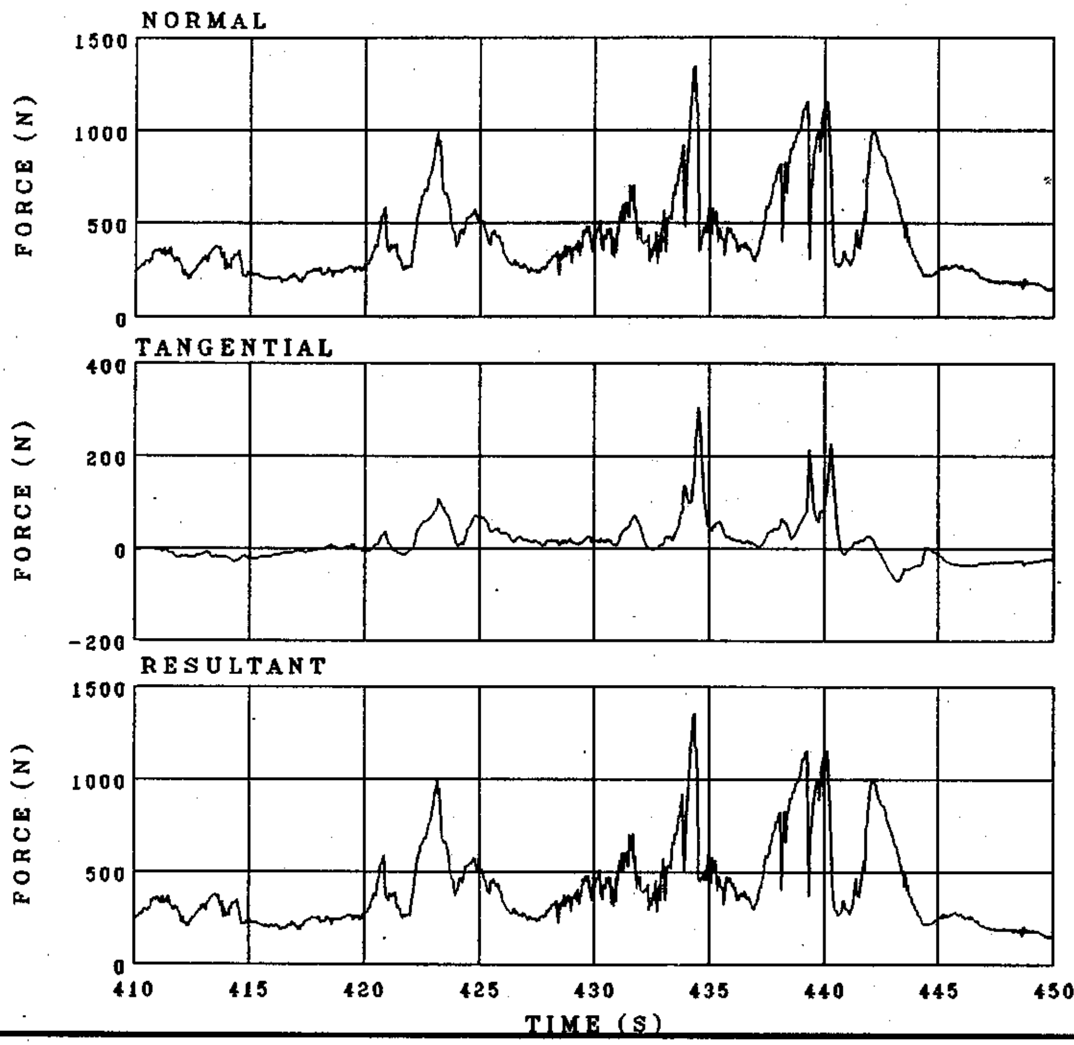
TN_007











FILE TN←008

TOTAL

NORMAL

MEAN FORCE = 409.9 N
MAX FORCE = 1349.0 N
MIN FORCE = 142.7 N

TANGENTIAL

MEAN FORCE = 13.32 N
MAX FORCE = 306.2 N
MIN FORCE = -68.55 N

RESULTANT

MEAN FORCE = 412.0 N
MAX FORCE = 1358.0 N
MIN FORCE = 144.0 N

TEST CONDITIONS

BOARD ANGLE = 15.00 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 85.00 kPa
ICE THICKNESS = 3.500 cm
ICE DENSITY = 0.9300 g/cc

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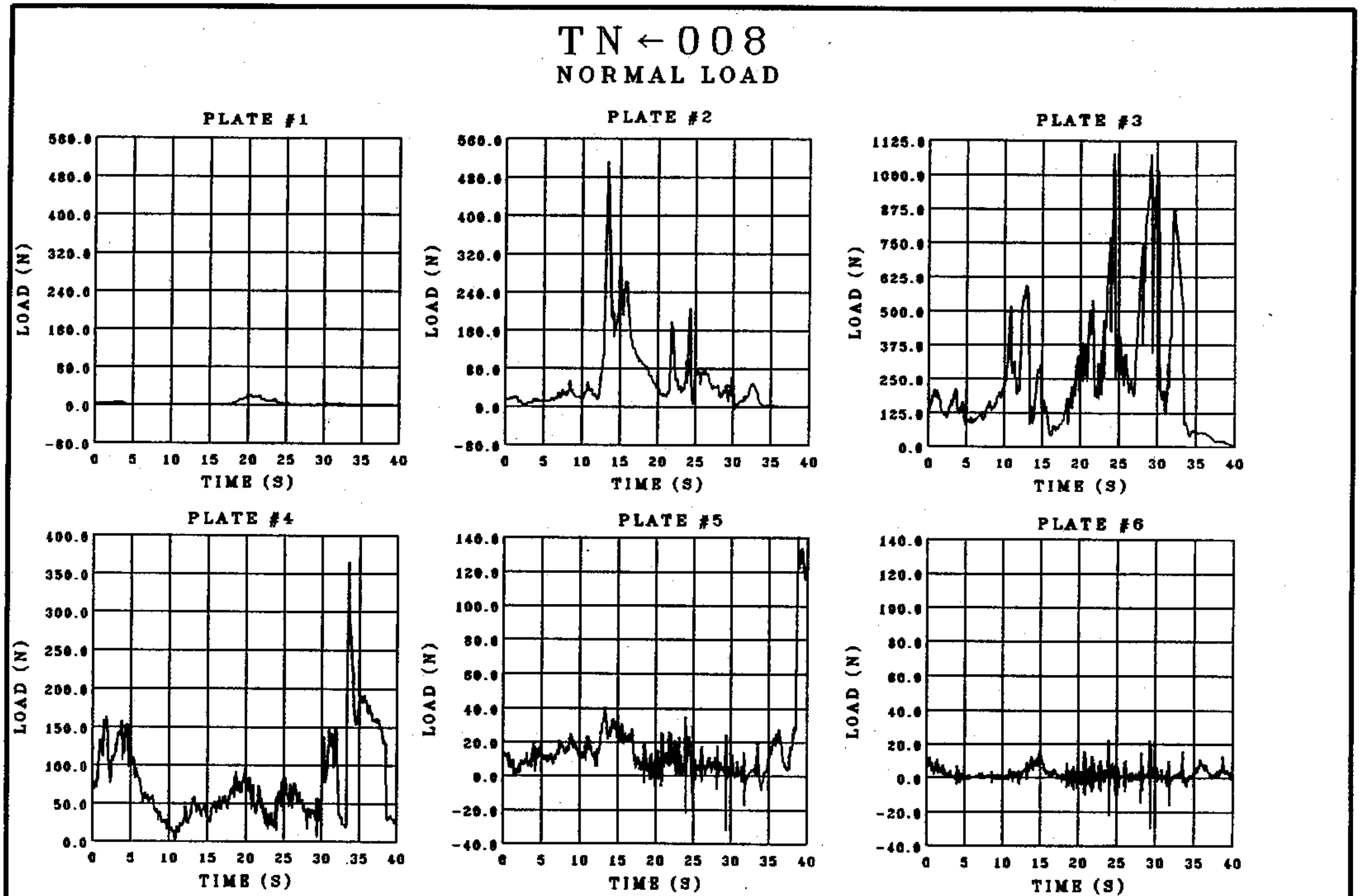
ICE PILEUP STUDY
for CANADIAN COAST GUARD



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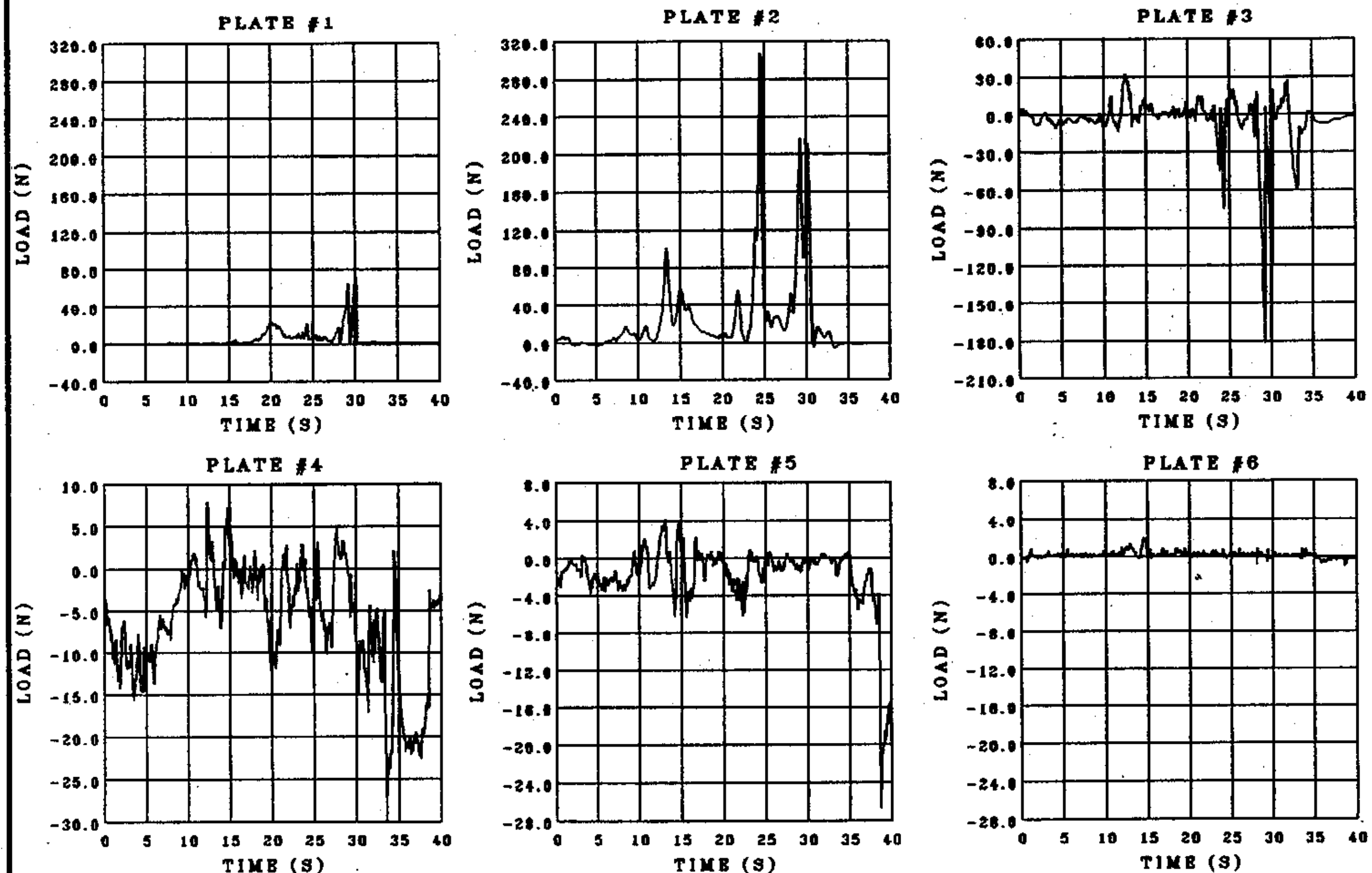
TN ← 008

TANGENTIAL LOAD



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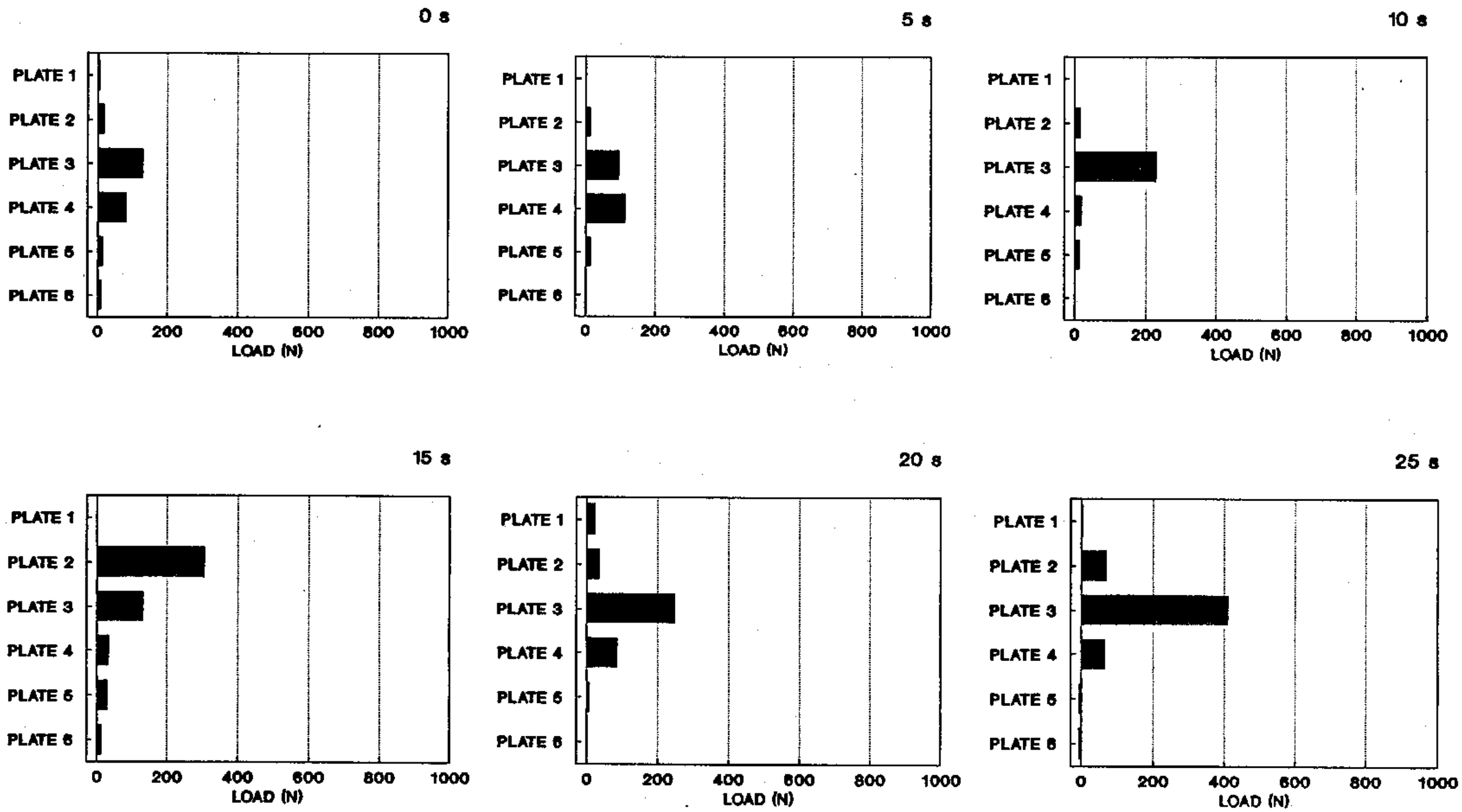
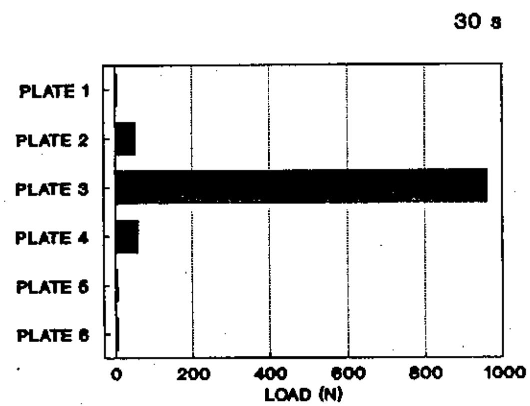
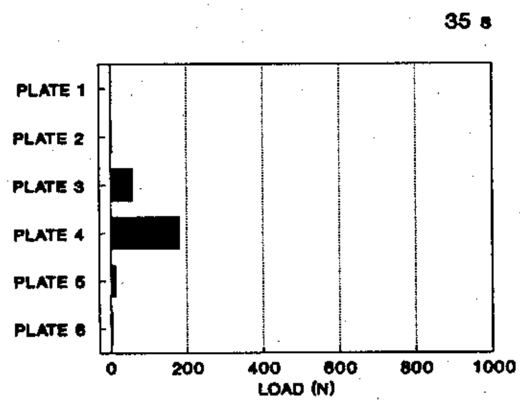
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TIME SEQUENCE : NORMAL LOADS
TN_008



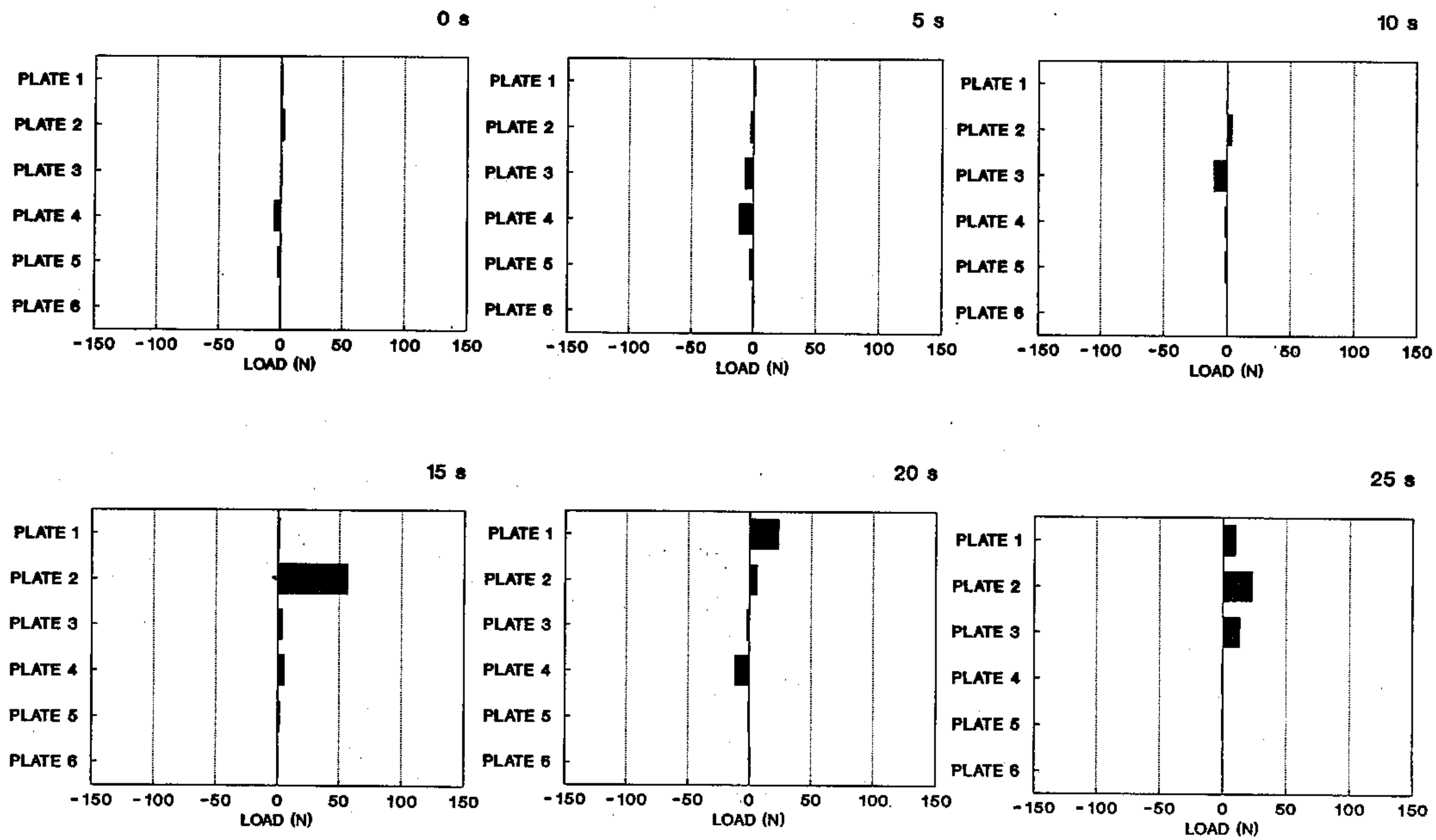
TIME SEQUENCE : NORMAL LOADS
TN_008





TIME SEQUENCE : TANGENTIAL LOADS

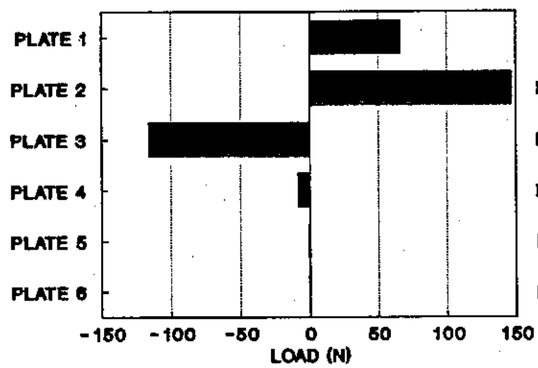
TN_008



TIME SEQUENCE : TANGENTIAL LOADS

TN_008

30 s



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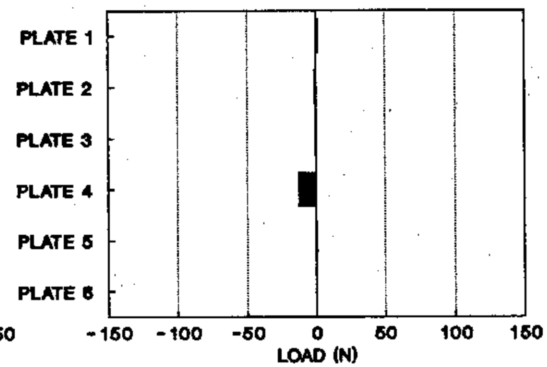

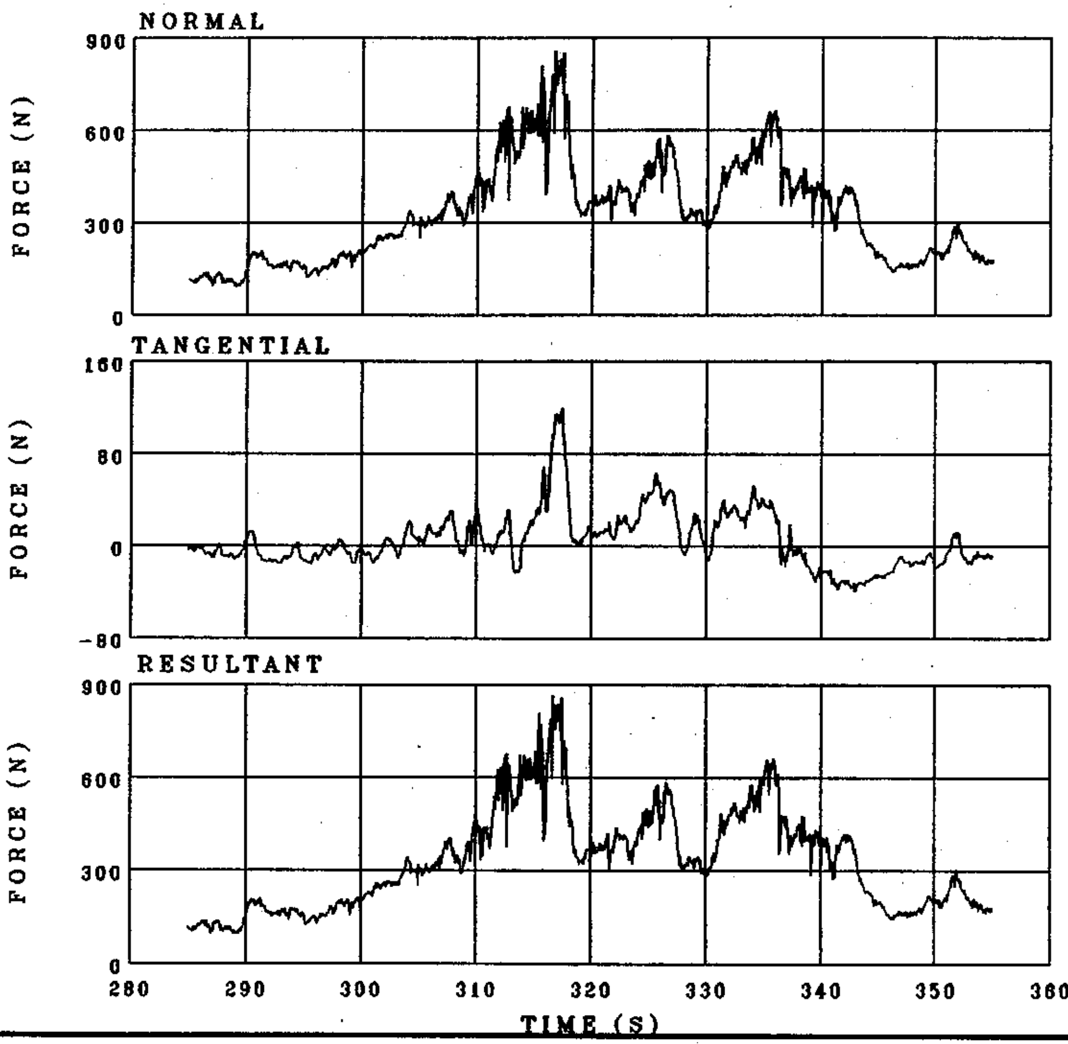

FILE TN←009

TOTAL

NORMAL

MEAN FORCE = 328.6 N
MAX FORCE = 859.3 N
MIN FORCE = 92.08 N

TANGENTIAL

MEAN FORCE = 4.397 N
MAX FORCE = 120.0 N
MIN FORCE = -39.71 N

RESULTANT

MEAN FORCE = 329.3 N
MAX FORCE = 864.3 N
MIN FORCE = 92.90 N

TEST CONDITIONS

BOARD ANGLE = 24.00 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 62.00 kPa
ICE THICKNESS = 3.600 cm
ICE DENSITY = 0.9300 g/cc

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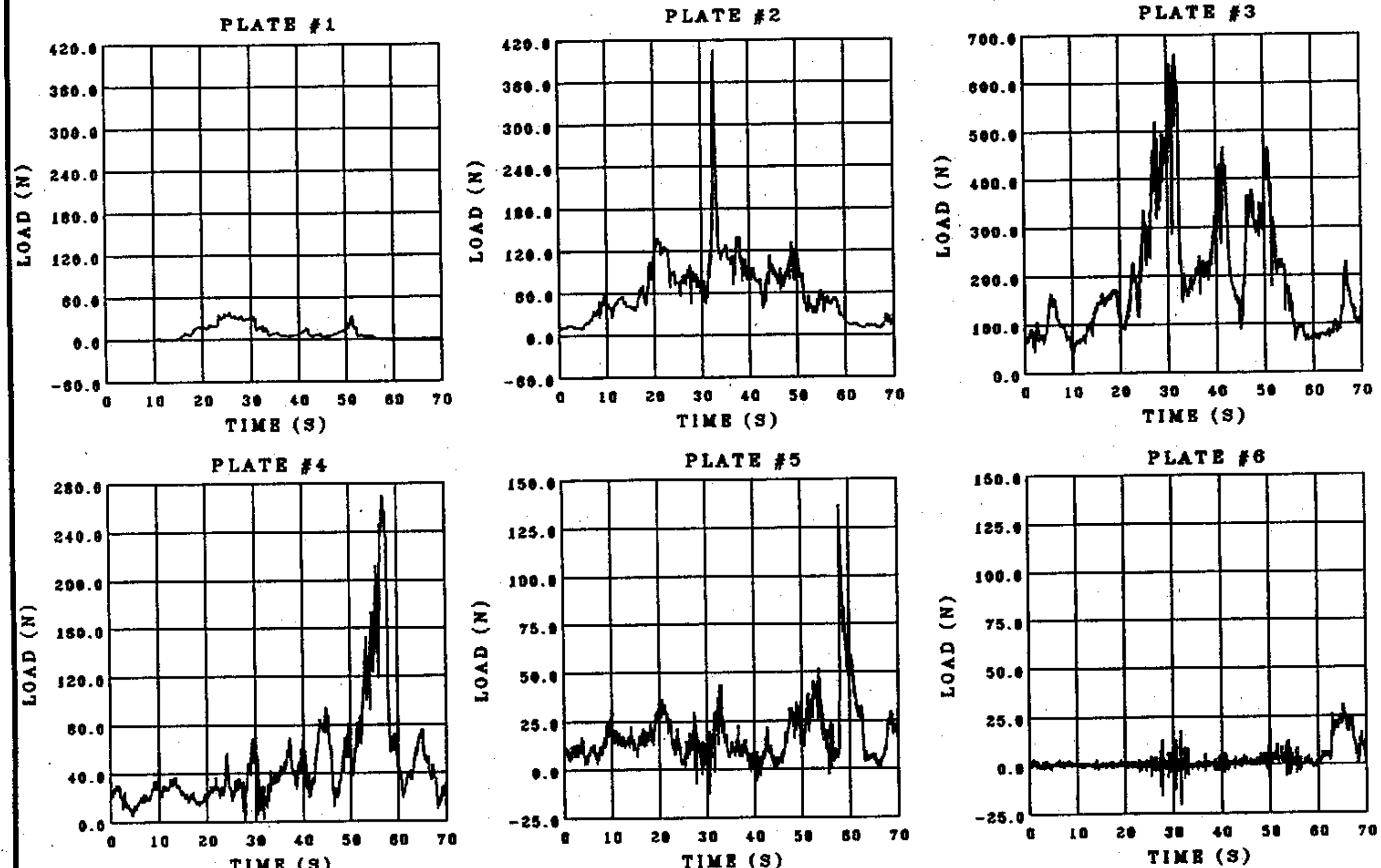
TN←009
NORMAL LOAD



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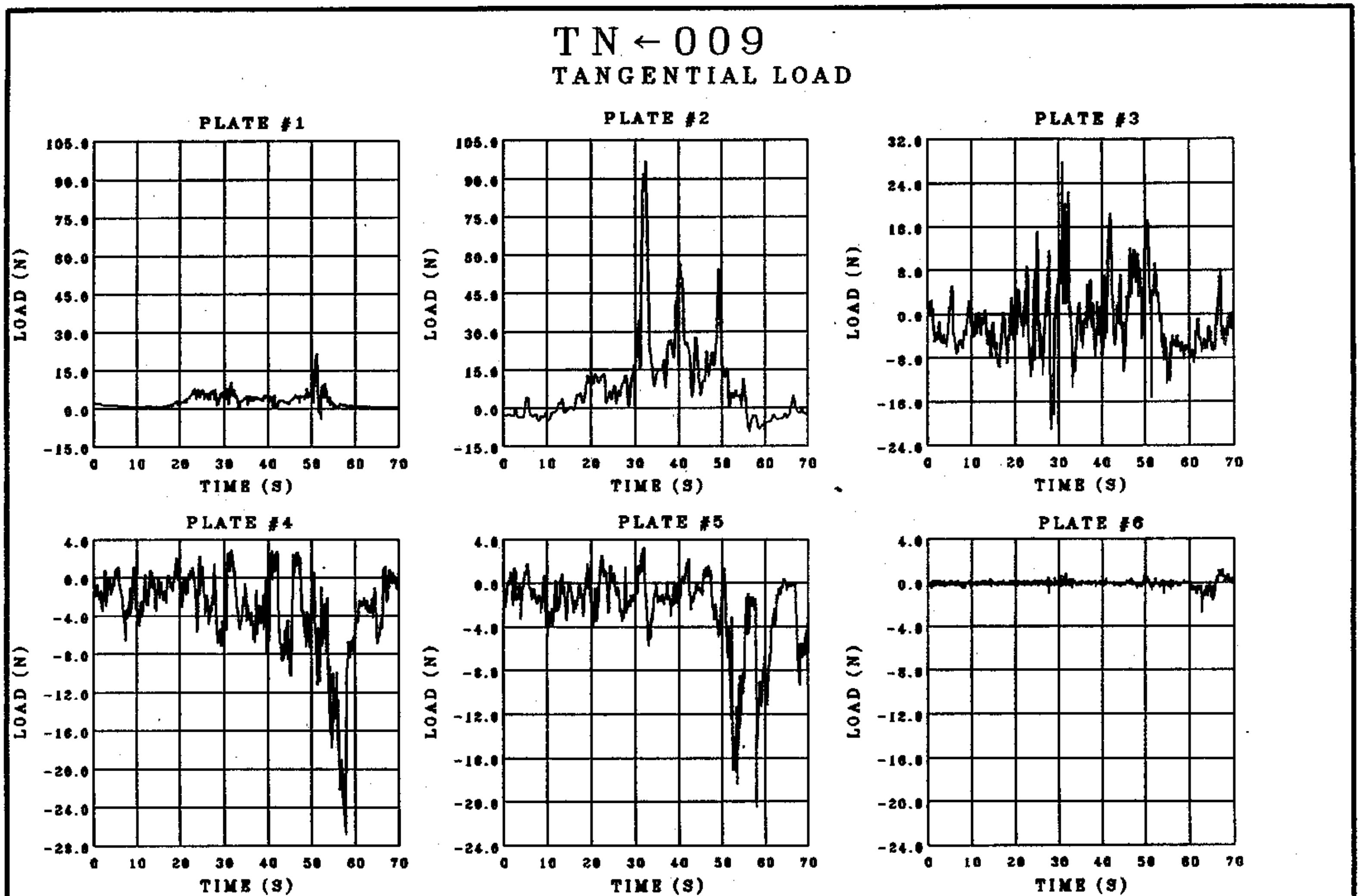
ICE PILEUP STUDY
for CANADIAN COAST GUARD



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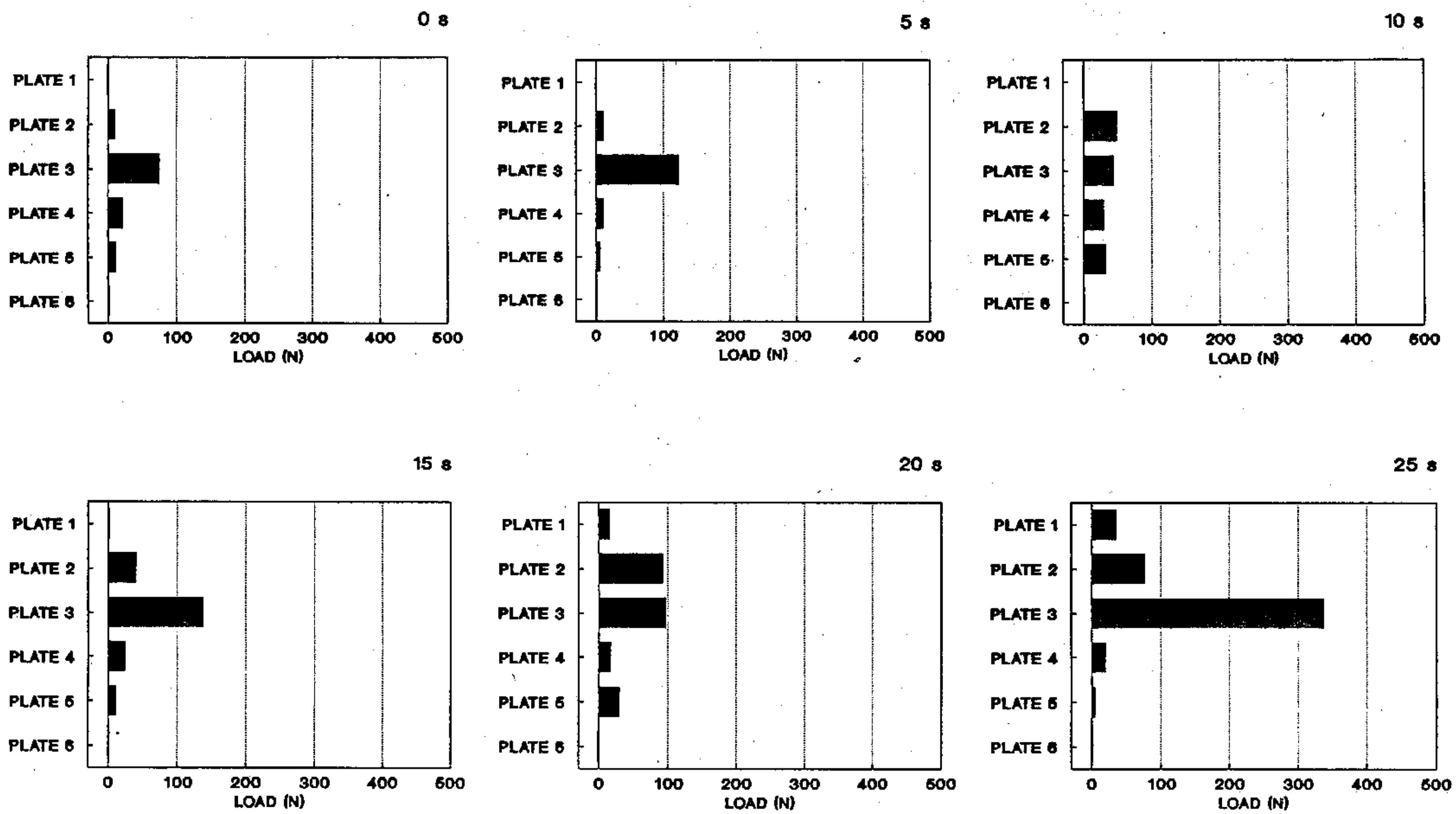
ICE PILEUP STUDY
for CANADIAN COAST GUARD

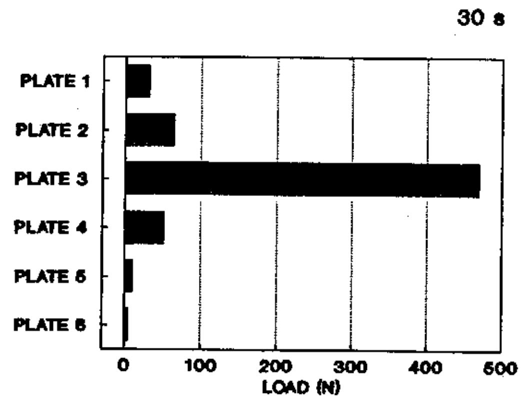
TIME SEQUENCE : NORMAL LOADS

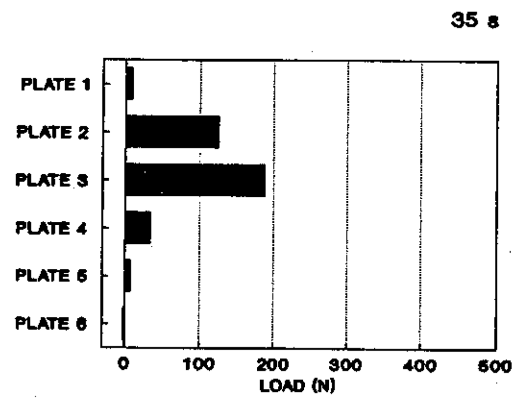
TN_009

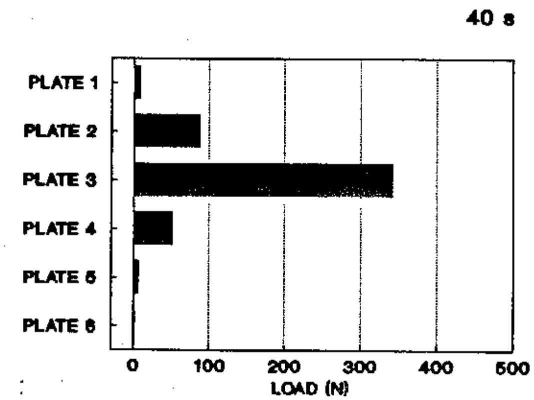


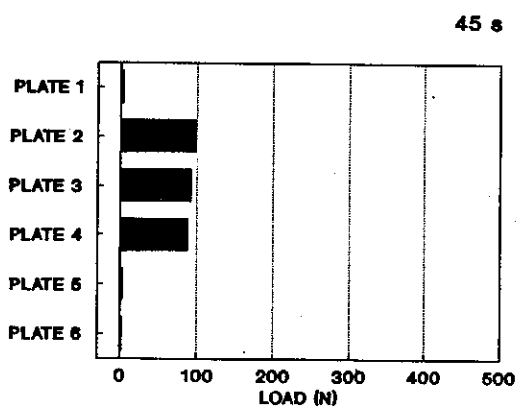
TIME SEQUENCE : NORMAL LOADS

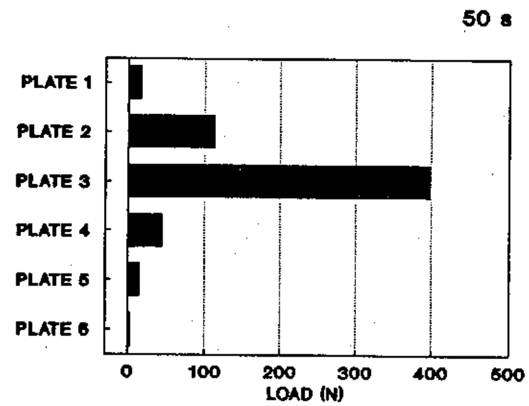
TN_009

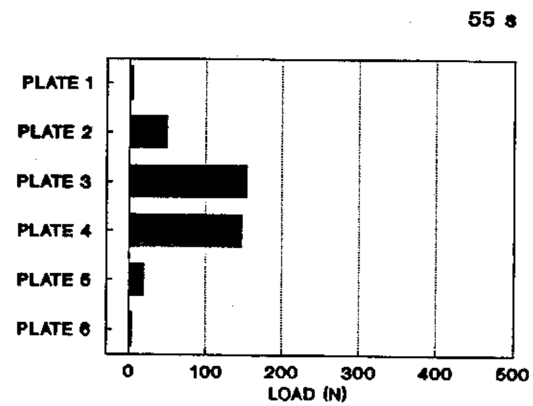






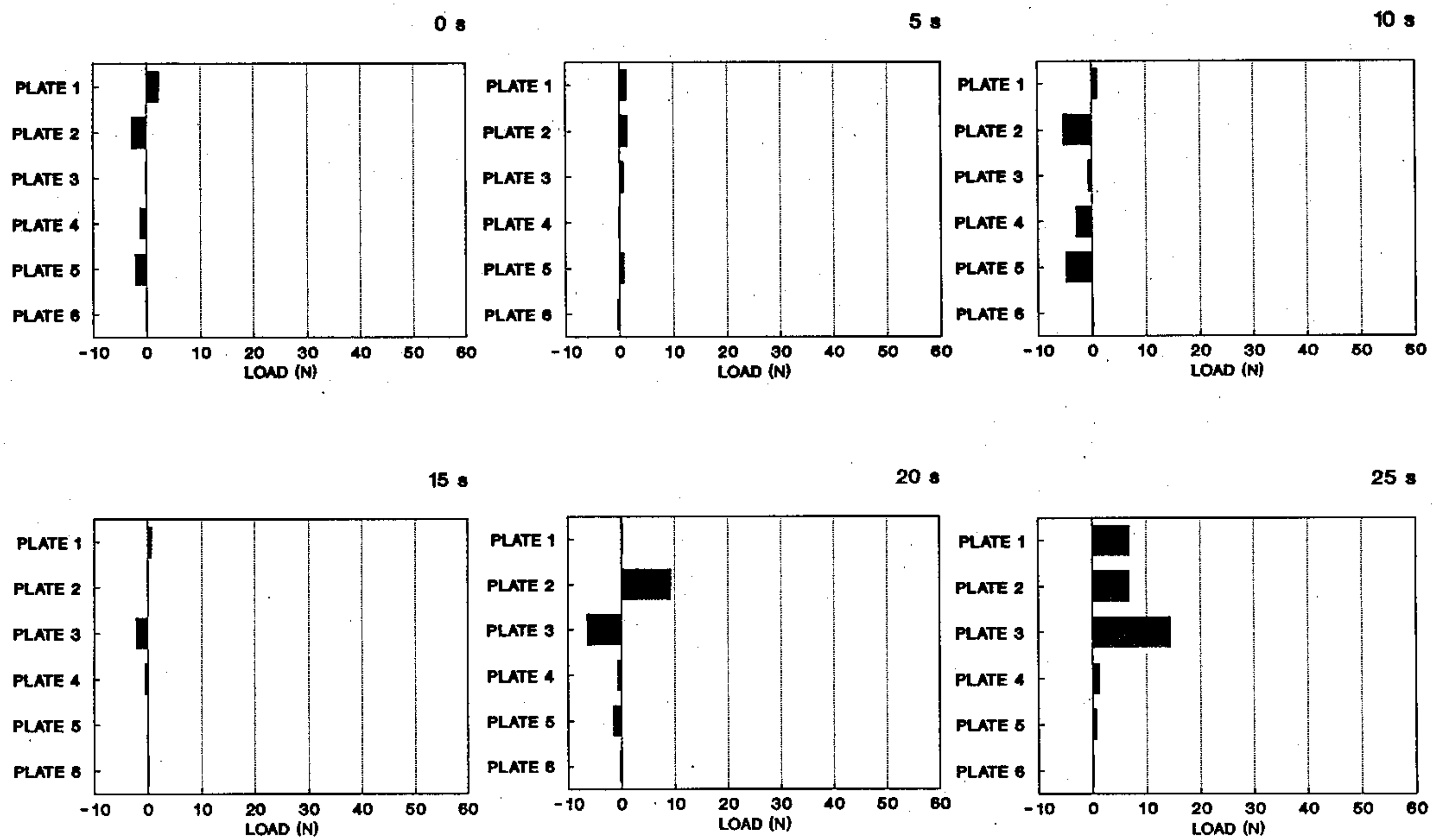






TIME SEQUENCE : TANGENTIAL LOADS

TN_009



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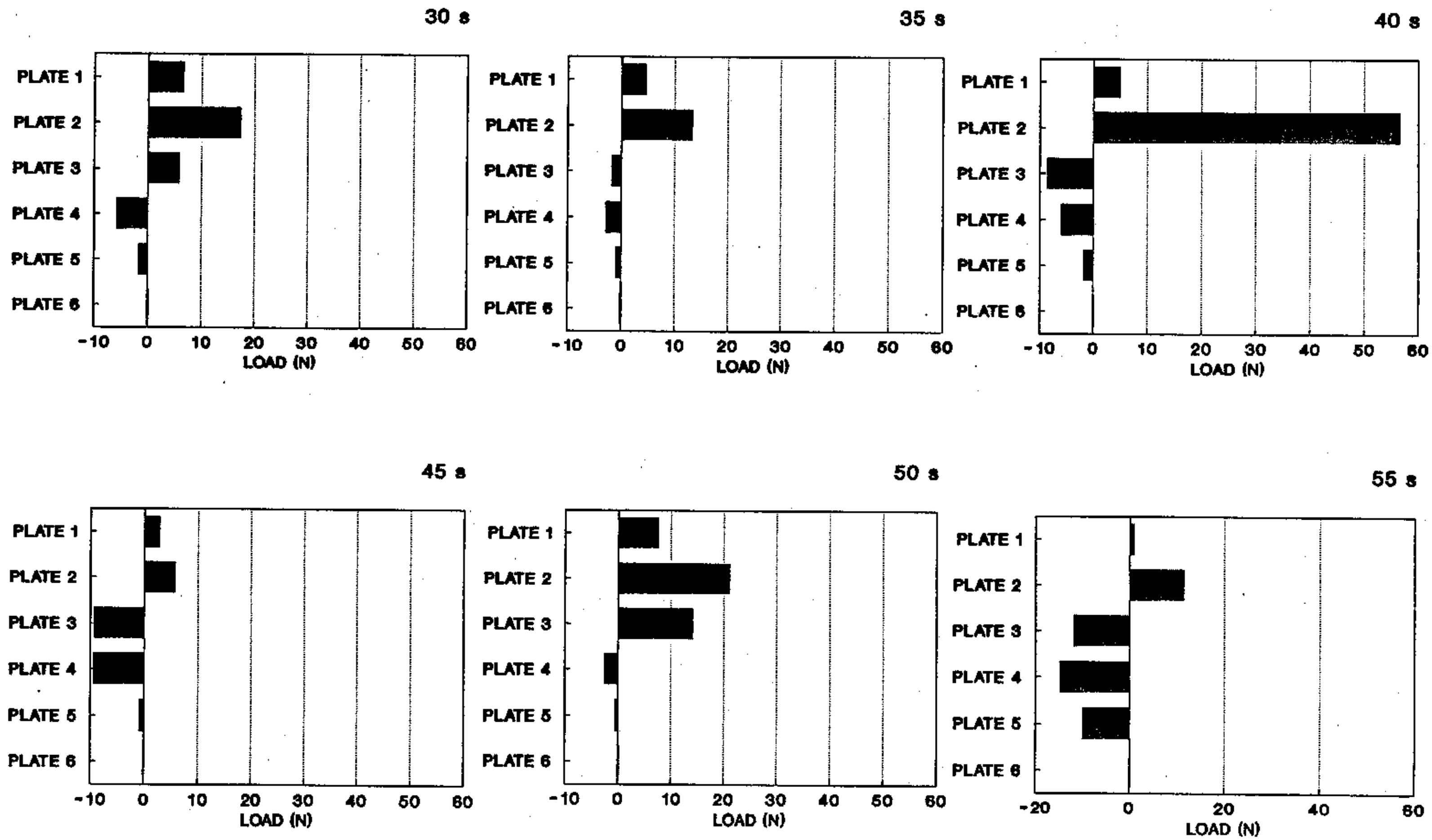
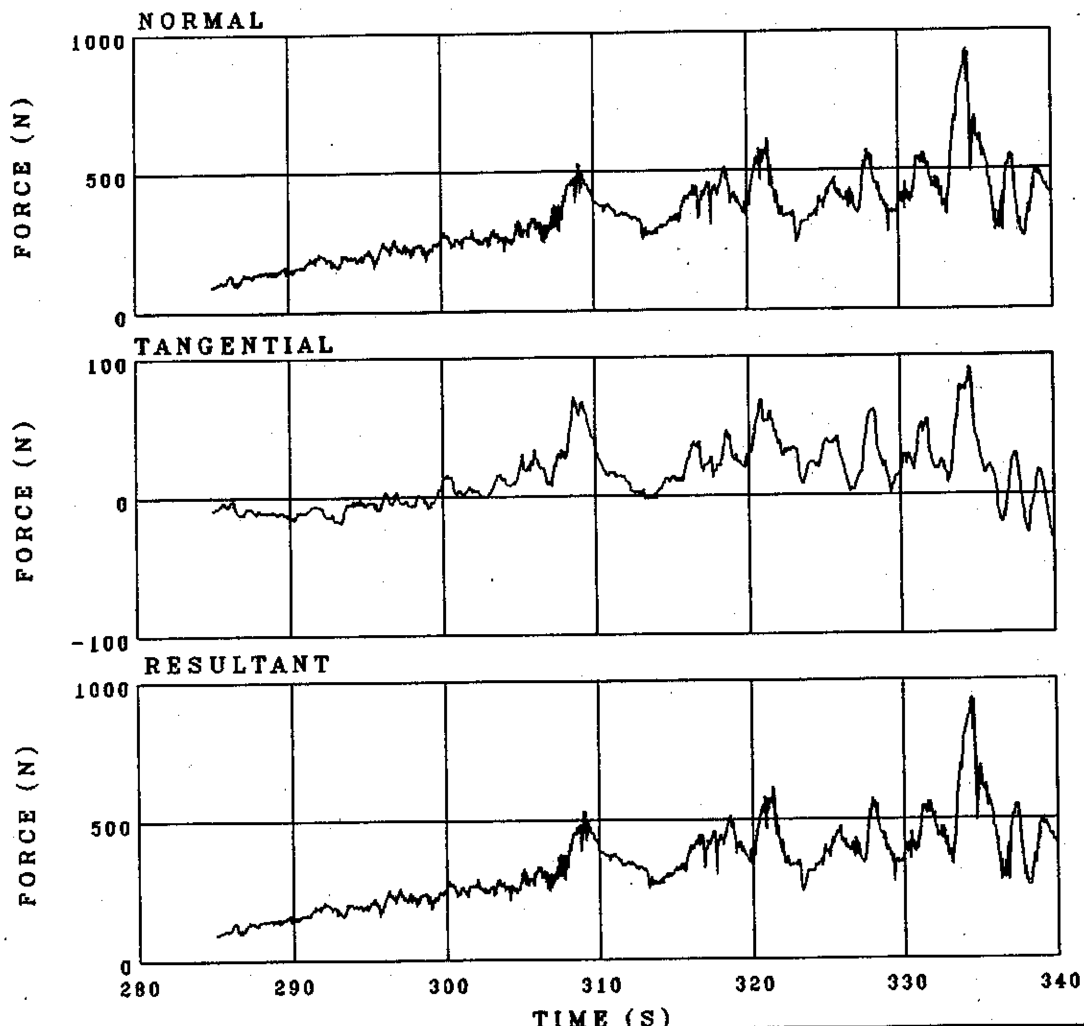
TN_009





FILE TN←010

TOTAL

NORMAL

MEAN FORCE = 332.0 N
MAX FORCE = 931.7 N
MIN FORCE = 91.26 N

TANGENTIAL

MEAN FORCE = 14.34 N
MAX FORCE = 90.39 N
MIN FORCE = -34.34 N

RESULTANT

MEAN FORCE = 332.6 N
MAX FORCE = 935.4 N
MIN FORCE = 91.78 N

TEST CONDITIONS

BOARD ANGLE = 24.00 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 60.00 kPa
ICE THICKNESS = 3.100 cm
ICE DENSITY = 0.8700 g/cc

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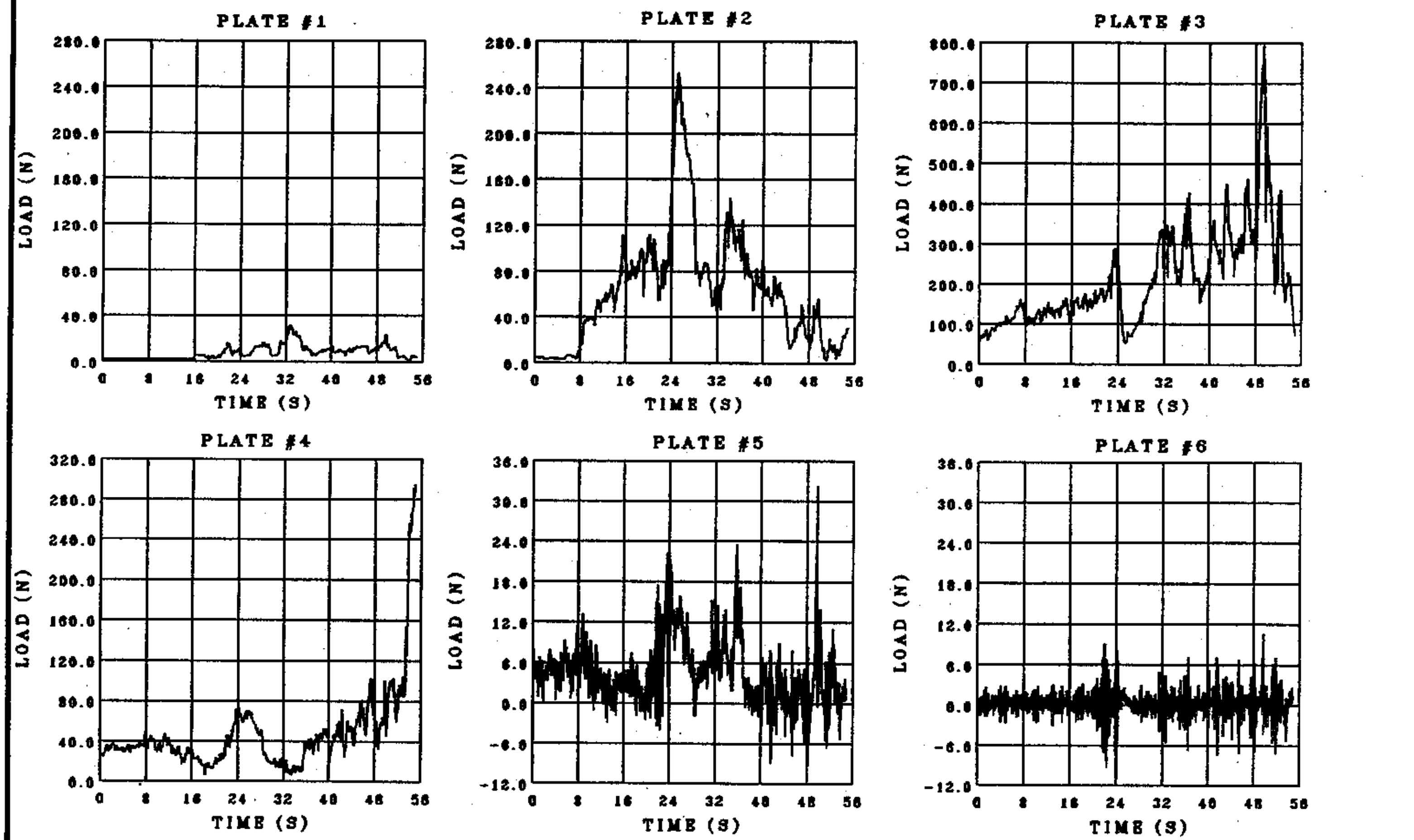
TN←010
NORMAL LOAD



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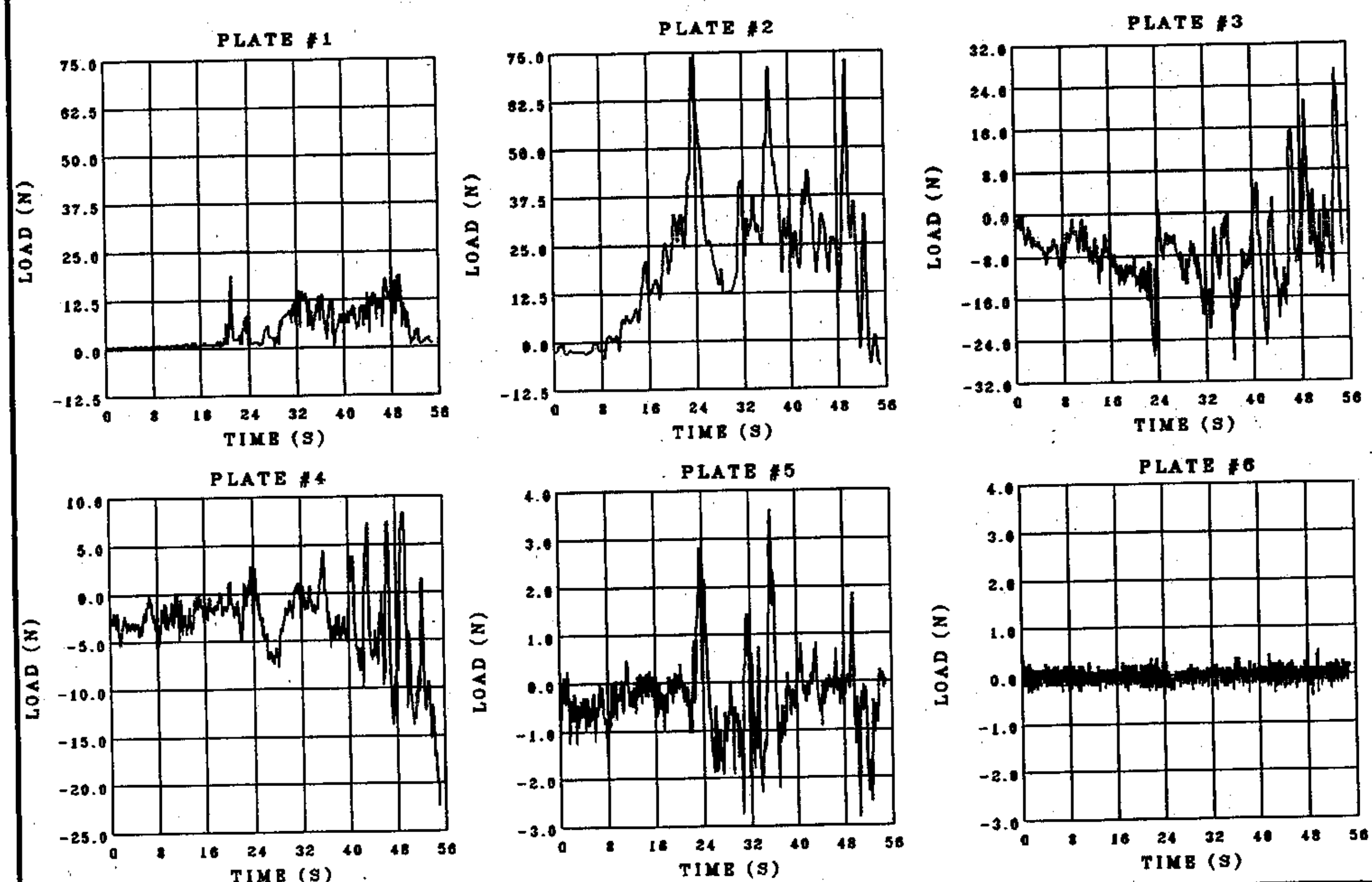
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN ← 010
TANGENTIAL LOAD



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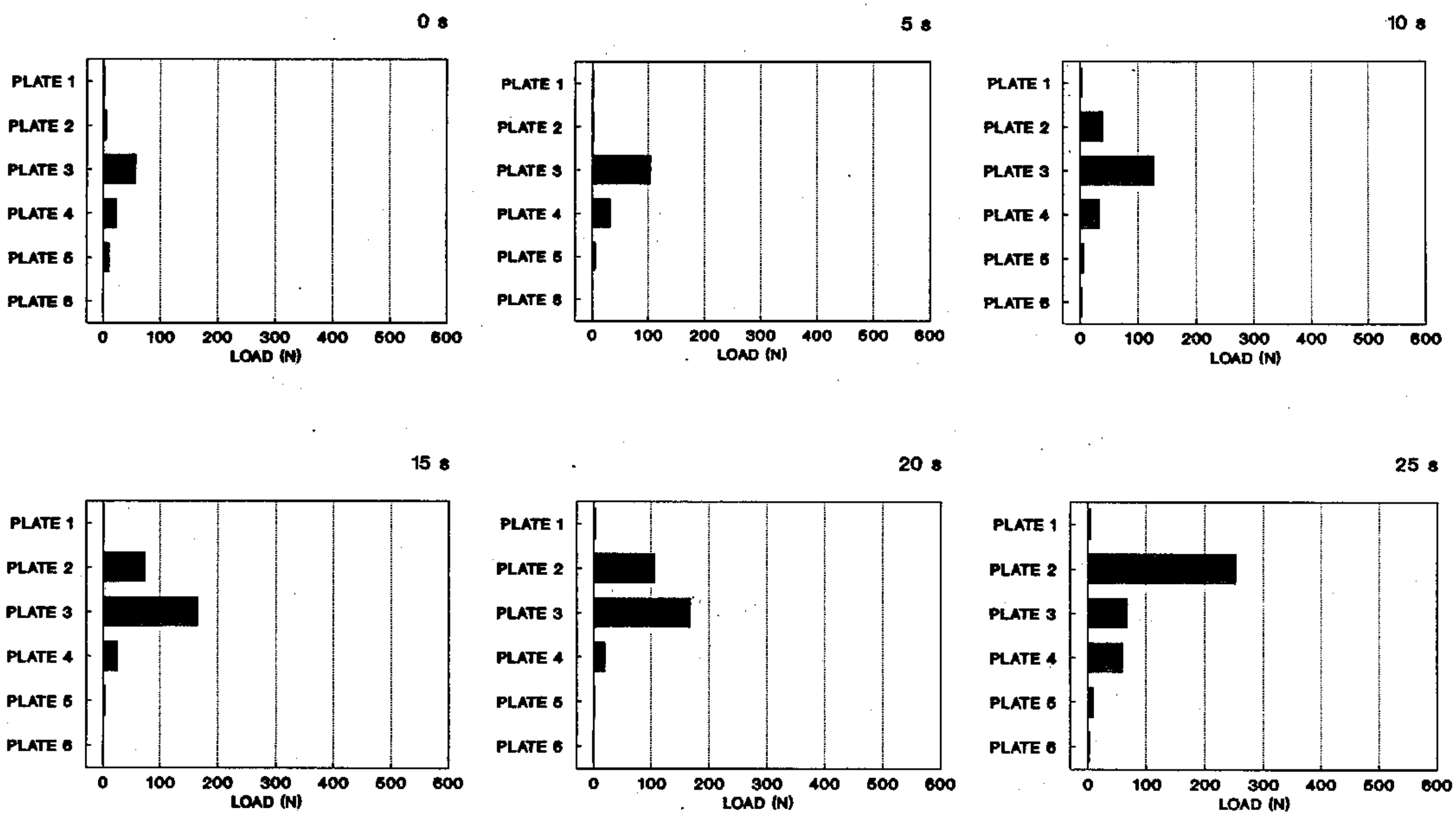
Conseil national de recherches Canada

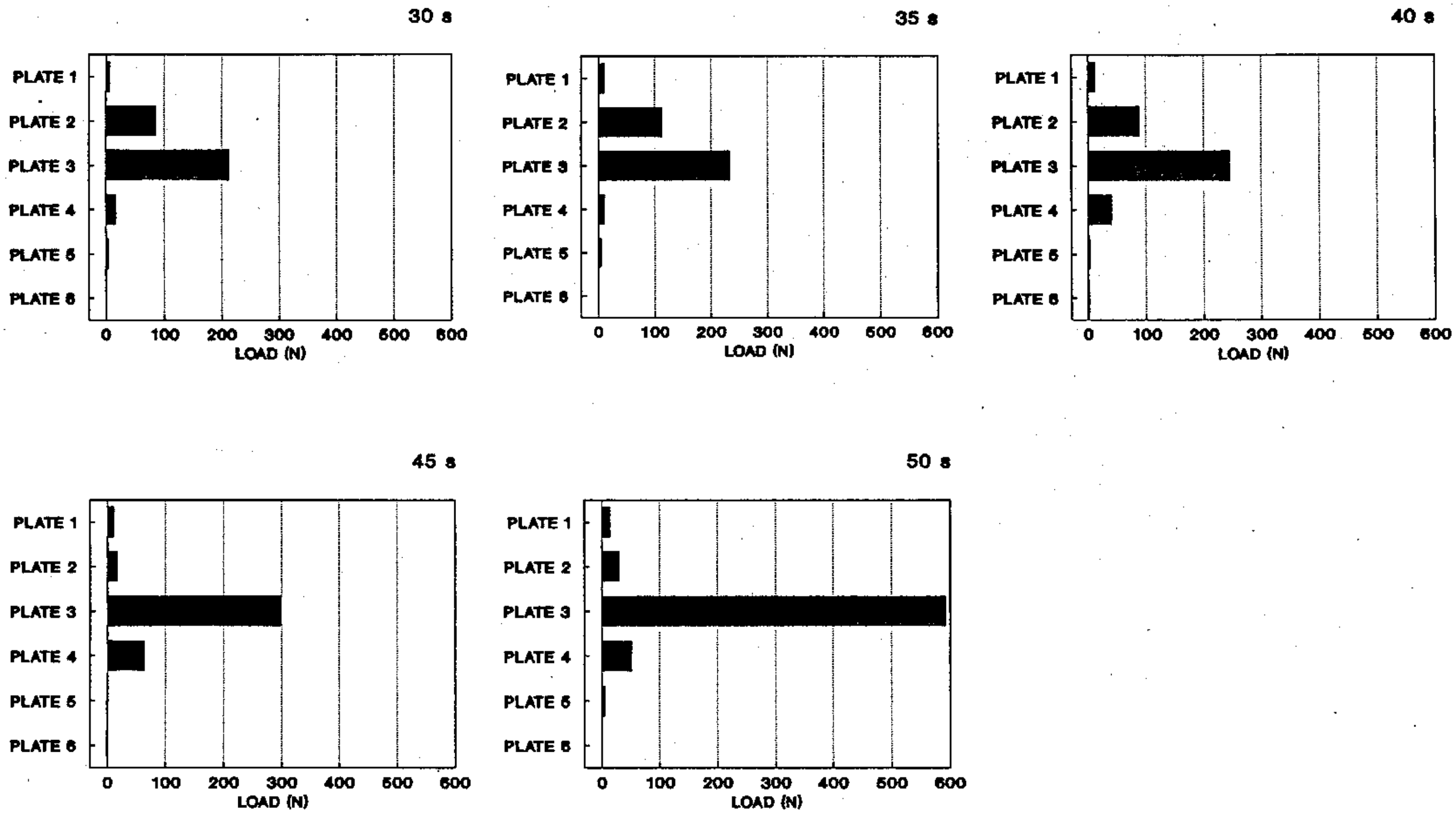
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TIME SEQUENCE : NORMAL LOADS

TN_010

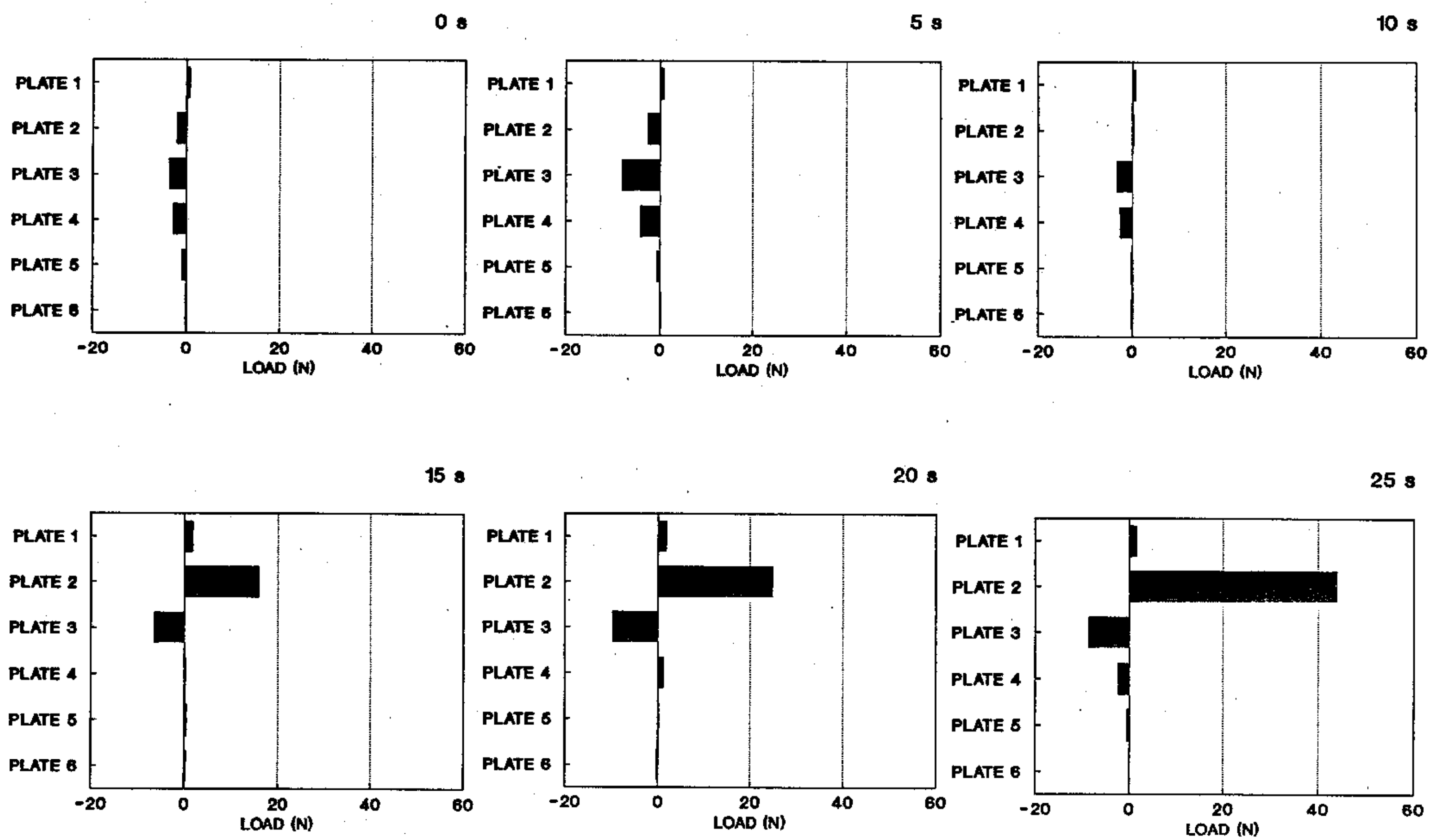


TIME SEQUENCE : NORMAL LOADS
TN_010



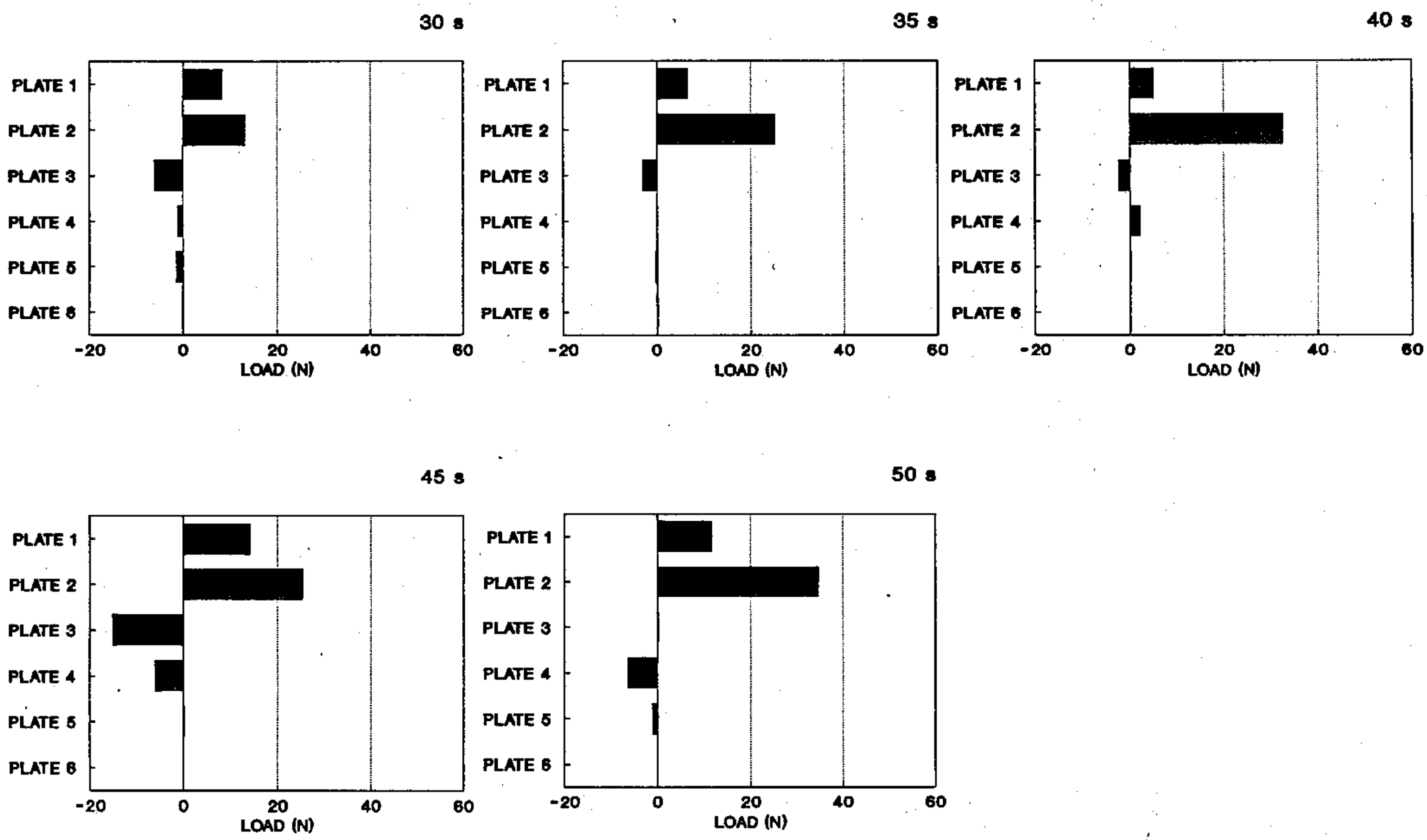
TIME SEQUENCE : TANGENTIAL LOADS

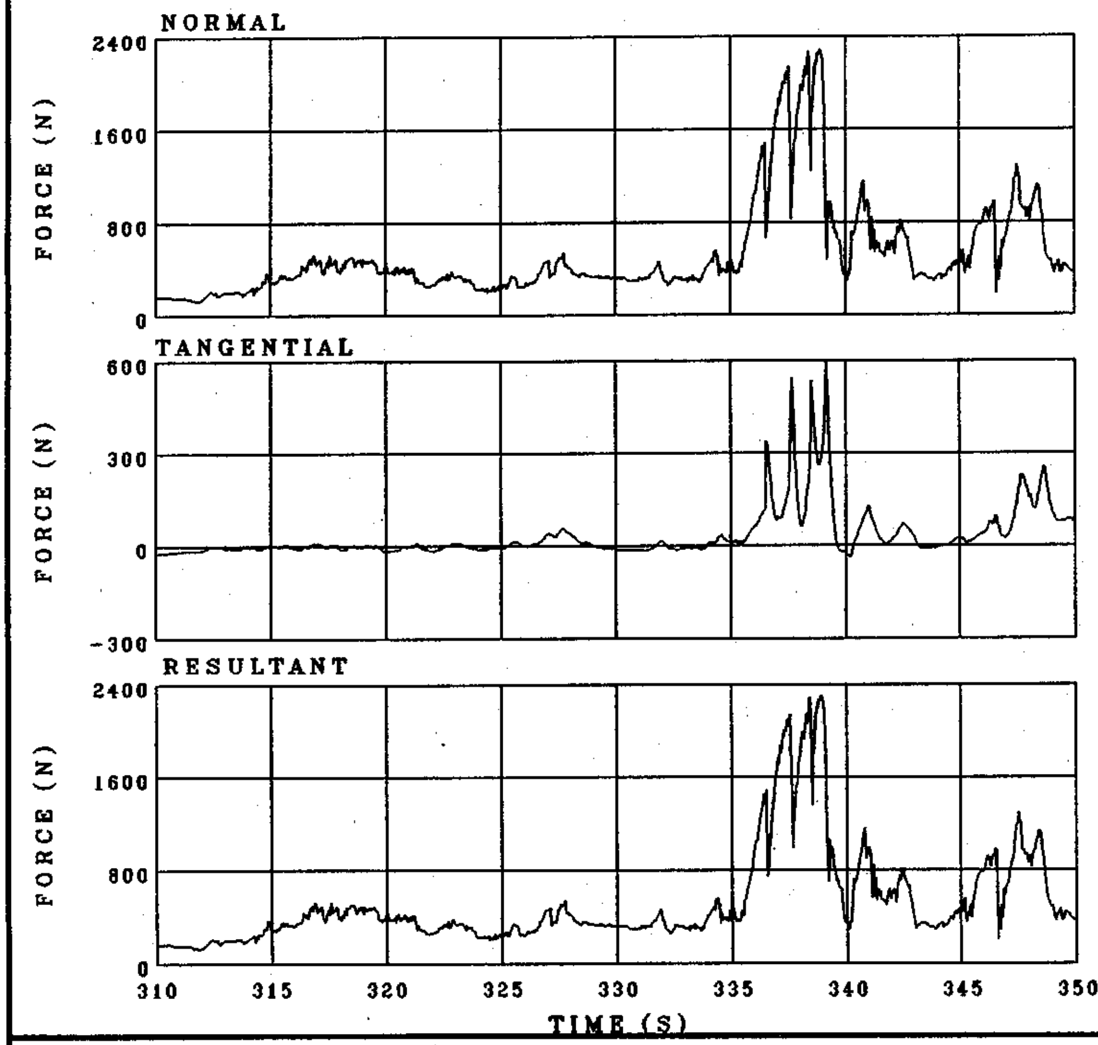
TN_010



TIME SEQUENCE : TANGENTIAL LOADS

TN_010





FILE TN←011

TOTAL

NORMAL

MEAN FORCE = 512.8 N
MAX FORCE = 2293.0 N
MIN FORCE = 116.5 N

TANGENTIAL

MEAN FORCE = 32.73 N
MAX FORCE = 596.5 N
MIN FORCE = -38.30 N

RESULTANT

MEAN FORCE = 516.7 N
MAX FORCE = 2308.0 N
MIN FORCE = 117.8 N

TEST CONDITIONS

BOARD ANGLE = 13.00 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 94.00 kPa
ICE THICKNESS = 3.300 cm
ICE DENSITY = 0.8900 g/cc

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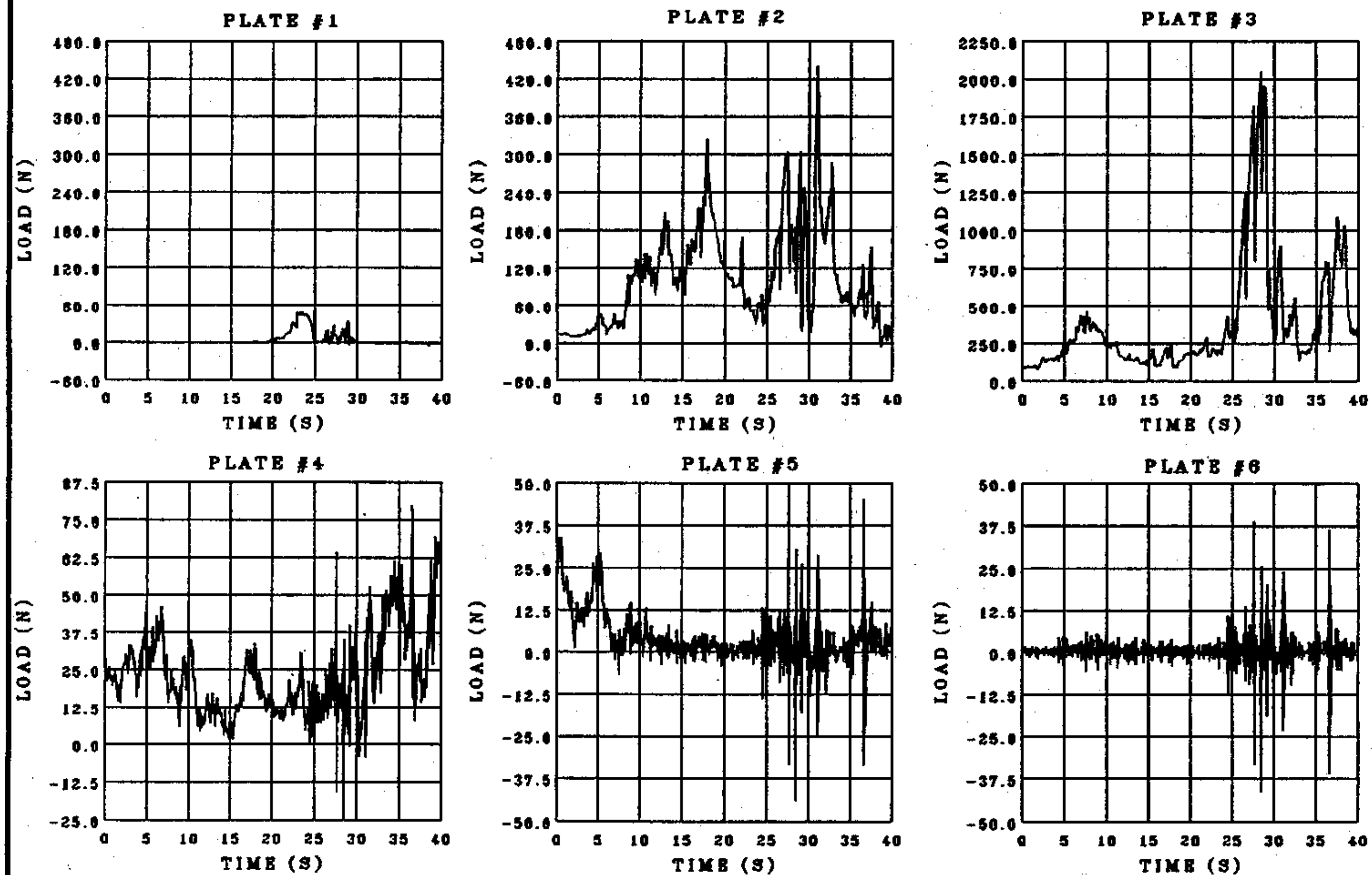
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←011
NORMAL LOAD



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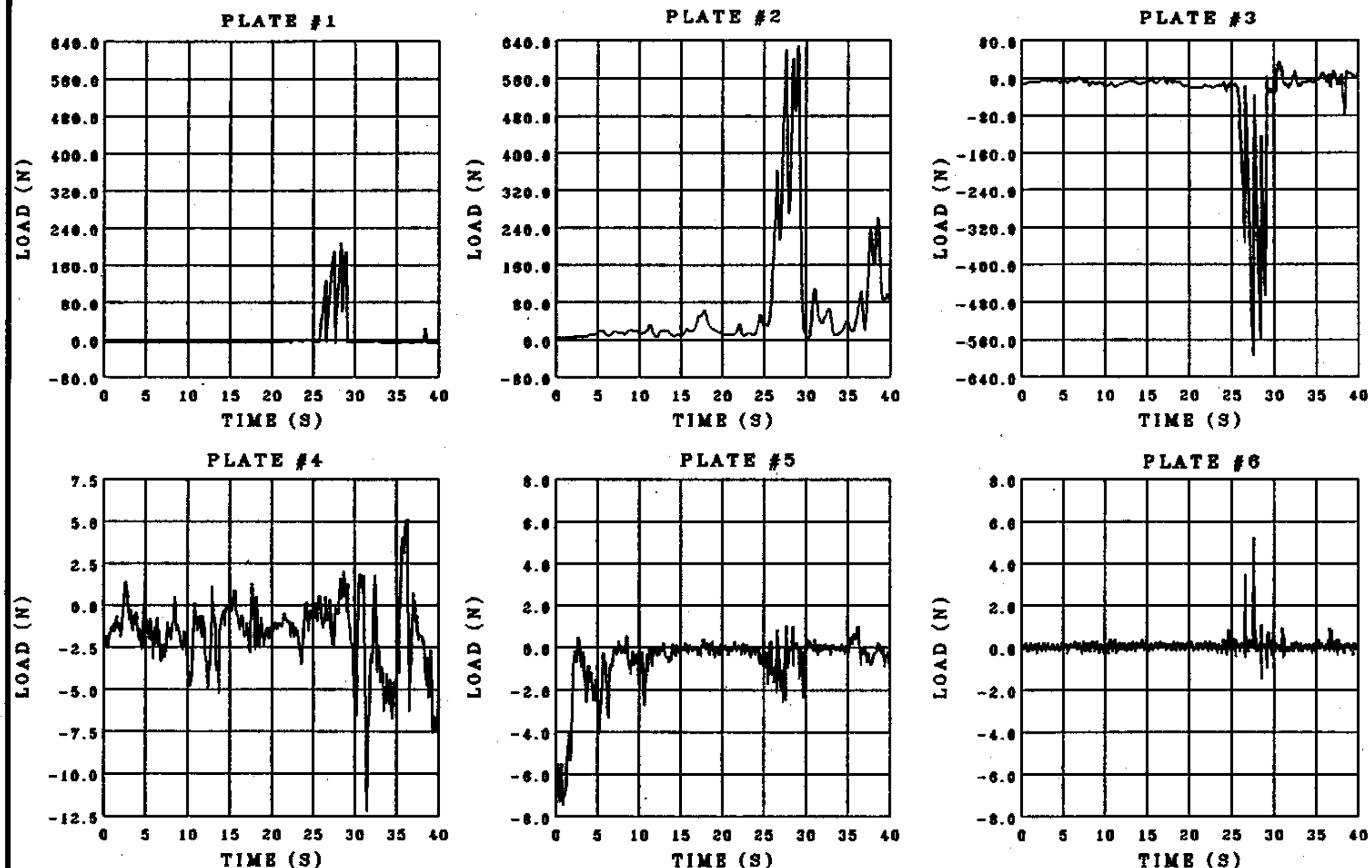
ICE PILEUP STUDY for CANADIAN COAST GUARD

TN←011
TANGENTIAL LOAD



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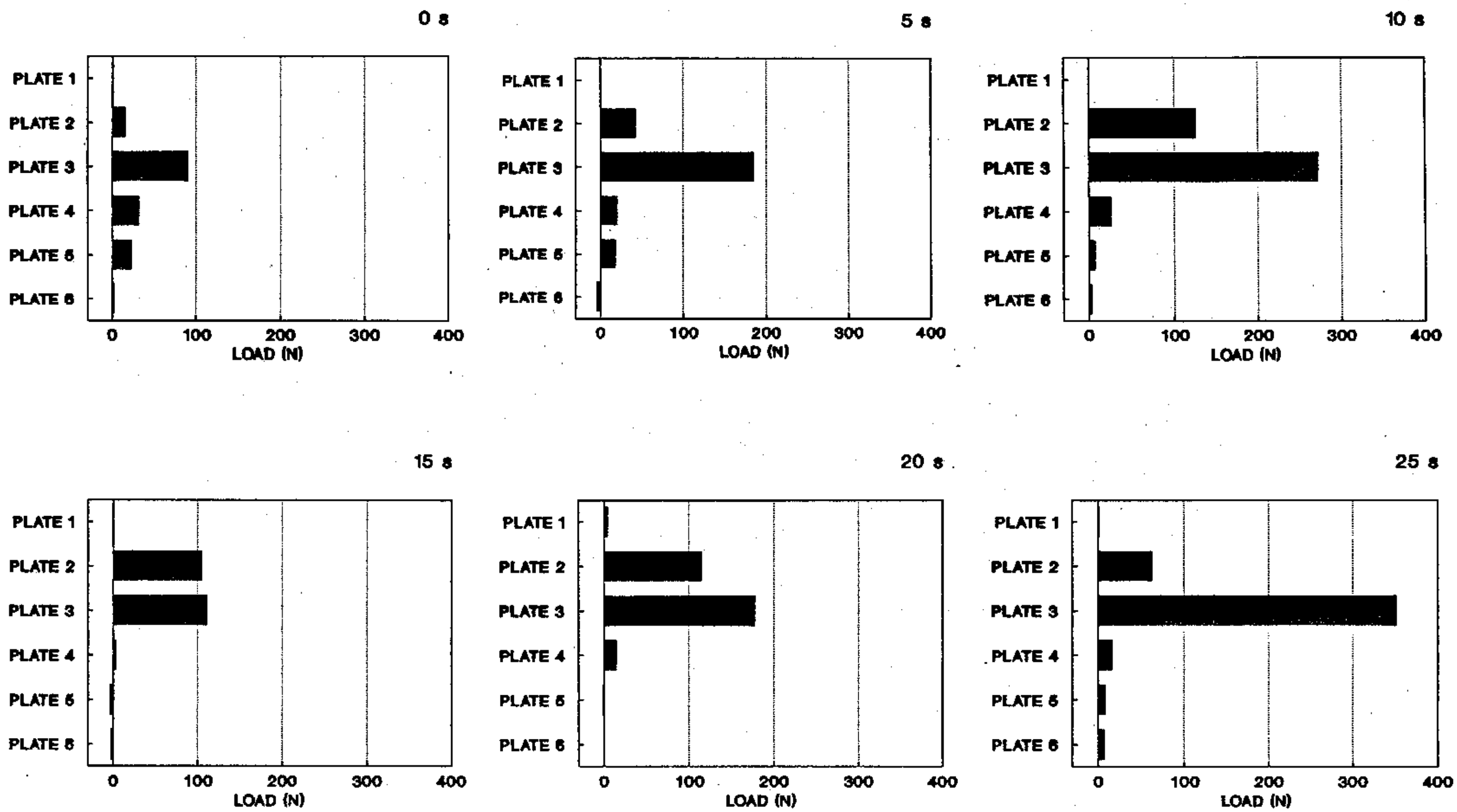
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TIME SEQUENCE : NORMAL LOADS
TN_011



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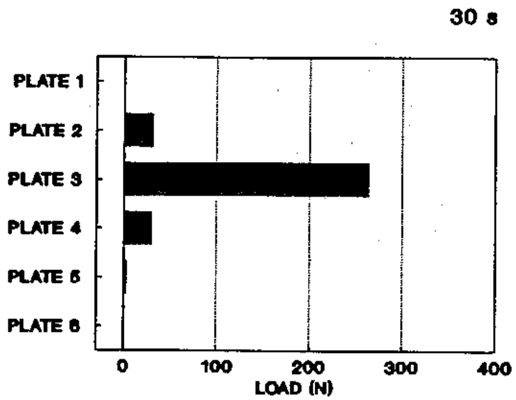

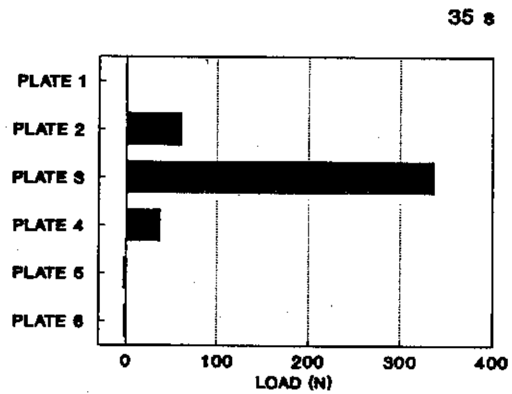

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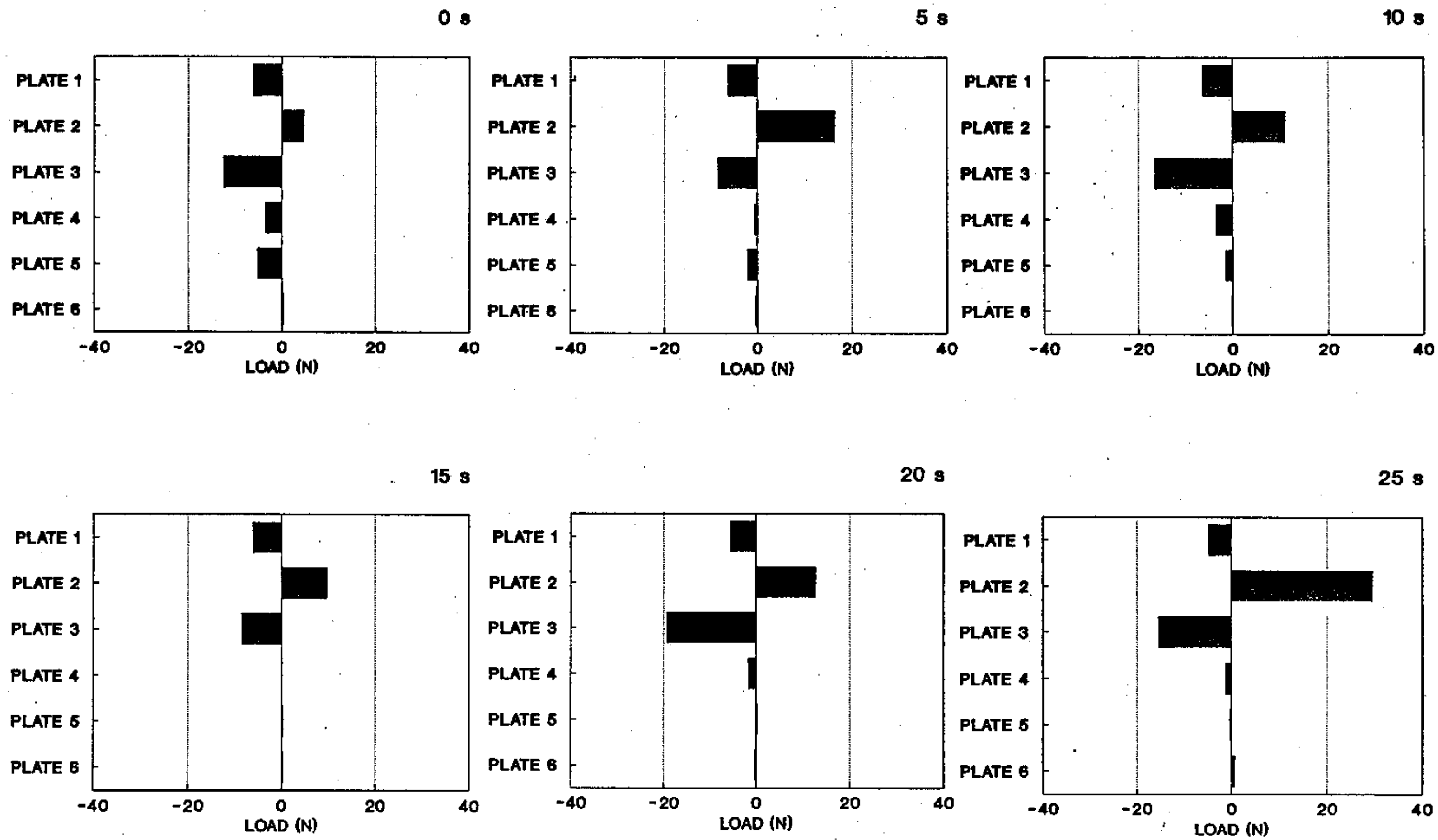

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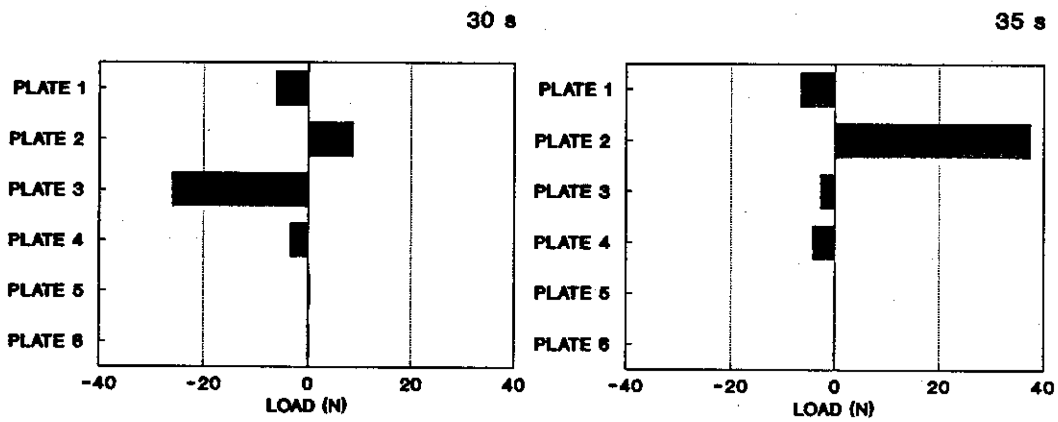

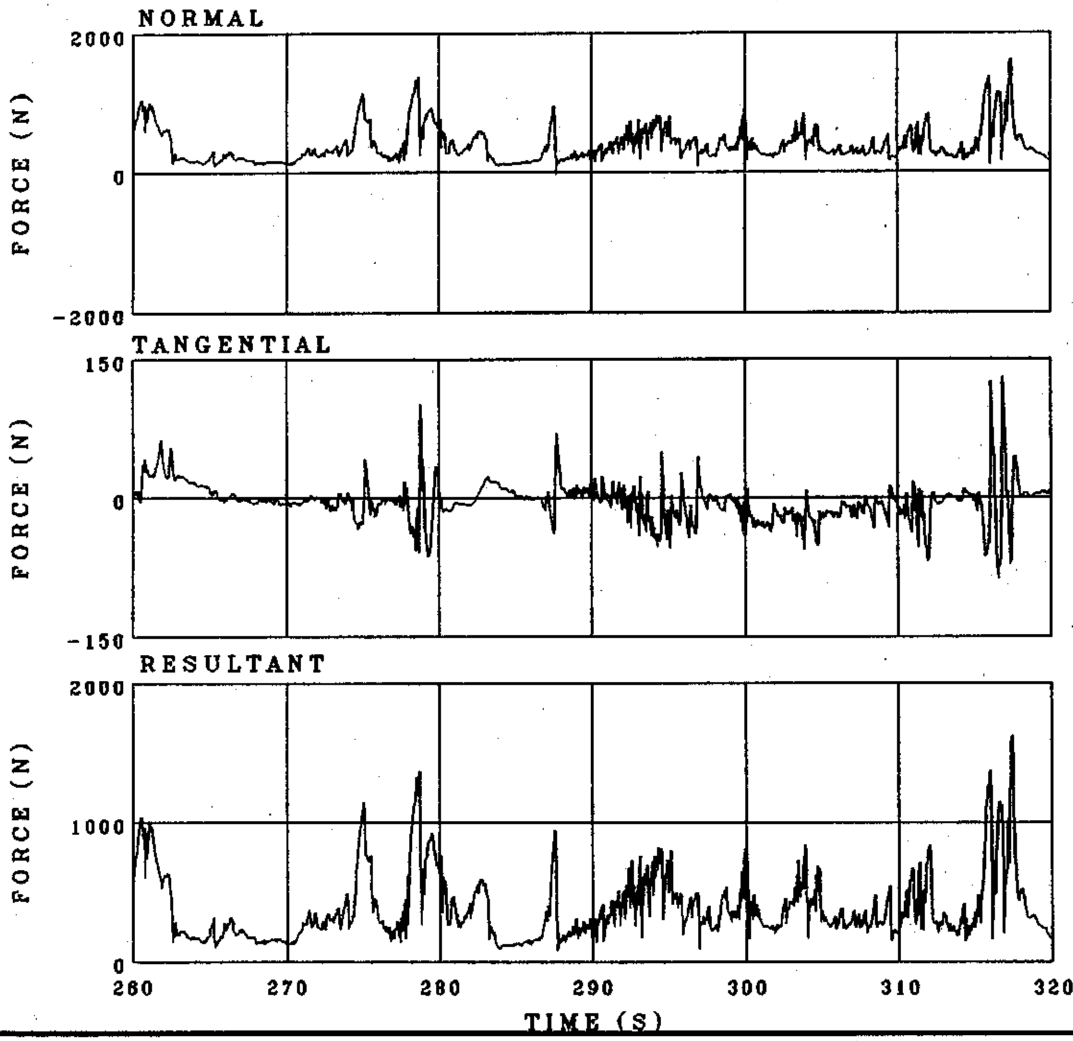

FILE TN←012

TOTAL

NORMAL

MEAN FORCE = 367.0 N
MAX FORCE = 1623.0 N
MIN FORCE = -36.02 N

TANGENTIAL

MEAN FORCE = -4.422 N
MAX FORCE = 130.9 N
MIN FORCE = -88.02 N

RESULTANT

MEAN FORCE = 387.7 N
MAX FORCE = 1624.0 N
MIN FORCE = 78.90 N

TEST CONDITIONS

BOARD ANGLE = 0.0 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 58.00 kPa
ICE THICKNESS = 3.200 cm
ICE DENSITY = 0.8800 g/cc

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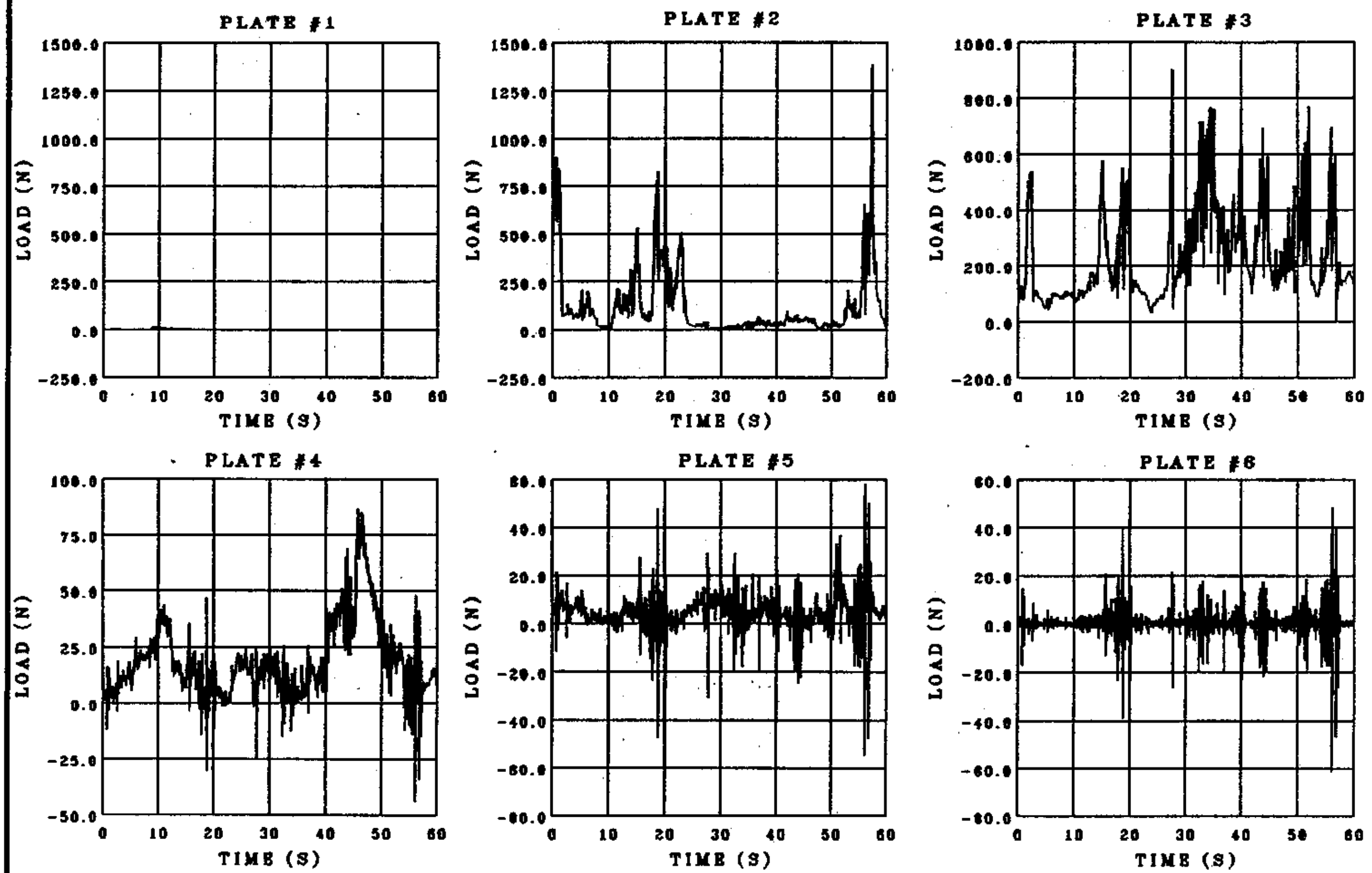
for CANADIAN COAST GUARD

TN←012
NORMAL LOAD



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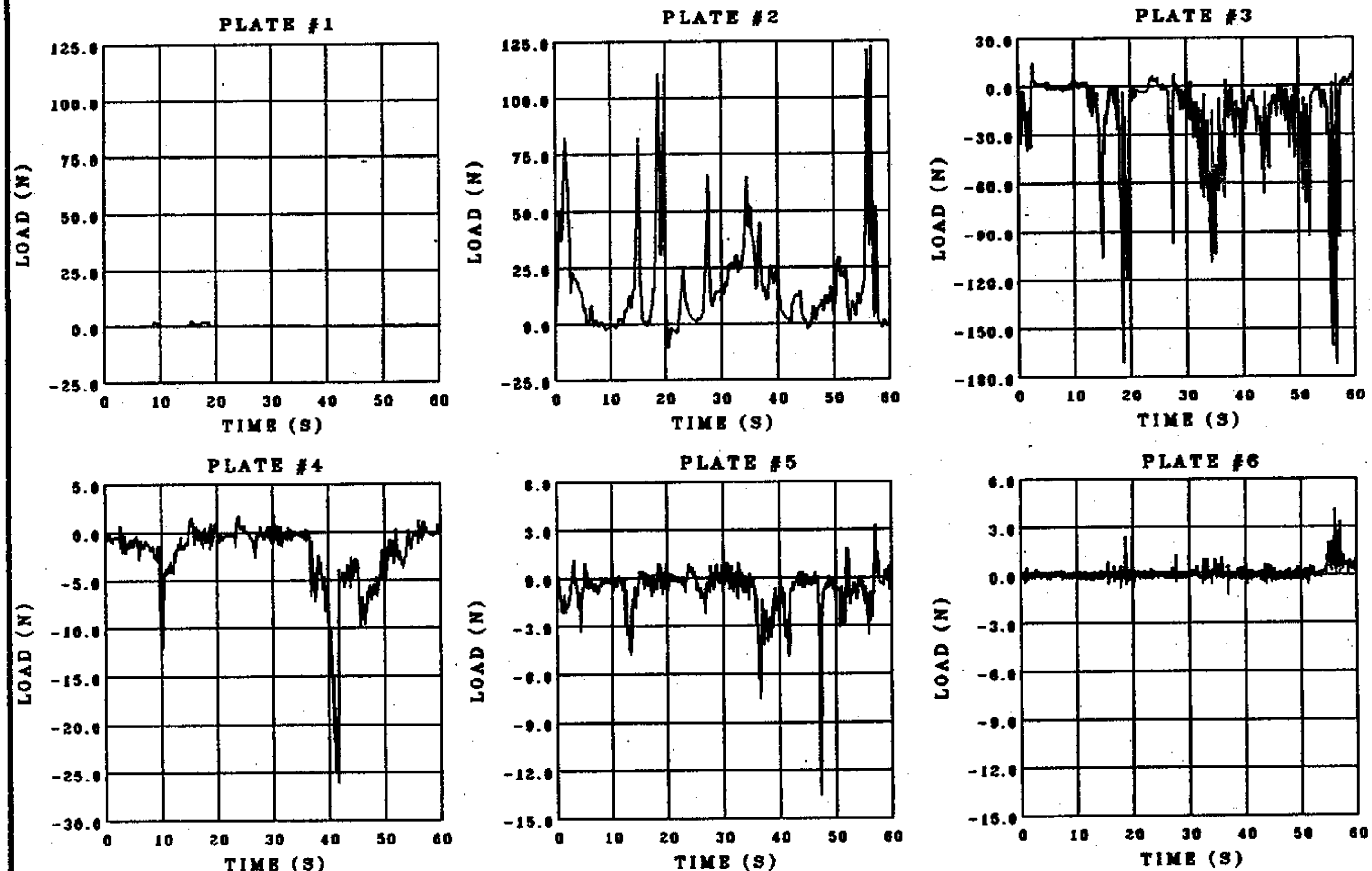
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TN←012
TANGENTIAL LOAD



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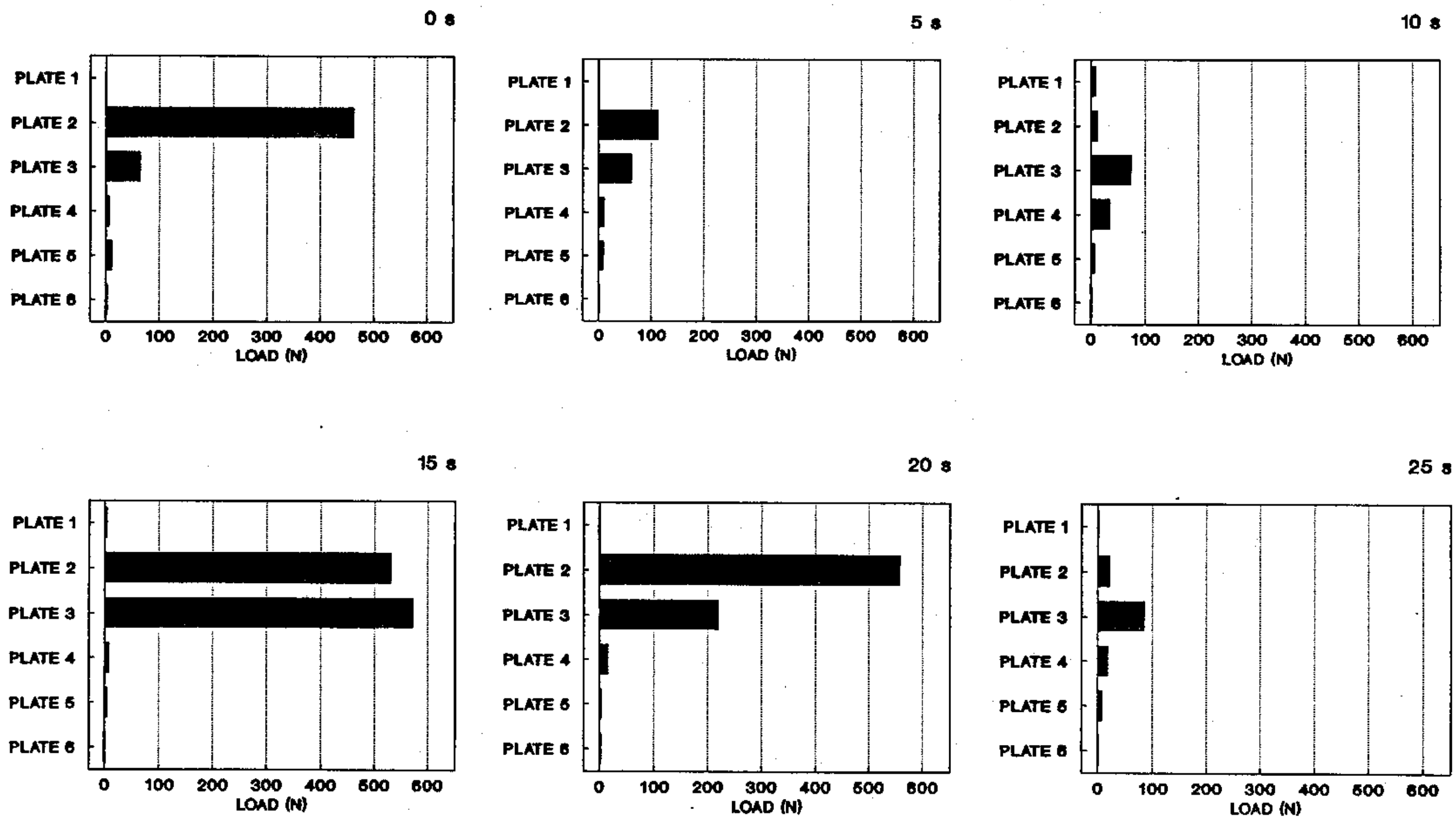
ICE PILEUP STUDY
for CANADIAN COAST GUARD

TIME SEQUENCE : NORMAL LOADS
TN_012



TIME SEQUENCE : NORMAL LOADS

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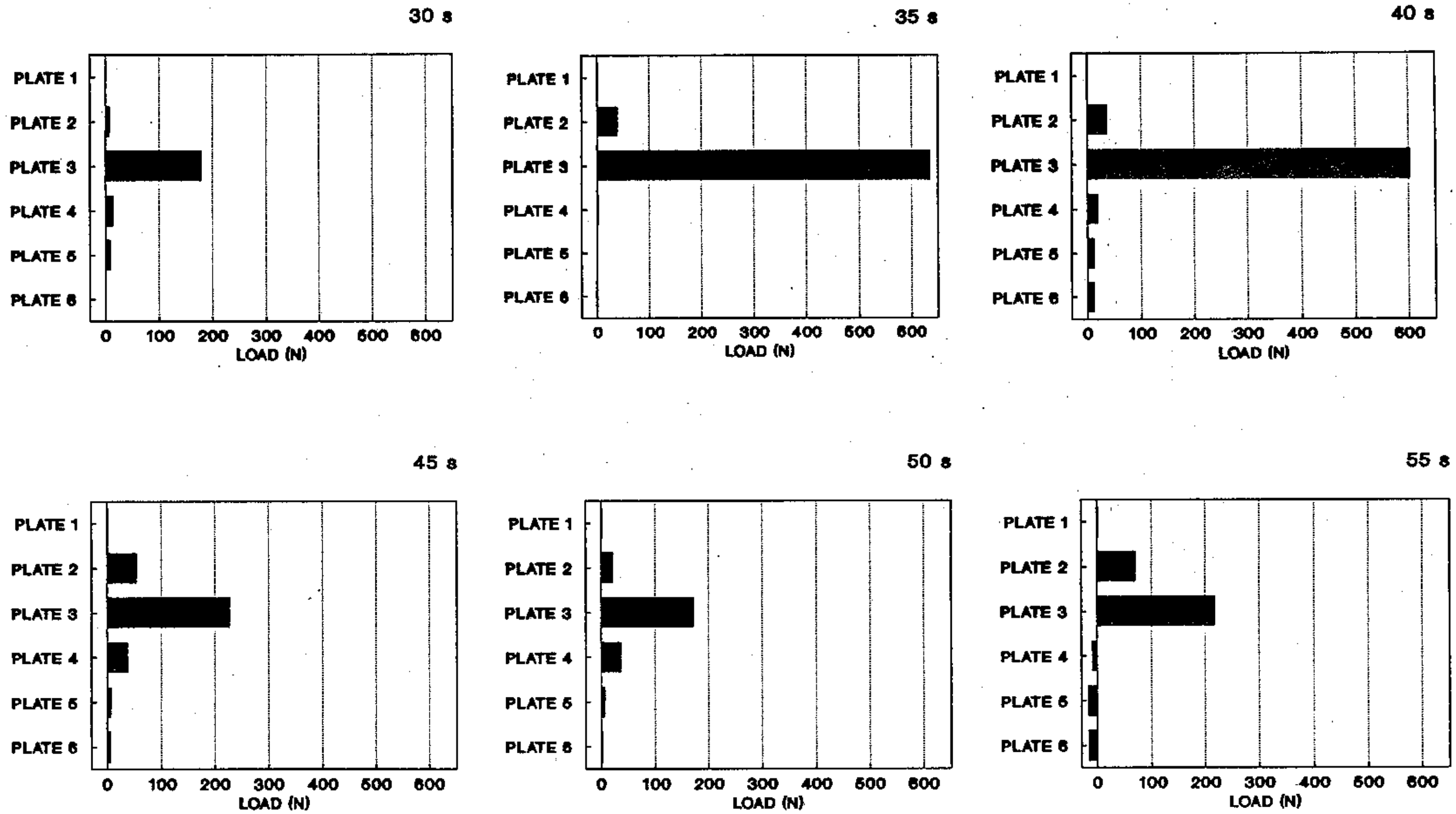

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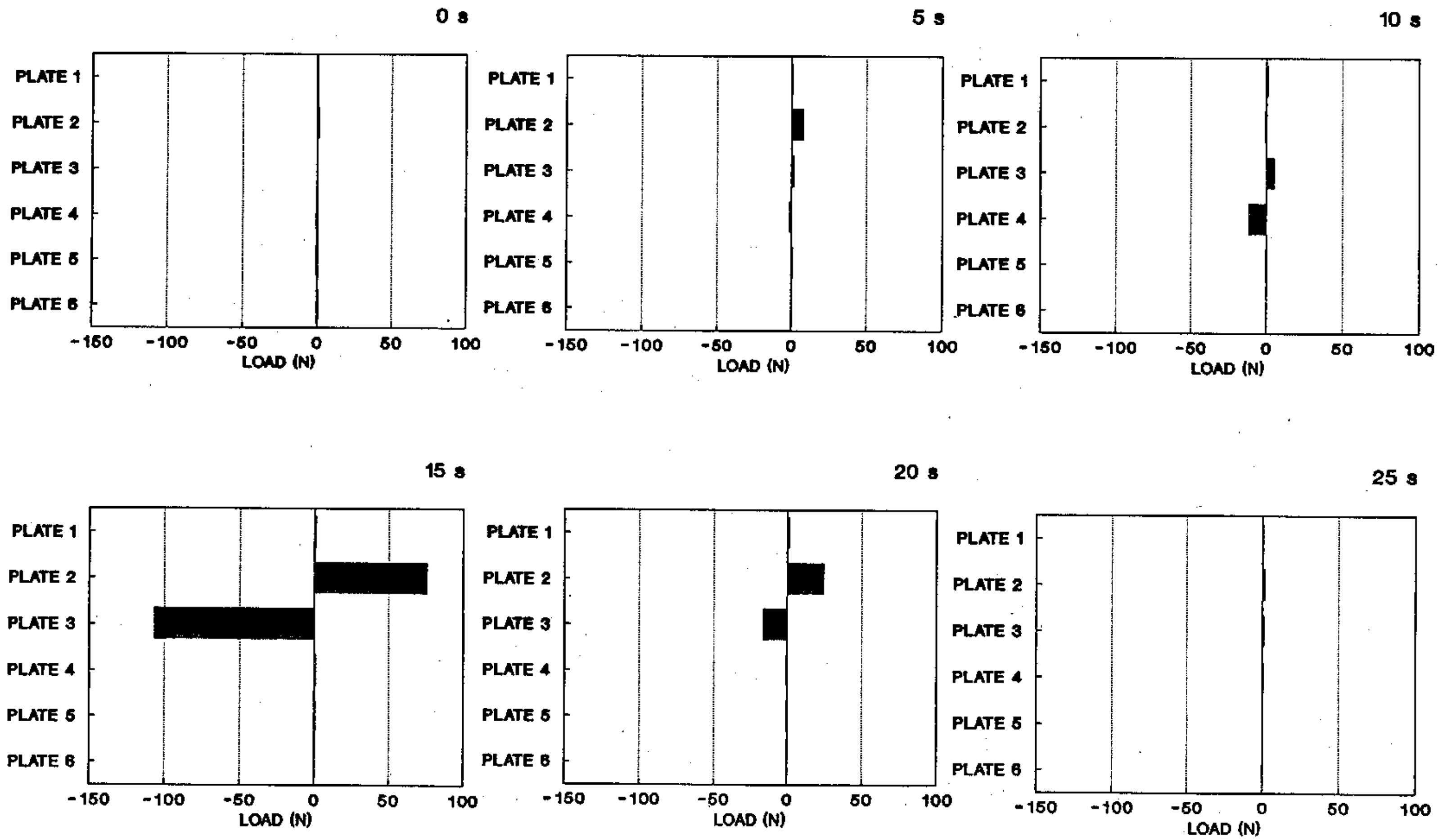
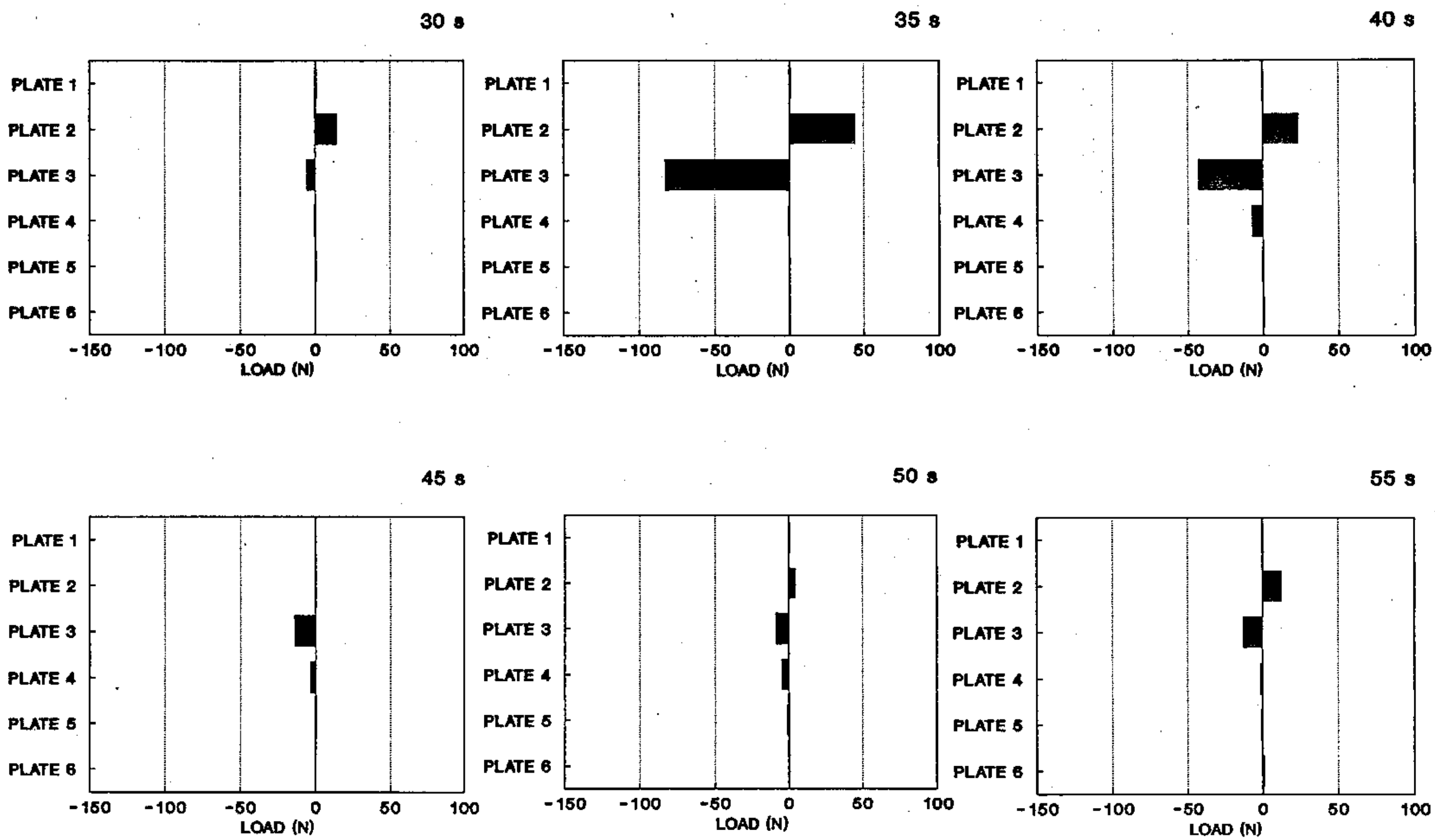
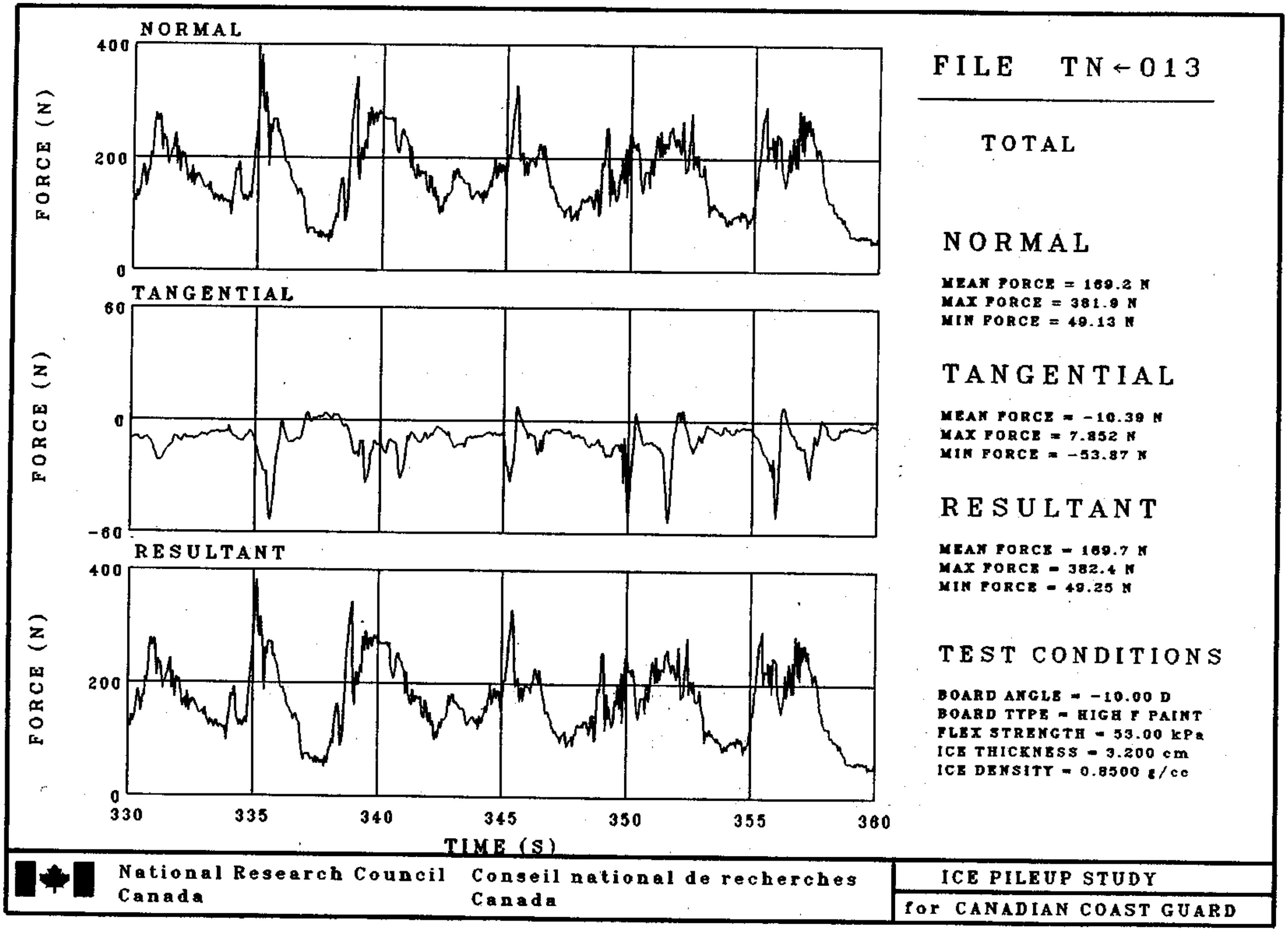


TIME SEQUENCE : TANGENTIAL LOADS

TN_012




NORMAL
TANGENTIAL
RESULTANT
FORCE (N)
400
200
0
60
0
-60
330
335
340
345
350
355
360
TIME (S)
FILE TN-013
TOTAL
NORMAL
MEAN FORCE = 169.2 N
MAX FORCE = 381.9 N
MIN FORCE = 49.13 N
TANGENTIAL
MEAN FORCE = -10.39 N
MAX FORCE = 7.852 N
MIN FORCE = -53.87 N
RESULTANT
MEAN FORCE = 169.7 N
MAX FORCE = 382.4 N
MIN FORCE = 49.25 N
TEST CONDITIONS
BOARD ANGLE = -10.00 D
BOARD TYPE = HIGH F PAINT
FLEX STRENGTH = 53.00 kPa
ICE THICKNESS = 3.200 cm
ICE DENSITY = 0.8500 g/cc
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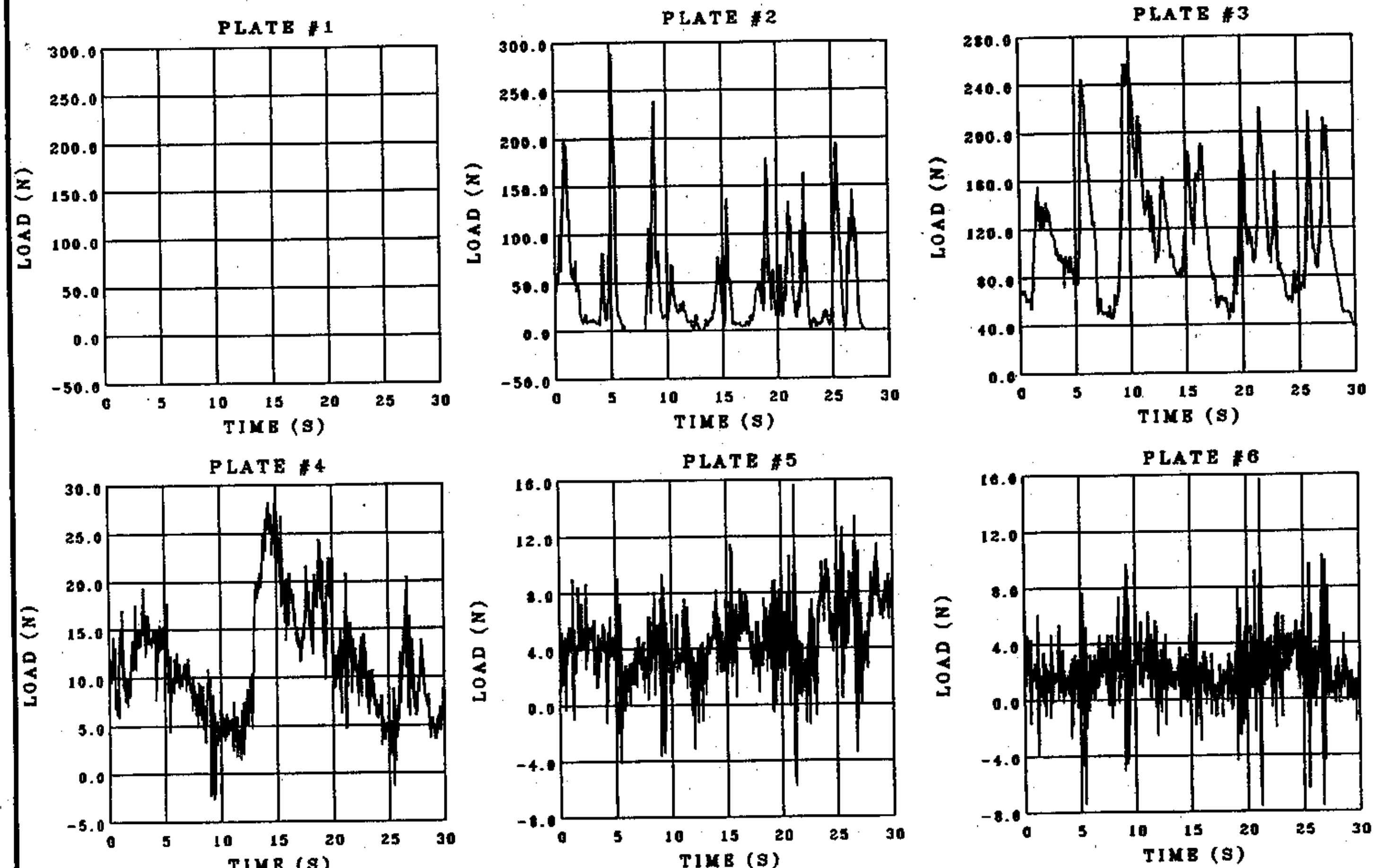
TN←013
NORMAL LOAD



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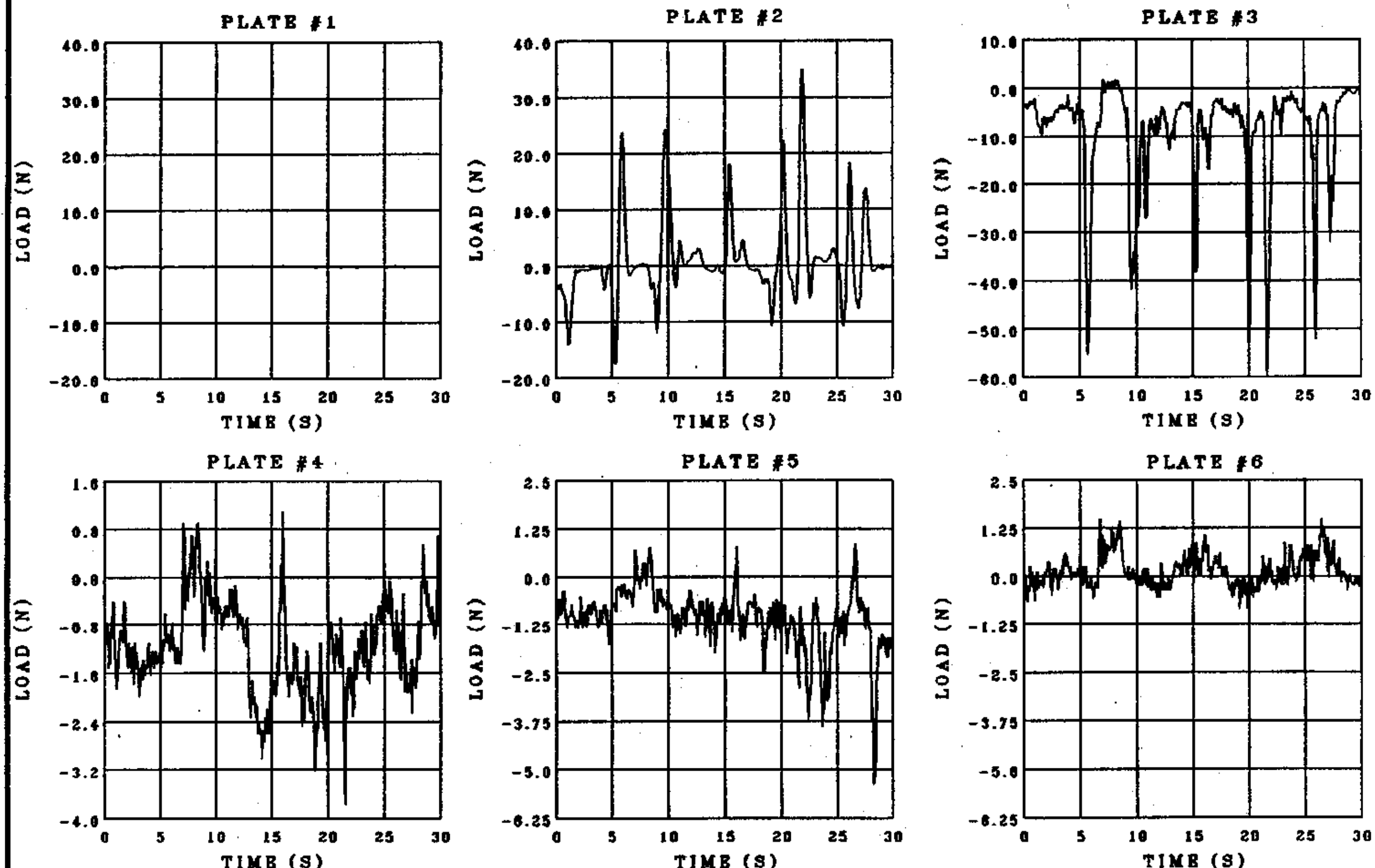
TN←013
TANGENTIAL LOAD



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ICE PILEUP STUDY
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TIME SEQUENCE : NORMAL LOADS

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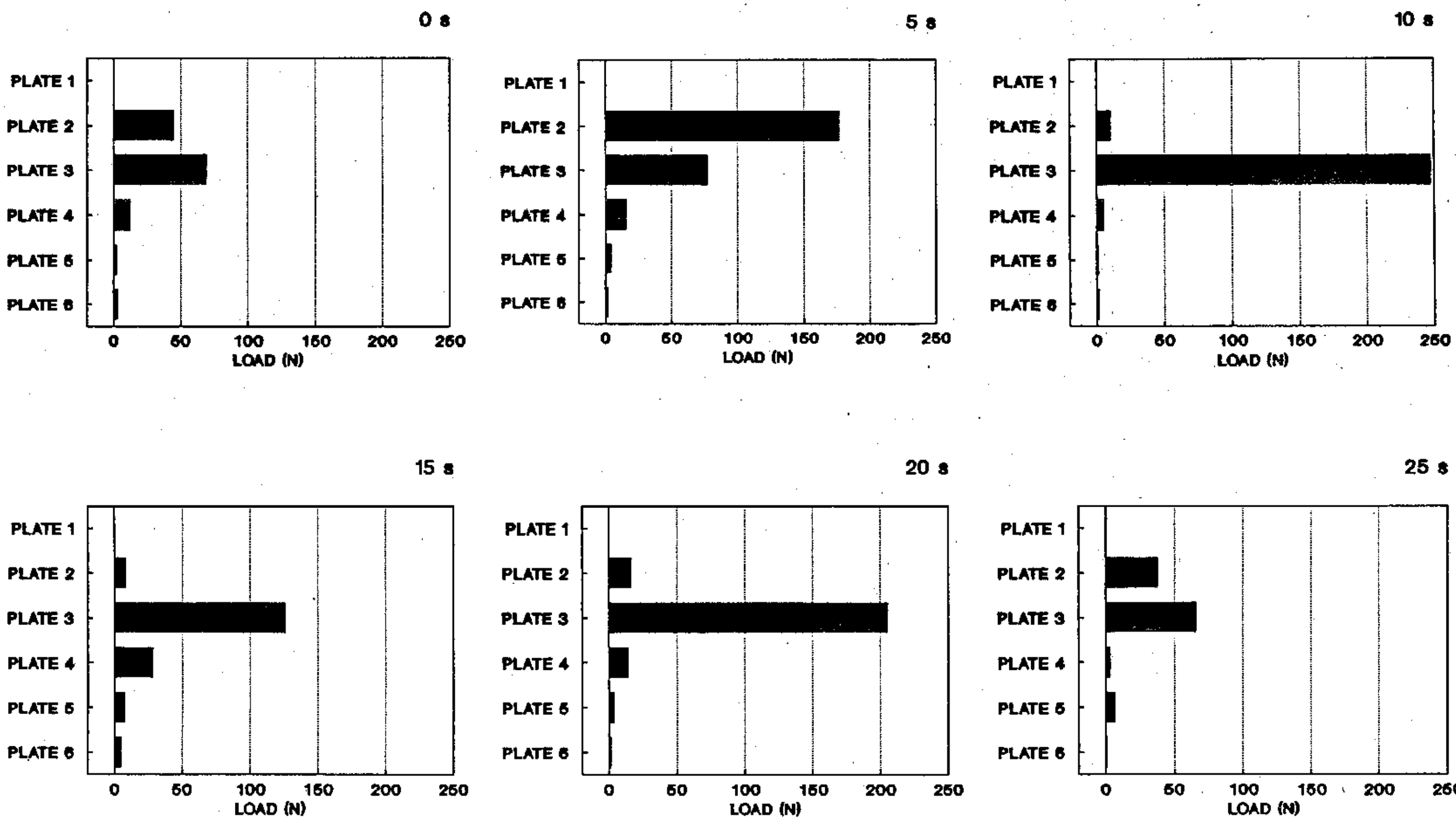

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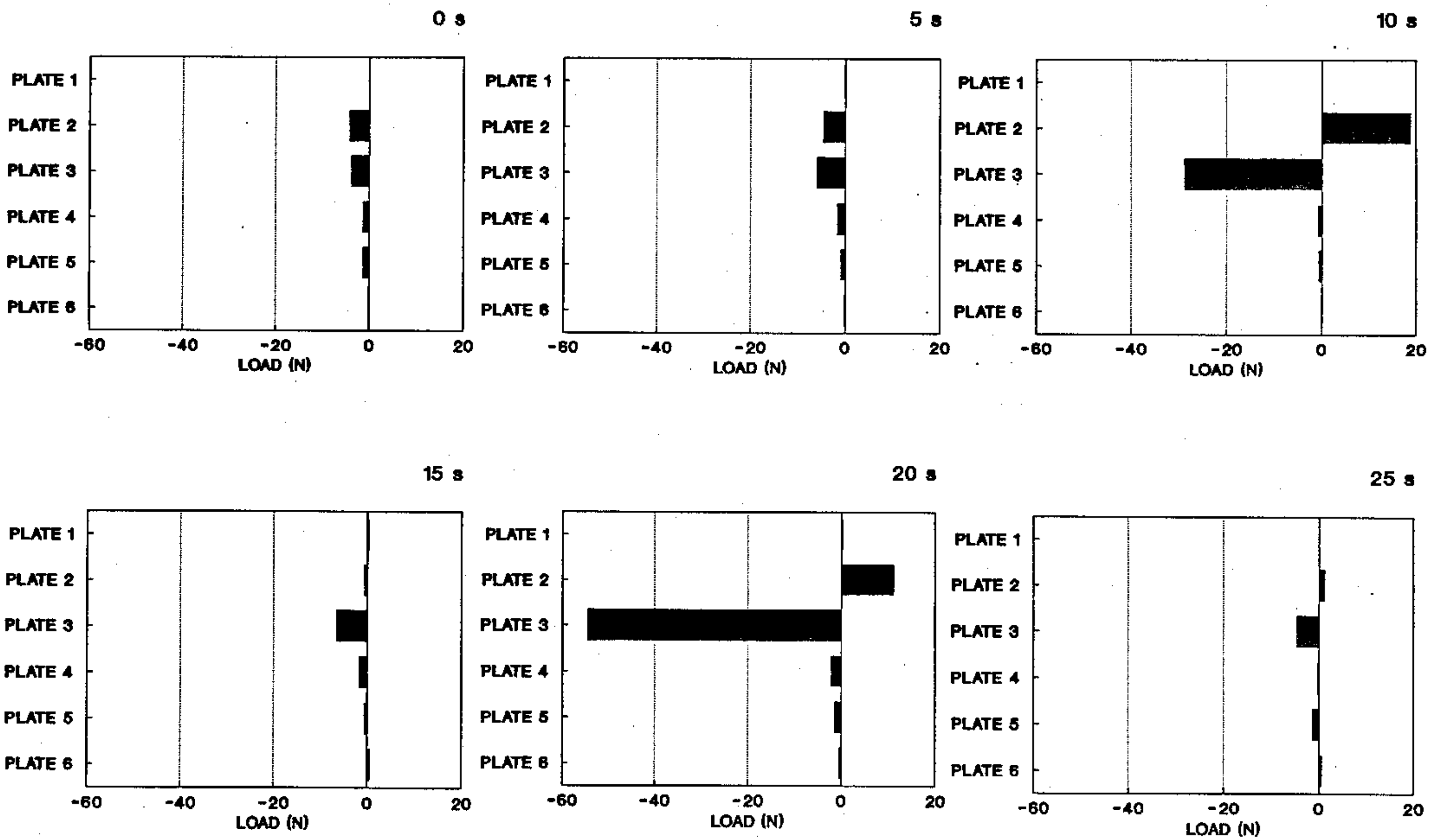

REPORT DOCUMENTATION PAGE/PAGE DE DOCUMENTATION DE RAPPORT

REPORT NO./ Nº DU RAPPORT	REPORT NO./ Nº DU RAPPORT	SECURITY CLASSIFICATION/ CLASSIFICATION DE SÉCURITÉ
1 TR-LT-021	2	3 __ Top Secret/Très secret __ Secret __ Confidential/Confidentiel __ Protected/Protégée X Unclassified/Non classifiée
DISTRIBUTION/DIFFUSION 4 __ Controlled/Controlée X Unlimited/Illimitée		

DECLASSIFICATION: DATE OR REASON/DÉCLASSEMENT: DATE OU RAISON

5

TITLE, SUBTITLE/TITRE, SOUT-TITRE

6 Model tests of pressured broken ice on a segmented inclined plane

AUTHOR(S)/AUTEUR(S)

7 G.W. Timco

SERIES/SÉRIE

8 Technical Report

CORPORATE AUTHOR/PERFORMING ORGANIZATION/
AUTEUR D'ENTREPRISE/AGENCE D'EXÉCUTION

National Research Council of Canada
9 Institute for Mechanical Engineering, Low Temperature Laboratory

SPONSORING OR PARTICIPATING AGENCY/
AGENCE DE SUBVENTION OU PARTICIPATION

10 This work was partially sponsored by the Canadian Coast Guard

DATE	FILE/DOSSIER	SPECIAL CODE/ CODE SPÉCIALE	PAGES	FIGURES	REFERENCES
11 1991/01	12	13	14 496	15 6	16 8

NOTES
17

DESCRIPTORS (KEY WORDS)/MOTS-CLÉS

18 Ice, rubble, structures, ships, loads, ride-up, pile-up

SUMMARY/SOMMAIRE
This report gives the full test results of a study of the ice loads and vertical load distribution on a structure subjected to moving ice.
19

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