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Cole, T.

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AUTHOR(S)

Tyler Cole

CORPORATE AUTHOR(S)/PERFORMING AGENCY(S)

Institute for Ocean Technology, National Research Council, St. John's, NL

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SUMMARY

The demand of oil and gas within the past few years has been developing exponentially. Along with this high demand, resource depletion is beginning to occur, causing the raising of market prices. This has enabled companies to begin production in areas that until recently were not economically possible. The industry has been undergoing extensive development because of this, constructing offshore platforms that have the ability to operate in ice-infested waters. Until now little knowledge has been collected on the dynamics of the ice forces against the platform. The purpose of this project was to gain knowledge of the dynamics of the ice forces against a platform. This report outlines the set-up, procedures and background knowledge.

ADDRESS

National Research Council
Institute for Ocean Technology
Arctic Avenue, P. O. Box 12093
St. John's, NL A1B 3T5
Tel.: (709) 772-5185, Fax: (709) 772-2462

National Research Council Canada
Conseil national de recherches Canada

Institute for Ocean Technology
Institut des technologies océaniques

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ABSTRACT

The demand of oil and gas with in the past few years has been developing exponentially. Along with this high demand, resource depletion is beginning to occur, causing the raising of market prices. This has enabled companies to begin production in areas that until recently were not economically possible. The industry has been undergoing extensive development because of this, constructing offshore platforms that have the ability to operate in ice-infested waters. Until now little knowledge has been collected on the dynamics of the ice forces against the platform. The purpose of this project was to gain knowledge of the dynamics of the ice forces against a platform. This report outlines the set-up, procedures and background knowledge.

ACKNOWLEDGMENTS

I was tasked to assist in the physical test of the model Kulluk in ice, take the ice properties, and preliminary analyse the data. The investigations presented in this report would not have been possible without the financial support of Dr. Michael Lau who provided supervision and mentoring during model testing, result analysis, and its documentation. The ice tank personnel's support is gratefully acknowledged.

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MODEL TESTS ON "KULLUK" IN ICE CONDITIONS

1 INTORDUCTION

Oil and gas are high demand non-renewable resources, which our modern world would suffer without. A large portion of the known oil and gas reserve is located in scantly explored offshore regions, some of them infested with ice that poses challenge and inhibits its recovery economically. Gas prices have increase steadily over the years due to the depletion of these resources. Recently, the price of gas has increased and reached a record high of $70 per barrel. The high price of oil and gas has made exploration and production economically viable in these harsh environments and stimulated exploration in these areas.

Ice can cause problems to drilling platforms. It may cause extensive damage to equipment and platforms, and endanger the life of the crew. One solution to the problem was to design structures with shapes inductive to effective ice breaking and defending. In 1983, a moored, downward breaking conical drill-ship called "Kulluk" was built (Figure 1). The structure was able to withstand the impact of level ice 1.2 metres thick without suspending operations. It was also equipped with a deflector ring around the bottom to stop ice from traveling below the structure endangering the mooring and drilling equipment. The structure has been operating in the Beaufort Sea from 1985, and extensive performance tests were performed on the vessel either through full-scale measurement during its operations or model tests during its design phase and on-going evaluations.

Tests using a 1:40 scale Kulluk model have been successfully conducted at the Institute for Ocean Technology's (NRC-IOT) ice tank in level, pre-sawn, and pack ice. Much information was collected. This report documents the preliminary data obtained during these tests.

1.1 Scopes and Objective

The three major areas of focus throughout this research were dynamic ice force time history, dominant period of ice force fluctuation, and added masses created by ice. The objective of this work is to obtain information of the dynamic response of the platform, which may provide an accurate emergency movement decision when unsafe ice conditions should arise, removing the possibility of unsafe operations and avoiding unnecessary delays. Information and knowledge on the impact of the ice environment on the platform in these areas could initiate the possibility of building a new platform with the ability to operate in more complex environmental conditions.

2 TEST SET-UP

2.1 Facility

The investigation took place at National Research Council's Institute for Ocean Technology situated in St. John's, Newfoundland in the ice tank. This tank contains a usable ice sheet length of 76 meters, width of 12 meters, and a tank depth of 3 meters making it the largest ice tank in the world. The 12-meter width of the sheet allows large/wide models to be tested. Smaller model tests can take place on the centreline, as well as the north and south quarter points. In addition to the ice-testing sheet, there is a 15-meter trimming dock, which is separated from the rest of the tank by a retractable thermal barrier. On the opposite end of the tank there is a melt pit. This is used for allowing the left over ice to melt, while allowing a new ice sheet to grow. The melt pit contains a sloped ramp to allow the used ice to be pushed in by the service carriage.

In order to grow an ice sheet a complex refrigeration system must be used to regulate the appropriate temperatures. The refrigeration system that is installed in NRC-IOT's ice tank is two-stage mechanical compression, with ammonia as the working fluid.

There are two carriages in the ice tank, without these machines testing would be impossible. The main carriage (towing carriage) is an 80,000 kg steel structure that is 15 meter in length, 14.2 meters wide and 3.96 meter high. The main carriage operates on four steel wheels and on four sprocket wheels, which are connected to a track, interlocking with the sprocket wheels allowing for speeds of 0.002 to 4 meters/second and the ability to instantaneously stop if necessary. The service carriage operates on four steel wheels, with the help of hydraulics. This carriage has a maximum speed of 0.5 meters/second. The carriage contains three working platforms, which can be raised individually or in unity. The working platform feature is used for ice control and testing, to check if the ice has reached the desired strength

2.2 Ice Production

The fluid, from which the ice is formed, is a water-based mixture with a complex chemical substance called EGADS, ethylene glycol ($HOCH_2CH_2OH$), aliphatic detergent and sugar ($C_{12}H_{22}O_{11}$). The percentage of the mixture is 0.39, 0.036, and 0.04 percent respectively. The basis behind this mixture is that during the freezing process is when the ice is forming it grows around the ethylene trapping it in little brine pockets. These brine pockets are required in order to reach the desired strength (to learn more see brain hills report). Being able to control the strength of the ice sheet is important in matching the scaling factor of the model. A major scaling problem encountered with EGADS mixture is the density. Water's density is not equal to that of seawater. This problem is solved through a bubble machine; this technology allows the inserting of bubbles into the ice during the growing process, causing the ice sheet to have a lower density without compromise the required strength. For procedure for making level, pre-sawn, and pack ice, see Section 3.2.

2.3 Ice Properties

Ice properties are extremely essential part of the testing in any experiment; with out accurate properties the data collected would not be complete for analysis. Properties must be recorded for every ice sheet; they are entered into NRC-IOT's database for quality control and future predictions. The particular properties that were collected in this experiment were ice thickness, and compressive (shear stress test) flexural strength (cantilever beam test), Young's modulus, ice density, and ice friction (see appendix C for description on each property).

2.3.1 Procedure

The procedure for taking ice properties varies for most of the different properties, for extensive procedures see Appendix C. Ice properties must be taking throughout the entire test period. The following procedure is for one sheet of ice; before the models first level ice run through, the modulus of elasticity (Young's modulus) must be taken. A main flexural strength (cantilever beam) test is done on both sides on the tank (North and South); this information is used to later produce a graph. A second flexural strength test called "beams on location" (BOL) is taken at the 15 and 30-meter mark to find the flexural strength accounting for time. The tests are done at the 15 and 30-meter mark because that is where the model will be tested. If BOL tests show that the ice is in the target range the carriage operator is told to make the first run. While the first run is being made a density is taken on the ice. Once the model has completed it run an Ice thickness test must be done at both sides of the channel that was created by the model every two meters. A test is done in pre-sawn ice (to see pre-sawn procedure see Section 3.2.2). While the run is in process, another main flexural test is done to complete the graph. BOL tests are again done (at the 35 and 50-meter mark) to find if the level ice is in the target strength range before the second level ice run is started. While the second level ice run is taking place another density is done on the ice. After the second level ice run another ice thickness is done on both side of the channel produced by the model. The Ice friction test is completed anytime during the day when the technicians are free to do so, however generally the ice friction is done at the end of the day.

2.4 Model Hydrostatics

The scale that was used in this test was 1:40. The full-scale information was taken from Comfort et al's ACL report (1982). See table 1 for the target values.

The hydrostatic information is useful in loading and stability studies during the design phase. Without proper knowledge of hydrostatics, even slight changes to a vessel could cause it to become unstable (lose equilibrium) and endanger equipment and lives of the crew.

2.5 Mooring System

The design for the mooring system of the Kulluk was a four-poll system. The poles were placed on the test frame forming a square. The mooring lines were connected to the Kulluk by load cells forming a 45-degree angle with the vertical and horizontal centre lines.

The actual mooring system that was in operation in the Beaufort Sea was a twelve line mooring system. A moored structure is recently known as favourable choice for an offshore oil and gas platform in ice-infested waters of medium depth. However until recently it is an area where little information has been collected.

During the model test of the Kulluk a four pole mooring system was used to simulate the behaviour of a 12-pole system that the actual ship was used.

The reason behind using the particular spring constants was that NRC-IOT chose to encompass the range of the mooring stiffness simulated in previous model tests as well as full-scale condition.

A wire cable acting as a mooring line, runs from the load cell that is connected to the Kulluk through a pulley on the bottom of the mooring pole and up to another pulley on the top of the mooring pole and attaching to a spring with a specific spring constant.

2.6 Equipment

2.6.1 Data Acquisitions and Instrumentations

The instrumentation used in these test were, 50 and 100 pound (0.222, and 0.445 kN) Intertechnology INC. load cells, which convert a force (tension) into a voltage reading. An optical tracking system known as Qualisys and a combination of accelerometers and angular rate sensors in a cube known as the MotionPak were used. There was an accelerometer placed on the carriage used from tracking the acceleration of the main carriage. Video cameras were placed to film the model from port, starboard bow, and underwater angles.

The MotionPak is a solid state, six degrees of freedom inertial sensing system. This device is used for measuring linear acceleration and angular rates in instrumentation and control applications; it is extremely reliable and compact. The MotionPak works by using micro machined quartz gyroscopes for angular rates and linear servo accelerometers are used for linear accelerations. The

MotionPak has six analog signal outputs, three for angular motion and three for linear motion; this outputs are connected to ICEDAS, which outputs them into an information database.

The Qualisys is a motion capture technology that is different from that used by the MotionPak - it uses optical motion sensors. A tree-like structure is placed on the model being tested (Figure 7). Digital infrared cameras are installed looking toward the tree-like structure, and its motion are acquired and analyzed. The cameras are the key hardware components in this motion capture system, the cameras send infrared light to the motion sensors on the model, this light is reflected to the camera, were the reflected data is used to calculate the position of the targets in space. This is the major difference between the MotionPak and the Qualisys motion capture system, the MotionPak is able to recorded the motion and the direction of the motion however it is unable to tell where the model is in space when it is not moving. The Qualisys motion capture system is able to tell where the model is in space and the movements.

During this experiment there was much video taken. There were four views filmed; port, starboard, bow, and underwater. The port and starboard cameras were connected to the mooring poles. The bow camera was connected to the test frame and gave a little bit of a top view as well. The underwater camera was connected to the underwater frame, which was towed along by the main carriage following the model. These videos have been edited and are organized for viewing each individual run. For a list of the videos that were taken see Appendix E. For information on file naming see appendix D.

All the data collected during this experiment had to be acquired and filtered. The data is sent from the outputs of the load cells, Qualisys and MotionPak, to a computer called ICEDAS; this computer complies and filters the data. Once ICEDAS has done all this a user can access the data and begin to receive the out readings and graphs, using our VMS system and the data acquisition computer.

2.6.2 Calibrations

2.6.2.1 Spring calibration

There were three different types of springs that were used in this experiment. The factory ratings of the spring constants of these springs were 1.191 kN/m (6.8 lb/in), 2.451 kN/m (14 lb/in), and 0.612 kN/m (3.54 lb/in). Springs constants (k) are different for every load that is used therefore the springs had to be calibrated. To calibrate a spring, it has to be hung from a higher surface. The distance from the top of the spring to the bottom of the spring is to be recorded as L_o. A weight is to be hung from the spring; the new distance from the top of the spring to the bottom of the spring is to be recorded as L_f. To find the value of the spring constant (k) we use the formula:

$$k\ (N/m) = F\ (N)/\Delta L\ (m) \quad \text{Equation 1}$$

where:

F is the force of the weight that is hung
ΔL is the difference between the distances
k is the spring constant

A graph of constant (kN/m) versus extension (m) is plotted the graph begins to increases exponentially and then at a certain force (weight) the graph changes into linear increasing. For graphs and data that was acquired see Appendix B.

2.6.2.2 Load cell calibration

Load cells are transducers that convert a force (weight) into a voltage that can be recorded on a computer and re-converted into a force reading from the voltage. For accurate testing the load cells have to be calibrated. For all calibration data see appendix B. To calibrate a load cell, it must be hung vertically, and weights must be hung from it and the output values recorded, and this is done for numerous loads. ICEDAS (the data acquisition computer, which all the information from the transducer channels is sent. ICEDAS contains the analog-digital convert cards) outputs the information in a graph that represents the force (weight) versus the input signal at A/D (analog/digital) converter.

2.6.2.3 MotionPak calibration

Calibration of the MotionPak requires it be placed on the model with the mounting plate down and the receptacle should be on the positive starboard (y-dir) direction side.

The three internal accelerometers must be calibrated, in unit of g's. It is calibrated using wedges. Wedges are objects that have known angles and can be move at known accelerations. Once all this is calibrated, the angular channels, which the MotionPak's output are plug into, must be calibrated. These channels can be calibrated by injected the calibration into the plugs, i.e. tell the computer what to read. Physical calibration can also be used. For more information on MotionPak calibration see "Institute for Marine Dynamics (IMD) quality system work instruction manual – calibration and alignment of the Systron Donner MotionPak sensor" by D. Cumming.

2.6.2.4 Qualisys calibration

When calibrating the Qualisys the infrared cameras must be installed facing the area when the model under examination will be positioned. A position calibration frame (a frame containing optical tracking markers) is placed where the model will be positioned. Check the makers on the Qualisys output screen. If all makers are in position a calibration program is to be ran to set the ranges and set-up the Qualisys for operation. For more information on Qualisys calibration see "IMD quality system work instruction manual – Qualisys Calibration" by M. Sullivan.

3 TEST PROGRAM

3.1 Test Matrix

A total of nine ice sheets with ice thickness ranging from 10 to 40mm were used in the present test series as shown in Table 2. Three sets of 4 linear tensions spring, which model global system stiffness, K, of 0.612, 1.191, and 2.451 kN/m respectively, were used. Each mooring stiffness were tested in three ice sheets of 20, 30 and 40mm, and in the case of K = 2.451 kN/m, an extra 10mm thick ice sheet was also tested.

For every ice sheet there were numerous runs, using different ice types such as, pre-swan, level, and pack ice. Excursion and decay tests were also conducted to assess the system static and dynamic response characteristics (for procedures for each test see Section 3.2).
Table 3 gives a typical test matrix for one ice sheet (40 mm). Figure 8 gives a drawing of ice sheet utilization. A complete list of the runs and the associate run naming convention are given in Appendix D.

For each ice sheet there was a master test plan created. Figure 8 is an example of one of those plans. In the plan it includes the position where the tests are to be conducted. The time it should take to conduct the tests is also included; this time takes into account ice preparation however this time does not leave room for error, therefore test plan tend to take longer than planed. The flexural strength range is included for the level ice on the test plan (pre-sawn and pack ice can not have a strength the ice is not in tacked). The target concentration for the pack ice is included on the test plan.

3.2 General Test Procedure

3.2.1 Level Ice

When testing level ice, the strength must be in the target range from testing. The procedure for testing level ice is to cut a semi-circle at the beginning of the ice sheet so that the Kulluk model will fit in snug; This is to minimize the effect of free edge on ice breaking. Once this has been done, the test run can begin using different velocities in the range of 0.025 – 0.3 m/s.

3.2.2 Pre-sawn Ice

When testing pre-sawn ice, preparation of the ice is essential to testing. The ice must have seven straight lines cut down the ice sheet, and a semi circle cut as well every meter. When the ice has been prepared the testing may begin. Sometimes with pre-sawn ice decay test are done during the run. If a decay test must be done a technician must be on the test frame during the run to perform the decay (decay test procedure: Section 4.2.1)

3.2.3 Packed Ice

When testing packed ice, the concentration must be set. There are three different concentrations that were used high, medium, and low. High concentration is in the range of 10/10 to 9/10; medium is roughly 9/10 to 8/10 and low is below 8/10. When the concentration is set, pictures must be taken from a top view, to later receive a better estimate of the concentration. Pictures start at the 10-meter mark and are taken every 10 meters. When the pictures have been taken the test run can begin using different velocities in the range of 0.025 – 0.3 m/s.

3.2.4 Open Water

When testing open waters, the only preparation is to make sure that there is no motion in the water before the run begins as to not skew the data. Open water tests have great importance, because when testing in the ice conditions the reaction forces are a combination of the water and ice reactions. With the open water test being completed the water reaction forces are known. A simple subtraction will result in revealing the ice reaction forces.

4 MOORING SYSTEM SPECIFIC TESTS

Platforms using mooring systems are different from the other categories of platforms, they are normally used in medium depth water, and recently they have show to be the best choice in ice-infested waters.

When testing mooring systems there are certain tests that must be preformed to gain knowledge in special areas. Dynamic coefficient, i.e., added mass and damping, in open water and in broken ice must be obtained. These coefficients are attained from decay test (Section 4.2). Mooring system stiffness, which defines the displacement response of the moored model to the global load, must be acquired. This is done through an excursion test (Section 4.1)

4.1 Excursion Test

4.1.1 Procedure

The excursion tests were performed in the surge (X) and the Sway (Y) directions. An in-line load cell was used to measure the load applied at the model in the respective direction. A schematic of the set-up is given in Figure 3. A cable was attached to the load cell and brought straight back in the direction of the excursion being tested. The cable ran through a pull system so that a tray can be hung from the other end of the cable. For each excursion test, the model was loaded with an increment of 5 kg increasing from 0 kg to 35 kg. The result displacement was measured by the Qualisys system. The data were analyzed to give the excursion or the stiffness curve. This data was also double checked with the theoretical values computed by the stiffness of springs used in the mooring system.

A total of fifteen excursion runs were conducted: thirteen for the surge-direction and two for the sway-direction as given in Table 4. For all system, the mooring stiffness behaves linearly. Figure 10 gives typical stiffness curve corresponding to each mooring stiffness if the system. The stiffness for each run is summarized in Table four.

4.2 Decay Test

During this experiment there were two different types of conditions that decay tests were preformed in, open waters and pre-sawn ice.
Due to the fact that the model was moving through ice during some of the decay tests, two properties had to be accounted for during these tests, added mass and damping imposed by the water and broken ice. (Section 4.3)

4.2.1 Procedure

To perform the decay test for pitch, sway and heave, the model was displaced in the respective direction using long wooden sticks and then suddenly released to cause the model to freely oscillate (Figure 11). The tests were performed in water to measure its added mass, damping coefficient and natural frequency in calm water condition. It was also performed in pre-sawn ice to measure the same induced by the broken ice. In additional to runs performed when the model was surrounded by broken ice of various ice thicknesses, runs were also conducted while the model was moving at a constant speed. This is to examine the effect of ice velocity on the dynamic characteristics of the mooring system. It a simpler procedure was used for decay runs for surge. For these tests, the model suddenly started moving at a short distance and came to a sudden stop, causing the model to oscillate in the surge direction right at the beginning and preceding the run. The decay measured at beginning of run would be subjected to model velocity and acceleration (while the model picked up speed), whereas the model was at dead stop proceeding to the run. Again, comparison of these runs will shed some lights on the effect of model motions on the dynamic characteristics of the mooring system. The decay tests in pre-sawn ice were preformed at three different velocities, 0, 0.01 and 0.2 m/s.

4.2.2 Data Reduction

The basis behind the decay test was to receive dynamic system information the damping coefficient, and period of the oscillation. After a decay test has been preformed the Qualisys and MotionPak outputted a graph (one for each, see appendix G for a sample output graph) from these graphs a time segment was selected for analysis. The data then was analysis by the computer; it outputs the damping coefficient and period of the selected time segment. The analysis is done using the following equation:

$$F(t) = (M_1 + M_2)\ddot{X} + C\dot{X} + X \qquad \text{Equation 2}$$

where:

M_1 = mass of model
M_2 = added mass (see section XX)
$\ddot{X}$ = acceleration at a specific time (second derivate of displacement with respect to time
$\dot{X}$ = velocity at a specific time (first derivate of displacement with respect to time).
X = displacement at a specific time
C = the linear damping coefficient

4.3 Added Mass

Accurate assessment of the added mass of water is essential in hydrodynamic analysis of floating moored structures. When the structures are operating in ice-infested waters the added mass of the ice is also crucial. In phase one of this project added mass was the key point of interest. Test results have shown that added mass induced by ice on the floating structures is substantial. Lau et al (1995) has identified a number of cases where added mass due to ice has had significant influences on the dynamic behaviour of the moored structures.

During this phase of the project (Phase 2) techniques have been developed for the measurements of added mass and its dynamic characteristics in ice. However this section has not been completed and will not be able to be included in this report.

4.3.1 Phase One

In Phase one of this project, Lau (1995) has used a new technique to measure the added mass of a fixed cone moving in icy water. He performed acceleration runs in water and broken ice respectively to estimate the added mass due to the water and the broken ice. For each ice condition, runs with a range of accelerations were performed. The Newton's second law applicable to runs conducted in ice with an arbitrary acceleration is as follows:

$$m_s \cdot a_n = F_{mea(n)} - F_{w(n)} - F_{i(n)} =$$
$$F_{mea(n)} - [F_{w(n)}(v) + m_w \cdot a_n] - [F_{i(n)}(const) + F_{i(n)}(v) + m_i \cdot a_n] \qquad \text{Equation 3}$$

The Newtonian equation for two different accelerations performed at the same pre-sawn condition can further be manipulated to give the formula for the added mass of ice:

$$m_i = \frac{(F_{a2n,v} - F_{a1n,v})}{(a_{2n} - a_{1n})} - (m_w + m_s) \qquad \text{Equation 4}$$

where:

m_i	= added mass of ice
m_w	= added mass of water
m_s	= mass of structure
a_1	= acceleration of the first run
a_2	= acceleration of the second run
$F_{a1,v}$	= measured global force on the structure at acceleration one in the same direction
$F_{a2,v}$	= measured global force on the structure at acceleration two in the same direction

The m_w is obtained through a similar acceleration run in open water see Phase one for details.

Results from Phase one suggested that velocity had little effect on the added mass. Referring to Figure 12 and 13, the graph results in linear curves for numerous different constant accelerations. Using these curves to produce another set of graphs that show the relationship between force and acceleration for the different velocities. This graphs (Figure 13), all have a similar slope, and through the use of Newton's 2nd law, Force equal mass times acceleration, to show mass equals force divided my acceleration. Noting that force over acceleration is the slop of the graph proves that velocity has minimal effect on added mass.

Once this was established the rest of the analysis, Phase one and Phase two, was based on the assumption that velocity has no influence on the added mass of ice.

To obtain the added mass of ice value using the manipulated Newtonian equation, the first term is the slop of the linear line (using Figure 14). The added mass of water is found by the force versus acceleration curve, obtained from the open water runs. The mass of the structure comes from the model specifics.

Using the information obtained from the numerous tests that were preformed, Figure 14 was produced. Using the added mass information that was obtained from Figure 14, another graph was produced showing the added mass of ice as a function of ice thickness (Figure 15).

5 ANALYSIS

This project required some in depth analysis of ice properties, previous data and current data. The ice property analysis, was needed to help understand the conditions of the ice during the time in which the tests where preformed, due to the fact that every test run did not have the same ice conditions. The previous data needed to be analysis for external consistency. The analysis of the current is only in the preliminary stage; limited amount of graphs have been produced for, level, ice conditions.
The analysis of the ice properties consisted of, entering the properties into an excel spreadsheets. This was required in order to identify and understand each ice sheet. Without this information the data for the individual runs would be skewed.

The analysis of the previous data was obtained through digitizing of previously released graphs. The graphs were released, however NRC-IOT did not have the values from the graphs. An image digitizer was used to find the data points on the graphs, a total of 21 graphs were digitized. The previous information was needed for external consistency of the current data, to see if NRC-IOT's data was skewed in any way. To digitize a graph, a program called ImageDIG was used. The program allows the user to select the minimums and maximums of the graph, and then to select points on the graph. The selected points are output into a file which can be imported into excel.

The analysis of the current data, which is know as the preliminary analysis, consisted of plotting numerous graphs from the data obtained from the many test runs preformed in the ice tank. Graphs for Peak Horizontal Load Vs Ice Velocity for every spring constant, Peak Horizontal Displacement Vs Ice Velocity for every spring constant, Peak Horizontal Load Vs Ice Thickness for each individual velocity and spring constant, and Peak Horizontal Displacement Vs Ice Thickness for each individual velocity and spring constant were produced. These graphs were produced for each different ice conditions (level ice, pre-sawn ice, pack ice, and open waters).

6 PRELIMINARY RESULTS

The results that have been produced at the point in time are only the preliminary results. Therefore please note that the follow results are all preliminary.

6.1 Data From Previous Series

The data that was obtained from the pervious testing was from other institutes such as, ARCTEC Canada Limited (ACL), Iowa Institute of Hydraulic Research (IIHR) and Hamburg Ship Model Basin (HSVA). These figures can be found in Appendix H, Figure 16 shows the previously mentioned data, together with full-scale data and NRC-IOT's preliminary data. On the graph it shows that the HSVA tests which was used as the primary basis for the "Kulluk's" ice design, show good agreement. The IIHR tests are slightly high. The ACL data are very high, almost by a doubling factor, however the simulated ice (wax ice) that was used at the time had a very larger coefficient of friction, producing ice interactions that were not seen in full scale with real ice. NRC-IOT's data is consisted with the other model test data, however the last spread of data is rather high, which may reflect the effect of velocity. It can be seen that there is minor effect from the different global stiffness, and there is a higher first order increase of force due to ice thickness, which was expected.

6.2 Dynamic Ice Force Time History

During the testing of the model in ice conditions many dynamic ice force time histories were outputted for every test run. Figures 17 to 20 give dynamic ice force time histories of different conditions. Figure 17, is a 20 mm level ice time history with a weak spring constant, ice sheet strength of 12 kPa, and a high velocity. Figure 18 is a 40 mm pack ice time history with a weak spring constant, medium ice concentration, and a high velocity. Figure 19 is a 40 mm pre-sawn ice time history with a weak spring constant, and a high velocity. Figure 20 is an open water time history with a high velocity. All of these time histories are all steady state; in each one the wave periods can be seen. From the time histories it can be seen on how the model acts in the surge direction, which in this project was the main direction of concern. For example in Figure 17 it can be seen that the model is always in the negative X position which makes sense due to the pushing of the ice on the model placing it in the negative X direction region.

6.3 Test Results (Graphed)

There was much data released from the testing, which was conducted. Many graphs were produced which can be viewed in Appendix I. Figure 21 is a sample of one of the peak horizontal (X) load vs ice velocity, with an ice thickness of 20 mm and level ice strength of 20 kPa. After the 0.05 m/s velocity, which is considered the high velocities, the graph seems to transform into a liner curve. However before the 0.05 m/s velocity, which is considered the low velocities, there seem to be non-linear curves almost “backwards J” like curves. The low velocity part of the curve shows the reactions in the ice to be more ductile, and the high velocity part of the curve shows the ice reactions are more brittle. Noting that at this time, this set of curves has not been proven to be true trends..

7 CONCLUSIONS

Here at NRC-IOT much testing is done at a very high work quality. During this work term I have learn very much useful knowledge. However I was unfortunate to see the data analysis of this project to the end. I was still fortunate enough to assist in the physical test of the model, taking of the ice properties, and preliminary analysis of the data.

From the preliminary results it has been shown that the model information is externally consisted with other institutes. It has also shown an interesting trend in the peak horizontal (X) load vs ice velocity curves. Nevertheless, there is much more analysis to be done before any real conclusions can be made.

8 REFERENCES

1 Environmental Modeling – Ice Version Two, By Brain Hill 3 November 1999

2 BEI MotionPak (http://www.systron.com/pro_motpk.asp)

3 Qualysis (www.qualysis.com/proreflex.html)

4 Dr. M. Lau Model test investigations added mass induced by ice on a moored downward conical structure in ice conditions, 4 May 2003

5 A Proposal for Doctoral Research In the Faculty of Engineering & Applied Science, By Jianfeng Tong, B.Eng., M. Eng., 26 October 2002

6 Resistance in Ice Version One, By Stephen J. Jones, 11 February 2000

7 IMD Quality System Work Instructioin Manual “Calibration and Alignment of Systron Donner MOTIONPAK sensor” by D. Cumming, 18 October 2000

8 IMD Quality System Work Instructioin Manual “Qualisys Calibration” by M. Sullivan 21 September 2000

Table 1: Hydrostatics of Kulluk and Model

	Scale	1	40
			NRC-IOT
Hydrostatic Property	Unit	Full Scale	Model Scale (measured)
Overall Beam	Meters (m)	81	2.025
Waterline Beam	Meters (m)	67.9	1.698
Beam at hull bottom	Meters (m)	62 (scaled up)	1.552
Depth	Meters (m)	18.4 (scaled up)	0.460
Draft	Meters (m)	11.5	0.288
Slope at Waterline	Degrees	31.5	31.4
Displacement	Kg	27999000 (approx.)	437.5
Vertical Centre of Gravity (VCG)	Meters (m)	13.2	0.330
Pitch Gyradius*	Meters (m)	17.78	0.445
Roll Gyradius*	Meters (m)	18.91	0.473
Vertical Moment Mass (Z dir.)	Kg*m	14.4092×10^9	140.715
Mass Moment of Inertia (Pitch)	Kg*m^2	9.0402×10^9	88.283
Mass Moment of Inertia (Roll)	Kg*m^2	10.139×10^9	99.014

**Due to the Kulluk symmetrical cone shape the Gyradius for pitch and roll can be taken as 0.4586 meters.*

Table 2: Instrumentations Used in Testing

Instrumentation	Description	Capacity	Manufacture
Load Cell (1)	A transducer, which converts force into electrical output.	50 lbs (0.222kN)	INTERTECHNOLOGY
Load Cell (2)	A transducer, which converts force into electrical output.	100 lbs (0.445 kN)	NTERTECHNOLOGY
Qualisys	An optical tracking system, using infrared cameras.	-	
MotionPak	A solid-state six degrees of freedom inertial sensing system.	-	BEI-TECHNOLOGY
Accelerometer	Measure the acceleration of the object to which it is attached.	+/- Volts DC	Q-Flex

Note: For more information on data specifics, or factor calibrations see appendix B.

Table 3: Ice sheet summary

Ice Sheet Name	Thickness (mm)	Spring Constant (kN/m)	Date
Kulluk8	30	2.451	August 26, 2005
Kulluk9	10	2.451	August 29, 2005
Kulluk10	20	2.451	August 30, 2005
Kulluk11	40	2.451	September 1, 2005
Kulluk12	20	1.191	September 2, 2005
Kulluk13	30	1.191	September 5, 2005
Kulluk14	40	1.191	September 9, 2005
Kulluk15	30	0.612	September 13, 2005
Kulluk16	20	0.612	September 14, 2005
Kulluk17	40	0.612	September 16, 2005

Table 4: Test matrix for 40mm of ice

Run Name	Ice Velocity	Strength	Ice Type	Test Location
	m/s	kPa		
LI40_K3_S20_VH	0.025	20	LI	Central/Fist half
LI40_K3_S20_VH	0.05	20	LI	Central/Fist half
LI40_K3_S20_VH	0.1	20	LI	Central/Fist half
LI40_K3_S20_VH	0.2	20	LI	Central/Fist half
LI40_K3_S20_VH	0.3	20	LI	Central/Fist half
LI40_K3_S20_VL	0.01	20	LI	Central/Fist half
LI40_K3_S20_VL	0.005	20	LI	Central/Fist half
PS40_K3_VH	0.025	0	PS	South Quarter Point
PS40_K3_VH	0.05	0	PS	South Quarter Point
PS40_K3_VH	0.1	0	PS	South Quarter Point
PS40_K3_VH	0.2	0	PS	South Quarter Point
PS40_K3_VH	0.3	0	PS	South Quarter Point
PS40_K3_VL	0.01	0	PS	South Quarter Point
PS40_K3_VL	0.005	0	PS	South Quarter Point
LI40_K3_S12_VH	0.05	12.5	LI	Central/Second half
LI40_K3_S12_VH	0.1	12.5	LI	Central/Second half
LI40_K3_S12_VH	0.2	12.5	LI	Central/Second half
LI40_K3_S12_VH	0.3	12.5	LI	Central/Second half
LI40_K3_S12_VL	0.01	12.5	LI	Central/Second half
LI40_K3_S12_VL	0.005	12.5	LI	Central/Second half
PS40_DECAY_K3_P_V0P2	0.2	0	PS	South Quarter Point
PS40_DECAY_K3_R_V0P2	0.2	0	PS	South Quarter Point
PS40_DECAY_K3_H_V0P2	0.2	0	PS	South Quarter Point
PS40_DECAY_K3_S_V0P2	0.2	0	PS	South Quarter Point
PS40_DECAY_K3_P_V0P01	0.01	0	PS	South Quarter Point
PS40_DECAY_K3_P	0	0	PS	South Quarter Point
PS40_DECAY_K3_R_V0P01	0.01	0	PS	South Quarter Point
PS40_DECAY_K3_R	0	0	PS	South Quarter Point
PS40_DECAY_K3_H_V0P01	0.01	0	PS	South Quarter Point
PS40_DECAY_K3_H	0	0	PS	South Quarter Point
PI40_CH_K3_VH	0.05	0	PSC10	North Quarter Point
PI40_CH_K3_VH	0.1	0	PSC10	North Quarter Point
PI40_CH_K3_VH	0.2	0	PSC10	North Quarter Point
PI40_CH_K3_VH	0.3	0	PSC10	North Quarter Point
PI40_CH_K3_VL	0.01	0	PSC10	North Quarter Point
PI40_CH_K3_VL	0.005	0	PSC10	North Quarter Point
PI40_CM_K3_VH	0.05	0	PSC9	North Quarter Point
PI40_CM_K3_VH	0.1	0	PSC9	North Quarter Point
PI40_CM_K3_VH	0.2	0	PSC9	North Quarter Point
PI40_CM_K3_VH	0.3	0	PSC9	North Quarter Point
PI40_CM_K3_VL	0.01	0	PSC9	North Quarter Point
PI40_CM_K3_VL	0.005	0	PSC9	North Quarter Point
PI40_CL_K3_VH	0.05	0	PSC8	Central/Second half
PI40_CL_K3_VH	0.1	0	PSC8	Central/Second half
PI40_CL_K3_VH	0.2	0	PSC8	Central/Second half
PI40_CL_K3_VH	0.3	0	PSC8	Central/Second half

PI40_CL_K3_VL	0.01	0	PSC8	Central/Second half
PI40_CL_K3_VL	0.005	0	PSC8	Central/Second half
EX_K3 X-dir	-	-	-	-
EX_K3 Y-dir	-	-	-	-

Table 5: Test matrix for all excursions

Test	Date	Direction	Target global Stiffness (K, kN/m)
EX_K1_003	25-Aug-05	X	1
EX_K1_028	26-Aug-05	X	1
EX_K1_070	01-Sep-05	X	1
EX_K2_090	02-Sep-05	X	2
EX_K2_108	06-Sep-05	X	2
EX_K2_109	06-Sep-05	X	2
EX_K2_118	07-Sep-05	X	2
EX_K2_136	09-Sep-05	X	2
EX_K3_154	12-Sep-05	X	4
EX_K3_156	13-Sep-05	X	4
EX_K3_187	14-Sep-05	X	4
EX_K3_216	16-Sep-05	X	4
EX_K3_245	17-Sep-05	X	4
EX_Y_K2_116	06-Sep-05	Y	2
EX_Y_K3_157	13-Sep-05	Y	4

Figure 1: Kulluk in Operation

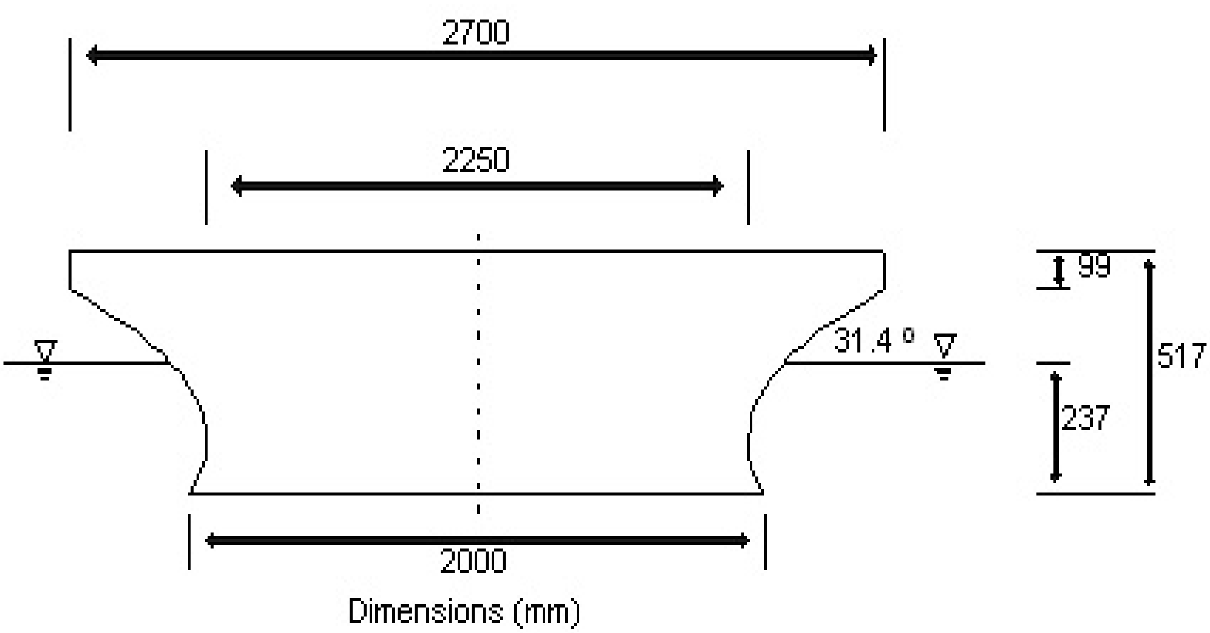


Figure 2: Kulluk Model Dimensions

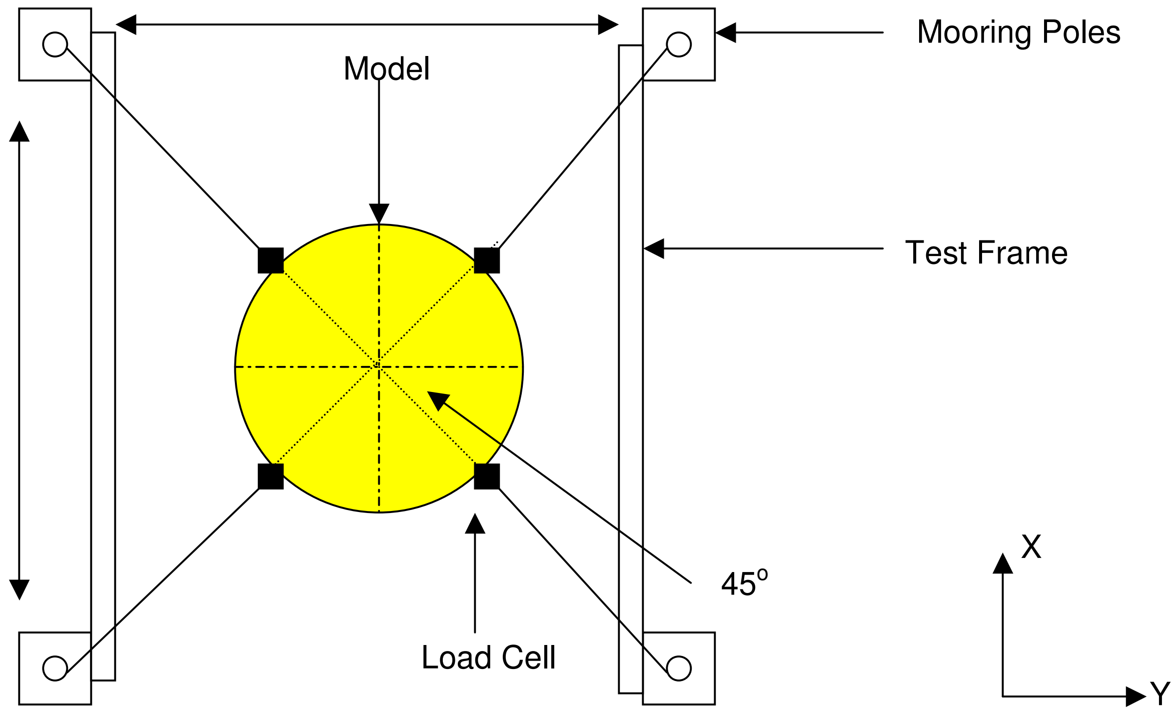


Figure 3: Top view of mooring system

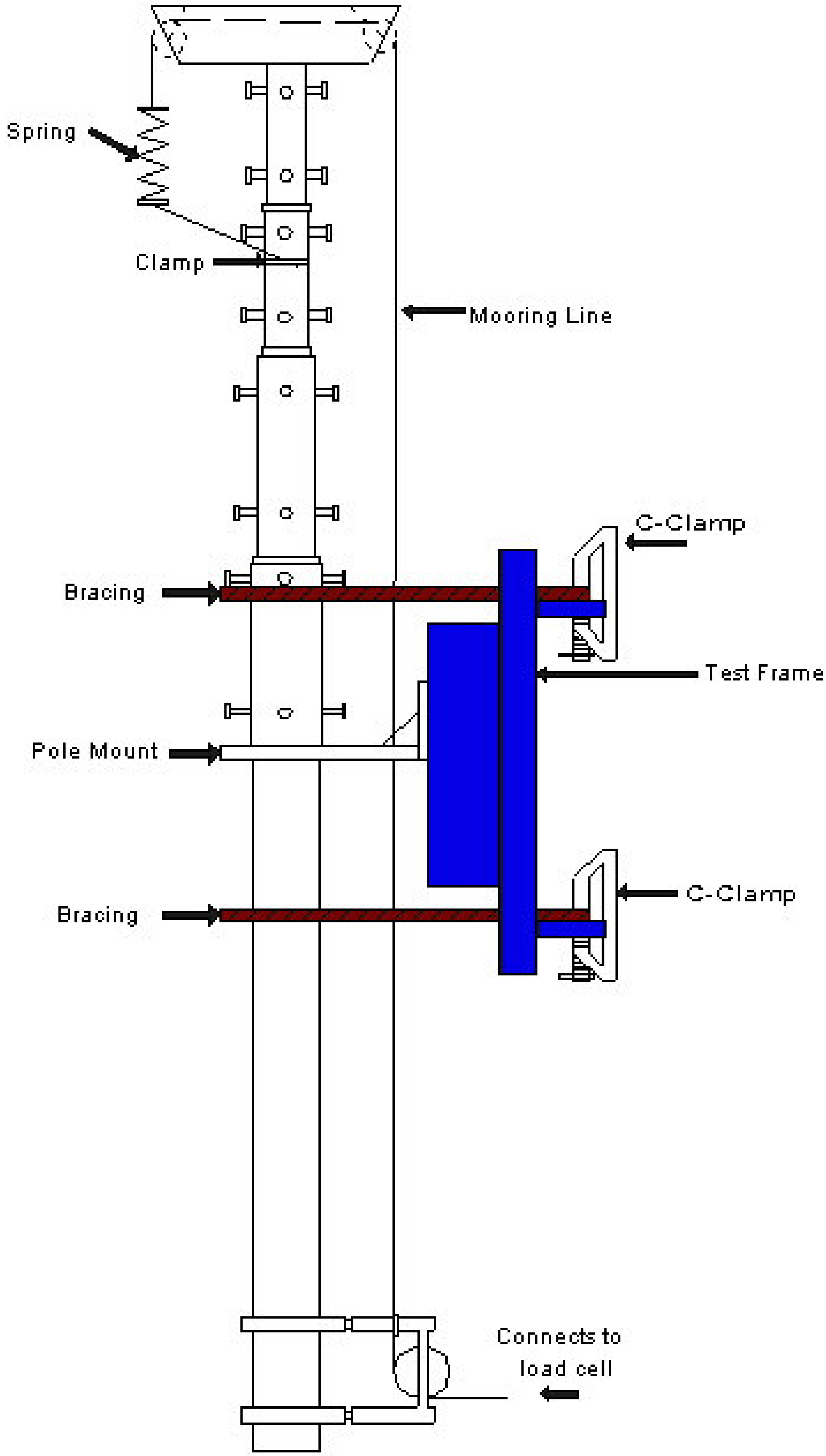


Figure 4: Mooring pole (figure not to scale)

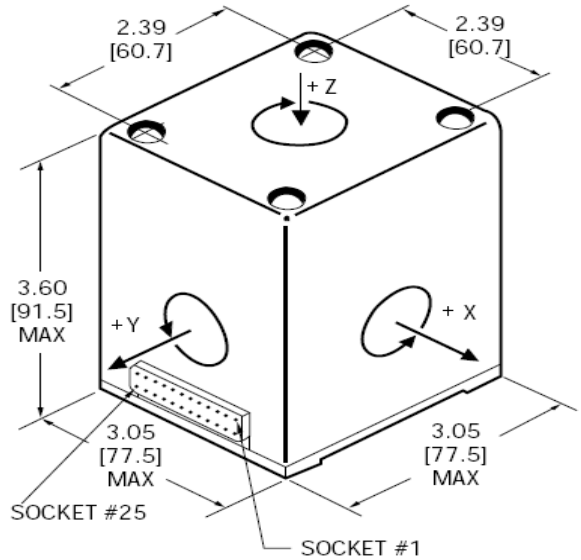


Figure 5: MotionPak (BEI Tech).


Figure 6: Digital Infrared Camera


Figure 7: Qualisys tree-like structure

PJ 2019, Phase 2.

#4 Presawn ice Constant Speed σ_f = 0kPa Time estimate: 1hr15min (Including pre-sawn)		#3 Level ice Constant Speed σ_f = 12.5kPa Time estimate: 45min	
#2 Presawn ice Acceleration σ_f = 0kPa Time estimate: 1hr15min (including ice Preswan)		#1 Level ice Constant Speed σ_f = 20kPa Time estimate: 45min	

Part 2

	#3 Pack Ice Constant Speed C = 8/10 Time estimate: 1hr 30min (include 1 hr ice cutting)	

Figure 8: Master Plan for Ice Usage

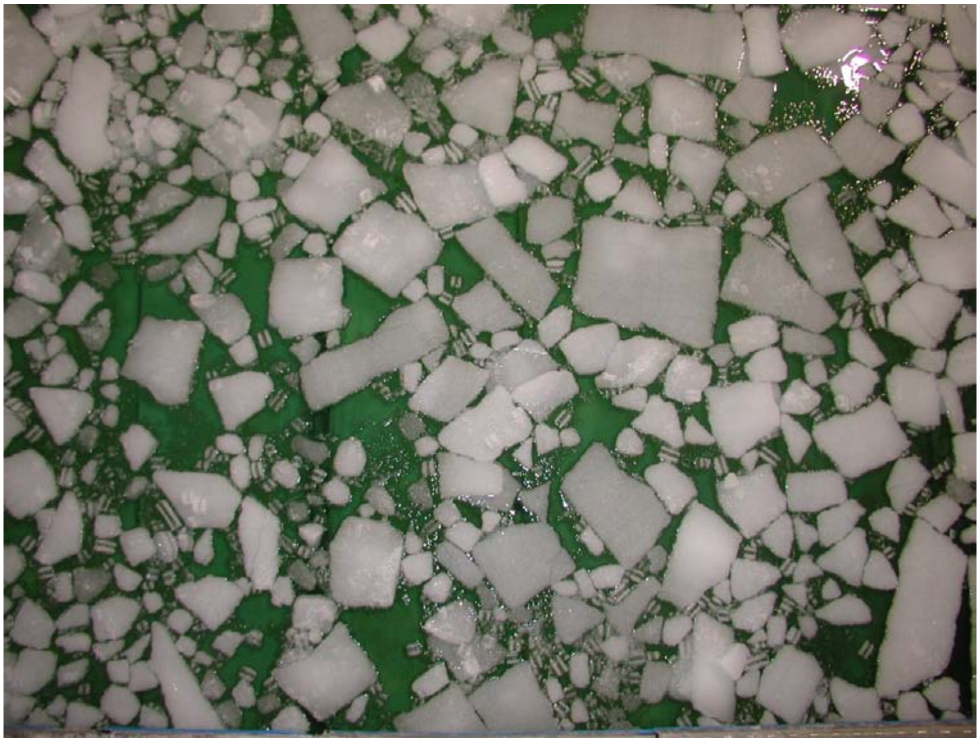


Figure 9: Low concentration pack ice

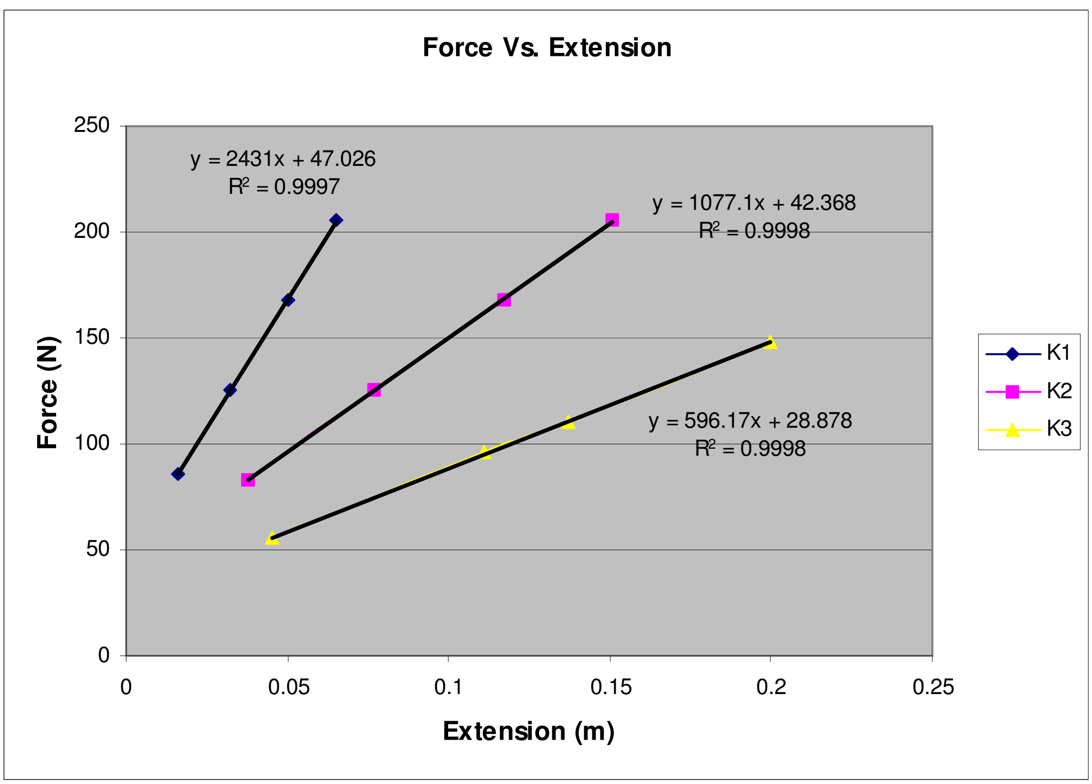


Figure 10: Stiffness curve

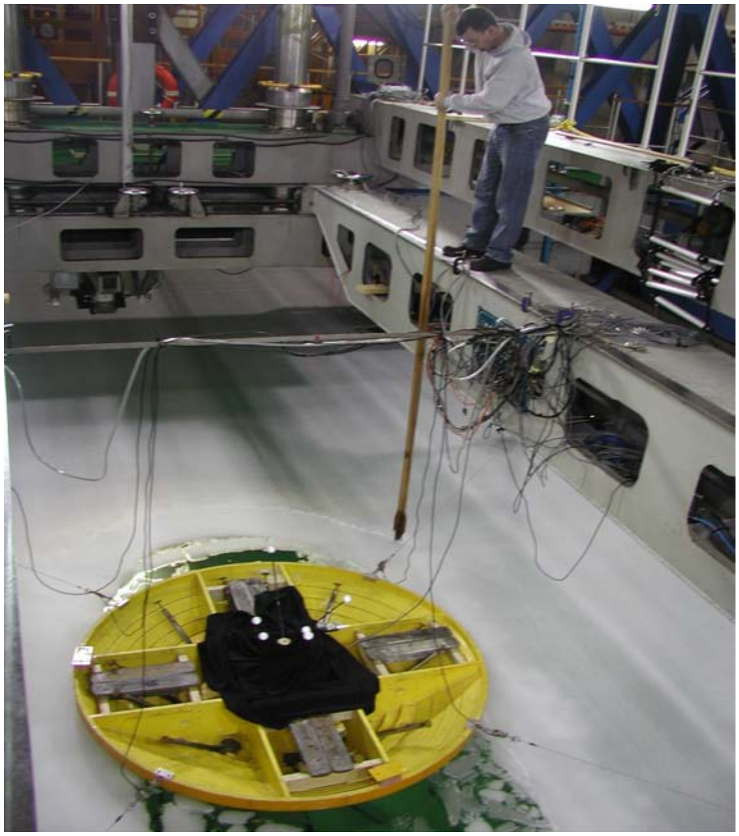


Figure 11: Decay test

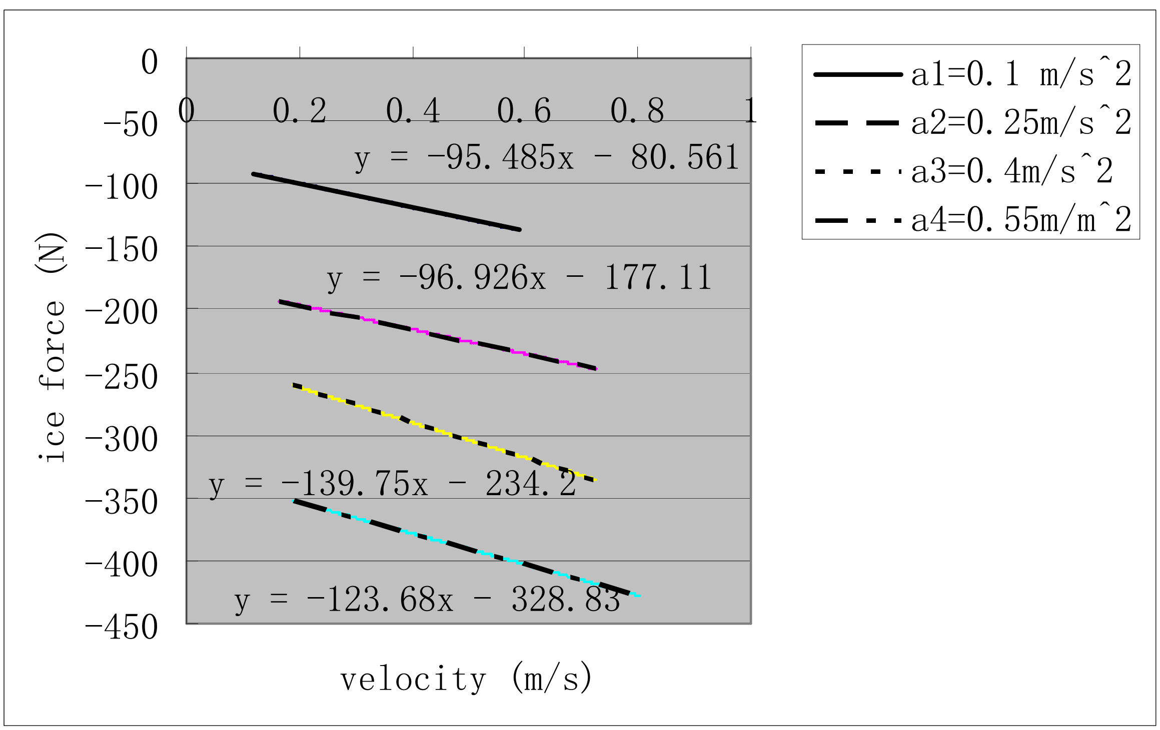


Figure 12: Relationship between ice force and velocity

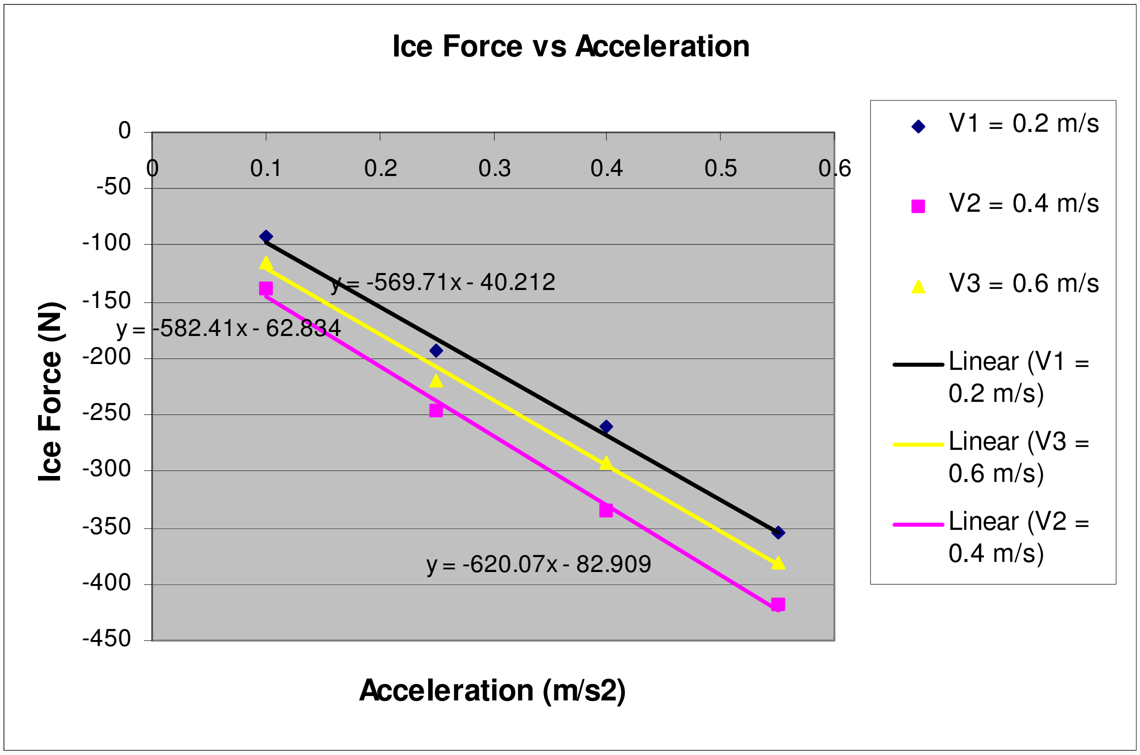


Figure 13: Relationship between ice force and acceleration with constant velocity

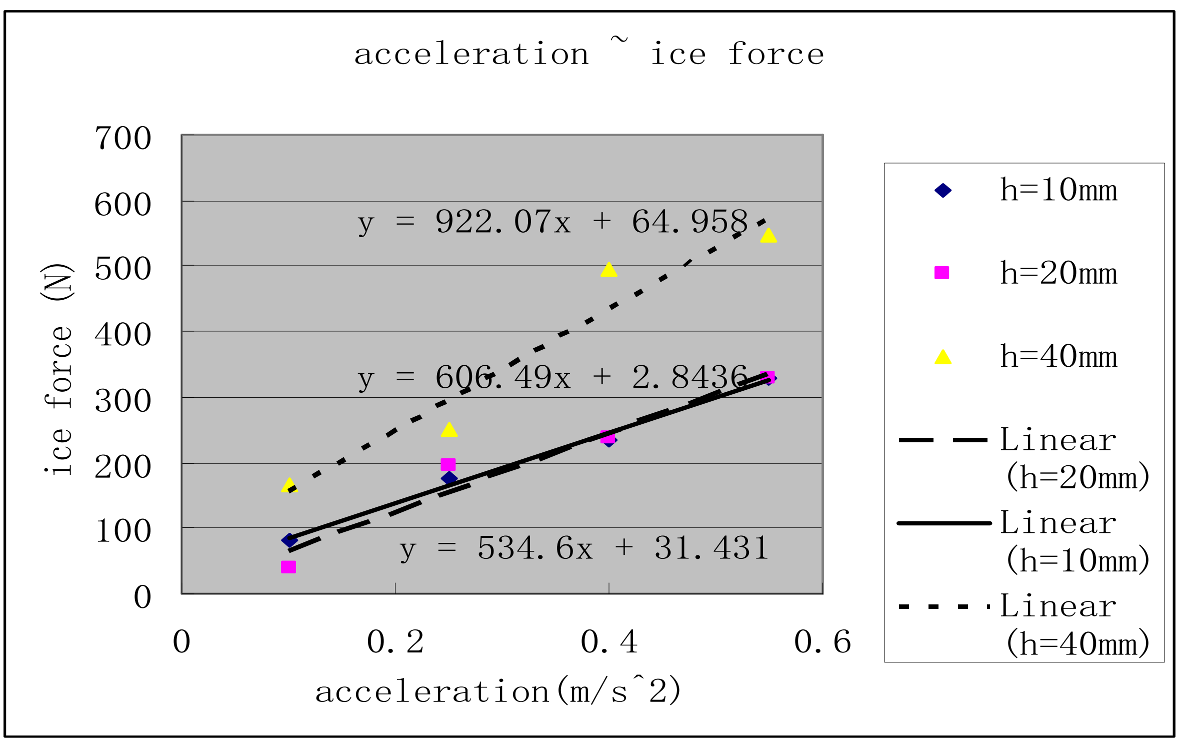


Figure 14: Relationship between ice force and acceleration

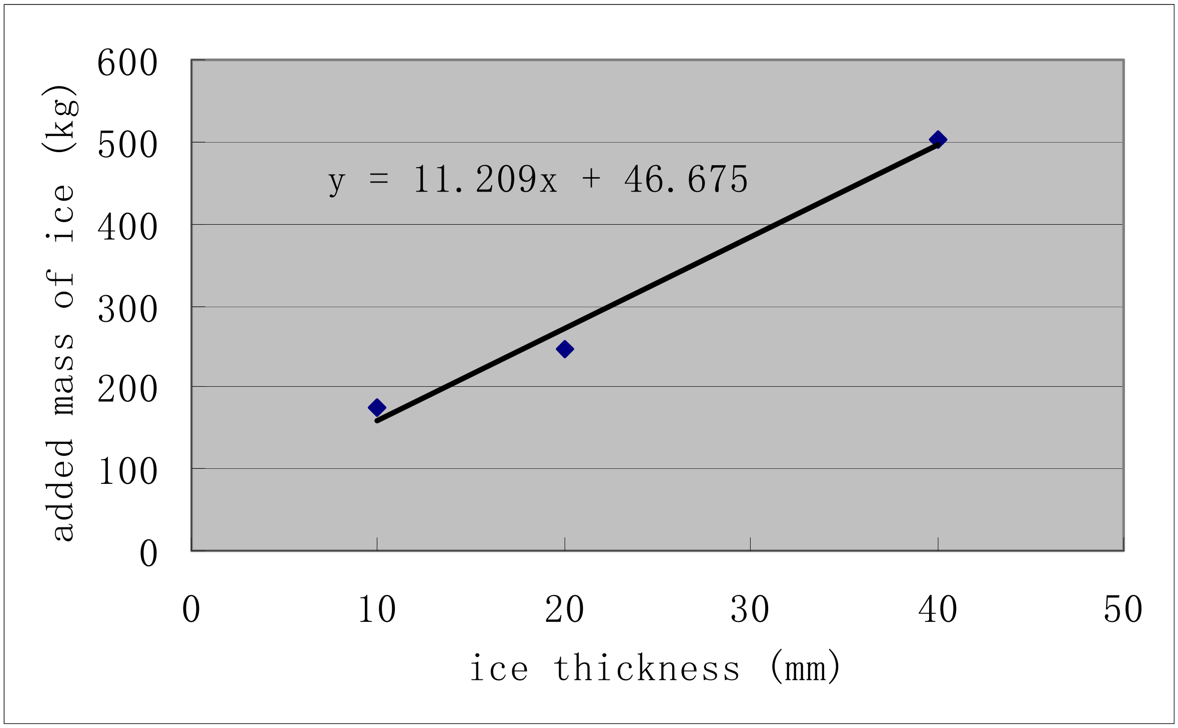


Figure 15: Relationship between added mass of ice and the thickness

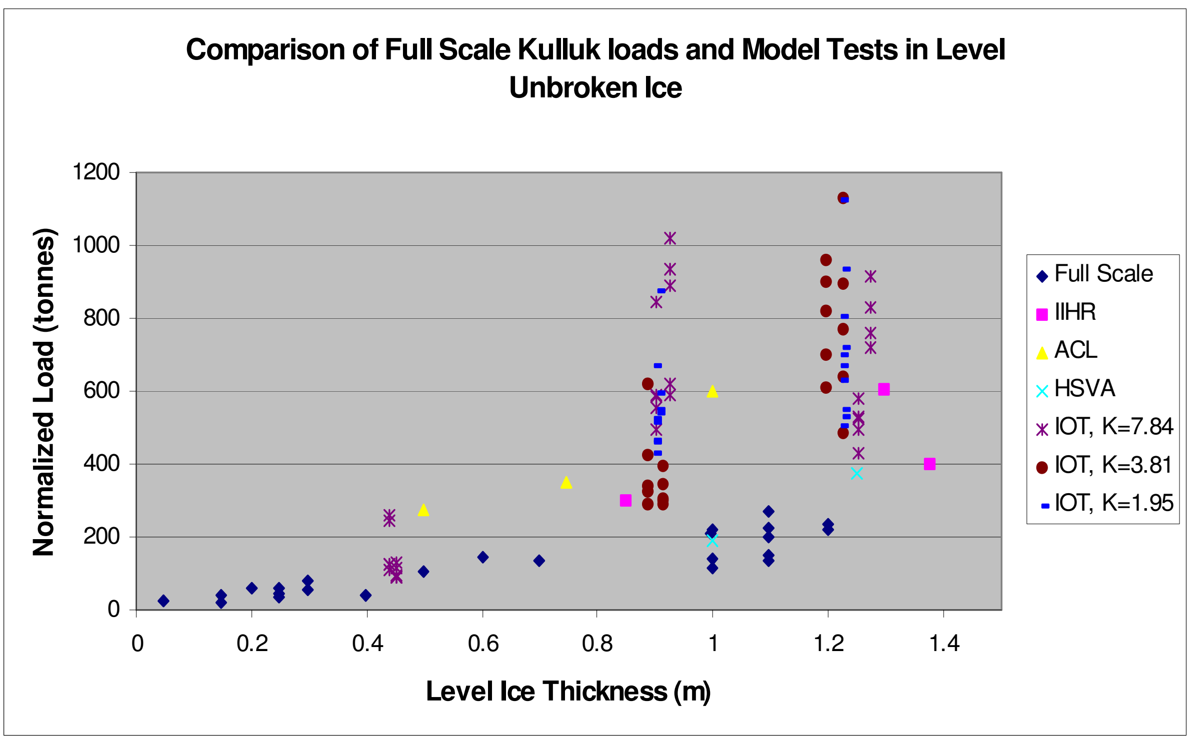


Figure 16: Relationship between normalized load and level ice thickness for different model tests and full scale

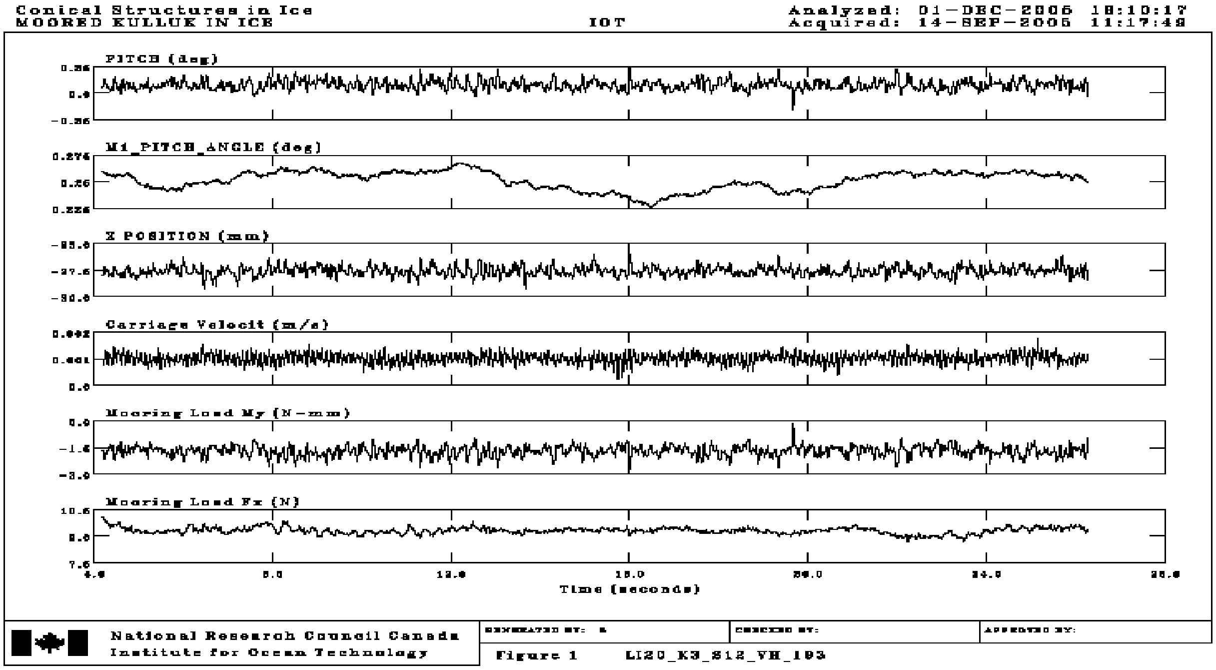


Figure 17: Dynamic ice force time history for level ice

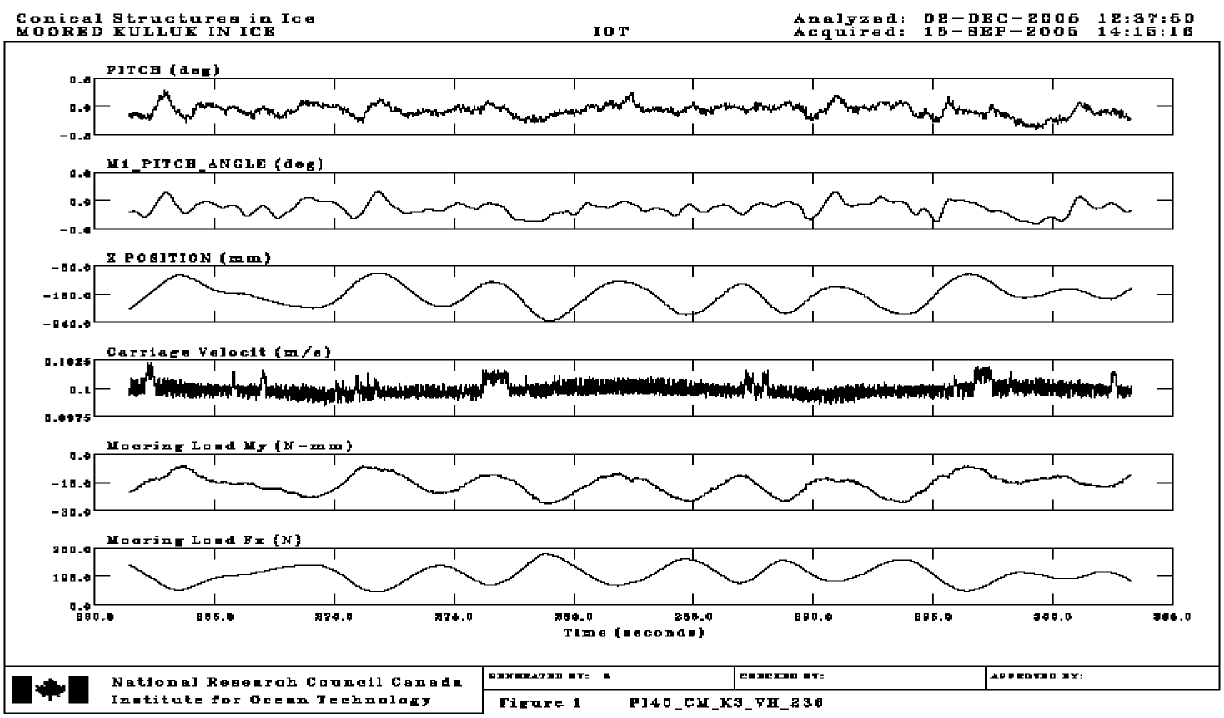


Figure 18: Dynamic ice force time history for pack-ice

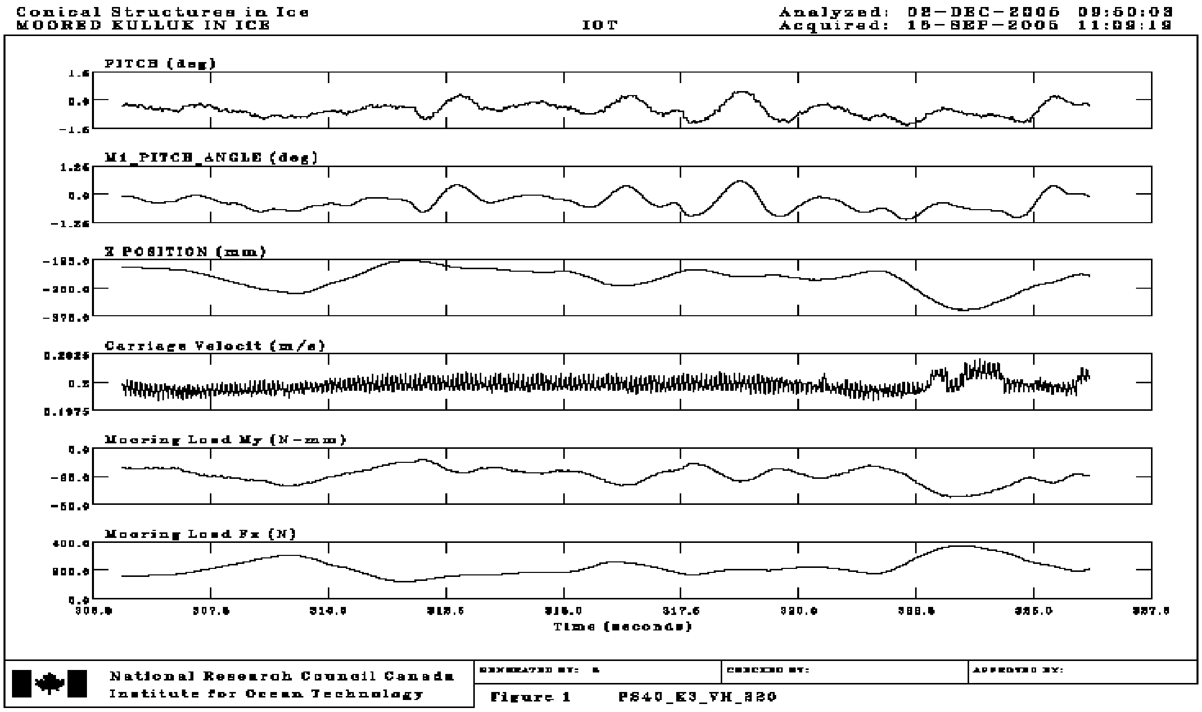


Figure 19: Dynamic ice force time history for pre-sawn ice

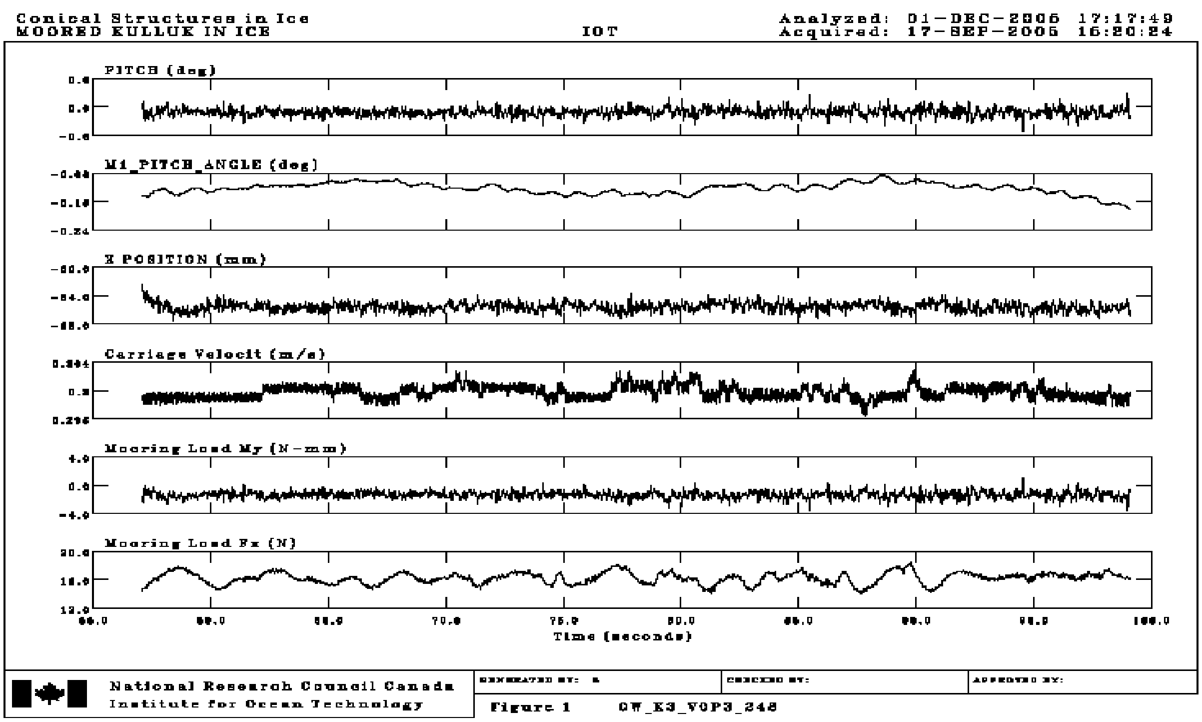


Figure 20: Dynamic ice force time history for open water

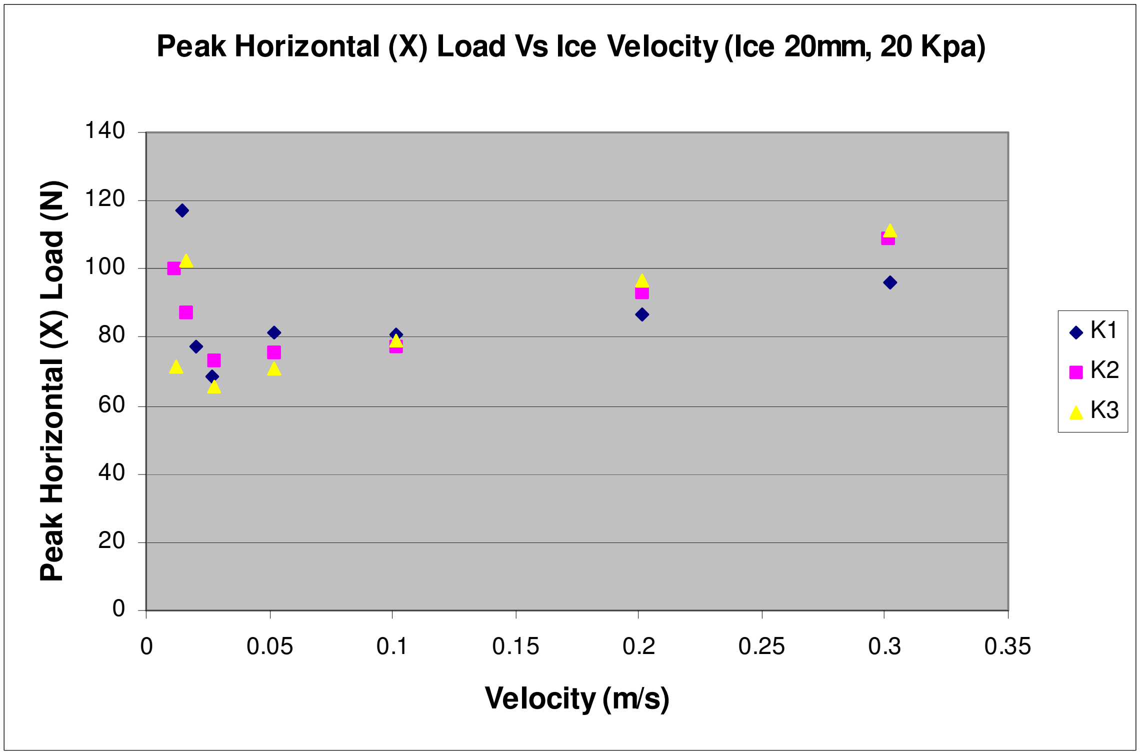
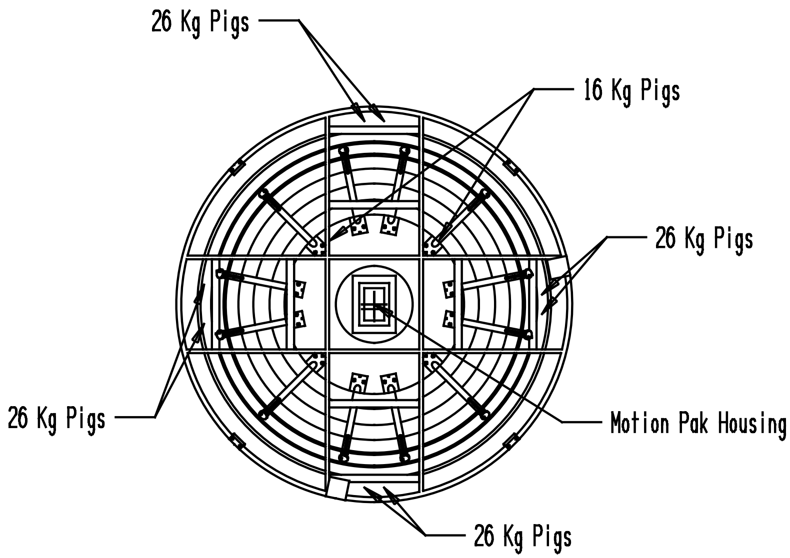


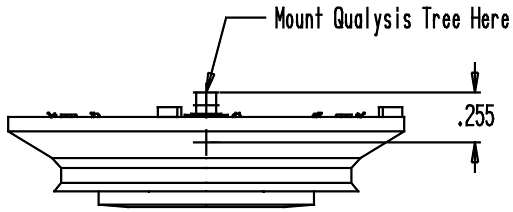
Figure 21: Sample relationship between peak horizontal load and velocity

Appendix A
Kulluk Model Information

This appendix contains:

- Conical Structures Kullluk 2005 Ballast
- Conical Structures Kulluk 2005 Outfit
- Conical Structures Mooring Mount
- Kulluk Mass Properties





Model Total Displacement 439.4 KG

Notes:
Deburr - Remove All Sharp Edges

Part File 2019 conical structures/tslade/cadkey/2019_metric.ckd

Note Units

National Research Council Canada
Conseil national de recherches Canada
NRC·CNRC

Institute for Marine Dynamics

Kerwin Place, P.O. Box 12093, Postal Station A
St. John's, Newfoundland A1B 3T5

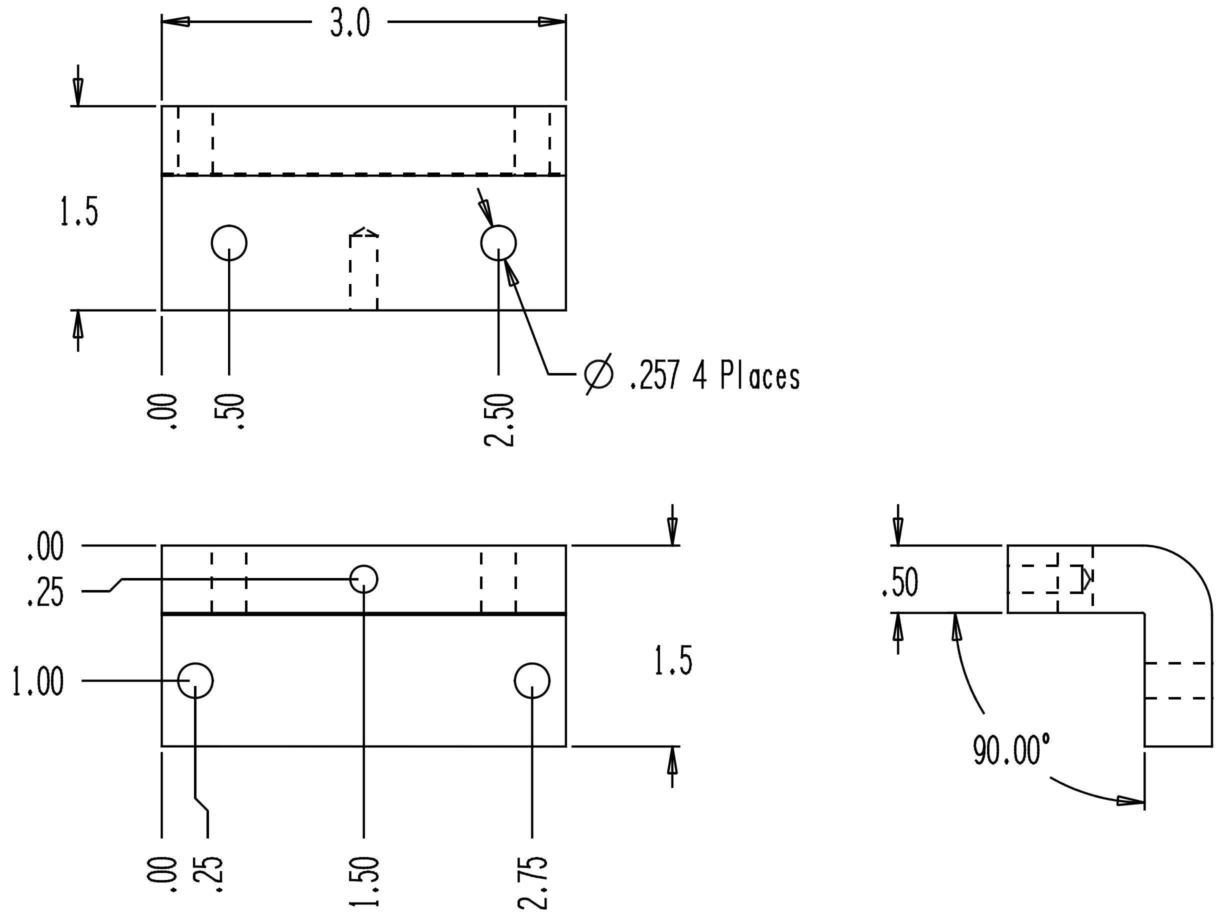
TOLERANCES
(unless specified)
0.X ± 0.03
0.XX ± 0.015
0.XXX ± 0.005
Angle +/- .5 deg.
Fabrication +/- .04
Fraction <6 Inch +/- 1/64
>6 Inch +/- 1/32

Material n/a
Heat Treatment
Finish
Dimensions In: Inches ☐ Meters ☒

Task 2019
Drawn T.Slade
Approved
Quantity 1

Title: Conical Structures
Kulluk 2005 Ballast

A2 Number 2005 Ballast
Scale n/a Date 02-Aug-2005 Sheet 1 of 1



Notes:

Deburr - Remove All Sharp Edges

Part File 2019X00

National Research Council Canada

Conseil national de recherches Canada

NRC-CNRC

TOLERANCES (unless specified)

0.X ± 0.03

0.XX ± 0.015

0.XXX ± 0.005

Angle +/- .5 deg.

Fabrication +/- .04

Fraction < 8 Inch +/- 1/64, > 8 Inch +/- 1/32

Material: 6061-T6 Al.

Heat Treatment

Institute for Marine Dynamics

Kerwin Place, P.O. Box 12093, Postal Station A
St. John's, Newfoundland A1B 3T5

2019

Drawn: T. Slade

Title: Conical Structures Mooring Mount

Quantity: 4

A3

Number: Mount

Scale: 1:1

Date: 21-July-05

Sheet 1 of 1

Kullk Mass Properties

PROJECT PARTICULARS

PROJECT DISCRIPTION	Conical Struct.
PROJECT NUMBER	2019
MODEL DESCRIPTION	Kulluk
MODEL NUMBER	644
DATE	15-Dec-05

MODEL PARTICULARS

LBP (m)	0.000
LOA (m)	2.025
BEAM (m) waterline	1.688
DEPTH MLD (m)	0.000
DRAFT (m)	0.285
DISPLACEMENT (kg)	419.700

Item	Mass (Kg)	Dimensions X (m)	Y* (m)	Z (m)	LCG. X. dist from AP (m)	VCG Z. dist from Baseline (m	TCG Y. dist from Centreline (m	Long. Momen Mass x X. dist (Kgm)	Vertical Momen Mass x Z. dist (Kgm)	Trans. Momen Mass x Y dist. (Kgm)	Mass Momen Long. {Pitch} (Kgm^2)	Mass Moment Trans. {Roll} (Kgm^2)	X^2*Mass (Kgm^2)
Fully Ballasted	430.320	N/A	N/A	N/A	0.000	0.327	0.000	0.000	140.715	0.000	**88.283**	**99.014**	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
								0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Totals	430.320	Kg						0.000	140.715	0.000	88.283	99.014	0.000

	Actual		Target		
DISPLACEMENT=	430.32	Kg	439.40	Kg	9.08
LCG=	0.000	m	0.000	m	
VCG=	0.327	m	0.330	m	
TCG=	0.000	m	0.000	m	
Radius of Gyration (pitch)=	0.453	m	0.445	m	
Radius of Gyration (roll)=	0.480	m	0.473	m	

Mass momment of Inertia (pitch)= 88.283 Kgm^2

Mass momment of Inertia (Roll)= 99.014 Kgm^2

Appendix B
Instrumentation and Calibration Details

This appendix contains:

- Q-Flex Accelerometer data sheet
- Data sheets for 100 lbf Load Cells (4)
- Data sheets for 50 lbf Load Cells (4)
- Channel 2 Calibration – X Inline load
- Channel 3 Calibration – Y Inline load
- Channel 5 Calibration – Load Cell (50lbf) – Port Forward
- Channel 6 Calibration – Load Cell (50lbf) – Starboard Forward
- Channel 7 Calibration – Load Cell (50lbf)– Port Aft
- Channel 8 Calibration – Load Cell (50lbf) – Starboard Aft
- Channel 9 Calibration – Load Cell (100lbf) – Port Forward
- Channel 10 Calibration – Load Cell (100lbf) – Starboard Forward
- Channel 11 Calibration – Load Cell (100lbf)– Port Aft
- Channel 12 Calibration – Load Cell (100lbf) – Starboard Aft
- Channel 13 Calibration – Qualysis – X Position
- Channel 14 Calibration – Qualysis – Y Position
- Channel 15 Calibration – Qualysis – Z Position
- Channel 16 Calibration – Qualysis – Yaw
- Channel 17 Calibration – Qualysis – Pitch
- Channel 18 Calibration – Qualysis – Roll
- Channel 19 Calibration – Qualysis – RMS
- Channel 23 Calibration – X
- Channel 24 Calibration – Y
- Channel 25 Calibration – Z
- Channel 26 Calibration – Z
- Channel 27 Calibration – X
- Channel 28 Calibration – X
- Channel 31 Calibration – Systrand Q-Flex QA900
- Channel 33 Calibration – Carriage D/A output (C and E) – Carriage Velocity
- Channel 34 Calibration – ITC Carriage D/A output (CnE) – Carriage Position
- Channel 36 Calibration – ONO SOKI128 AND F/V801 – Carriage Speed (F/V)

A10655.JPG

DIS: 4-Aug-98 BC: A10655

NTEP CERTIFICATE OF CONFORMANCE CALIBRATION DATA

Class IIIL / Single LC / 10000 divisions
Vmin: 0.004 Lbs / Min Dead Ld: 2.0 Lbs
Compensated Temp: 14 to 104 deg F

Full Scale Output: 3.132 mV/V
Safe Overload: 150 % of Capacity
Rated Excitation: 10.0 Vdc

Wiring Code:
+ Excitation: Red + Output: Green
- Excitation: Black - Output: White

Input Resistance: 380 ohms
Output Resistance: 350 ohms
Insulation Res: > 1000 Megohms @ 50 Vdc
Barometric Effect: Nil

Model	60001A100-1000
S/N	732494
CAP	100 Lbs
FSO	3.132 mV/V
Cert#	86-043
Date	9/18/97

Data obtained utilizing standards traceable to the National Institute of Standards and Technology.

Q.A. APPROVAL [signature]
MICHAEL J. MATSUMOTO

SENSORTRONICS

NATIONAL CONFERENCE ON WEIGHTS AND MEASURES NTEP

Factory Mutual System Approved
INT. SAFE
NONINCENDIVE
CL I,II,III DIV 1,2
GPS A-G HAZ LOC
PER DWG 20038
TEMP CODE:T4

A10500.JPG

Tension only

LOAD CELL CALIBRATION CERTIFICATE

Operating Temp Range: 0 to 150 deg F

Full Scale Output: 3.148 mV/V

Safe Overload: 150 % of Capacity

Maximum Excitation: 15.0 Vac or Vdc

Wiring Code:

+ Excitation: Red   + Output: Green
- Excitation: Black   - Output: White

Zero Balance: 1.00 %FS

Thermal Zero Shift: < 0.0015 %FS/degF

Thermal Span Shift: < 0.0008 %FS/degF

Creep (20 minutes): < 0.03 %FS

Hysteresis: < 0.020 %FS

Non-Linearity: < 0.030 %FS

Non-Repeatability: < 0.020 %FS

Input Resistance: 380 ohms

Output Resistance: 350 ohms

Insulation Res: > 1000 Megohms @ 50 Vdc

Barometric Effect: Nil

Model	60001-100	
S/N	683211	
CAP	100	Lbs
FSO	3.148	mV/V
Date	3/6/97	

Factory Mutual System Approved

INT. SAFE
NONINCENDIVE
CL I,II,III DIV 1,2
GPS A-G HAZ LOC
PER DWG 20038
TEMP CODE: T4

Data obtained utilizing standards traceable to the National Institute of Standards and Technology.

Q.A. APPROVAL

MICHAEL J. MATSUMOTO

A10296.JPG

INTERTECHNOLOGY INC.

1 SCARSDALE ROAD, DON MILLS, ONTARIO M3B 2R2 PHONE: (416) 445-5500 FAX: (416) 445-1170 TELEX: 06-966772
Montreal (514) 683-0930 Ottawa (613) 723-1828 London (519) 668-7477 Winnipeg (204) 895-2037 Calgary (403) 256-3088
Vancouver (604) 270-9538

BC: A10296

LOAD CELL CALIBRATION CERTIFICATE

Full Scale Output: 3.125 mV/V
Zero Balance: 1.0 %FS

Creep (20 Minutes): < 0.03 %FS
Non-Repeatability: < 0.02 %FS
Non-Linearity: < 0.03 %FS
Hysteresis: < 0.02 %FS
Maximum Excitation: 15V AC or DC

Wiring Code

+ Excitation: Red   + Signal: Green
- Excitation: Black   - Signal: White

Insulation Res.: > 1000 Megohms @ 50 VDC
Safe Overload: 150% of Capacity

Operating Temp. Range: 0 to 150 °F
Thermal Zero Shift: < 0.0015 %FS/°F
Thermal Span Shift: < 0.0008 %FS/°F
Barometric Effect: Nil

Date obtained utilizing standards Traceable to the National Institute of Standards and Technology.

Model: 60001-50
S/N: 373562
Cap.: 50 lbs.
FSO: 3.125 mV/V

50 301 0115

.A. APPROVAL: Michael J. Matsumoto
MICHAEL J. MATSUMOTO

Factory Mutual System Approved | INTRINSICALLY SAFE CL I, DIV I, GPS. A-D PER DWG 20038 TEMP. CODE T4

A10296

A10294.JPG

INTERTECHNOLOGY INC.

1 SCARSDALE ROAD, DON MILLS, ONTARIO M3B 2R2 PHONE: (416) 445-5500 FAX: (416) 445-1170 TELEX: 06-966772
Montreal (514) 683-0930 Ottawa (613) 723-1828 London (519) 668-7477 Winnipeg (204) 895-2037 Calgary (403) 256-3088
Vancouver (604) 270-9538

LOAD CELL CALIBRATION CERTIFICATE

Full Scale Output: 3.129 mV/V
Zero Balance: 1.0 %FS

Creep (20 Minutes): < 0.03 %FS
Non-Repeatability: < 0.02 %FS
Non-Linearity: < 0.03 %FS
Hysteresis: < 0.02 %FS
Maximum Excitation: 15V AC or DC

Insulation Res.: > 1000 Megohms @ 50 VDC
Safe Overload: 150% of Capacity

Operating Temp. Range: 0 to 150 °F
Thermal Zero Shift: < 0.0015 %FS/°F
Thermal Span Shift: < 0.0008 %FS/°F
Barometric Effect: Nil

Wiring Code

+ Excitation: Red + Signal: Green
− Excitation: Black − Signal: White

Data obtained utilizing standards Traceable to the National Institute of Standards and Technology.

Model: 60001-50
S/N: 373563
Cap.: 50 lbs.
FSO: 3.129 mV/V

50 301 0115

Q.A. APPROVAL: Michael J. Matsumoto
MICHAEL J. MATSUMOTO

A10294

Factory Mutual System Approved
INTRINSICALLY SAFE
CLI, DIV I, GPS. A-D
PER DWG 20038
TEMP. CODE T4

A10293.JPG

INTERTECHNOLOGY INC.

1 SCARSDALE ROAD, DON MILLS, ONTARIO M3B 2R2 PHONE: (416) 445-5500 FAX: (416) 445-1170 TELEX: 06-966772
Montreal (514) 683-0930 Ottawa (613) 723-1828 London (519) 668-7477 Winnipeg (204) 895-2037 Calgary (403) 256-3088
Vancouver (604) 270-9538

LOAD CELL CALIBRATION CERTIFICATE

Full Scale Output: 3.298 mV/V
Zero Balance: 1.0 %FS

Creep (20 Minutes): < 0.03 %FS
Non-Repeatability: < 0.02 %FS
Non-Linearity: < 0.03 %FS
Hysteresis: < 0.02 %FS
Maximum Excitation: 15V AC or DC

Wiring Code

+ Excitation: Red + Signal: Green
− Excitation: Black − Signal: White

Insulation Res.: > 1000 Megohms @ 50 VDC
Safe Overload: 150% of Capacity

Operating Temp. Range: 0 to 150 °F
Thermal Zero Shift: < 0.0015 %FS/°F
Thermal Span Shift: < 0.0008 %FS/°F
Barometric Effect: Nil

Data obtained utilizing standards Traceable to the National Institute of Standards and Technology.

Model: 60001-50
S/N: 373560
Cap.: 50 lbs.
FSO: 3.298 mV/V

50 301 0115

A10293

.A. APPROVAL: Michael J. Matsumoto
MICHAEL J. MATSUMOTO

Factory Mutual System Approved | INTRINSICALLY SAFE CL I, DIV I, GPS. A-D PER DWG 20098 TEMP. CODE T4

A10658.JPG

DIS: 04-Aug-98 BC: A10658

LOAD CELL CALIBRATION CERTIFICATE

Operating Temp Range: 0 to 150 deg F
Full Scale Output: 3.243 mV/V
Safe Overload: 150 % of Capacity

Maximum Excitation: 15.0 Vac or Vdc
Wiring Code:
- + Excitation: Red   + Output: Green
- - Excitation: Black   - Output: White

Zero Balance: 1.00 %FS
Thermal Zero Shift: < 0.0015 %FS/degF
Thermal Span Shift: < 0.0008 %FS/degF
Creep (20 minutes): < 0.03 %FS
Hysteresis: < 0.020 %FS
Non-Linearity: < 0.030 %FS
Non-Repeatability: < 0.020 %FS
Input Resistance: 380 ohms
Output Resistance: 350 ohms
Insulation Res: > 1000 Megohms @ 50 Vdc
Barometric Effect: Nil

Model	60001-50	
S/N	735312	
CAP	50	Lbs
FSO	3.243	mV/V
Date	10/1/97	

Data obtained utilizing standards traceable to the National Institute of Standards and Technology.

Q.A. APPROVAL

MICHAEL J. MATSUMOTO

SENSORTRONICS

Factory Mutual System Approved
INT. SAFE NONINCENDIVE CL I,II,III DIV 1,2 GPS A-G
HAZ LOC TEMP CODE:T4 OP TEMP: 0 TO 150°F
ENTITY PARAM: Vmax=30V Imax=600mA Ci=0µF Li=0mH
PER DWG: 20038

A10656.JPG

DIS: 4-Aug-98 BC: A10656

NTEP CERTIFICATE OF CONFORMANCE CALIBRATION DATA

Class IIIL / Single LC / 10000 divisions
Vmin: 0.004 Lbs / Min Dead Ld: 2.0 Lbs
Compensated Temp: 14 to 104 deg F

Full Scale Output: 3.168 mV/V
Safe Overload: 150 % of Capacity
Rated Excitation: 10.0 Vdc

Wiring Code:
+ Excitation: Red + Output: Green
- Excitation: Black - Output: White

Input Resistance: 380 ohms
Output Resistance: 350 ohms
Insulation Res: > 1000 Megohms @ 50 Vdc
Barometric Effect: Nil

Model	60001A100-1000
S/N	732493
CAP	100 Lbs
FSO	3.168 mV/V
Cert#	86-043
Date	9/18/97

Data obtained utilizing standards traceable to the National Institute of Standards and Technology.

Q.A. APPROVAL Michael J. Matsumoto
MICHAEL J. MATSUMOTO

SENSORTRONICS

NATIONAL CONFERENCE ON WEIGHTS AND MEASURES NTEP

Factory Mutual System Approved
INT. SAFE
NONINCENDIVE
CL I,II,III DIV 1,2
GPS A-G HAZ LOC
PER DWG 20038
TEMP CODE: T4

A10643.JPG

DIS: 22-July-98 BC: A10643

NTEP CERTIFICATE OF CONFORMANCE CALIBRATION DATA

Class IIIL / Single LC / 10000 divisions
Vmin: 0.004 Lbs / Min Dead Ld: 2.0 Lbs
Compensated Temp: 14 to 104 deg F

Full Scale Output: 3.190 mV/V
Safe Overload: 150 % of Capacity
Rated Excitation: 10.0 Vdc

Wiring Code:
+ Excitation: Red + Output: Green
- Excitation: Black - Output: White

Input Resistance: 380 ohms
Output Resistance: 350 ohms
Insulation Res: > 1000 Megohms @ 50 Vdc
Barometric Effect: Nil

Model	60001A100-1000
S/N	732492
CAP	100 Lbs
FSO	3.190 mV/V
Cert#	86-043
Date	9/18/97

Data obtained utilizing standards traceable to the National Institute of Standards and Technology.

Q.A. APPROVAL [signature]
MICHAEL J. MATSUMOTO

SENSORTRONICS

NATIONAL CONFERENCE ON WEIGHTS AND MEASURES NTEP

Factory Mutual System Approved
INT. SAFE
NONINCENDIVE
CL I,II,III DIV 1,2
GPS A-G HAZ LOC
PER DWG 20038
TEMP CODE:T4

A10916.JPG

S/N 942
S/C S/N G6OJ9

ATP DATA SHEET
Q-Flex Accelerometer

HYB S/N 621

SDC P/N 979-1400-001
Model No. QA1400-AA01

Date: 12-16-86
Tech: 8503

Ref. Para.	Test	Limits	Data
5.2	Scale Factor Bias	1.32 mA/g ± 10% 0 ± 10 mg	E_1 1.3691 V E_2 -1.3698 V SF 1.36945 mA/g Bias -.26 mg
5.3	Axis Misalignment	0 ± 2 mrad Transfer data from 979-1400-501	E_3 +.31 mV E_4 -.33 mV Ar -.23 mrad
5.4	Self Test Voltage	+ST ≤ -10 Vdc -ST ≥ +10 Vdc	+ST = -11.8 V -ST = +11.8 V
5.4	Self Test Current	Output Change 0.755 g ±10%/mA	Accept ✓ Reject
5.5	Temp Sensor Output	T_A +273.15 ± 2uA (T_A = Ambient Temp)	T_A = N/A °C T_S = N/A uA
5.6	Insulation Resistance	≥100MΩ	IR = 7101 MΩ
5.7	Leak Test	≤1 x 10^{-6} cc/Sec	<1x10⁻⁶ cc/Sec
6.0	BTC (Transfer from QC-149)	See Table I	BTC = 7.0 ug/°C
7.0	Examination of Product	Per -201	Accept [stamp: SDC 45] Reject

FSCM NO.	SIZE		SH REV
97896	A	979-1400-701	C
		SHEET A1	

A10916.JPG

S/N 942
S/C S/N GGOJ9

HYB S/N 621

ATP DATA SHEET
Q-Flex Accelerometer

SDC P/N 979-1400-001
Model No. QA1400-AA01

Date: 12-16-86
Tech: 8503

Ref. Para.	Test	Limits	Data
5.2	Scale Factor Bias	1.32 mA/g ± 10% 0 ± 10 mg	E_1 1.3691 V E_2 -1.3698 V SF 1.36945 mA/g Bias -.26 mg
5.3	Axis Misalignment	0 ± 2 mrad Transfer data from 979-1400-501	E_3 +.31 mV E_4 -.33 mV Ar -.23 mrad
5.4	Self Test Voltage	+ST ≤ -10 Vdc -ST ≥ +10 Vdc	+ST = -11.8 V -ST = +11.8 V
5.4	Self Test Current	Output Change 0.755 g ±10%/mA	Accept ✓ Reject
5.5	Temp Sensor Output	T_A +273.15 ± 2uA (T_A = Ambient Temp)	T_A = N/A °C T_S = N/A uA
5.6	Insulation Resistance	≥100MΩ	IR = >1M MΩ
5.7	Leak Test	≤1 x 10^{-6} cc/Sec	<1x10^{-6} cc/Sec
6.0	BTC (Transfer from QC-149)	See Table I	BTC = 7.0 ug/°C
7.0	Examination of Product	Per -201	Accept SDC 45 Reject

FSCM NO.	SIZE		SH REV
97896	A	979-1400-701	C
		SHEET A1	

Calibration of ICEDAS Channel 27 — 13:00 22 August 2005

Project: Conical Structures in Ice **Facility:** Ice Tank

Sensor: X **Model:** N/A **Serial Number:** N/A

Programmable Gain: 1 **Plug-In Gain:** 1 **Filter Frequency:** 100.0 Hz

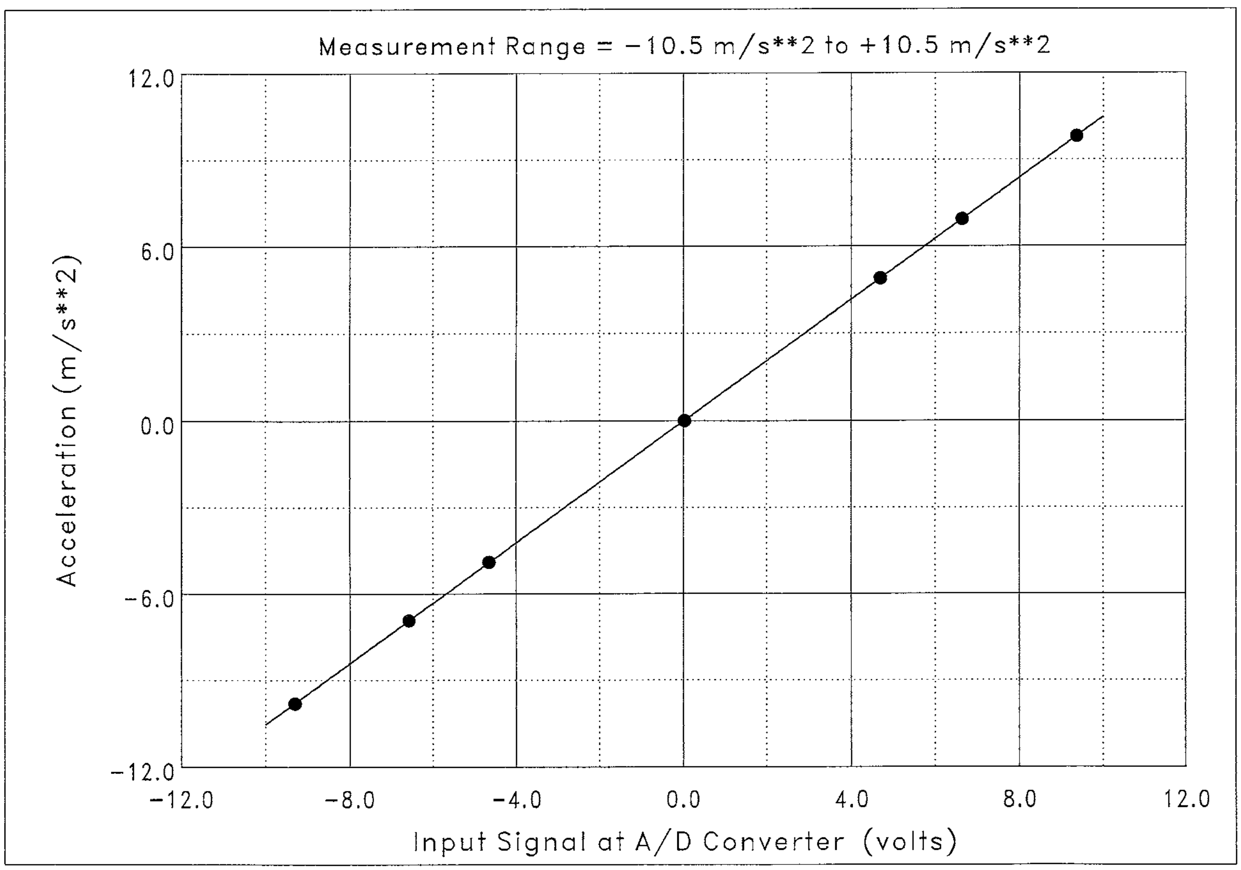
Data Point No.	Input Signal (volts)	Physical Value (m/s**2)	Fitted Curve Value (m/s**2)	Error (m/s**2)	
1	0.025	0.0000	−0.0004	−0.0004451	
2	4.698	4.9040	4.9038	−0.0002217	
3	−4.655	−4.9040	−4.9123	−0.0082941	⇐ Maximum Error
4	−6.581	−6.9353	−6.9341	0.0012112	
5	6.631	6.9353	6.9331	−0.0021639	
6	9.374	9.8080	9.8121	0.0041256	
7	−9.314	−9.8080	−9.8022	0.0057878	

Maximum Error = −0.0423 % of Calibration Range.

Definition of Calibration Curve
Polynomial Degree = 1 (Linear Fit)

$$Y = C_0 + C_1 \cdot V$$

where $Y(t)$ = Acceleration (m/s**2),
$V(t)$ = input signal at A/D converter (volts),
C_0 = −0.0267982 m/s**2,
and C_1 = 1.04959 (m/s**2)/volt .



Calibration of ICEDAS Channel 23 13:06 22 August 2005

Project: Conical Structures in Ice **Facility:** Ice Tank

Sensor: Y **Model:** N/A **Serial Number:** N/A

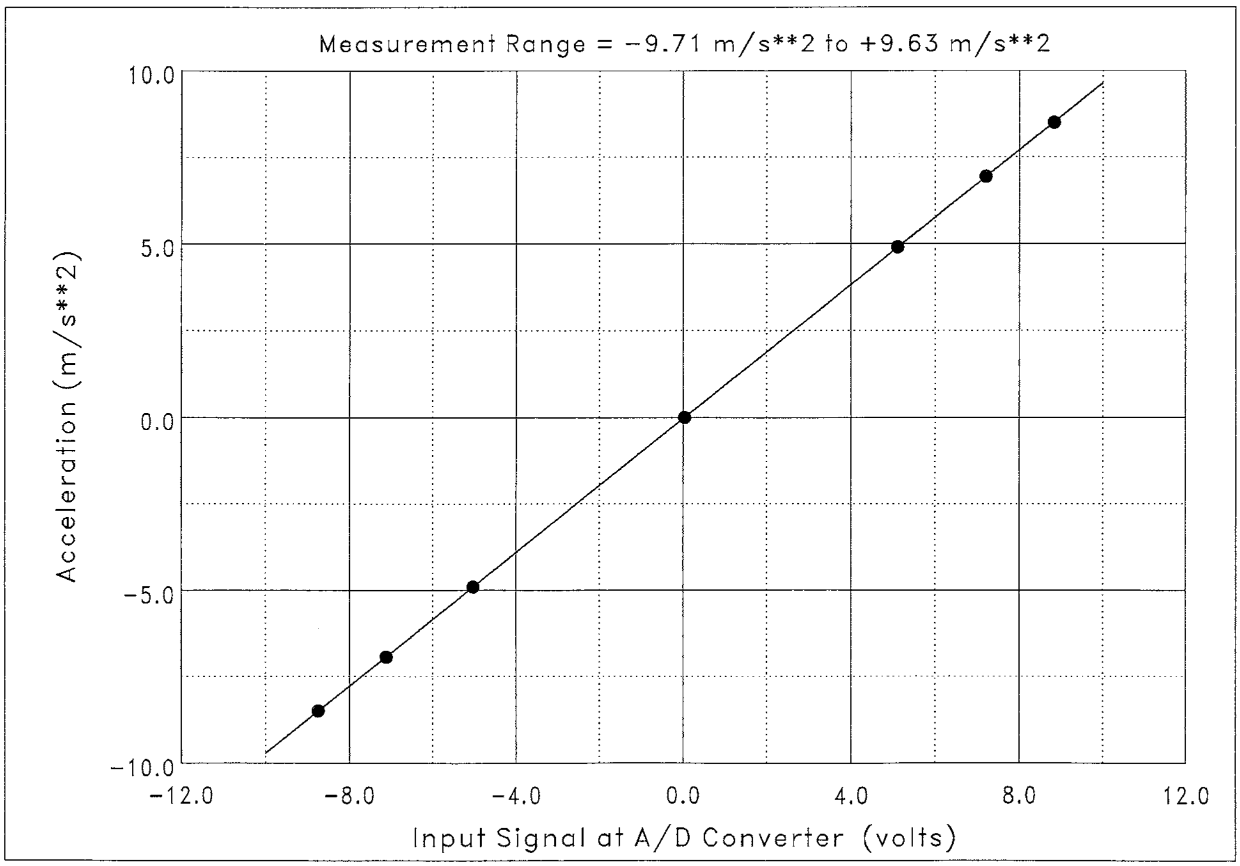
Programmable Gain: 1 **Plug-In Gain:** 1 **Filter Frequency:** 100.0 Hz

Data Point No.	Input Signal (volts)	Physical Value (m/s**2)	Fitted Curve Value (m/s**2)	Error (m/s**2)	
1	0.037	0.0000	−0.0029	−0.002913	
2	5.110	4.9040	4.9040	−0.000022	
3	−5.030	−4.9040	−4.9035	0.000510	
4	−7.118	−6.9353	−6.9229	0.012432	
5	7.198	6.9353	6.9229	−0.012441	⇐ Maximum Error
6	8.834	8.4940	8.5055	0.011494	
7	−8.751	−8.4940	−8.5031	−0.009059	
Maximum Error = −0.0732 % of Calibration Range.					

Definition of Calibration Curve
Polynomial Degree = 1 (Linear Fit)

$$Y = C_0 + C_1 \cdot V$$

where $Y(t)$ = Acceleration (m/s**2),
$V(t)$ = input signal at A/D converter (volts),
C_0 = -0.0387277 m/s**2,
and C_1 = 0.967208 (m/s**2)/volt.



Calibration of ICEDAS Channel 25 13:14 22 August 2005

Project: Conical Structures in Ice **Facility:** Ice Tank

Sensor: Z **Model:** N/A **Serial Number:** N/A

Programmable Gain: 1 **Plug-In Gain:** 1 **Filter Frequency:** 100.0 Hz

Data Point No.	Input Signal (volts)	Physical Value (m/s**2)	Fitted Curve Value (m/s**2)	Error (m/s**2)	
1	−4.681	9.8080	9.8054	−0.002568	
2	−0.001	0.0000	−0.0002	−0.000246	
3	−2.333	4.9040	4.8855	−0.018466	⇐ Maximum Error
4	−2.348	4.9040	4.9180	0.014041	
5	−3.316	6.9353	6.9451	0.009783	
6	−4.054	8.4940	8.4915	−0.002542	

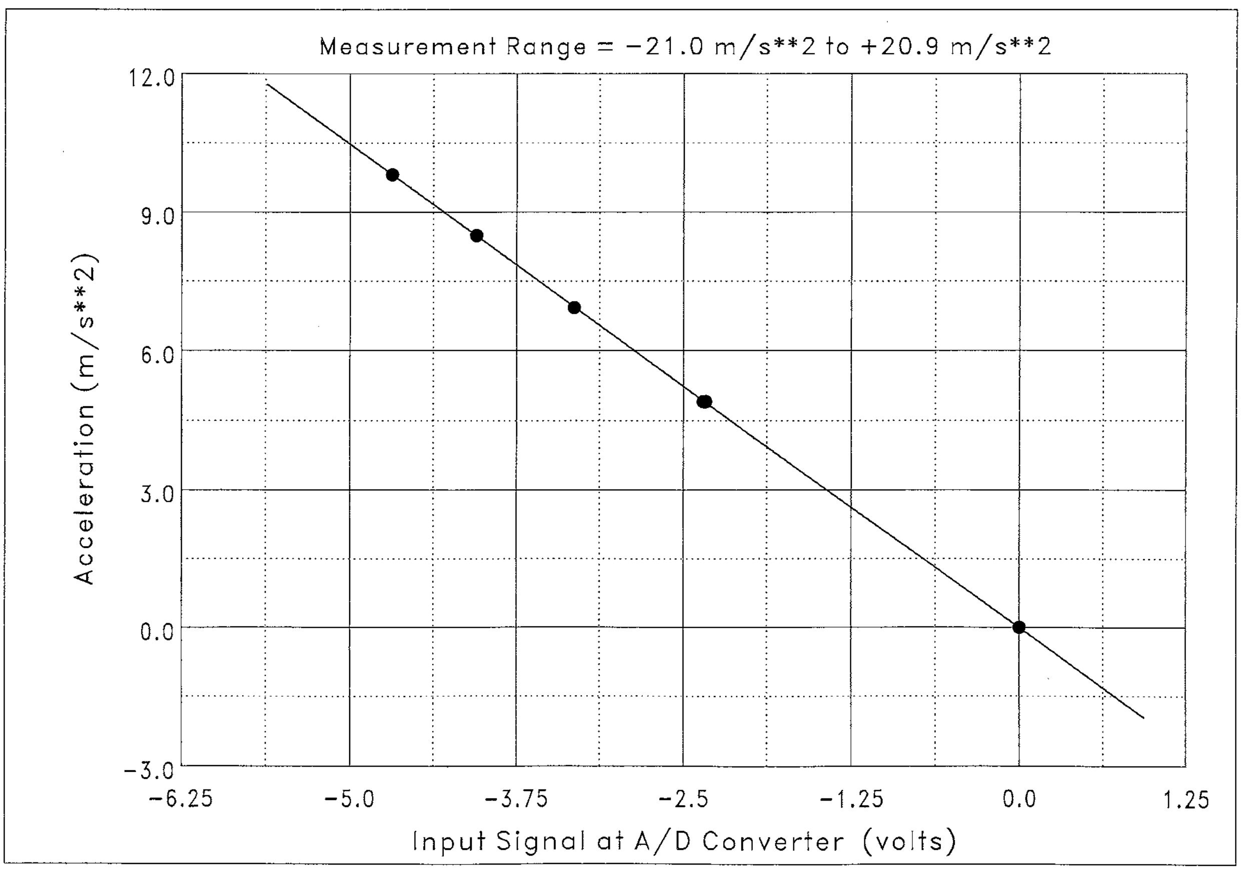
Maximum Error = −0.188 % of Calibration Range.

Definition of Calibration Curve

Polynomial Degree = 1 (Linear Fit)

$$Y = C_0 + C_1 \cdot V$$

where $Y(t)$ = Acceleration (m/s**2),
$V(t)$ = input signal at A/D converter (volts),
C_0 = −0.00199790 m/s**2,
and C_1 = −2.09515 (m/s**2)/volt.



Calibration of ICEDAS Channel 28 13:25 22 August 2005

Project: Conical Structures in Ice **Facility:** Ice Tank

Sensor: X **Model:** N/A **Serial Number:** N/A

Programmable Gain: 1 **Plug-In Gain:** 1 **Filter Frequency:** 100.0 Hz

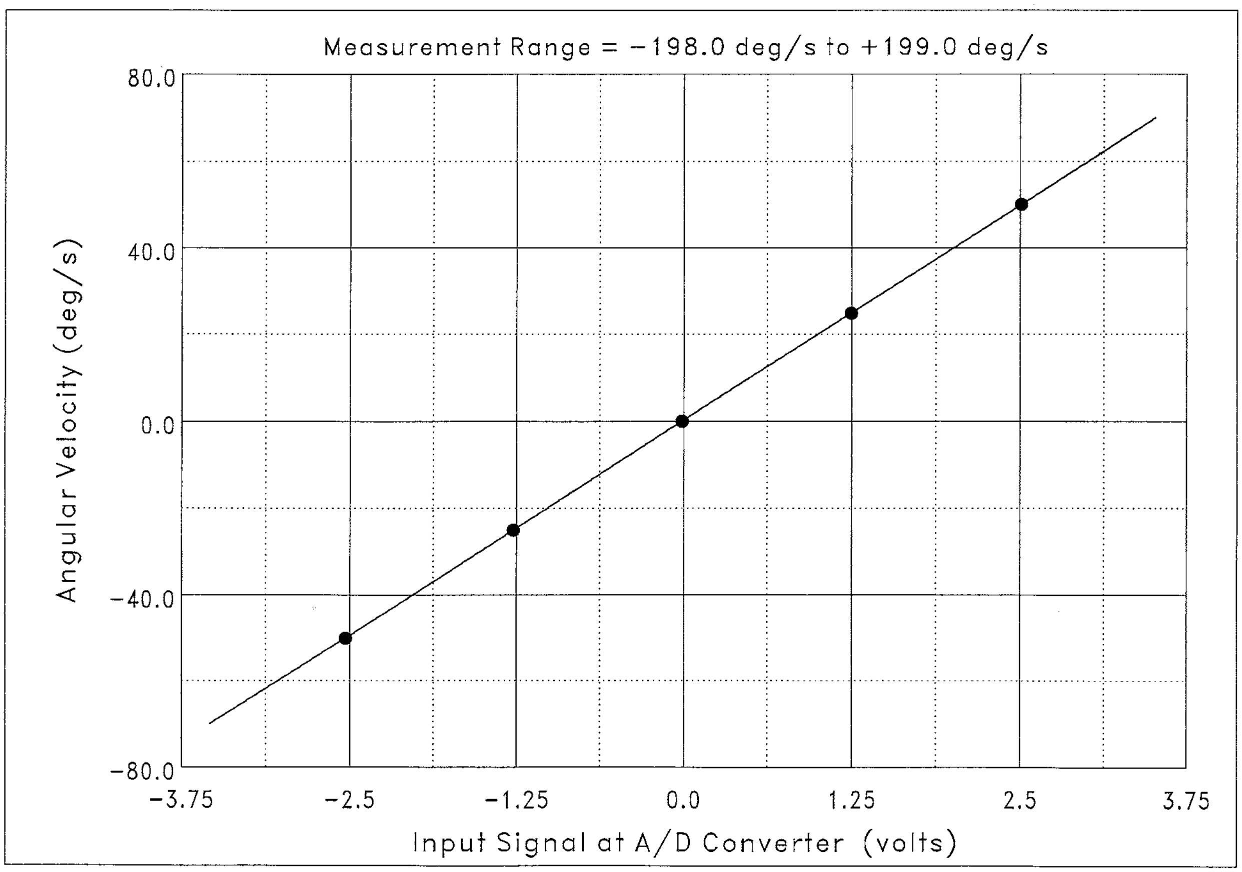
Data Point No.	Input Signal (volts)	Physical Value (deg/s)	Fitted Curve Value (deg/s)	Error (deg/s)	
1	−0.013	0.000	−0.003	−0.0033177	
2	2.507	50.000	49.998	−0.0022049	
3	−2.533	−50.000	−50.000	0.0000191	
4	1.248	25.000	25.005	0.0049763	⇐ Maximum Error
5	−1.273	−25.000	−24.999	0.0005283	
Maximum Error = 0.00498 % of Calibration Range.					

Definition of Calibration Curve

Polynomial Degree = 1 (Linear Fit)

$$Y = C_0 + C_1 \cdot V$$

where $Y(t)$ = Angular Velocity (deg/s),
$V(t)$ = input signal at A/D converter (volts),
C_0 = 0.250884 deg/s,
and C_1 = 19.8417 (deg/s)/volt .



Calibration of ICEDAS Channel 24 13:29 22 August 2005

Project: Conical Structures in Ice **Facility:** Ice Tank

Sensor: Y **Model:** N/A **Serial Number:** N/A

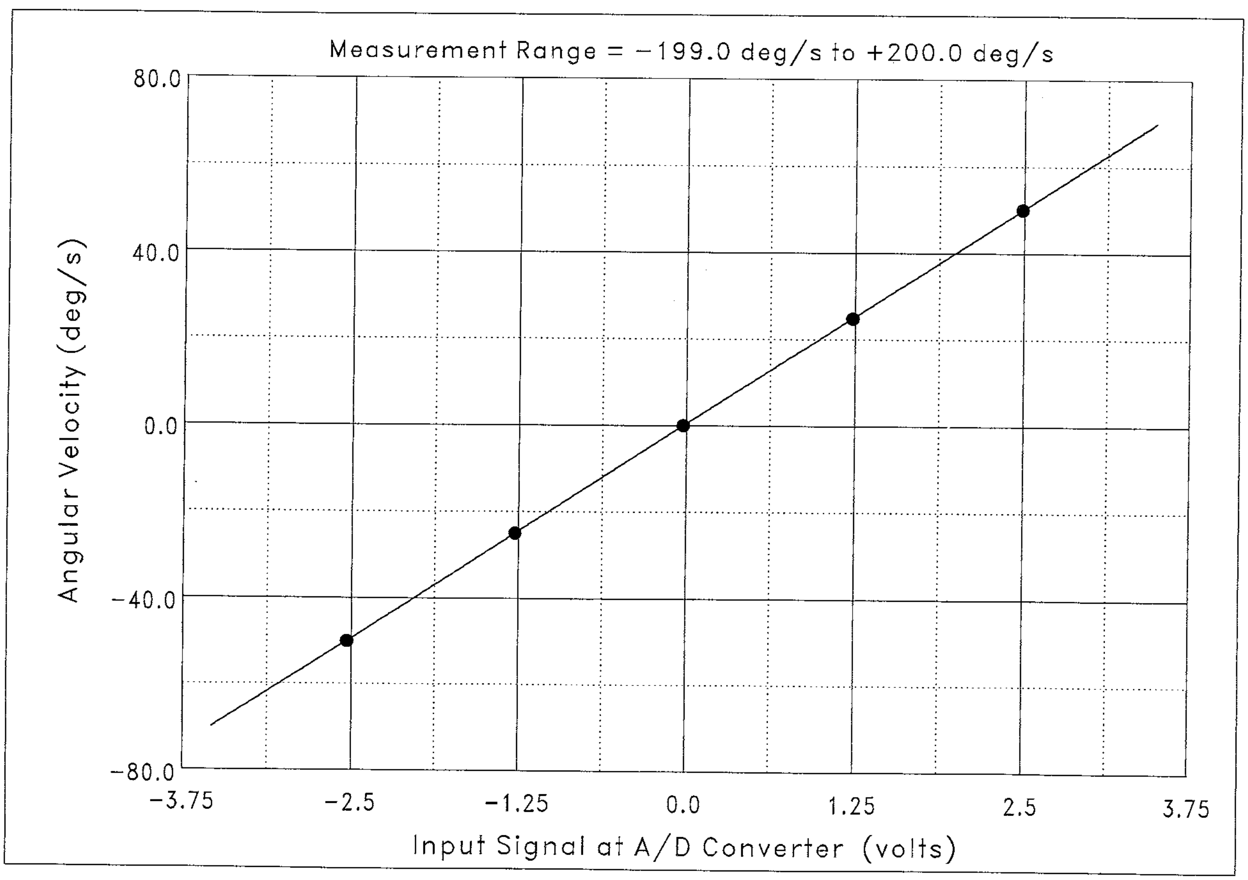
Programmable Gain: 1 **Plug-In Gain:** 1 **Filter Frequency:** 100.0 Hz

Data Point No.	Input Signal (volts)	Physical Value (deg/s)	Fitted Curve Value (deg/s)	Error (deg/s)	
1	2.488	50.000	49.999	−0.0014687	
2	−2.533	−50.000	−50.001	−0.0014458	
3	−0.022	0.000	−0.002	−0.0018533	
4	1.233	25.000	25.002	0.0024109	⇐ Maximum Error
5	−1.277	−25.000	−24.998	0.0023613	
Maximum Error = 0.00241 % of Calibration Range.					

Definition of Calibration Curve
Polynomial Degree = 1 (Linear Fit)

$$Y = C_0 + C_1 \cdot V$$

where $Y(t)$ = Angular Velocity (deg/s),
$V(t)$ = input signal at A/D converter (volts),
C_0 = 0.441485 deg/s,
and C_1 = 19.9152 (deg/s)/volt .



Calibration of ICEDAS Channel 26 13:33 22 August 2005

Project: Conical Structures in Ice **Facility:** Ice Tank

Sensor: Z **Model:** N/A **Serial Number:** N/A

Programmable Gain: 1 **Plug-In Gain:** 1 **Filter Frequency:** 100.0 Hz

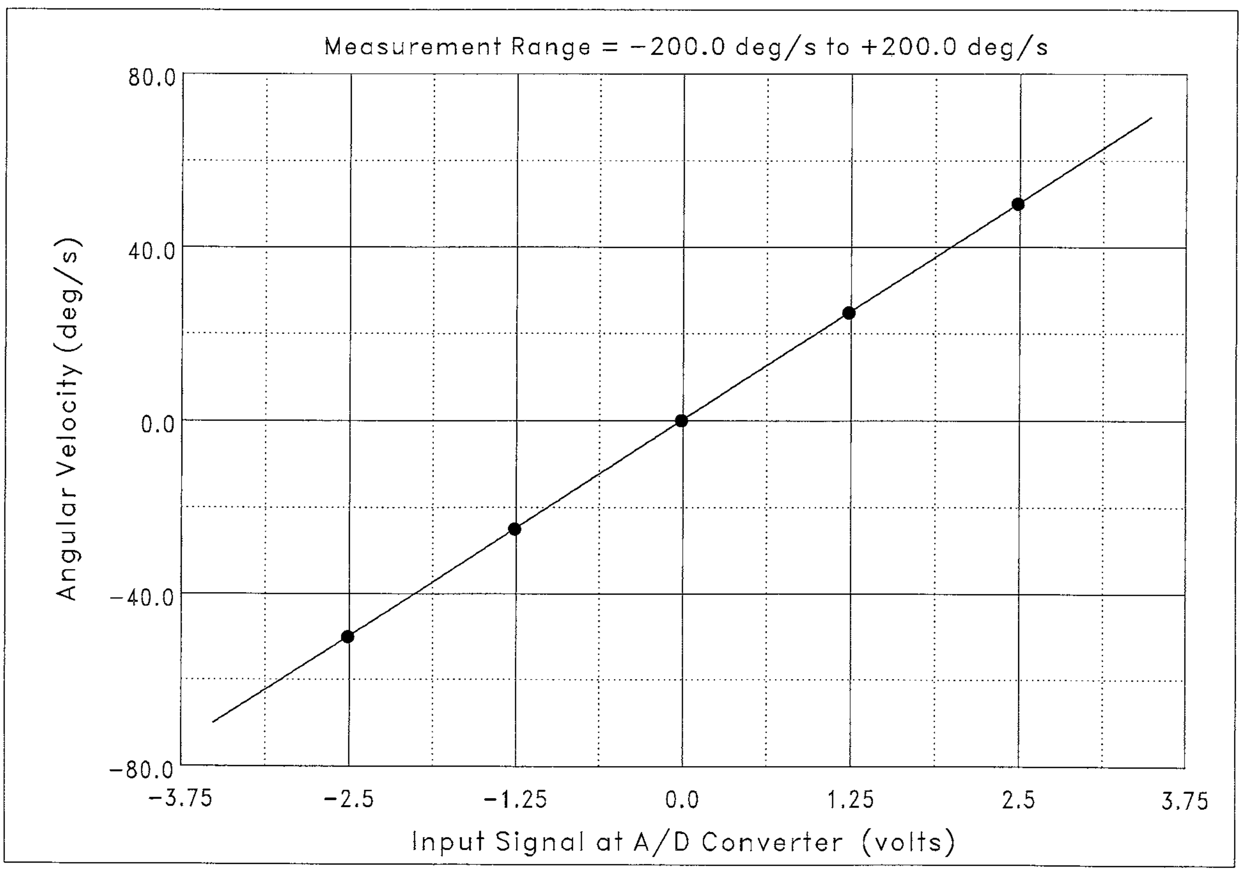
Data Point No.	Input Signal (volts)	Physical Value (deg/s)	Fitted Curve Value (deg/s)	Error (deg/s)	
1	−0.013	0.000	0.000	−0.0004576	
2	2.484	50.000	50.001	0.0006599	
3	−2.511	−50.000	−50.003	−0.0027390	
4	1.235	25.000	24.998	−0.0021286	
5	−1.262	−25.000	−24.995	0.0046654	⇐ Maximum Error
Maximum Error = 0.00467 % of Calibration Range.					

Definition of Calibration Curve

Polynomial Degree = 1 (Linear Fit)

$$Y = C_0 + C_1 \cdot V$$

where $Y(t)$ = Angular Velocity (deg/s),
$V(t)$ = input signal at A/D converter (volts),
C_0 = 0.268151 deg/s,
and C_1 = 20.0196 (deg/s)/volt .



Calibration of ICEDAS Channel 31 08:09 23 August 2005

Project: Conical Structures in Ice **Facility:** Ice Tank

Sensor: TEST FRAME ACCEL **Model:** SYSTRAND QFLEX QA900 **Serial Number:** NRC A10916

Programmable Gain: 1 **Plug-In Gain:** 10 **Filter Frequency:** 100.0 Hz

Data Point No.	Input Signal (volts)	Physical Value (m/s**2)	Fitted Curve Value (m/s**2)	Error (m/s**2)	
1	−2.594	−2.5385	−2.6429	−0.10442	
2	2.257	2.5385	2.4199	−0.11857	
3	6.627	6.9353	6.9807	0.04543	
4	4.630	4.9040	4.8963	−0.00765	
5	−4.705	−4.9040	−4.8452	0.05876	
6	0.059	0.0000	0.1264	0.12644	⇐ Maximum Error

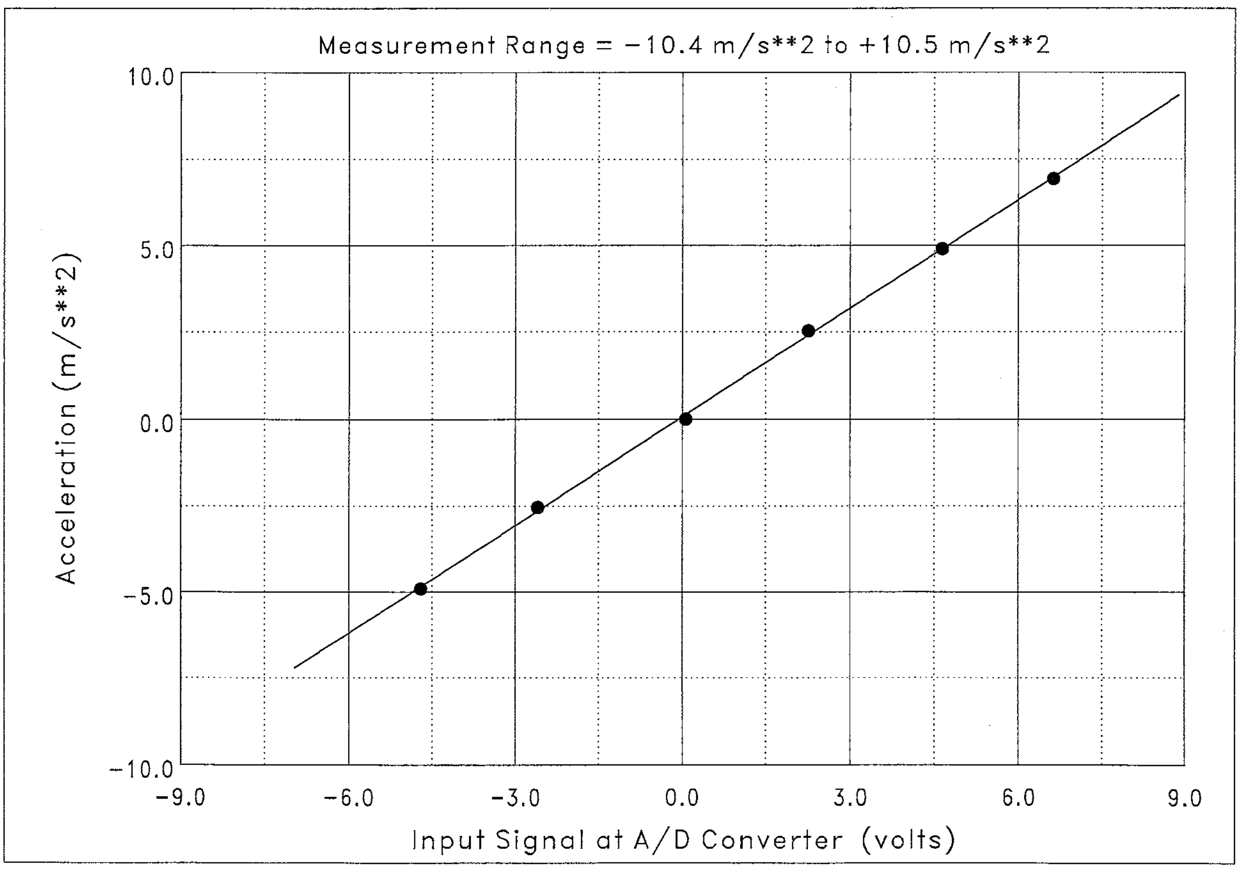
Maximum Error = 1.07 % of Calibration Range.

Definition of Calibration Curve

Polynomial Degree = 1 (Linear Fit)

$$Y = C_0 + C_1 \cdot V$$

where $Y(t)$ = Acceleration (m/s**2),
$V(t)$ = input signal at A/D converter (volts),
C_0 = 0.0644860 m/s**2,
and C_1 = 1.04357 (m/s**2)/volt.



Calibration of ICEDAS Channel 13 14:41 24 August 2005

Project: Conical Structures in Ice **Facility:** Ice Tank

Sensor: X POSITION **Model:** QUALYSIS **Serial Number:** N/A

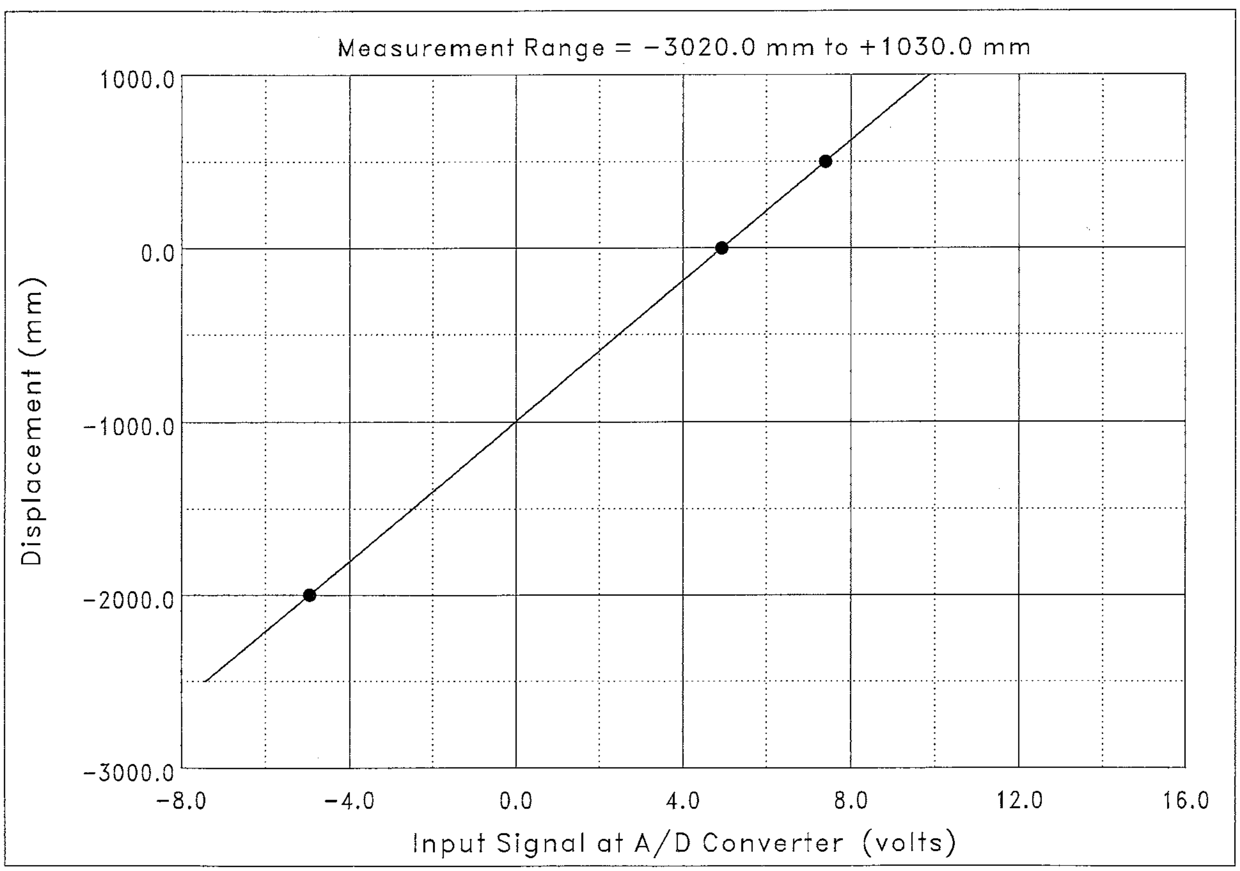
Programmable Gain: 1 **Plug-In Gain:** 1 **Filter Frequency:** 10.0 Hz

Data Point No.	Input Signal (volts)	Physical Value (mm)	Fitted Curve Value (mm)	Error (mm)	
1	−4.956	−2000.0	−2000.0	−0.010498	
2	7.401	500.0	500.0	−0.041992	
3	4.930	0.0	0.1	0.052490	⇐ Maximum Error
Maximum Error = 0.00210 % of Calibration Range.					

Definition of Calibration Curve
Polynomial Degree = 1 (Linear Fit)

$$Y = C_0 + C_1 \cdot V$$

where $Y(t)$ = Displacement (mm),
$V(t)$ = input signal at A/D converter (volts),
C_0 = −997.360 mm,
and C_1 = 202.314 mm/volt .



Calibration of ICEDAS Channel 14 14:44 24 August 2005

Project: Conical Structures in Ice **Facility:** Ice Tank

Sensor: Y POSITION **Model:** QUALYSIS **Serial Number:** N/A

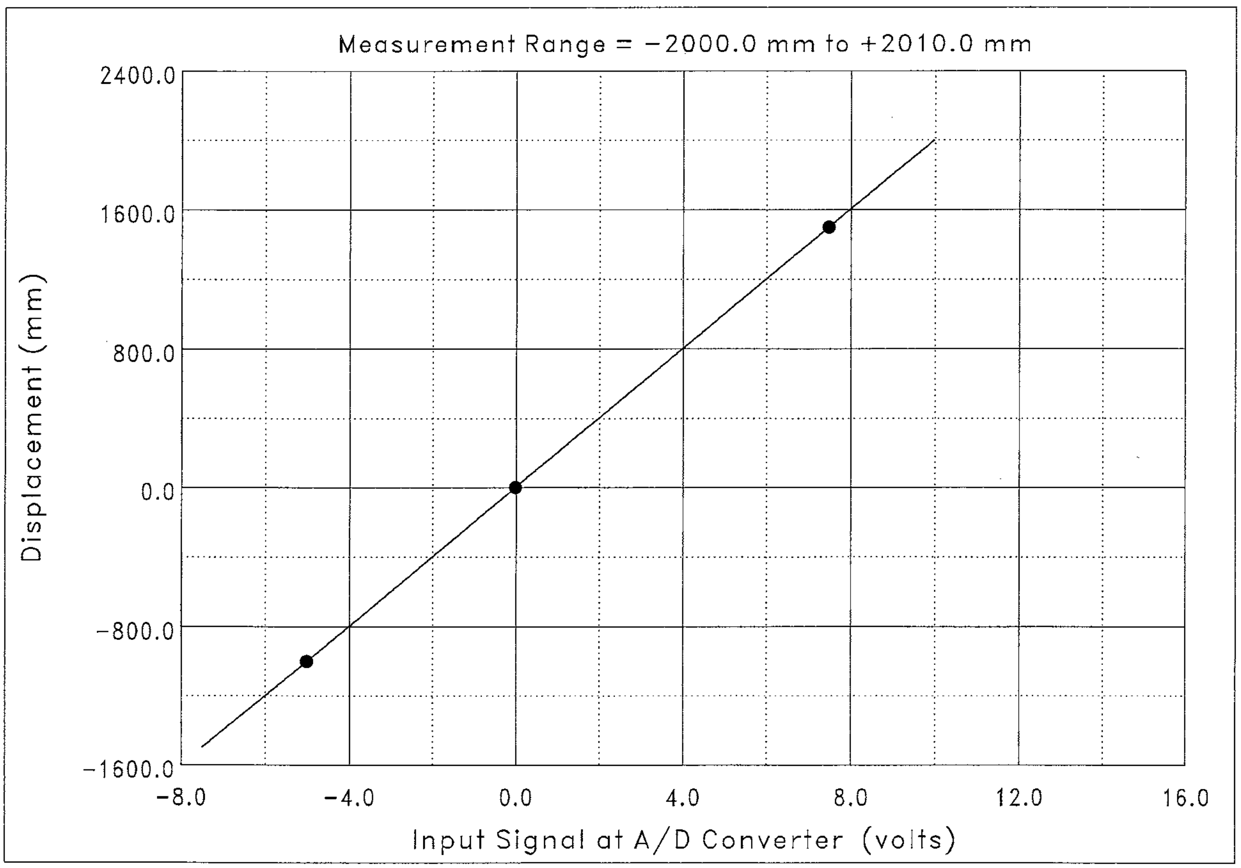
Programmable Gain: 1 **Plug-In Gain:** 1 **Filter Frequency:** 10.0 Hz

Data Point No.	Input Signal (volts)	Physical Value (mm)	Fitted Curve Value (mm)	Error (mm)	
1	−0.021	0.0	0.0	−0.036658	⇐ Maximum Error
2	−5.014	−1000.0	−1000.0	0.021973	
3	7.471	1500.0	1500.0	0.014648	
Maximum Error = −0.00147 % of Calibration Range.					

Definition of Calibration Curve
Polynomial Degree = 1 (Linear Fit)

$$Y = C_0 + C_1 \cdot V$$

where $Y(t)$ = Displacement (mm),
$V(t)$ = input signal at A/D converter (volts),
C_0 = 4.07704 mm,
and C_1 = 200.232 mm/volt .



Calibration of ICEDAS Channel 15 14:48 24 August 2005

Project: Conical Structures in Ice **Facility:** Ice Tank

Sensor: Z POSITION **Model:** QUALYSIS **Serial Number:** N/A

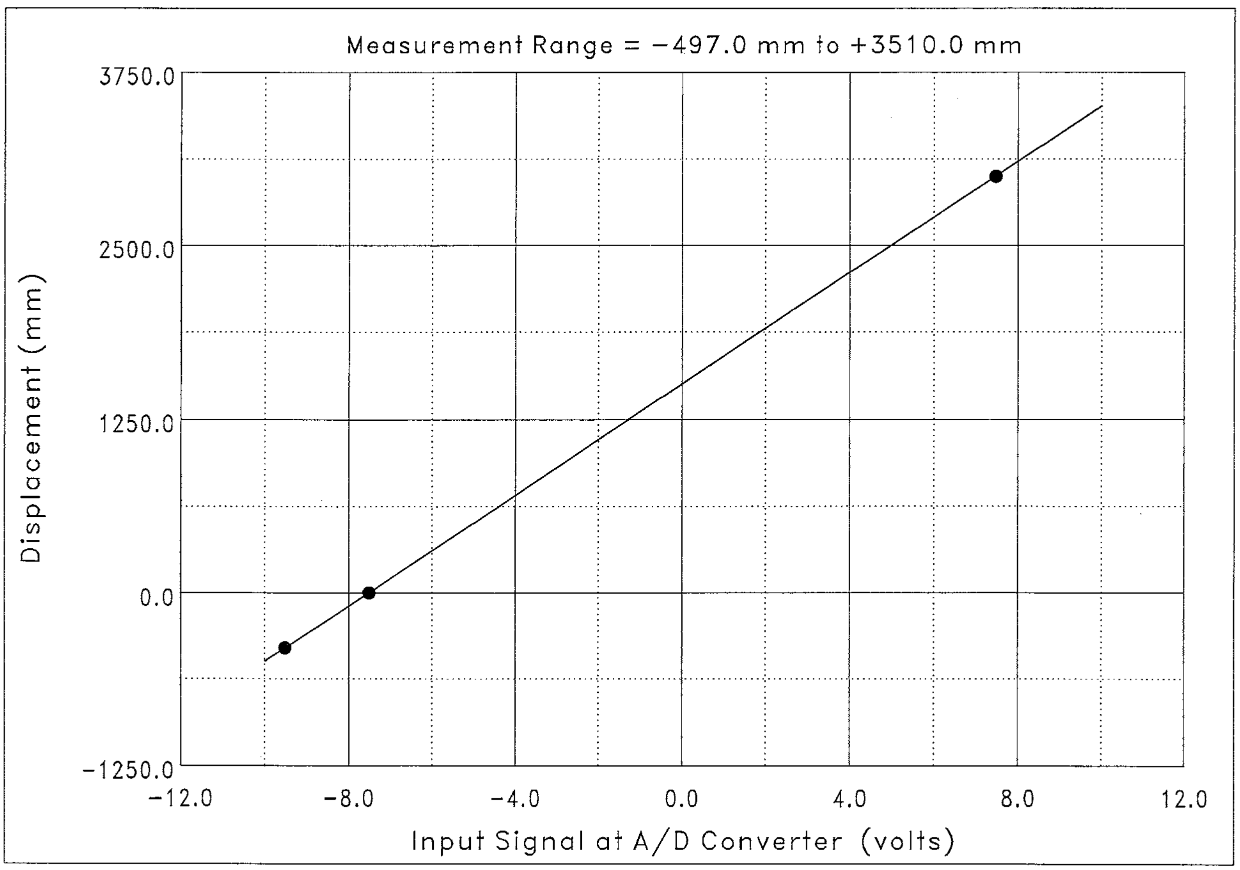
Programmable Gain: 1 **Plug-In Gain:** 1 **Filter Frequency:** 10.0 Hz

Data Point No.	Input Signal (volts)	Physical Value (mm)	Fitted Curve Value (mm)	Error (mm)	
1	−9.518	−400.0	−400.0	−0.029907	
2	7.465	3000.0	3000.0	−0.003906	
3	−7.520	0.0	0.0	0.033936	⇐ Maximum Error
Maximum Error = 0.000998 % of Calibration Range.					

Definition of Calibration Curve Polynomial Degree = 1 (Linear Fit)

$$Y = C_0 + C_1 \cdot V$$

where $Y(t)$ = Displacement (mm),
$V(t)$ = input signal at A/D converter (volts),
C_0 = 1505.47 mm,
and C_1 = 200.202 mm/volt .



Calibration of ICEDAS Channel 17 — 14:55 24 August 2005

Project: Conical Structures in Ice

Facility: Ice Tank

Sensor: PITCH

Model: QUALYSIS

Serial Number: N/A

Programmable Gain: 1

Plug-In Gain: 1

Filter Frequency: 10.0 Hz

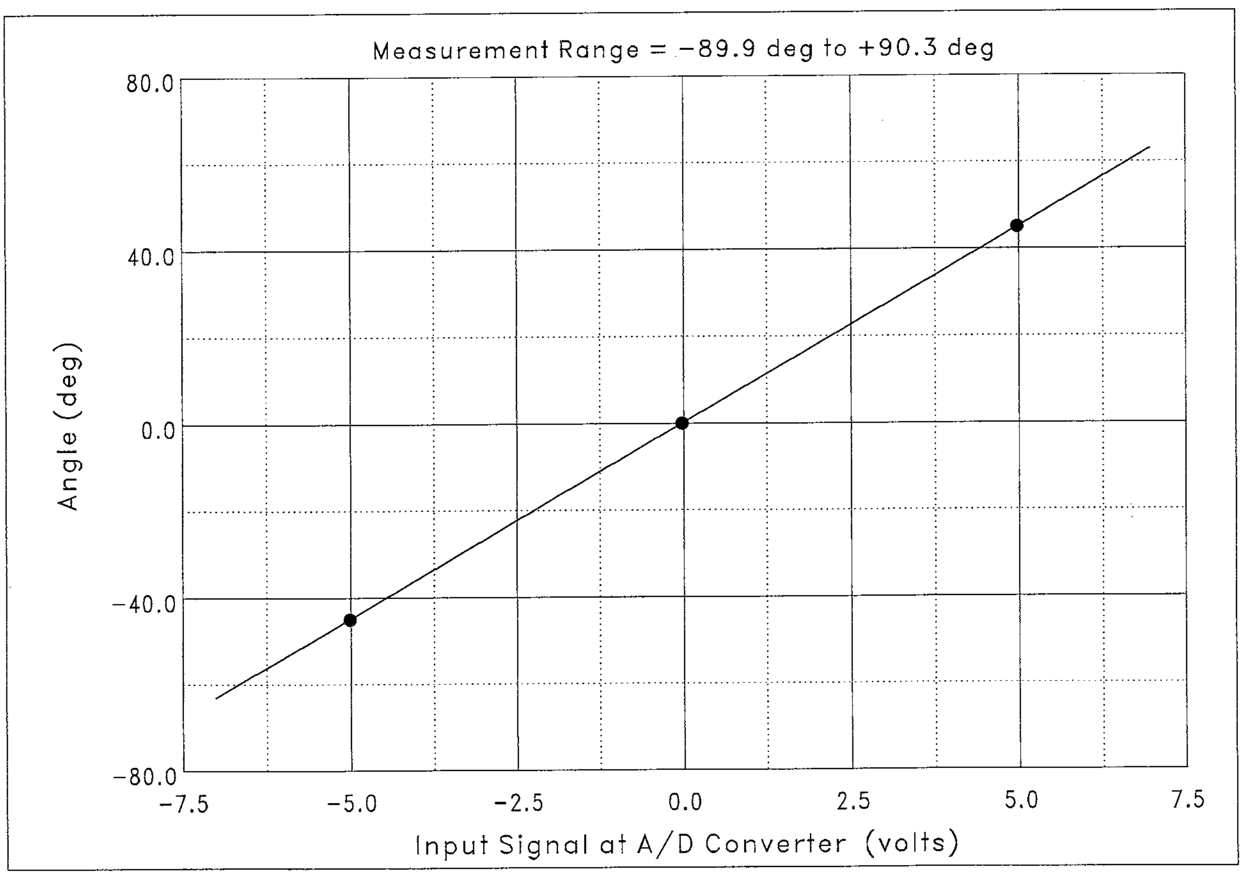
Data Point No.	Input Signal (volts)	Physical Value (deg)	Fitted Curve Value (deg)	Error (deg)	
1	−0.022	0.000	−0.003	−0.0028087	⇐ Maximum Error
2	−5.017	−45.000	−44.999	0.0014038	
3	4.973	45.000	45.001	0.0014038	
Maximum Error = −0.00312 % of Calibration Range.					

Definition of Calibration Curve

Polynomial Degree = 1 (Linear Fit)

$$Y = C_0 + C_1 \cdot V$$

where $Y(t)$ = Angle (deg),
$V(t)$ = input signal at A/D converter (volts),
C_0 = 0.197656 deg,
and C_1 = 9.00876 deg/volt .



Calibration of ICEDAS Channel 19 14:58 24 August 2005

Project: Conical Structures in Ice **Facility:** Ice Tank

Sensor: RMS **Model:** N/A **Serial Number:** N/A

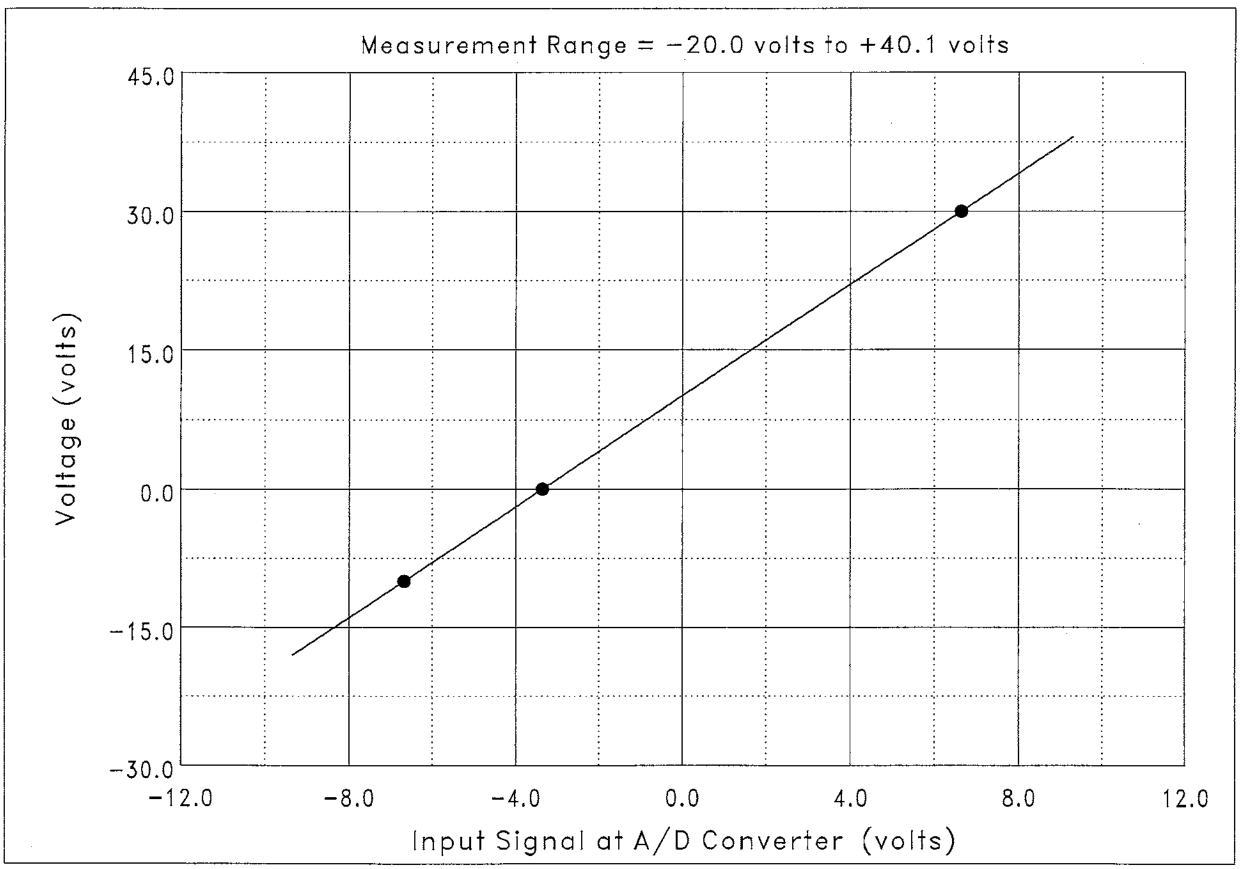
Programmable Gain: 1 **Plug-In Gain:** 1 **Filter Frequency:** 10.0 Hz

Data Point No.	Input Signal (volts)	Physical Value (volts)	Fitted Curve Value (volts)	Error (volts)	
1	−3.354	0.000	0.000	−0.00041103	⇐ Maximum Error
2	−6.683	−10.000	−10.000	0.00030804	
3	6.634	30.000	30.000	0.00010490	
Maximum Error = −0.00103 % of Calibration Range.					

Definition of Calibration Curve
Polynomial Degree = 1 (Linear Fit)

$$Y = C_0 + C_1 \cdot V$$

where $Y(t)$ = Voltage (volts),
$V(t)$ = input signal at A/D converter (volts),
C_0 = 10.0735 volts,
and C_1 = 3.00362 volts/volt.



Calibration of ICEDAS Channel 12 — 14:32 19 August 2005

Project: Conical Structures in Ice — **Facility:** Ice Tank

Sensor: MOOR8(STBD AFT) — **Model:** 100LB — **Serial Number:** N/A

Programmable Gain: 1 — **Plug-In Gain:** 200 — **Filter Frequency:** 10.0 Hz

Data Point No.	Input Signal (volts)	Physical Value (N)	Fitted Curve Value (N)	Error (N)	
1	1.000	0.00	0.65	0.64959	⇐ Maximum Error
2	1.617	49.03	49.11	0.07703	
3	2.235	98.07	97.77	−0.30064	
4	2.856	147.10	146.54	−0.56447	
5	3.481	196.13	195.69	−0.44321	
6	4.109	245.17	245.05	−0.12024	
7	4.738	294.20	294.55	0.34821	
8	5.362	343.23	343.59	0.35373	
Maximum Error = 0.189 % of Calibration Range.					

Definition of Calibration Curve

Polynomial Degree = 1 (Linear Fit)

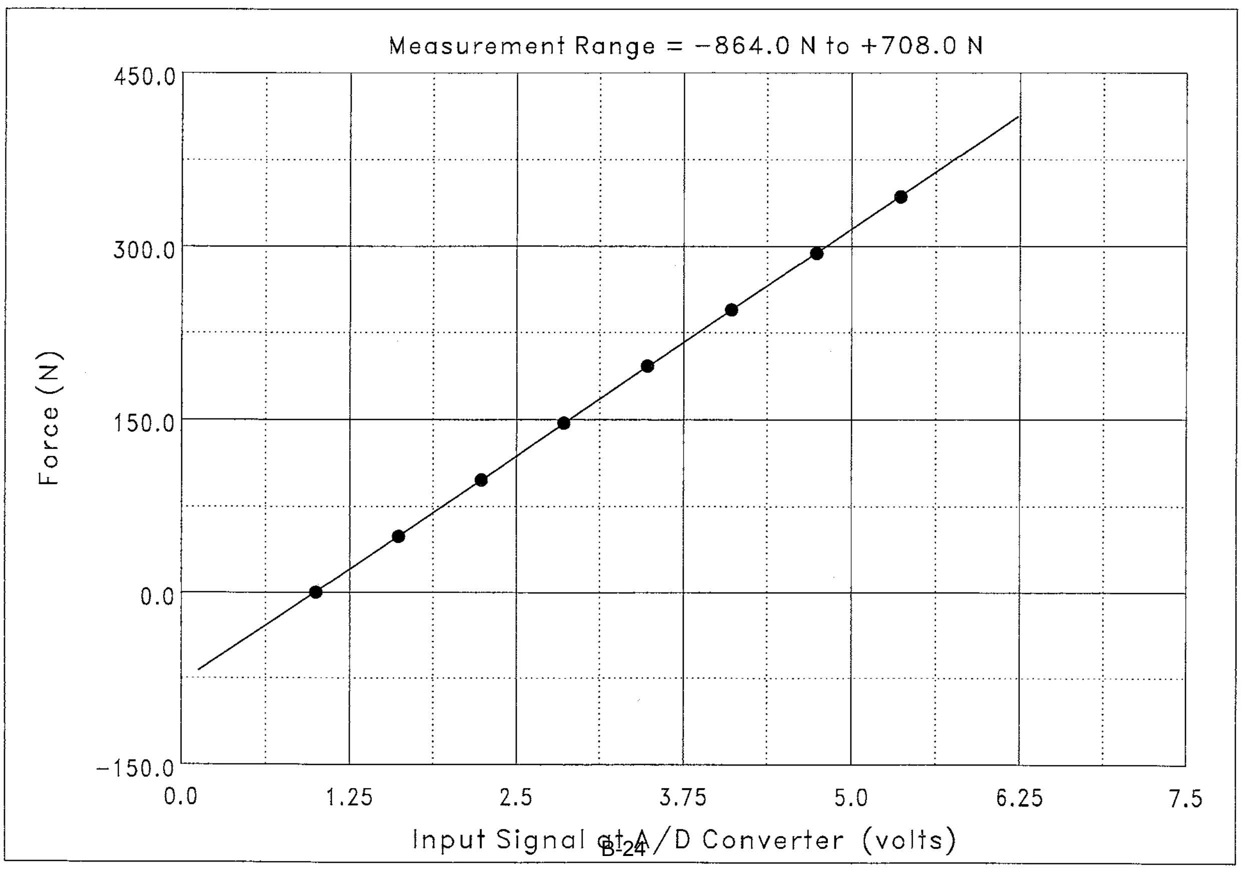
$$Y = C_0 + C_1 \cdot V$$

where $Y(t)$ = Force (N),

$V(t)$ = input signal at A/D converter (volts),

C_0 = -77.9859 N,

and C_1 = 78.6232 N/volt.



Calibration of ICEDAS Channel 11 14:32 19 August 2005

Project: Conical Structures in Ice | **Facility:** Ice Tank

Sensor: MOOR7(PORT AFT) | **Model:** 100LB | **Serial Number:** A10364

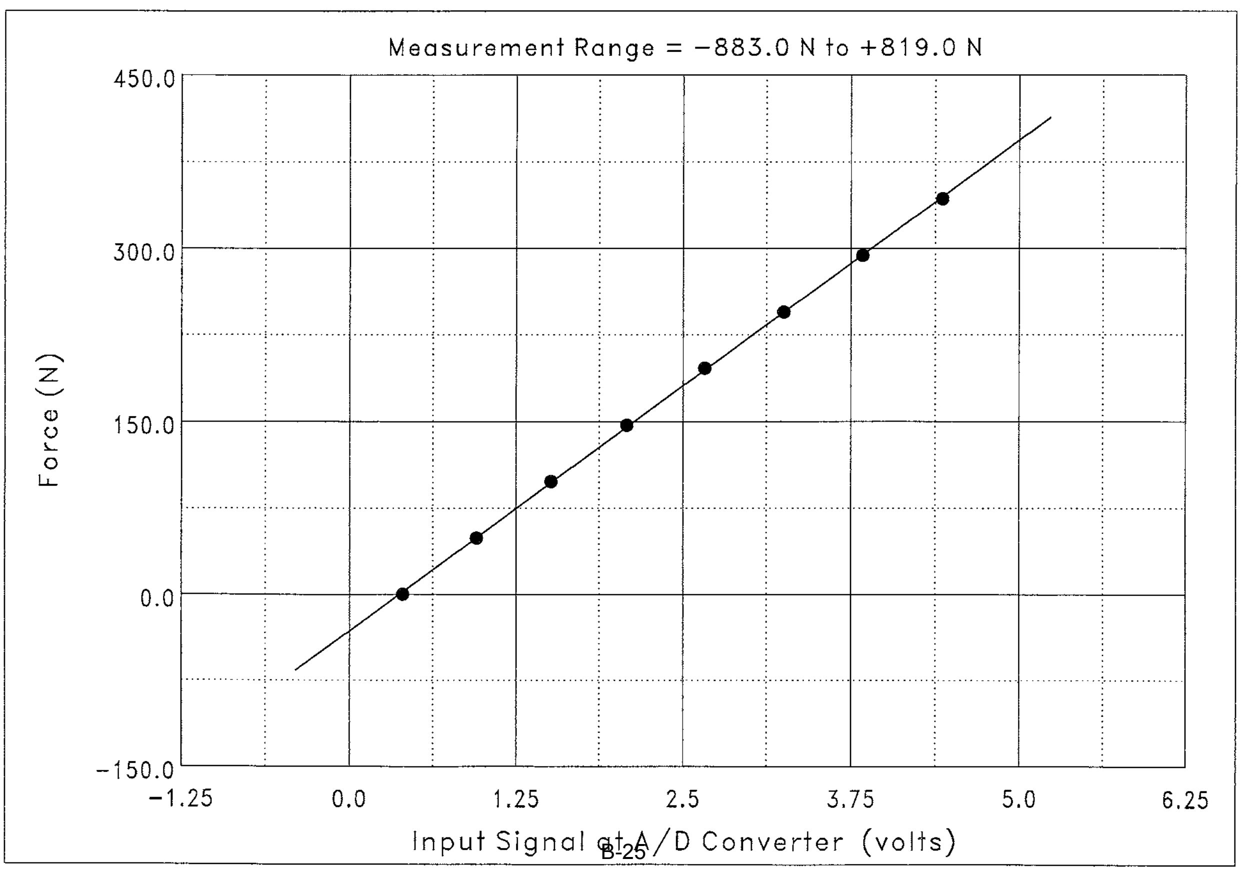
Programmable Gain: 1 | **Plug-In Gain:** 200 | **Filter Frequency:** 10.0 Hz

Data Point No.	Input Signal (volts)	Physical Value (N)	Fitted Curve Value (N)	Error (N)	
1	0.402	0.00	2.30	2.3011	⇐ Maximum Error
2	0.954	49.03	49.30	0.2641	
3	1.511	98.07	96.73	−1.3409	
4	2.083	147.10	145.38	−1.7178	
5	2.665	196.13	194.86	−1.2731	
6	3.253	245.17	244.90	−0.2627	
7	3.838	294.20	294.72	0.5206	
8	4.426	343.23	344.74	1.5086	
Maximum Error = 0.670 % of Calibration Range.					

Definition of Calibration Curve
Polynomial Degree = 1 (Linear Fit)

$$Y = C_0 + C_1 \cdot V$$

where $Y(t)$ = Force (N),
$V(t)$ = input signal at A/D converter (volts),
C_0 = -31.8697 N,
and C_1 = 85.0856 N/volt .



Calibration of ICEDAS Channel 10 14:32 19 August 2005

Project: Conical Structures in Ice **Facility:** Ice Tank

Sensor: MOOR6(STBD FWD) **Model:** 100LB **Serial Number:** A10643

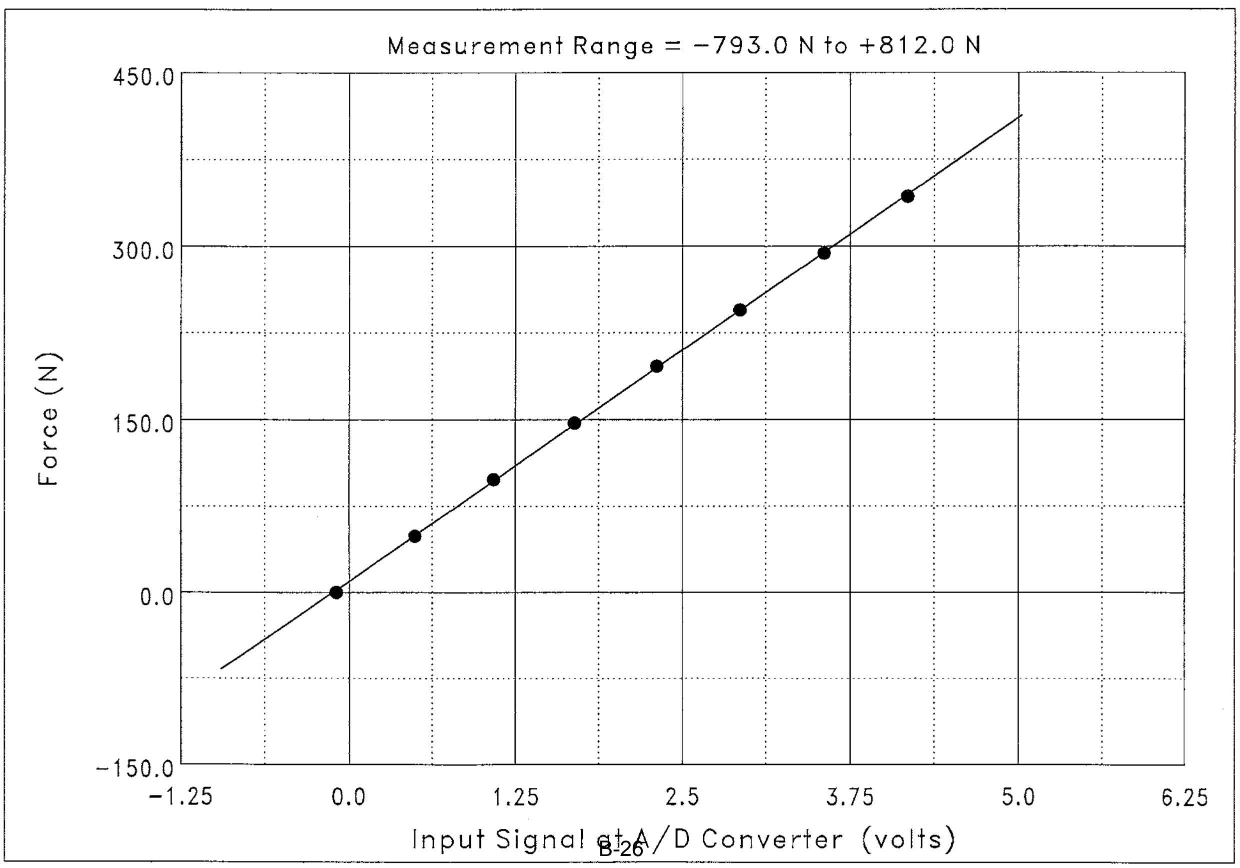
Programmable Gain: 1 **Plug-In Gain:** 200 **Filter Frequency:** 10.0 Hz

Data Point No.	Input Signal (volts)	Physical Value (N)	Fitted Curve Value (N)	Error (N)	
1	−0.094	0.00	2.05	2.0520	⇐ Maximum Error
2	0.494	49.03	49.26	0.2265	
3	1.087	98.07	96.82	−1.2415	
4	1.693	147.10	145.49	−1.6061	
5	2.312	196.13	195.09	−1.0409	
6	2.934	245.17	245.01	−0.1534	
7	3.554	294.20	294.77	0.5676	
8	4.173	343.23	344.43	1.1957	
Maximum Error = 0.598 % of Calibration Range.					

Definition of Calibration Curve
Polynomial Degree = 1 (Linear Fit)

$$Y = C_0 + C_1 \cdot V$$

where $Y(t)$ = Force (N),
$V(t)$ = input signal at A/D converter (volts),
C_0 = 9.61176 N,
and C_1 = 80.2418 N/volt.



Calibration of ICEDAS Channel 9   14:32   19 August 2005

Project: Conical Structures in Ice   **Facility:** Ice Tank

Sensor: MOOR5(PORT FWD)   **Model:** 100LB   **Serial Number:** A10656

Programmable Gain: 1   **Plug-In Gain:** 200   **Filter Frequency:** 10.0 Hz

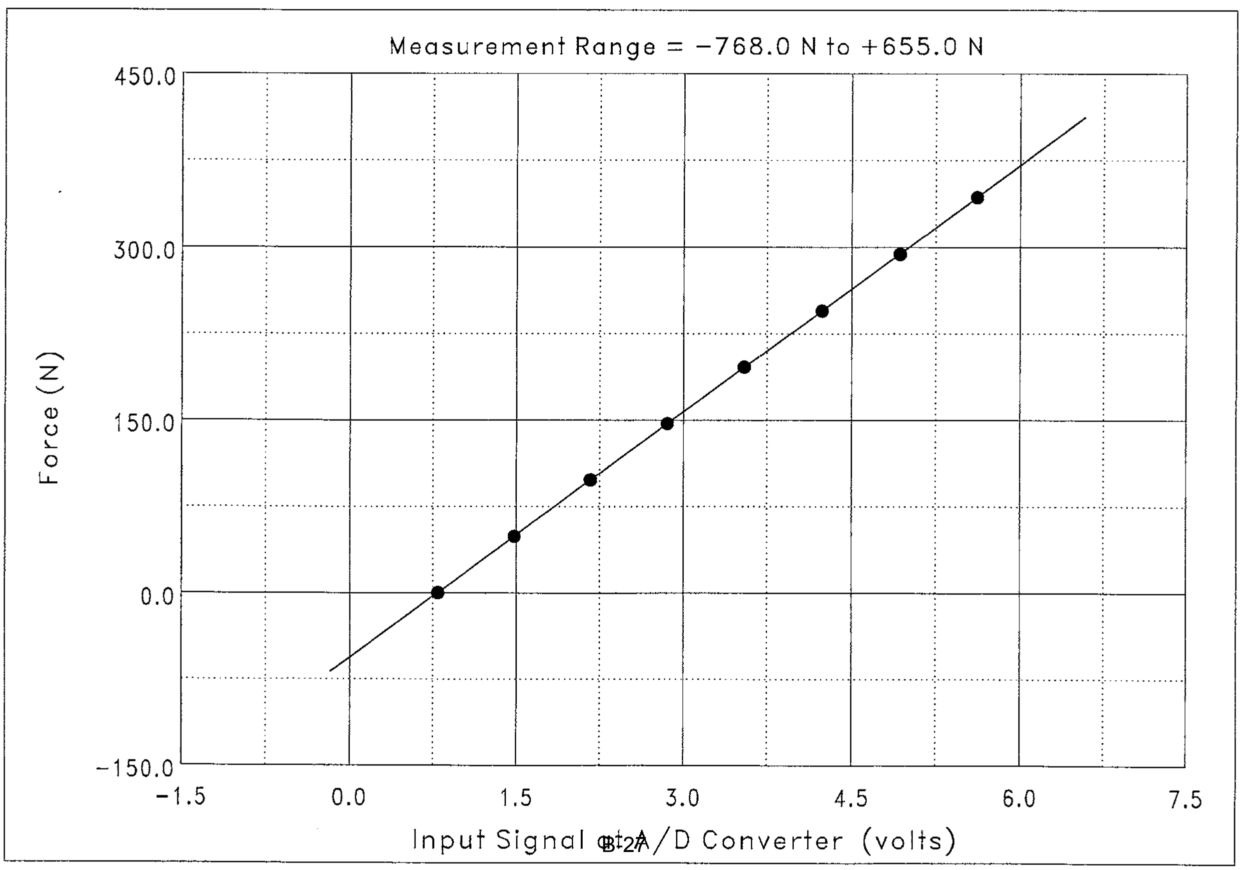
Data Point No.	Input Signal (volts)	Physical Value (N)	Fitted Curve Value (N)	Error (N)	
1	0.793	0.00	0.12	0.12070	
2	1.481	49.03	49.08	0.04487	
3	2.169	98.07	98.01	−0.05385	
4	2.856	147.10	146.92	−0.17970	⇐ Maximum Error
5	3.546	196.13	196.03	−0.10246	
6	4.238	245.17	245.20	0.03635	
7	4.928	294.20	294.31	0.11032	
8	5.616	343.23	343.26	0.02383	
Maximum Error = −0.0524 % of Calibration Range.					

Definition of Calibration Curve

Polynomial Degree = 1 (Linear Fit)

$$Y = C_0 + C_1 \cdot V$$

where $Y(t)$ = Force (N),
$V(t)$ = input signal at A/D converter (volts),
C_0 = −56.2586 N,
and C_1 = 71.1401 N/volt .



Calibration of ICEDAS Channel 8 15:23 19 August 2005

Project: Conical Structures in Ice **Facility:** Ice Tank

Sensor: MOOR4(STBD AFT) **Model:** 60001-50 **Serial Number:** A10658

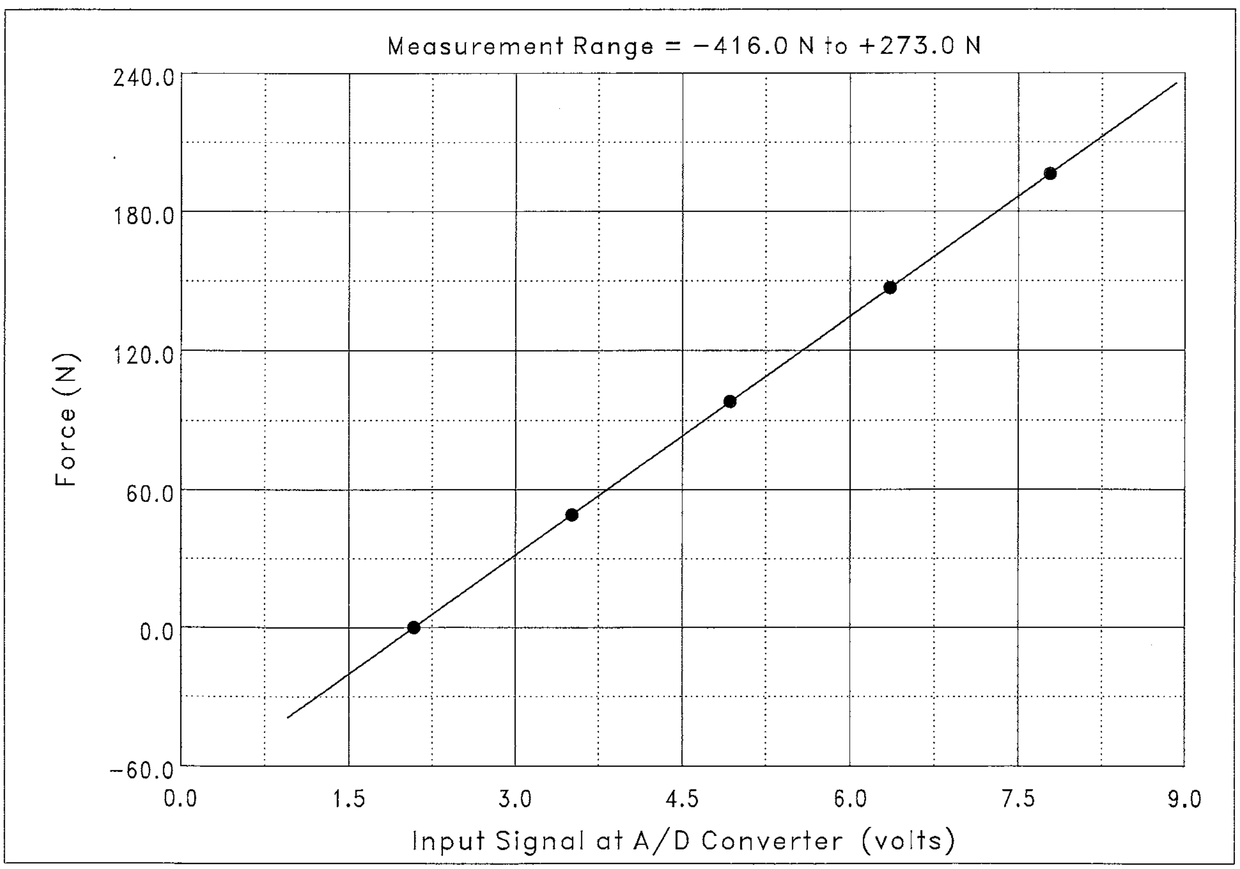
Programmable Gain: 1 **Plug-In Gain:** 200 **Filter Frequency:** 10.0 Hz

Data Point No.	Input Signal (volts)	Physical Value (N)	Fitted Curve Value (N)	Error (N)	
1	2.086	0.00	0.06	0.061989	
2	3.509	49.03	49.03	−0.000549	
3	4.930	98.07	97.98	−0.085358	
4	6.354	147.10	147.02	−0.075104	
5	7.783	196.13	196.23	0.098984	⇐ Maximum Error
Maximum Error = 0.0505 % of Calibration Range.					

Definition of Calibration Curve
Polynomial Degree = 1 (Linear Fit)

$$Y = C_0 + C_1 \cdot V$$

where $Y(t)$ = Force (N),
$V(t)$ = input signal at A/D converter (volts),
C_0 = -71.7850 N,
and C_1 = 34.4351 N/volt.



Calibration of ICEDAS Channel 7 15:23 19 August 2005

Project: Conical Structures in Ice **Facility:** Ice Tank

Sensor: MOOR3(PORT AFT) **Model:** 60001-50 **Serial Number:** A10293

Programmable Gain: 1 **Plug-In Gain:** 200 **Filter Frequency:** 10.0 Hz

Data Point No.	Input Signal (volts)	Physical Value (N)	Fitted Curve Value (N)	Error (N)	
1	1.350	0.00	0.87	0.86971	⇐ Maximum Error
2	2.622	49.03	48.45	−0.58821	
3	3.929	98.07	97.36	−0.70528	
4	5.251	147.10	146.84	−0.26012	
5	6.587	196.13	196.82	0.68390	
Maximum Error = 0.443 % of Calibration Range.					

Definition of Calibration Curve

Polynomial Degree = 1 (Linear Fit)

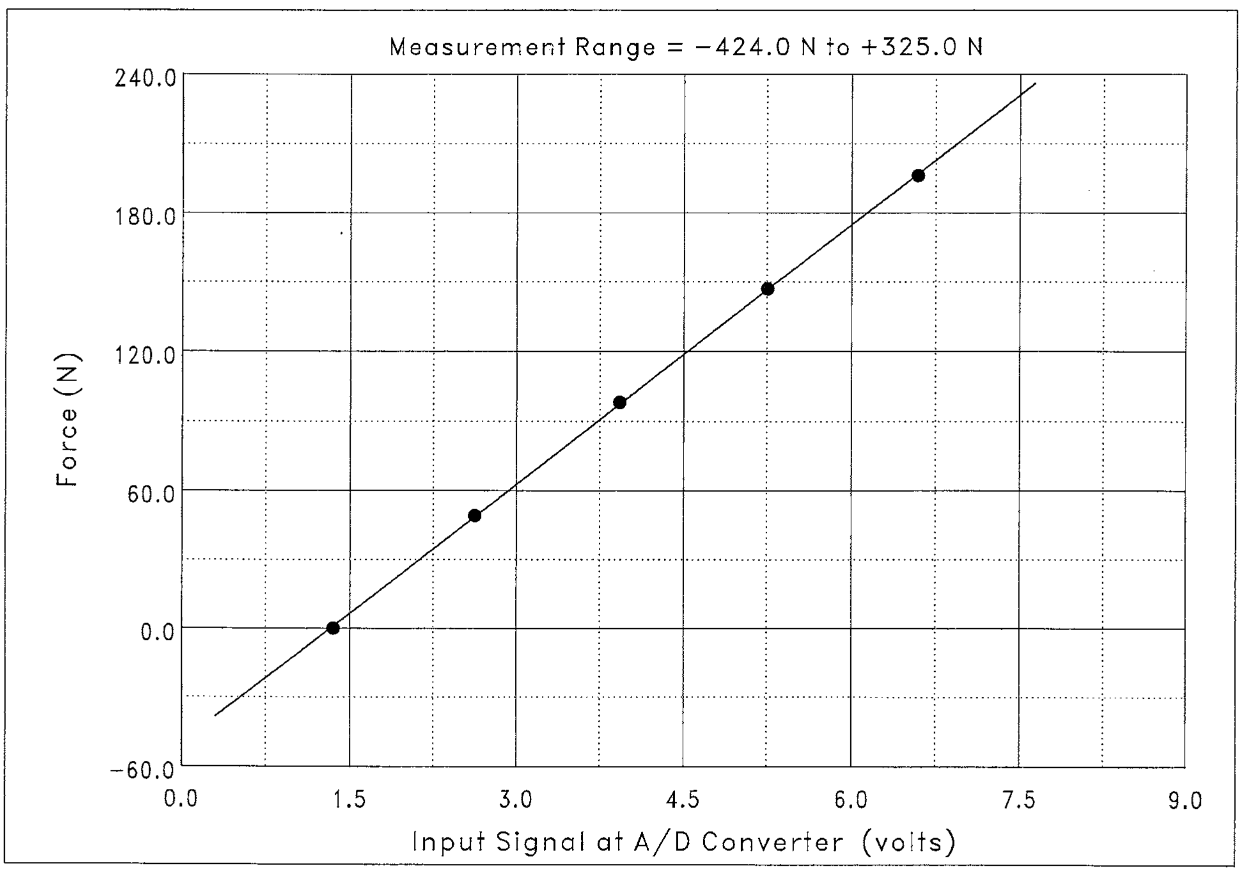
$$Y = C_0 + C_1 \cdot V$$

where $Y(t)$ = Force (N),

$V(t)$ = input signal at A/D converter (volts),

C_0 = −49.6397 N,

and C_1 = 37.4145 N/volt .



Calibration of ICEDAS Channel 5 15:23 19 August 2005

Project: Conical Structures in Ice **Facility:** Ice Tank

Sensor: MOOR1(PORT FWD) **Model:** 60001-50 **Serial Number:** A10296

Programmable Gain: 1 **Plug-In Gain:** 200 **Filter Frequency:** 10.0 Hz

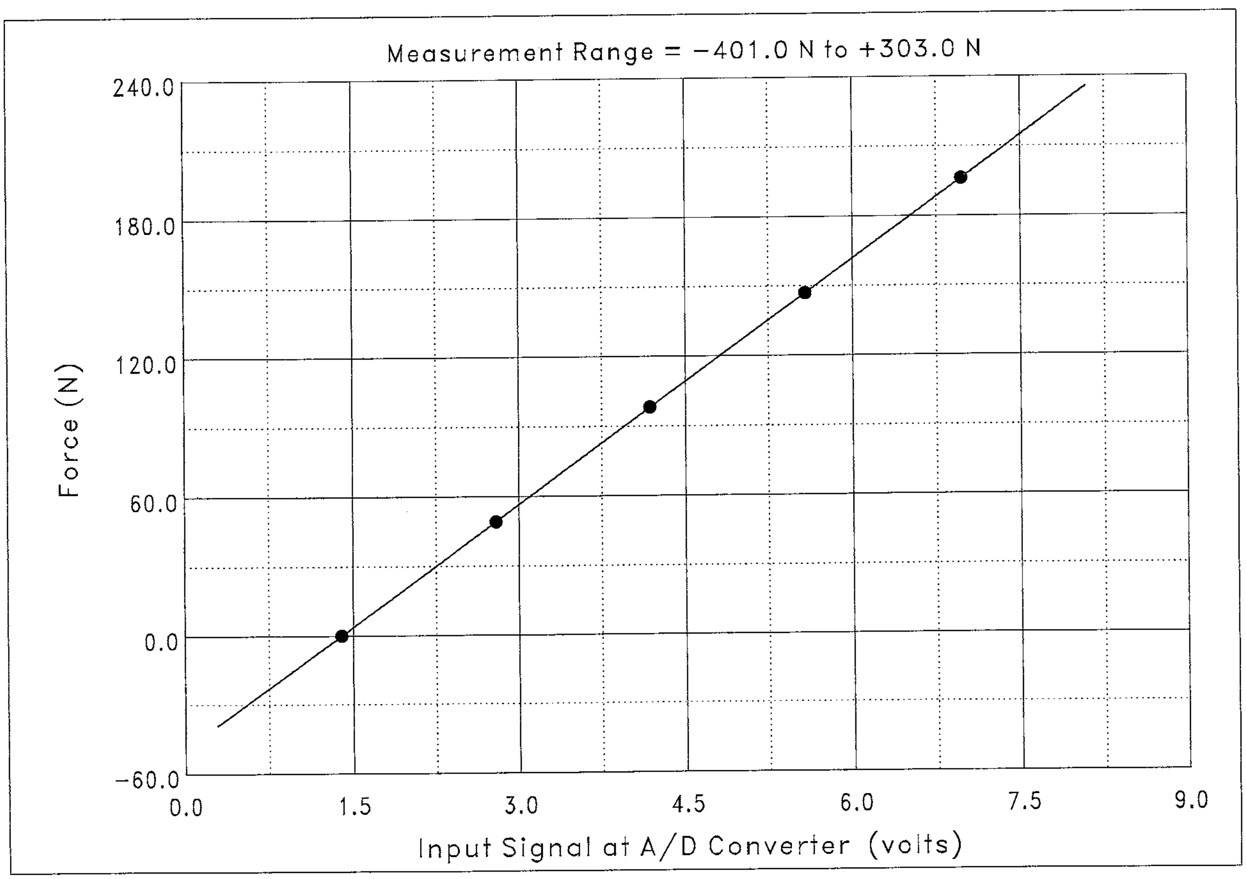
Data Point No.	Input Signal (volts)	Physical Value (N)	Fitted Curve Value (N)	Error (N)	
1	1.399	0.00	0.05	0.049335	
2	2.791	49.03	49.03	0.001492	
3	4.183	98.07	98.00	−0.069733	
4	5.576	147.10	147.04	−0.061951	
5	6.974	196.13	196.21	0.080887	⇐ Maximum Error
Maximum Error = 0.0412 % of Calibration Range.					

Definition of Calibration Curve

Polynomial Degree = 1 (Linear Fit)

$$Y = C_0 + C_1 \cdot V$$

where $Y(t)$ = Force (N),
$V(t)$ = input signal at A/D converter (volts),
C_0 = −49.1765 N,
and C_1 = 35.1870 N/volt.



Calibration of ICEDAS Channel 6 — 15:23 19 August 2005

Project: Conical Structures in Ice | **Facility:** Ice Tank

Sensor: MOOR2(STBD FWD) | **Model:** 60001-50 | **Serial Number:** A10294

Programmable Gain: 1 | **Plug-In Gain:** 200 | **Filter Frequency:** 10.0 Hz

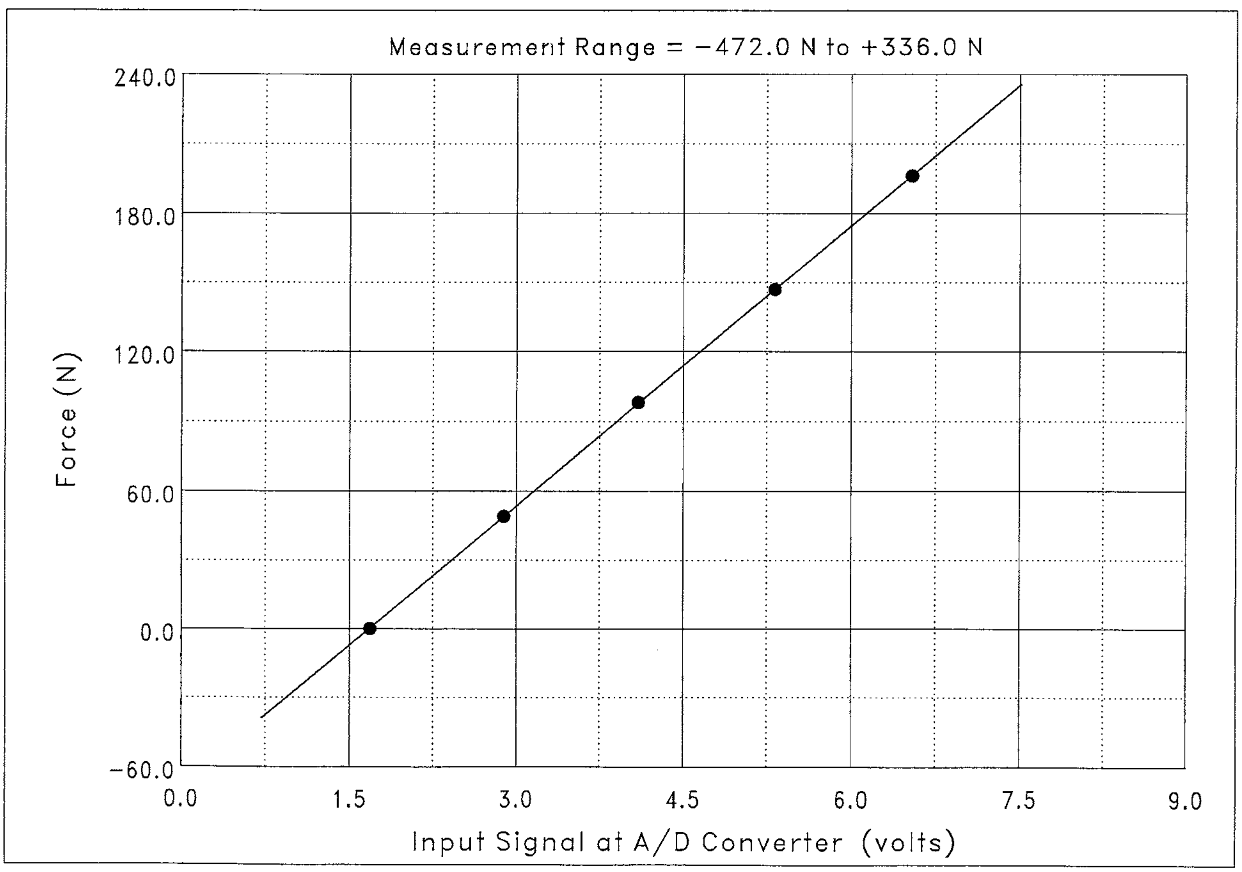
Data Point No.	Input Signal (volts)	Physical Value (N)	Fitted Curve Value (N)	Error (N)	
1	1.686	0.00	0.30	0.30326	⇐ Maximum Error
2	2.887	49.03	48.85	−0.18107	
3	4.098	98.07	97.79	−0.27402	
4	5.316	147.10	146.98	−0.11600	
5	6.539	196.13	196.40	0.26782	
Maximum Error = 0.155 % of Calibration Range.					

Definition of Calibration Curve

Polynomial Degree = 1 (Linear Fit)

$$Y = C_0 + C_1 \cdot V$$

where $Y(t)$ = Force (N),
$V(t)$ = input signal at A/D converter (volts),
C_0 = −67.8049 N,
and C_1 = 40.4056 N/volt.



Calibration of ICEDAS Channel 6 15:23 19 August 2005

Project: Conical Structures in Ice **Facility:** Ice Tank

Sensor: MOOR2(STBD FWD) **Model:** 60001-50 **Serial Number:** A10294

Programmable Gain: 1 **Plug-In Gain:** 200 **Filter Frequency:** 10.0 Hz

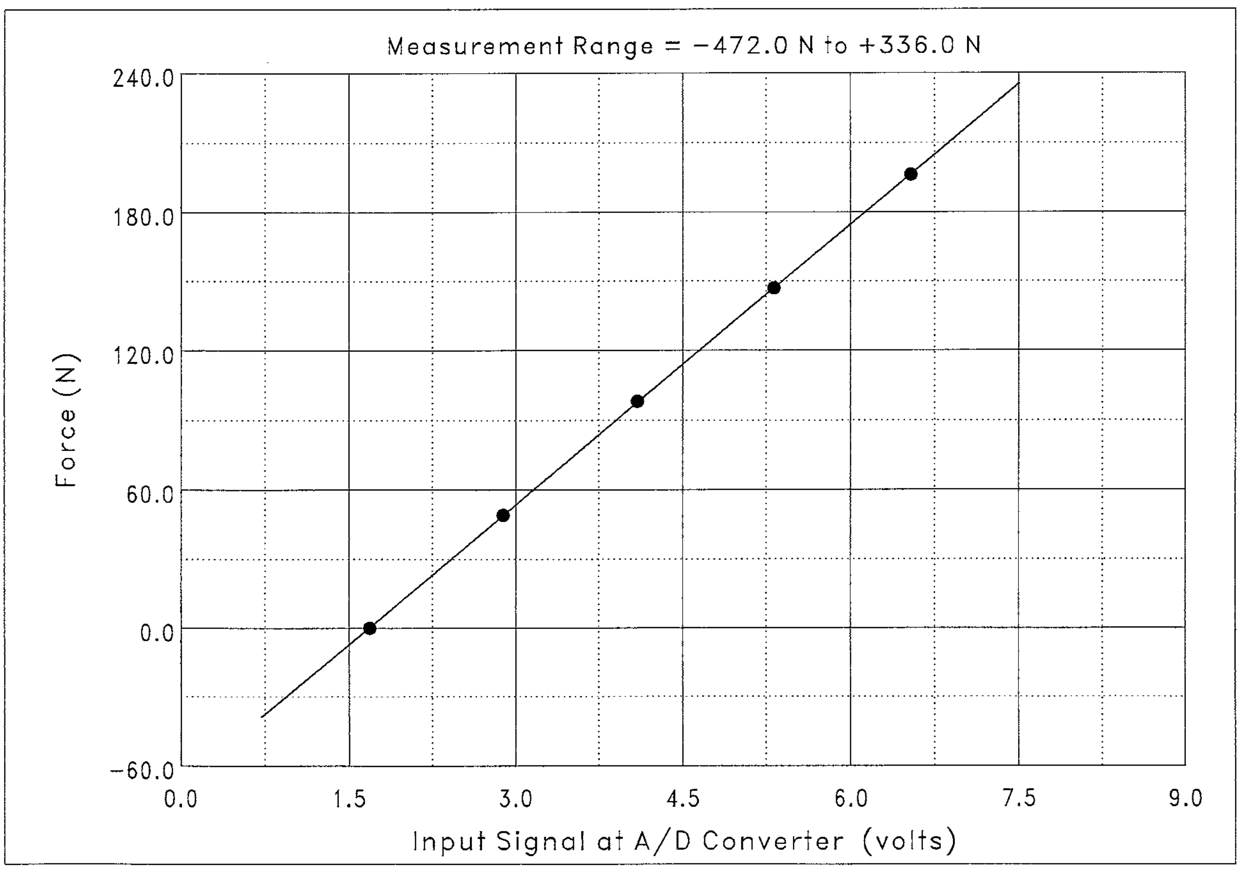
Data Point No.	Input Signal (volts)	Physical Value (N)	Fitted Curve Value (N)	Error (N)	
1	1.686	0.00	0.30	0.30326	⇐ Maximum Error
2	2.887	49.03	48.85	−0.18107	
3	4.098	98.07	97.79	−0.27402	
4	5.316	147.10	146.98	−0.11600	
5	6.539	196.13	196.40	0.26782	
Maximum Error = 0.155 % of Calibration Range.					

Definition of Calibration Curve

Polynomial Degree = 1 (Linear Fit)

$$Y = C_0 + C_1 \cdot V$$

where $Y(t)$ = Force (N),
$V(t)$ = input signal at A/D converter (volts),
C_0 = -67.8049 N,
and C_1 = 40.4056 N/volt.



Calibration of ICEDAS Channel 2 08:15 25 August 2005

Project: Conical Structures in Ice **Facility:** Ice Tank

Sensor: X Inline Load **Model:** 60001A100-1000 **Serial Number:** IOT# A10655 S/N 732494

Programmable Gain: 1 **Plug-In Gain:** 200 **Filter Frequency:** 10.0 Hz

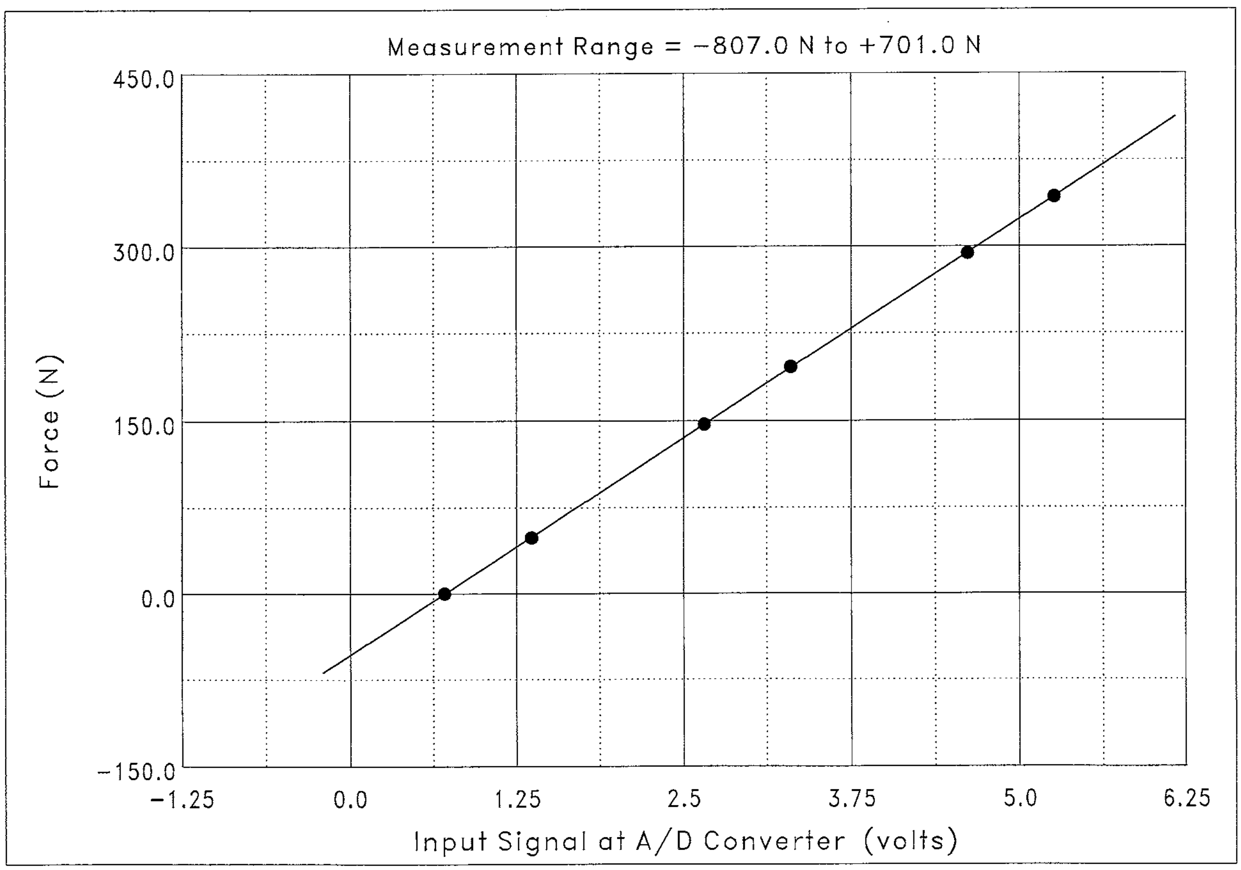
Data Point No.	Input Signal (volts)	Physical Value (N)	Fitted Curve Value (N)	Error (N)	
1	0.709	0.00	−0.04	−0.03912	
2	3.301	196.13	195.39	−0.74538	⇐ Maximum Error
3	5.263	343.23	343.35	0.11407	
4	1.365	49.03	49.42	0.38456	
5	2.660	147.10	147.08	−0.02220	
6	4.615	294.20	294.51	0.30814	
Maximum Error = −0.217 % of Calibration Range.					

Definition of Calibration Curve

Polynomial Degree = 1 (Linear Fit)

$$Y = C_0 + C_1 \cdot V$$

where $Y(t)$ = Force (N),
$V(t)$ = input signal at A/D converter (volts),
C_0 = −53.4864 N,
and C_1 = 75.3995 N/volt .



Calibration of ICEDAS Channel 3 08:15 25 August 2005

Project: Conical Structures in Ice **Facility:** Ice Tank

Sensor: Y Inline Load **Model:** 60001100 **Serial Number:** IOT# A10500 S/N 683211

Programmable Gain: 1 **Plug-In Gain:** 200 **Filter Frequency:** 10.0 Hz

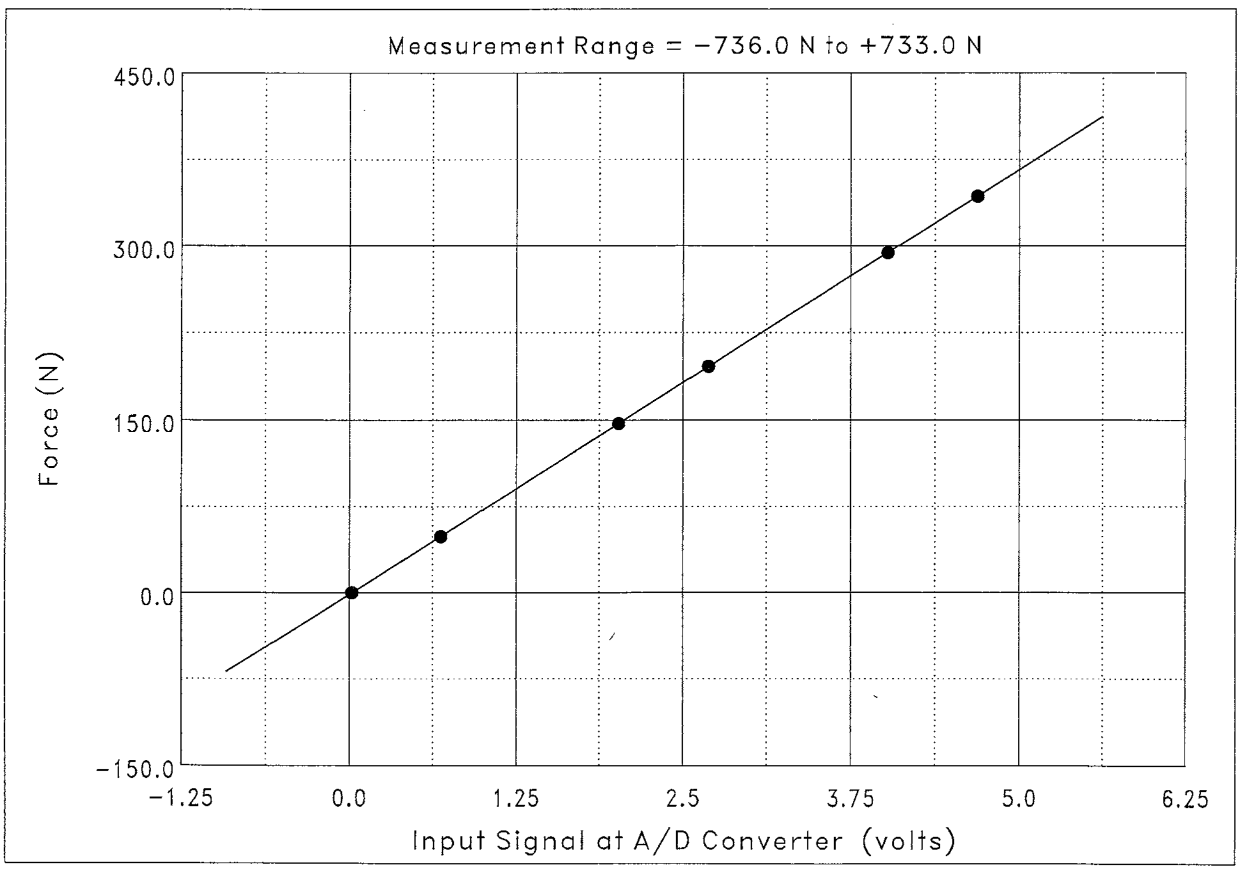
Data Point No.	Input Signal (volts)	Physical Value (N)	Fitted Curve Value (N)	Error (N)	
1	0.019	0.00	−0.05	−0.05024	
2	2.688	196.13	196.11	−0.02075	
3	4.690	343.23	343.23	−0.00430	
4	0.688	49.03	49.16	0.12508	⇐ Maximum Error
5	2.020	147.10	147.00	−0.09538	
6	4.024	294.20	294.25	0.04562	
Maximum Error = 0.0364 % of Calibration Range.					

Definition of Calibration Curve

Polynomial Degree = 1 (Linear Fit)

$$Y = C_0 + C_1 \cdot V$$

where $Y(t)$ = Force (N),
$V(t)$ = input signal at A/D converter (volts),
C_0 = -1.43289 N,
and C_1 = 73.4870 N/volt.



Calibration of ICEDAS Channel 2 08:15 25 August 2005

Project: Conical Structures in Ice **Facility:** Ice Tank

Sensor: X Inline Load **Model:** 60001A100-1000 **Serial Number:** IOT# A10655 S/N 732494

Programmable Gain: 1 **Plug-In Gain:** 200 **Filter Frequency:** 10.0 Hz

Data Point No.	Input Signal (volts)	Physical Value (N)	Fitted Curve Value (N)	Error (N)	
1	0.709	0.00	−0.04	−0.03912	
2	3.301	196.13	195.39	−0.74538	⇐ Maximum Error
3	5.263	343.23	343.35	0.11407	
4	1.365	49.03	49.42	0.38456	
5	2.660	147.10	147.08	−0.02220	
6	4.615	294.20	294.51	0.30814	
Maximum Error = −0.217 % of Calibration Range.					

Definition of Calibration Curve

Polynomial Degree = 1 (Linear Fit)

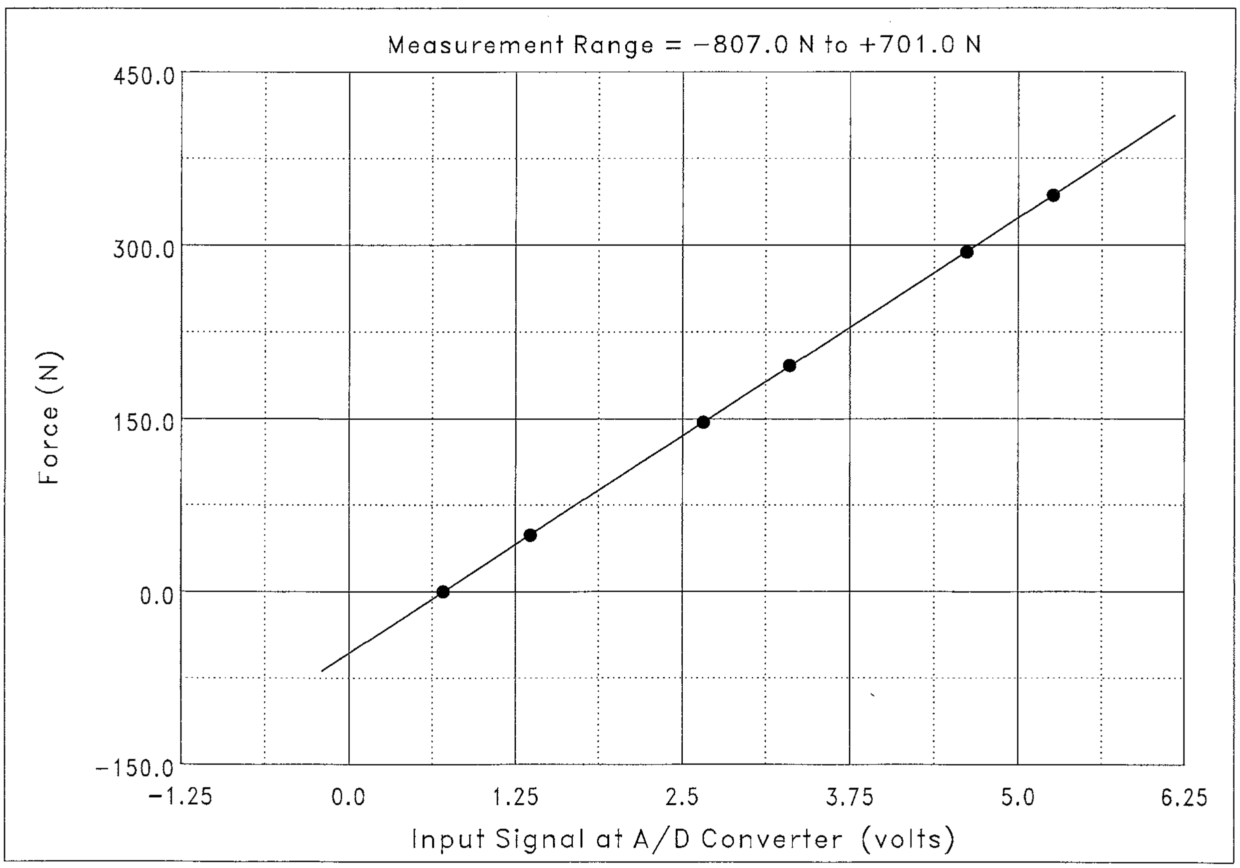
$$Y = C_0 + C_1 \cdot V$$

where $Y(t)$ = Force (N),

$V(t)$ = input signal at A/D converter (volts),

C_0 = −53.4864 N,

and C_1 = 75.3995 N/volt.



Calibration of ICEDAS Channel 3 08:15 25 August 2005

Project: Conical Structures in Ice **Facility:** Ice Tank

Sensor: Y Inline Load **Model:** 60001100 **Serial Number:** IOT# A10500 S/N 683211

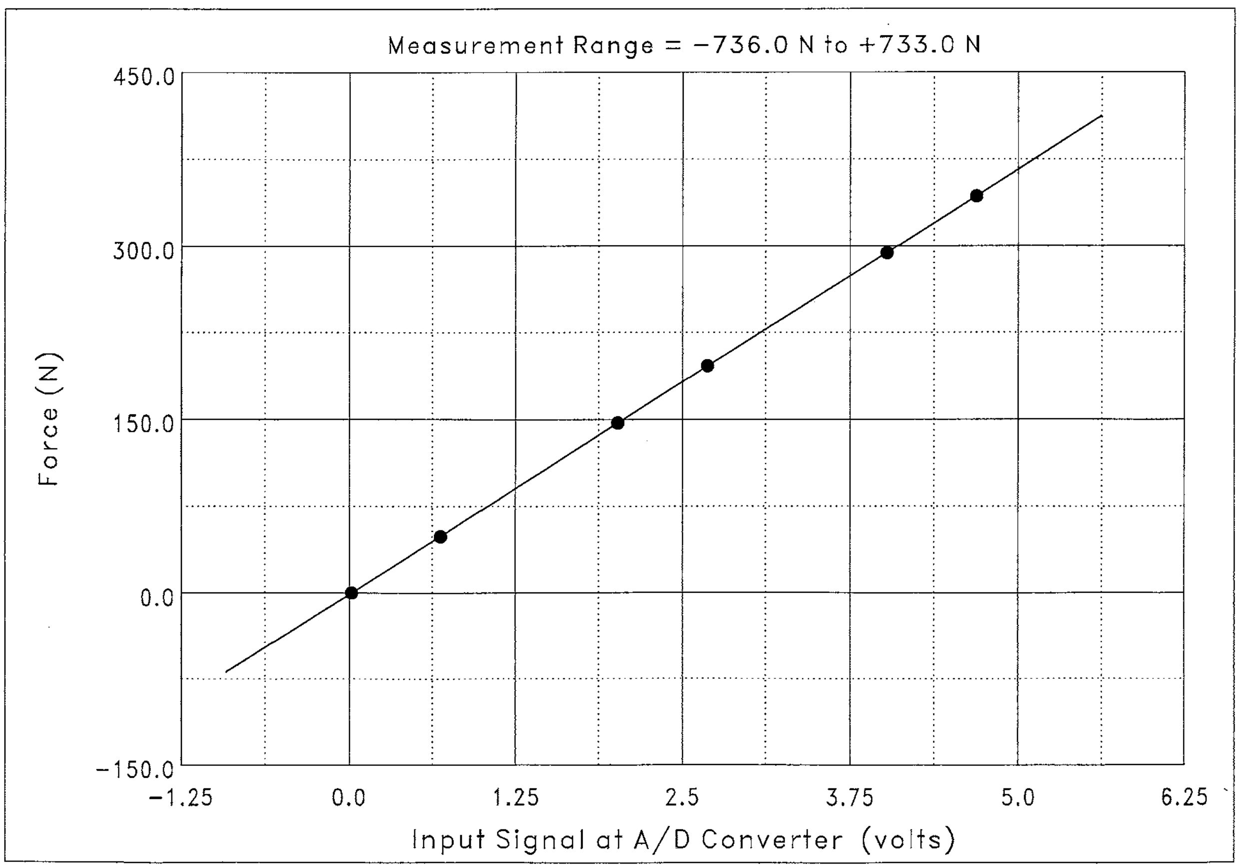
Programmable Gain: 1 **Plug-In Gain:** 200 **Filter Frequency:** 10.0 Hz

Data Point No.	Input Signal (volts)	Physical Value (N)	Fitted Curve Value (N)	Error (N)	
1	0.019	0.00	−0.05	−0.05024	
2	2.688	196.13	196.11	−0.02075	
3	4.690	343.23	343.23	−0.00430	
4	0.688	49.03	49.16	0.12508	⇐ Maximum Error
5	2.020	147.10	147.00	−0.09538	
6	4.024	294.20	294.25	0.04562	
Maximum Error = 0.0364 % of Calibration Range.					

Definition of Calibration Curve
Polynomial Degree = 1 (Linear Fit)

$$Y = C_0 + C_1 \cdot V$$

where $Y(t)$ = Force (N),
$V(t)$ = input signal at A/D converter (volts),
C_0 = −1.43289 N,
and C_1 = 73.4870 N/volt.



Calibration of ICEDAS Channel 3 08:15 25 August 2005

Project: Conical Structures in Ice **Facility:** Ice Tank

Sensor: Y Inline Load **Model:** 60001100 **Serial Number:** IOT# A10500 S/N 683211

Programmable Gain: 1 **Plug-In Gain:** 200 **Filter Frequency:** 10.0 Hz

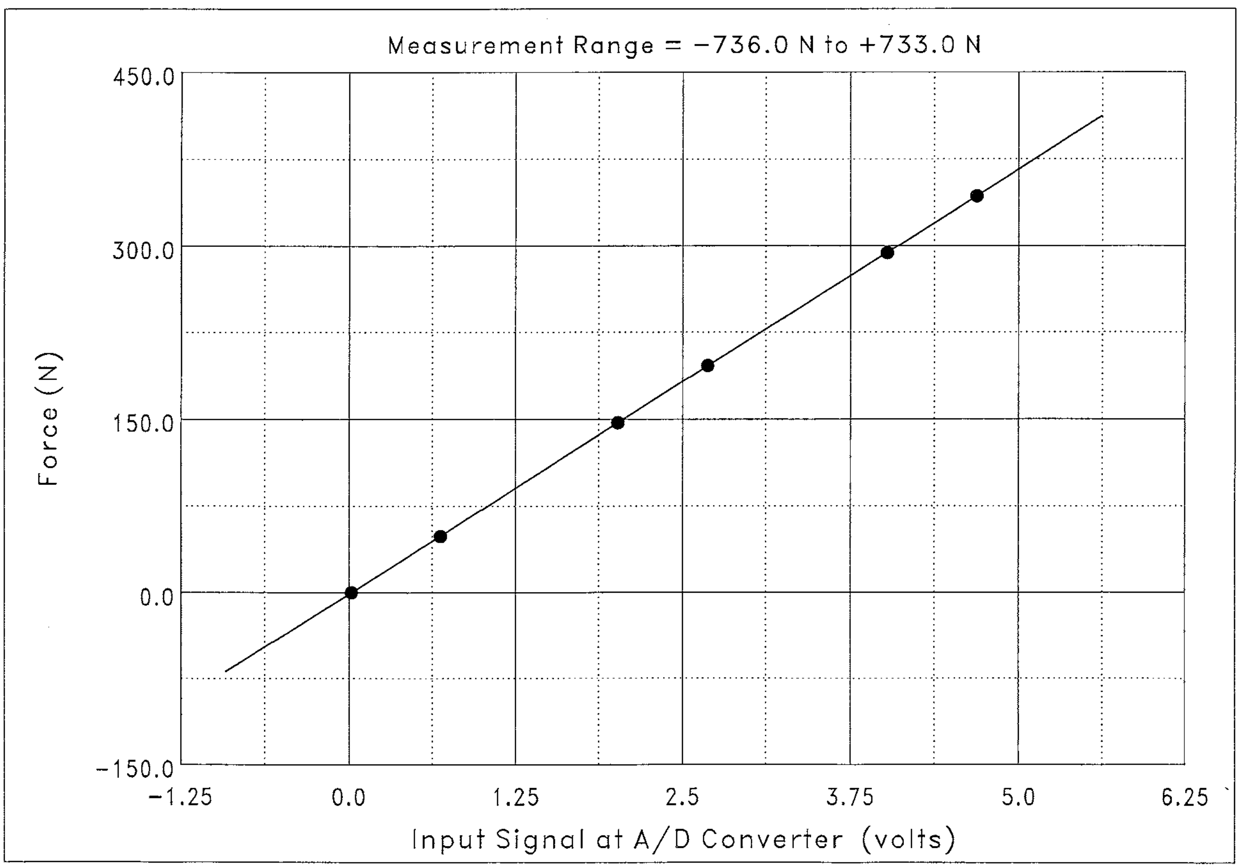
Data Point No.	Input Signal (volts)	Physical Value (N)	Fitted Curve Value (N)	Error (N)	
1	0.019	0.00	−0.05	−0.05024	
2	2.688	196.13	196.11	−0.02075	
3	4.690	343.23	343.23	−0.00430	
4	0.688	49.03	49.16	0.12508	⇐ Maximum Error
5	2.020	147.10	147.00	−0.09538	
6	4.024	294.20	294.25	0.04562	
Maximum Error = 0.0364 % of Calibration Range.					

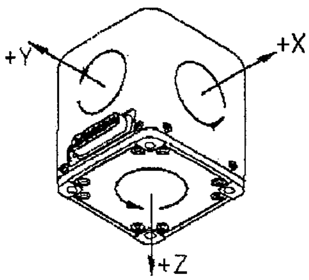
Definition of Calibration Curve

Polynomial Degree = 1 (Linear Fit)

$$Y = C_0 + C_1 \cdot V$$

where $Y(t)$ = Force (N),
$V(t)$ = input signal at A/D converter (volts),
C_0 = −1.43289 N,
and C_1 = 73.4870 N/volt .





The measurement center of the MotionPak co-ordinate system is located 50 mm (1.968 in) from the base and 38.1 mm (1.500 in) from either side of the unit. The unit should be located with the mounting plane down and the receptacle should be on the positive y (starboard) side.

The three accelerometers must be calibrated in units of g's and must measure the earth's gravity field when the model is stationary. In other words the heave accelerometer will read -1.0 g, while the surge and sway accelerometers will read 0.0 g when the model is level and stationary. The yaw, pitch and roll rates should also be measuring 0.0 degrees per second when the model is level and stationary.

Polarity of Motions Calculated by MOTIONPAK		
Positive Roll	Starboard Side Down	(Angular around X-axis)
Positive Pitch	Bow Up	(Angular around Y-axis)
Positive Yaw	Bow Turning to Starboard	(Angular around Z-axis)
Positive Surge	Forward Motion	(Linear X-axis)
Positive Sway	Motion to Starboard	(Linear Y-axis)
Positive Heave	Downward Motion	(Linear Z-axis)

Following the standard SNAME convention, rotation occurs in Yaw, Pitch and Roll order.

→ For Calibrated earth gravity = 9.81 g

The angular channels have to be calibrated by manually entering the calibration factors in the *Final Test Data Sheet* supplied by Systron Donner with each Unit. The linear channels can be calibrated either by manually entering calibration factors in the *Final Test Data Sheet* or with a physical calibration. If a manual entry calibration is performed on the linear channels, then a **-1.0 g** offset will need to be entered for the z-axis channel (heave), and a **0.0 g** offset will need to be entered for both the x and y-axis channels.

Offset Values if Manual Entry Calibration of Linear Channels is Performed			
Channel	X-axis (surge)	Y-axis (sway)	Z-axis (heave)
Offset Value	0.0 g	0.0 g	-1.0 g

Suggestion :- Add 3 new channels for accel.
- manually entering calibration factors

Orientation and Entered Values for a Physical Calibration of Linear Channels			
	Entered Values		
Orientation	X-axis (surge)	Y-axis (sway)	Z-axis (heave)
Mounting plate down	0.0 g	0.0 g	-1.0 g
Unit on it's side	1.0 g (axis up)	1.0 g (axis up)	0.0 g
Unit on it's side	-1.0 g (axis down)	-1.0 g (axis down)	0.0 g
Mounting plate up	0.0 g	0.0g	+1.0 g

The following checks should be performed after the unit is installed in the model. Data should be collected for a minimum of 5 second with the model level and stationary. Then for each of the linear axes, the model should be pushed (acceleration) in the positive direction and then held there for 5 seconds. For the angular rates, the model should be rotated in the positive direction of rotation and held there for 5 seconds. The data should be plotted, visually examined to verify that they correspond to the tests performed on the sensor.

Calibration of ICEDAS Channel 33 11:46 13 October 2004

Project: Conical Structures in Ice **Facility:** Ice Tank

Sensor: Carriage Velocity **Model:** Carriage D/A Output (C and E) **Serial Number:** N/A

Programmable Gain: 1 **Plug-In Gain:** 1 **Filter Frequency:** 10.0 Hz

Data Point No.	Input Signal (volts)	Physical Value (m/s)	Fitted Curve Value (m/s)	Error (m/s)	
1	5.993	3.0000	3.0000	$0.50068E-05$	
2	−6.006	0.0000	0.0000	$0.23842E-05$	
3	1.994	2.0000	2.0000	$-0.73910E-05$	⇐ Maximum Error
Maximum Error = −0.000246 % of Calibration Range.					

Definition of Calibration Curve

Polynomial Degree = 1 (Linear Fit)

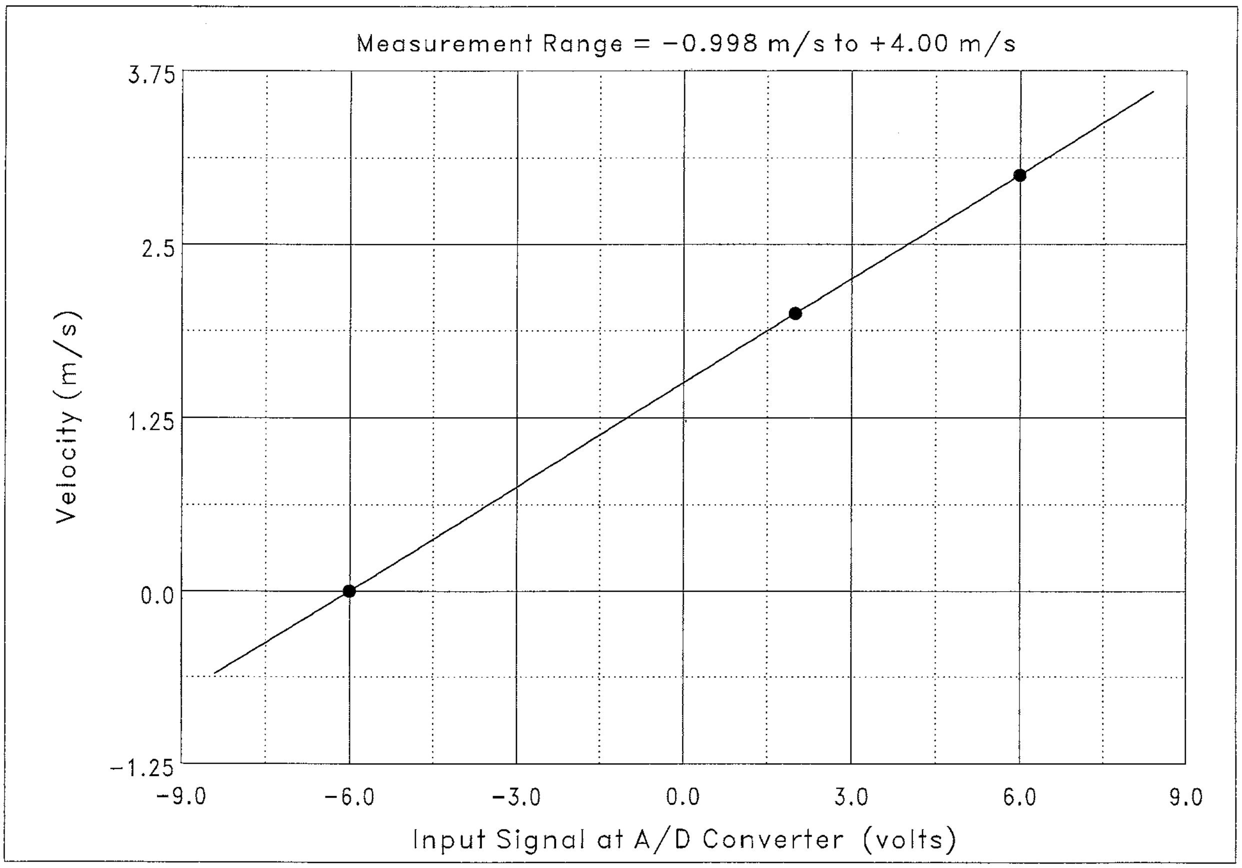
$$Y = C_0 + C_1 \cdot V$$

where $Y(t)$ = Velocity (m/s),

$V(t)$ = input signal at A/D converter (volts),

C_0 = 1.50160 m/s,

and C_1 = 0.250008 (m/s)/volt.



Calibration of ICEDAS Channel 34 14:24 22 November 2004

Project: Conical Structures in Ice **Facility:** Ice Tank

Sensor: Carriage position **Model:** ITC Carriage D/A output (CnE) **Serial Number:** N/A

Programmable Gain: 1 **Plug-In Gain:** 1 **Filter Frequency:** 10.0 Hz

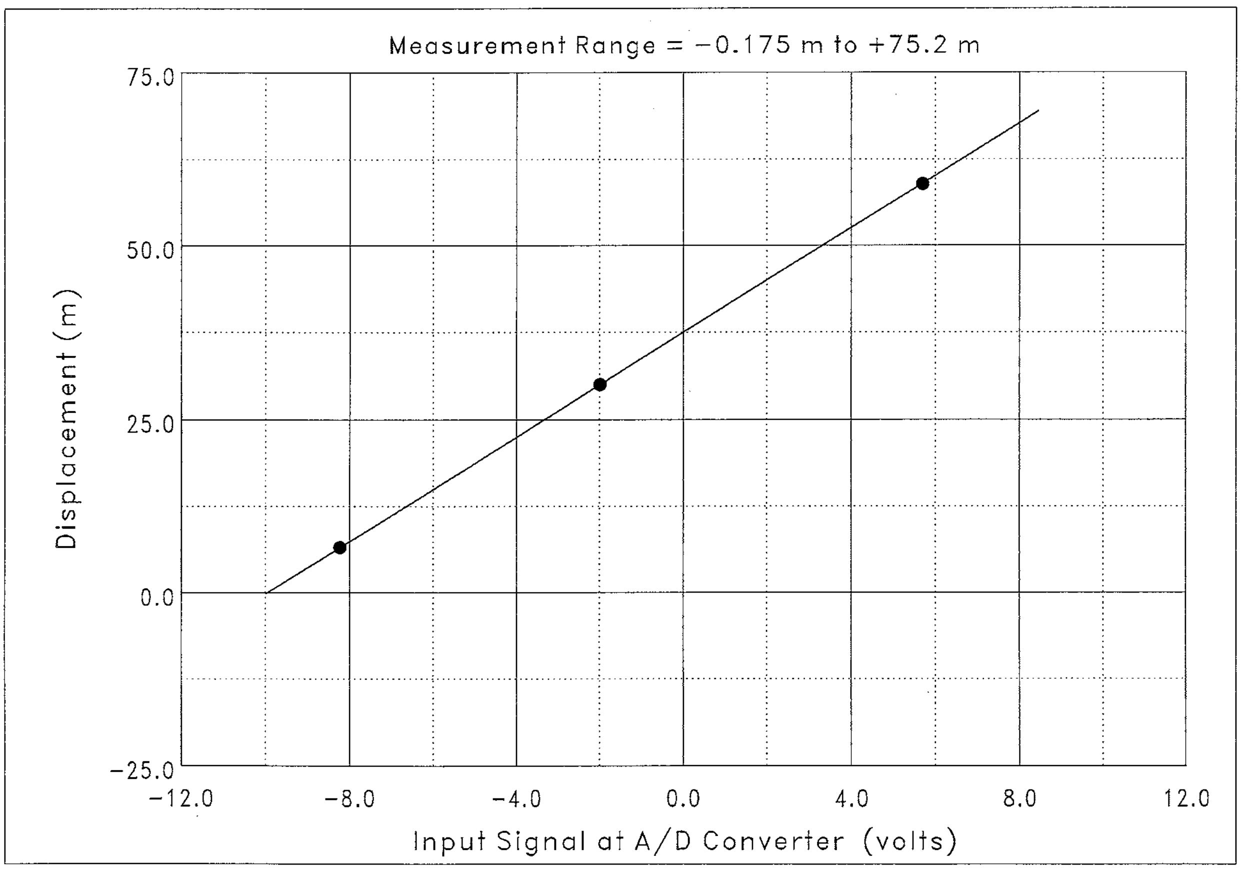
Data Point No.	Input Signal (volts)	Physical Value (m)	Fitted Curve Value (m)	Error (m)	
1	−8.231	6.500	6.493	−0.006948	
2	5.687	58.961	58.955	−0.005657	
3	−1.985	30.024	30.037	0.012602	⇐ Maximum Error
Maximum Error = 0.0240 % of Calibration Range.					

Definition of Calibration Curve

Polynomial Degree = 1 (Linear Fit)

$$Y = C_0 + C_1 \cdot V$$

where $Y(t)$ = Displacement (m),
$V(t)$ = input signal at A/D converter (volts),
C_0 = 37.5198 m,
and C_1 = 3.76952 m/volt .



Calibration of ICEDAS Channel 36 08:04 01 September 2005

Project: Conical Structures in Ice **Facility:** Ice Tank

Sensor: CARRIAGE SPEED (F/V) **Model:** ONO SOKI128 AND F/V801 **Serial Number:** N/A

Programmable Gain: 1 **Filter Frequency:** 10.0 Hz

Data Point No.	Input Signal (volts)	Physical Value (m/s)	Fitted Curve Value (m/s)	Error (m/s)	
1	4.982	0.050000	0.050024	0.000023663	⇐ Maximum Error
2	8.974	0.090000	0.089987	−0.000013113	
3	0.984	0.010000	0.010001	0.000000769	
4	0.083	0.001000	0.000989	−0.000011079	
5	−0.005	0.000100	0.000100	−0.000000234	
Maximum Error = 0.0263 % of Calibration Range.					

Definition of Calibration Curve

Polynomial Degree = 1 (Linear Fit)

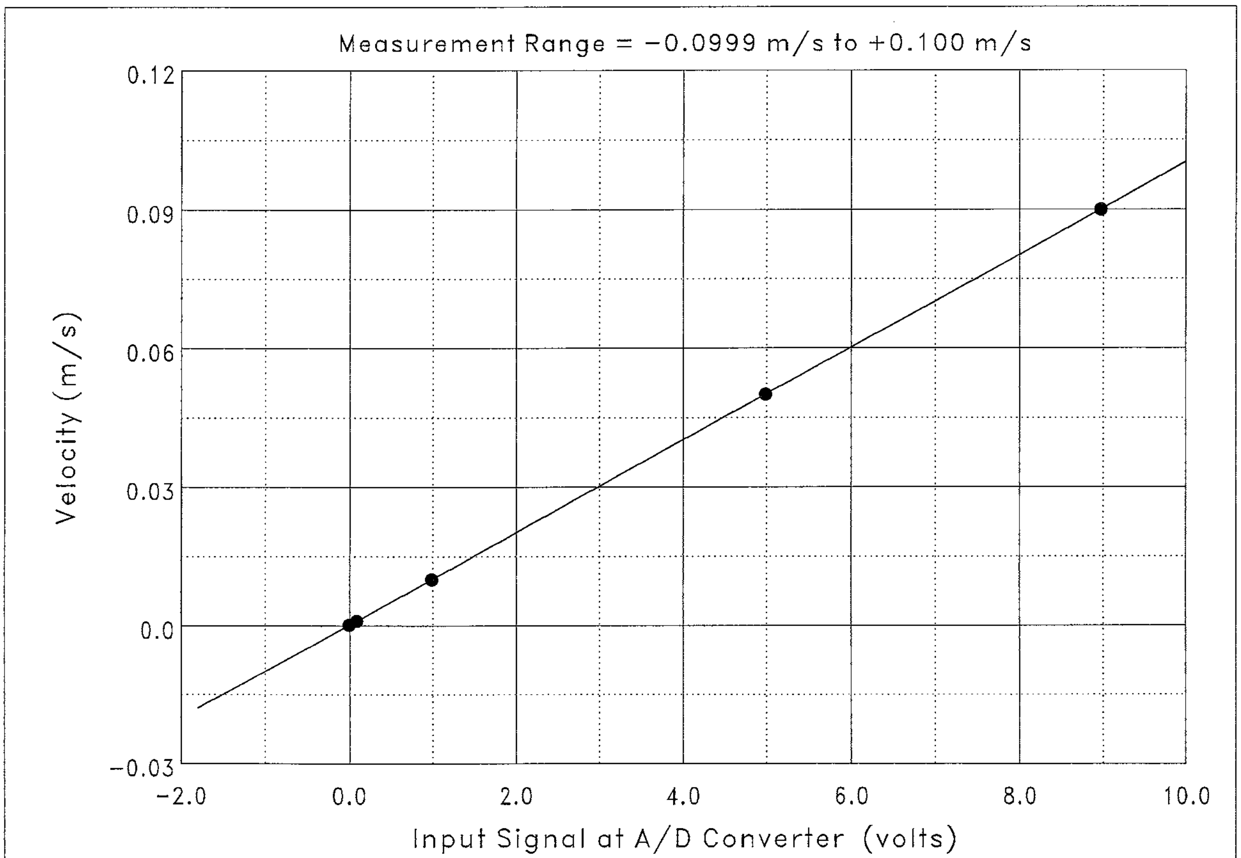
$$Y = C_0 + C_1 \cdot V$$

where $Y(t)$ = Velocity (m/s),

$V(t)$ = input signal at A/D converter (volts),

C_0 = 0.000153961 m/s,

and C_1 = 0.0100103 (m/s)/volt.



Calibration of ICEDAS Channel 18 09:53 06 September 2005

Project: Conical Structures in Ice **Facility:** Ice Tank

Sensor: ROLL **Model:** QUALYSIS **Serial Number:** N/A

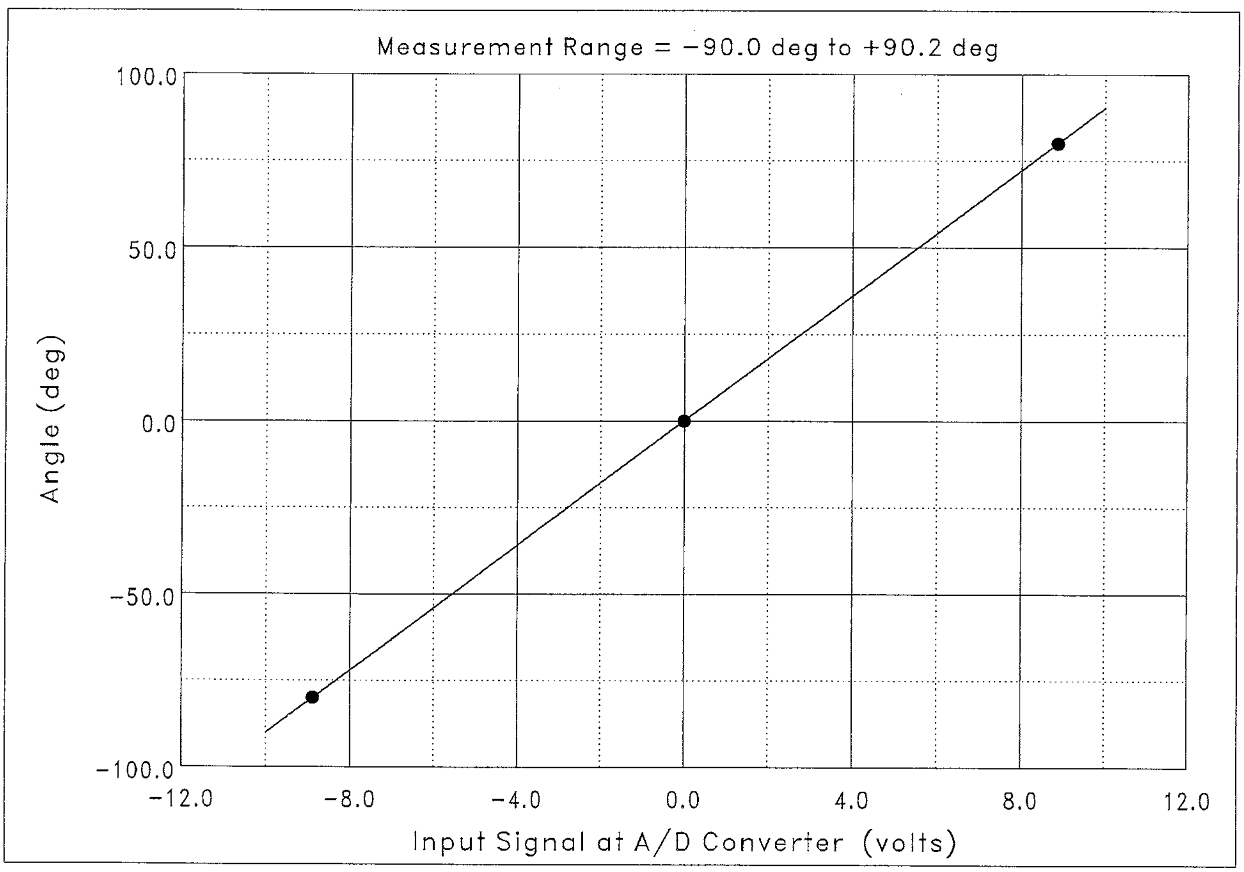
Programmable Gain: 1 **Plug-In Gain:** 1 **Filter Frequency:** 10.0 Hz

Data Point No.	Input Signal (volts)	Physical Value (deg)	Fitted Curve Value (deg)	Error (deg)	
1	−8.889	−80.000	−79.999	0.0009232	
2	−0.013	0.000	−0.002	−0.0018381	⇐ Maximum Error
3	8.864	80.000	80.001	0.0009232	
Maximum Error = −0.00115 % of Calibration Range.					

Definition of Calibration Curve
Polynomial Degree = 1 (Linear Fit)

$$Y = C_0 + C_1 \cdot V$$

where $Y(t)$ = Angle (deg),
$V(t)$ = input signal at A/D converter (volts),
C_0 = 0.112318 deg,
and C_1 = 9.01248 deg/volt.



Appendix C
Ice Properties

This appendix contains:

- Ice properties information
- Ice Properties for each ice sheet

Ice Property Information

i. Ice thickness

Ice thickness is measured at the beginning of the testing of each individual ice sheet. The thicknesses normally are taken at the 20, 40, and 60 meter marks, at both the north and south quarter points. Immediately after the first run though the level ice the thickness is again recorded at every 2 meters through the channel that was created by the model. The thickness is taken at both sides of the channel north/south.

ii. Cantilever Beam

The purpose of the cantilever beam property is to find the flexural strength of the ice through the linear elastic beam theory, which is:

$$\sigma_f = \frac{6PL}{WH_f^2}$$

where:

- σ_f = the flexural strength
- P = the force to break the beam
- L = the length of the beam
- W = width
- H_f = thickness

The procedure for carrying out the cantilever beam is to cut five beams in the ice, one side still attached to the ice sheet. The size of the beam should have a thickness, width, and length ratio of 1:2:5. Four of the beams are to be broken downward, and one beam is to be broken upwards using a hand held spring gauge (this is for the downward breaking model, for an upward breaking model it is four broken upwards and one broken downwards). The mean flexural strength is calculated for the four points; this value is the flexural strength at the position where the cantilever beam was taken.

iii. Young's Modulus

The procedure for calculating Young's modulus of the ice sheet is outlined by the ITTC Ice Committee (Kato et al. 1998). The equations that are used to calculate young's modulus are:

$$E = \frac{12(1 - v^2)kl_c^4}{h^3}$$

where

$$l_c^2 = \left(\frac{\Delta P}{\Delta W}\right)\frac{1}{8k}Z$$

where

$$Z = 1 + \frac{\alpha^2}{2\pi}\left(\ln\frac{\gamma\alpha}{2} - \frac{5}{4}\right)$$

where

- $\alpha = r/lc$
- $\ln \gamma = 0.5772$ (Euler's constant)
- k = Specific weight of water
- $Z \approx 1$ for values of $\alpha < 0.2$
- lc = Characteristic length
- E = Modulus of elasticity
- r = Radius of the circular loading plate
- ΔP = Increments of load
- Δw = the deflection
- h = Thickness
- v = Poisson's ratio (assumed to be 0.3)

iv. Ice Density

As an ice sheet is tempered, the ethylene glycol causes the ice to melt internally, which changes the density. The density must be recorded throughout the testing period and recorded. The density is determined by taking a beaker partially filled with EGADS fluid. A sample of the ice is placed in the beaker; the ice will float on top of the water. The breaker is then placed on a weigh scale this weight is recorded. Pushing on the ice with a special device to submerge it while give a new weight, this is recorded. The difference between the two weights multiplied by the gravitational constant (9.81 m/s^2) will give the submerging force. This force is recorded, and the volume of the sample is recorded. The density is then calculated by:

$$\rho_i = \rho_w - \frac{F}{V}$$

where

- ρ_i = the density of the ice sample
- ρ_w = the density of the EGADS fluid
- F = submerging force
- V = the volume of the ice sample

v. Shear Strength

When performing a shear strength test, an ice sample of dimensions 200 millimetres by 300 millimetres is removed form the ice sheet. The sample then has a puck with a radius of 17.5 millimetres punched through it, using a compression machine recording the load required to punch out the puck. The shear strength is then calculated by:

$$\sigma_s = \frac{P}{0.11h}$$

where

- σ_s = shear strength
- P = the load to punch out the puck
- h = ice thickness

vi. Ice Friction

The reason behind this friction test is to determine the coefficient of friction between the surfaces of the model against the top surface of the ice. The frictions are measured by taking an ice sample and holding it in place with a load cell, while the section of the model's surface is moved underneath it, at a constant speed. All the information is received by using a machine called a "Friction Jig." For information on this piece of equipment see Bell and Newbury (1991).

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ARCTIC VESSEL RESEARCH SECTION

ICE MECHANICAL PROPERTIES SUMMARY

Test Name: KULLUK8   Project Number: 2019

Warm up commenced: 23:16 25-AUG-2005

```
    Time  Warm-up  Loc   hi    Sf    Lc    E   E/Sf Lc/hi  K1c Sf/K1c Sc/s Rhoi
           hrs           mm    kPa   cm   MPa              N/m  m-.5  kPa Mg/m3

    0850    9.55^M                         N  32.3_ 1.3 n= 3^M                            +^M
^M                      S  30.3_ 0.8 n= 3^M                                +^M

    0900    9.72^M                       40S  31.4        30.  28.4 1187   9.6^M

    0930   10.22^M                       40N  32.3    34._ 3.7^M                                 +^M
^M                         32.3   16.(u/d 45%)^M

    0934   10.29^M                       40S  32.1    22._ 2.4^M                                 +^M
^M                         32.0   20.(u/d 89%)^M

    1104   11.79^M                       35N  31.1                                              .863^M

    1120   12.05^M                         N  31.2_ 0.8 n=17^M                            +^M
^M                      S  30.7_ 0.8 n=17^M                                +^M

    1201   12.74^M                       39N  32.5    15._ 1.2^M                                 +^M
^M                         32.4   10.(u/d 69%)^M

    1203   12.77^M                       39S  32.4    18._ 2.1^M                                 +^M
^M                         32.4    9.(u/d 51%)^M

    1207   12.84^M                       39S  32.8                                   s   25.6_ 2.6^M

    1211   12.90^M                       39N  32.7                                   s   25.3_ 3.8^M

    1219   13.04^M                       39N  32.2                                   c   58.7_ 9.1^M

    1228   13.19^M                       39S  32.9                                   c   65.3_ 4.7^M

    1237   13.34^M                       36S  31.8                                          .876^M

    1247   13.50^M                         N  29.4_ 0.9 n=17^M                            +^M
^M                      S  29.4_ 0.9 n=17^M                                +^M

    1340   14.39^M                       64N  31.4                                          .865^M

    1348   14.52^M                         N  31.8_ 0.4 n=14^M                            +^M
^M                      S  31.9_ 0.6 n=14^M                                +^M

    1350   14.55^M                       38N  30.5    10._ 2.2^M                                 +^M
^M                         32.3    5.(u/d 48%)^M

    1355   14.64^M                       38S  33.3    11._ 1.0^M                                 +^M
^M                         33.0    4.(u/d 37%)^M
```

Run #	Date	Time	Hours from Warm-up	Flexural Strength north	south	mean
1	08/26/2005	1030	11.22	25.8	19.2	22.5
2	08/26/2005	1300	13.72	13.1	13.0	13.0

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ARCTIC VESSEL RESEARCH SECTION

ICE MECHANICAL PROPERTIES SUMMARY

Test Name: KULLUK9 Project Number: 2019

Warm up commenced: 09:07 29-AUG-2005

```
    Time  Warm-up  Loc   hi    Sf    Lc    E   E/Sf Lc/hi  K1c Sf/K1c Sc/s Rhoi
           hrs           mm    kPa   cm   MPa              N/m  m-.5  kPa Mg/m3

    1322   4.24^M                          N  11.4_ 0.4 n= 3^M                              +^M
^M                      S  10.6_ 0.4 n= 3^M                              +^M

    1335   4.45^M                        40S  11.6   12._ 2.0^M                                     +^M
^M                         11.0    9.(u/d 72%)^M

    1337   4.49^M                        40N  11.2   13._ 2.9^M                                     +^M
^M                         11.3    7.(u/d 55%)^M

    1451   5.72^M                        39S  11.5   14._ 2.5^M                                     +^M
^M                         11.4    7.(u/d 46%)^M

    1456   5.80^M                        39N  11.5   15._ 4.1^M                                     +^M
^M                         11.6   10.(u/d 65%)^M

    1508   6.00^M                        32S  11.2                                               .874^M

    1514   6.10^M                          N  11.2_ 0.3 n=15^M                              +^M
^M                      S  11.3_ 0.9 n=15^M                              +^M

    1633   7.42^M                        43N  11.2   14._ 1.7^M                                     +^M
^M                         11.2    7.(u/d 52%)^M

    1637   7.49^M                        43S  12.1   13._ 1.2^M                                     +^M
^M                         12.0   10.(u/d 75%)^M
```

Run #	Date	Time	Hours from Warm-up	Flexural Strength north	Flexural Strength south	Flexural Strength mean
1	08/29/2005	1430	5.37	15.0	13.9	14.4
2	08/29/2005	1700	7.87	14.1	12.8	13.5

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ARCTIC VESSEL RESEARCH SECTION

ICE MECHANICAL PROPERTIES SUMMARY

Test Name: KULLUK10   Project Number: 2019

Warm up commenced: 03:07 30-AUG-2005

```
    Time  Warm-up  Loc   hi    Sf    Lc    E   E/Sf Lc/hi  K1c Sf/K1c Sc/s Rhoi
           hrs           mm    kPa   cm   MPa              N/m  m-.5  kPa Mg/m3

    0842    5.59^M                            N  22.6_ 1.3 n= 3^M                          +^M
^M                       S  20.9_ 0.5 n= 3^M                             +^M

    0858    5.85^M                      40S  22.8       23.  23.9 2585  10.0^M

    0924    6.28^M                      40S  23.1    9._ 1.9^M                                    +^M
^M                          22.8    5.(u/d 49%)^M

    0926    6.31^M                      40N  23.4   12._ 1.2^M                                    +^M
^M                          23.3    6.(u/d 47%)^M

    1100    7.88^M                      38N  23.8   12._ 1.2^M                                    +^M
^M                          24.1    4.(u/d 32%)^M

    1103    7.93^M                      38S  23.8   11._ 1.5^M                                    +^M
^M                          23.6    5.(u/d 50%)^M

    1134    8.45^M                      33S  22.6                                               .914^M
^M                     60N  22.9                                        .876^M

    1136    8.48^M                            N  22.5_ 0.5 n=16^M                          +^M
^M                       S  22.6_ 0.4 n=16^M                             +^M

    1205    8.96^M                      45S  22.7                                      s   26.1_ 2.4^M

    1210    9.05^M                      45N  22.6                                      s   25.8_ 1.3^M

    1236    9.48^M                      45N  22.1                                      c   25.8_ 2.9^M

    1243    9.60^M                      34N  22.8                                               .873^M

    1249    9.70^M                      45S  22.5                                      c   40.3_ 4.7^M

    1252    9.75^M                      37N  23.4    9._ 0.6^M                                    +^M
^M                          23.7    4.(u/d 51%)^M

    1300    9.88^M                      37S  23.1    9._ 1.4^M                                    +^M
^M                          23.3    3.(u/d 39%)^M

    1349   10.70^M                            N  22.8_ 0.5 n=17^M                          +^M
^M                       S  23.5_ 0.5 n=17^M                             +^M
```

Run #	Date	Time	Hours from Warm-up	Flexural Strength north	south	mean
1	08/30/2005	1100	7.88	12.0	10.6	11.3
2	08/30/2005	1300	9.88	8.4	8.7	8.6

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ARCTIC VESSEL RESEARCH SECTION

ICE MECHANICAL PROPERTIES SUMMARY

Test Name: KULLUK11 Project Number: 2019

Warm up commenced: 19:58 31-AUG-2005

```
    Time  Warm-up  Loc   hi    Sf    Lc    E   E/Sf Lc/hi  K1c Sf/K1c Sc/s Rhoi
           hrs           mm    kPa   cm   MPa               N/m  m-.5  kPa Mg/m3

    0827   12.48^M                          N  45.3_ 1.7 n= 3^M                        +^M
^M                    S  42.2_ 0.5 n= 3^M                        +^M

    0843   12.75^M                        40S  44.3        44.  47.0 1910  10.0^M

    0909   13.18^M                        39S  45.0   23._ 1.2^M                              +^M
^M                       44.7   19.(u/d 81%)^M

    0917   13.31^M                        39N  45.3   25._ 2.0^M                              +^M
^M                       44.6   17.(u/d 69%)^M

    1052   14.90^M                          N  43.8_ 1.4 n=15^M                        +^M
^M                    S  43.3_ 1.1 n=15^M                        +^M

    1128   15.50^M                        39S  45.2                                s   39.7_ 1.2^M

    1136   15.63^M                        39N  45.5                                s   29.0_ 4.6^M

    1145   15.78^M                        38S  46.2   16._ 0.5^M                              +^M
^M                       45.2   12.(u/d 73%)^M

    1148   15.83^M                        38N  44.8   19._ 0.9^M                              +^M
^M                       44.5   13.(u/d 67%)^M

    1200   16.03^M                          N  41.6_ 1.5 n=15^M                        +^M
^M                    S  41.6_ 1.5 n=15^M                        +^M

    1205   16.11^M                        38S  45.1                                c  102.9_16.8^M

    1218   16.33^M                        38N  45.0                                c   73.4_15.5^M

    1321   17.38^M                          N  45.1_ 1.1 n=14^M                        +^M
^M                    S  44.7_ 1.3 n=14^M                        +^M
```

Run #	Date	Time	Hours from Warm-up	Flexural Strength north	south	mean
1	09/01/2005	1000	14.03	23.0	20.6	21.8
2	09/01/2005	1230	16.53	17.1	14.5	15.8

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ARCTIC VESSEL RESEARCH SECTION

ICE MECHANICAL PROPERTIES SUMMARY

Test Name: KULLUK12   Project Number: 2019

Warm up commenced: 03:04   2-SEP-2005

```
    Time  Warm-up  Loc   hi    Sf    Lc    E   E/Sf Lc/hi  K1c Sf/K1c Sc/s Rhoi
           hrs           mm    kPa   cm   MPa              N/m  m-.5  kPa Mg/m3

    0828    5.40^M                          N  22.9_ 1.0 n= 3^M                          +^M
^M                    S  21.6_ 0.4 n= 3^M                          +^M

    0838    5.56^M                  40S  22.3        25.  37.4 2476  11.2^M

    0854    5.83^M                  40S  22.8   15._ 2.2^M                                      +^M
^M                       27.8    4.(u/d 29%)^M

    0855    5.85^M                  40N  23.5   28._ 2.8^M                                      +^M
^M                       23.5   10.(u/d 35%)^M

    0920    6.26^M                  40S  23.8                                        s   40.5_ 5.8^M

    0925    6.35^M                  40N  23.8                                        s   65.4_15.3^M

    0932    6.46^M                  40N  23.3                                        c  101.5_ 8.2^M

    0935    6.51^M                  40S  22.9                                        c   82.2_11.2^M

    1008    7.06^M                  31N  22.8                                            .853^M

    1012    7.13^M                          N  22.7_ 0.6 n=15^M                          +^M
^M                    S  23.0_ 0.3 n=15^M                          +^M

    1036    7.53^M                  39N  23.9   24._ 5.3^M                                      +^M
^M                       23.8    6.(u/d 24%)^M
^M                  39N  23.9   24._ 5.3^M                                 +^M
^M                       23.8    6.(u/d 24%)^M

    1045    7.68^M                  39S  23.8   16._ 4.4^M                                      +^M
^M                       23.7    7.(u/d 41%)^M
^M                  39S  23.8   16._ 4.4^M                                 +^M
^M                       23.7    7.(u/d 41%)^M

    1104    8.00^M                  31S  22.7                                            .853^M

    1127    8.38^M                          N  22.2_ 0.3 n=15^M                          +^M
^M                    S  22.2_ 0.3 n=15^M                          +^M

    1153    8.81^M                  42S  23.4   16._ 4.8^M                                      +^M
^M                       23.8    7.(u/d 45%)^M
^M                  42S  23.4   13._ 1.3^M                                 +^M
^M                       23.8    7.(u/d 54%)^M

    1158    8.90^M                  42N  24.3   20._ 3.0^M                                      +^M
^M                       25.0    7.(u/d 35%)^M
^M                  42N  24.3   20._ 3.0^M                                 +^M
^M                       25.0    7.(u/d 35%)^M

    1232    9.46^M                  63S  23.1                                            .865^M

    1236    9.53^M                          N  23.6_ 0.5 n=16^M                          +^M
^M                    S  23.4_ 0.6 n=16^M                          +^M
```

Run #	Date	Time	Hours from Warm-up	Flexural Strength north	south	mean
1	09/02/2005	0930	6.43	26.3	14.9	20.6
2	09/02/2005	1200	8.93	19.7	15.8	17.8

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ARCTIC VESSEL RESEARCH SECTION

ICE MECHANICAL PROPERTIES SUMMARY

Test Name: KULLUK13 Project Number: 2019

Warm up commenced: 23:16 6-SEP-2005

```
    Time  Warm-up  Loc    hi    Sf    Lc    E   E/Sf Lc/hi  K1c Sf/K1c Sc/s Rhoi
           hrs            mm    kPa   cm   MPa              N/m  m-.5  kPa Mg/m3

    0826    9.15^M                     N  31.1_ 1.3 n= 3^M                          +^M
^M                      S  29.7_ 0.4 n= 3^M                    +^M

    0838    9.35^M                   40S  30.1      30.  31.1 2035  10.0^M

    0858    9.69^M                   40S  31.3   15._ 0.5^M                                +^M
^M                         31.0    5.(u/d 32%)^M

    0903    9.77^M                   40N  30.6   19._ 2.6^M                                +^M
^M                         30.4    9.(u/d 47%)^M

    1006   10.82^M                   31S  29.8                                          .842^M

    1010   10.89^M                     N  30.4_ 0.6 n=16^M                          +^M
^M                      S  30.9_ 0.9 n=16^M                    +^M

    1039   11.37^M                   38N  30.7   18._ 1.6^M                                +^M
^M                         30.3    6.(u/d 32%)^M

    1041   11.40^M                   38S  31.3   13._ 4.5^M                                +^M
^M                         31.3    5.(u/d 36%)^M

    1058   11.69^M                   39S  31.4                                 s   23.9_ 4.5^M

    1103   11.77^M                   39N  30.7                                 s   26.9_ 4.8^M

    1114   11.95^M                     N  29.9_ 0.3 n=15^M                          +^M
^M                      S  29.9_ 0.3 n=15^M                    +^M

    1129   12.20^M                   39N  31.4                                 c   57.4_11.0^M

    1134   12.29^M                   39S  30.8                                 c   69.6_12.1^M

    1200   12.72^M                     N  30.4_ 0.4 n=15^M                          +^M
^M                      S  30.6_ 0.5 n=15^M                    +^M

    1227   13.17^M                   61S  30.9                                          .865^M
```

Run #	Date	Time	Hours from Warm-up	Flexural Strength north	south	mean
1	09/07/2005	0930	10.22	18.5	14.2	16.4
1130	09/07/2005	1130	12.22	18.2	11.9	15.0

NRC - INSTITUTE FOR MARINE DYNAMICS

ARCTIC VESSEL RESEARCH SECTION

ICE MECHANICAL PROPERTIES SUMMARY

Test Name: KULLUK14   Project Number: 2019

Warm up commenced: 20:13   8-SEP-2005

```
    Time  Warm-up  Loc    hi    Sf    Lc    E   E/Sf Lc/hi  K1c Sf/K1c Sc/s Rhoi
           hrs            mm    kPa   cm   MPa              N/m  m-.5  kPa Mg/m3

    0818   12.07^M                          N  41.5_ 1.5 n= 3^M                          +^M
^M                     S  40.6_ 0.5 n= 3^M                          +^M

    0834   12.34^M                        40S  41.9        47.  70.0 2750  11.2^M

    0908   12.90^M                        40N  42.3   33._ 1.6^M                                +^M
^M                        42.5   18.(u/d 54%)^M

    0910   12.94^M                        40S  41.9   25._ 2.5^M                                +^M
^M                        41.5   16.(u/d 64%)^M

    0947   13.55^M                        40N  42.4                              s   49.2_ 5.0^M

    0952   13.64^M                        40S  42.1                              s   27.8_ 2.4^M

    1000   13.77^M                        40N  42.1                              c  101.5_14.0^M

    1007   13.89^M                        40S  42.0                              c   86.3_ 7.1^M

    1037   14.39^M                        31S  41.4                                    .846^M

    1045   14.52^M                        39N  42.0   28._ 4.1^M                                +^M
^M                        42.0   20.(u/d 70%)^M

    1050   14.60^M                          N  41.1_ 0.9 n=15^M                          +^M
^M                     S  41.3_ 0.9 n=15^M                          +^M

    1051   14.62^M                        38N  43.6   20._ 2.4^M                                +^M
^M                        41.7   16.(u/d 81%)^M

    1137   15.39^M                        41S  41.6   24._ 1.0^M                                +^M
^M                        41.7   15.(u/d 61%)^M

    1139   15.42^M                        41N  42.4   30._ 3.4^M                                +^M
^M                        42.5   17.(u/d 55%)^M

    1227   16.22^M                        60S  42.0                                    .859^M

    1234   16.34^M                          N  41.3_ 0.6 n=16^M                          +^M
^M                     S  41.4_ 0.7 n=16^M                          +^M
```

Run #	Date	Time	Hours from Warm-up	Flexural Strength north	south	mean
1	09/09/2005	1000	13.77	29.7	24.8	27.2
2	09/09/2005	1200	15.77	28.7	24.0	26.3

NRC - INSTITUTE FOR MARINE DYNAMICS

ARCTIC VESSEL RESEARCH SECTION

ICE MECHANICAL PROPERTIES SUMMARY

Test Name: KULLUK15 Project Number: 2019

Warm up commenced: 23:21 12-SEP-2005

```
    Time  Warm-up  Loc    hi     Sf    Lc    E   E/Sf Lc/hi  K1c Sf/K1c Sc/s Rhoi
           hrs            mm    kPa   cm   MPa               N/m  m-.5  kPa Mg/m3

    0827    9.10^M                           N  31.3_ 1.5 n= 3^M                                +^M
^M                      S  29.8_ 0.4 n= 3^M                                  +^M

    0838    9.28^M                         40S  30.7       34.  49.6 3457  11.1^M

    0902    9.68^M                         40S  30.8   15._ 0.8^M                                      +^M
^M                         30.9    4.(u/d 28%)^M

    0906    9.75^M                         40N  30.4   17._ 4.0^M                                      +^M
^M                         30.5    7.(u/d 43%)^M

    0927   10.10^M                         40S  31.0                                       s   42.9_10.6^M

    0932   10.18^M                         40N  30.6                                       s   29.5_ 6.8^M

    0957   10.60^M                         40N  30.5                                       c   51.9_ 3.3^M

    1006   10.75^M                         40S  31.3                                       c   45.9_ 2.5^M

    1017   10.93^M                         42N  30.6   19._ 2.3^M                                      +^M
^M                         30.3    5.(u/d 25%)^M

    1019   10.97^M                         42S  30.8   16._ 2.5^M                                      +^M
^M                         30.3    5.(u/d 34%)^M

    1025   11.07^M                         31S  30.1                                              .845^M

    1028   11.12^M                           N  30.7_ 0.5 n=15^M                                +^M
^M                      S  30.9_ 0.7 n=15^M                                  +^M

    1200   12.65^M                         60S  30.1                                              .860^M

    1205   12.73^M                           N  30.3_ 0.5 n=16^M                                +^M
^M                      S  31.0_ 0.9 n=16^M                                  +^M
```

Run #	Date	Time	Hours from Warm-up	Flexural Strength north	Flexural Strength south	Flexural Strength mean
1	09/13/2005	0930	10.15	17.5	15.0	16.2
2	09/13/2005	1130	12.15	22.0	16.7	19.3

NRC - INSTITUTE FOR MARINE DYNAMICS

ARCTIC VESSEL RESEARCH SECTION

ICE MECHANICAL PROPERTIES SUMMARY

Test Name: KULLUK16 Project Number: 2019

Warm up commenced: 03:05 14-SEP-2005

```
    Time  Warm-up  Loc   hi    Sf    Lc    E   E/Sf Lc/hi  K1c Sf/K1c Sc/s Rhoi
           hrs           mm    kPa   cm   MPa              N/m  m-.5  kPa Mg/m3

    0828    5.37^M                         N  22.0_ 0.8 n= 3^M                          +^M
^M                    S  21.7_ 0.3 n= 3^M                           +^M

    0840    5.57^M                       40S  21.7       24.  36.1 2800  11.2^M

    0912    6.10^M                       40S  22.5   13._ 0.5^M                                 +^M
^M                       22.5    6.(u/d 49%)^M

    0916    6.17^M                       40N  23.6   13._ 1.4^M                                 +^M
^M                       23.9    4.(u/d 29%)^M

    0939    6.55^M                       40S  22.8                                    s   25.7_ 3.7^M

    0942    6.60^M                       40N  23.4                                    c   56.1_ 6.6^M
^M                   40N  22.9                                 s   28.4_ 3.8^M

    1015    7.15^M                       40S  22.2                                    c   42.2_ 5.9^M

    1025    7.32^M                       33S  21.7                                            .853^M

    1030    7.40^M                         N  22.3_ 0.3 n=15^M                          +^M
^M                    S  22.6_ 0.3 n=15^M                           +^M

    1052    7.77^M                       39N  23.1   10._ 1.5^M                                 +^M
^M                       23.8    6.(u/d 62%)^M

    1055    7.82^M                       39S  22.8   12._ 0.9^M                                 +^M
^M                       22.9    5.(u/d 42%)^M

    1120    8.23^M                         N  22.4_ 0.3 n=15^M                          +^M
^M                    S  22.9_ 0.3 n=15^M                           +^M

    1153    8.78^M                       60S  22.4                                            .845^M

    1320   10.23^M                         N  23.1_ 0.6 n=14^M                          +^M
^M                    S  22.7_ 0.9 n=14^M                           +^M
```

Run #	Date	Time	Hours from Warm-up	Flexural Strength north	south	mean
1	09/14/2005	0930	6.40	12.5	12.5	12.5
2	09/14/2005	1100	7.90	9.7	11.7	10.7

NRC - INSTITUTE FOR MARINE DYNAMICS

ARCTIC VESSEL RESEARCH SECTION

ICE MECHANICAL PROPERTIES SUMMARY

Test Name: KULLUK17 Project Number: 2019

Warm up commenced: 20:13 15-SEP-2005

```
    Time  Warm-up  Loc    hi     Sf     Lc     E    E/Sf Lc/hi  K1c Sf/K1c Sc/s Rhoi
            hrs           mm    kPa    cm    MPa              N/m  m-.5  kPa Mg/m3

    0817   12.06^M                        N  43.7_ 2.0 n= 3^M                          +^M
^M                   S  41.9_ 0.5 n= 3^M                          +^M

    0913   13.00^M                      40N  45.5   28._ 1.8^M                              +^M
^M                      45.0   23.(u/d 82%)^M

    0921   13.13^M                      40S  44.9   25._ 1.9^M                              +^M
^M                      44.7   20.(u/d 80%)^M

    0943   13.50^M                      40S  44.7        46.  51.6 2202  10.2^M

    0947   13.56^M                      40N  45.3                                    s   51.5_ 4.5^M

    0955   13.70^M                      40S  45.5                                    s   35.7_ 3.9^M

    1002   13.81^M                      40N  45.1                                    c  123.9_12.2^M

    1009   13.93^M                      40S  44.7                                    c  103.5_ 8.4^M

    1047   14.56^M                      31S  42.7                                          .861^M

    1050   14.61^M                        N  42.8_ 0.7 n=15^M                          +^M
^M                   S  43.2_ 1.4 n=15^M                          +^M

    1113   15.00^M                      38S  47.1   18._ 3.9^M                              +^M
^M                      43.9   12.(u/d 66%)^M

    1115   15.03^M                      38N  45.4   19._ 1.6^M                              +^M
^M                      46.1    9.(u/d 48%)^M

    1222   16.15^M                      61S  43.1                                          .868^M

    1224   16.18^M                        N  43.2_ 1.0 n=16^M                          +^M
^M                   S  43.9_ 1.1 n=16^M                          +^M
```

Run #	Date	Time	Hours from Warm-up	Flexural Strength north	south	mean
1	09/16/2005	1000	13.78	24.0	22.4	23.2
2	09/16/2005	1200	15.78	15.8	16.2	16.0

Appendix D
Naming Convention and Test Log

This appendix contains:

- The naming convention
- The test log

The naming convention:

Level ice runs would be LI40_K3_S20_VH:

- LI40 corresponds to level ice 40 millimetres thick
- K3 means spring constant 3 (14 lbf/in)
- S20 is Strength 20 Mpa
- VH stands for Velocity High (i.e. 0.025 m/s – 0.3 m/s)

Pre-sawn runs would be PS40_K2_VM:

- PS40 corresponds to pre-sawn ice 40 millimetres thick
- K2 means spring constant 2 (6.8 lbf/in)
- VL stands for velocity low (i.e. 0.01 m/s – 0.005 m/s)

Pack ice runs would be PI40_CH_K3_VL:

- PI40 corresponds to packed ice 40 millimetres thick
- CH means concentration high (CM = concentration medium, CL = concentration low)
- K3 stands for spring constant 3 (14 lbf/in)
- VL means velocity low

Decay runs would be PS40_DECAY_K1_H_V0P01, PS40_DECAY_K1_H, or DECAY_K1_H:

- PS40 corresponds to pre-sawn ice 40 millimetres thick
- DECAY means it is a decay test
- K1 means spring constant 1 (3.5 lbf/in)
- H stands for a heave decay (R = roll, S = surge)
- V0P01 means velocity 0.01m/s (V0P2 = velocity 0.2 m/s)
- If the last part (V0P01) is left out it means a zero velocity decay

For Excursion test the naming would be EX_Y_K2:

- EX means excursion
- Y means Y direction (X = X direction)
- K2 stands for spring constant 2 (6.8 lbf/in)

ICE TANK | **R, P, OL, and Ice Carriage Log** | **Client:** | **Client: IOT**

Proj 42_2019_26 | **Project Name: Conical Structures in Ice** | **Sub-Client**

				Model Speed(m/s)					Open Wate		Ice Condition					Comments
Date	Data Acquisition Start Time or Time of Event	GDAC File Name	Video Start	v1	v2	v3	v4	V5	Open Water(Y/N)	Water Temp (ºC)	Quarter Point (CC or SQP)	Level Ice (thickness mm)	PRESAWN	SPRING	Pack Ice Conc.	
17-Dec-04	15:00:00								X		cc					
20-Dec-04	8:00:00								X		cc					
20-Dec-04	14:50:50	XPULL_001							X							
20-Dec-04	14:03:10	BOLLARD_002							X							
20-Dec-04	15:57:21	XPULL_003							X		cc					
20-Dec-04	16:30:00	BOLLARD_004														

24-Aug-05	13:38:59	TEST_DAC_001												K1		K1 = 14LBS SPRINGS
25-Aug-05	8:20:42	ZERO_RUN_002												K1		
25-Aug-05																
25-Aug-05	8:54:24	EX_K1_003							X					K1		0-350N @ 50N INC.
25-Aug-05		DECAY_K1_P_004												K1		REPEAT
25-Aug-05	9:16:26	DECAY_K1_P_005												K1		pushing down with stick from test frame
25-Aug-05	9:26:09	DECAY_K1_P_006												K1		
25-Aug-05	9:29:45	DECAY_K1_P_007												K1		
25-Aug-05		DECAY_K1_P_008												K1		
25-Aug-05																
25-Aug-05	9:36:53	DECAY_K1_R_009												K1		
25-Aug-05	9:39:56	DECAY_K1_R_010												K1		
25-Aug-05	9:42:17	DECAY_K1_R_011												K1		
25-Aug-05																
25-Aug-05	9:44:55	DECAY_K1_H_012												K1		
25-Aug-05	9:47:38	DECAY_K1_H_013												K1		
25-Aug-05	9:50:34	DECAY_K1_H_014												K1		
25-Aug-05														K1		
25-Aug-05	10:07:07	OW_K1_VL_015		0.010	0.025	0.050								K1		
25-Aug-05	10:15:21	OW_K1_VM_016		0.100	0.200									K1		
25-Aug-05	10:19:51	OW_K1_V0P3_017		0.300										K1		
25-Aug-05																
25-Aug-05	14:05:11	ZERO_RUN_018												K1		
25-Aug-05																
25-Aug-05	14:15:59	OW_K1_VL_019		0.010	0.025	0.050								K1		
25-Aug-05	14:20:40	OW_K1_VM_020		0.100	0.200									K1		
25-Aug-05	14:23:43	OW_K1_V0P3_021		0.300										K1		
25-Aug-05	16:59:20	Survey_022												K1		

ICE TANK | **R, P, OL, and Ice Carriage Log** | **Client:** | **Client: IOT**

Proj 42_2019_26 | **Project Name: Conical Structures in Ice** | **Sub-Client**

Date	Data Acquisition Start Time or Time of Event	GDAC File Name	Video Start	Model Speed(m/s) v1	v2	v3	v4	V5	Open Water(Y/N)	Water Temp (ºC)	Ice Condition Quarter Point (CC or SQP)	Level Ice (thickness mm)	PRESAWN	SPRING	Pack Ice Conc.	Comments
25-Aug-05	17:25:11	Survey_023												K1		
25-Aug-05	20:45:00	Qualysis re calibrated												K1		Qualysis re calibrated
25-Aug-05	21:24:39	Survey_024												K1		
25-Aug-05	21:39:51	Survey_025												K1		
25-Aug-05	22:21:00															working Me thinks…Gone Home
26-Aug-05		icesheet Kulluk8.1005										30				Hi=30mm Strength 20 kpa
26-Aug-05	7:41:43	zerorun_026												K1		before modulus
26-Aug-05																
26-Aug-05	9:14:19	QUAL_CHECK_027												K1		Qualysis is not working
26-Aug-05																
26-Aug-05	9:32:15	EX_K1_028												K1		0- PAN,5-35KG @ 5KG INC.
26-Aug-05			TAPE #1													
26-Aug-05	10:22:56	LI30_K1_S20_VH_029	0:00:00	0.025	0.050	0.100	0.200	0.300			CC	X		K1		
26-Aug-05	10:42:28	LI30_K1_S20_VI_030	6:19:00	0.010	0.005						CC	X		K1		
26-Aug-05																
26-Aug-05	12:00:11	ZERO_RUN_031														
26-Aug-05																
26-Aug-05	12:02:22	PS30_K1_VL_032	19:44:00	0.010	0.005						SQP		X	K1		
26-Aug-05	12:18:14	PS30_K1_VH_033	31:59:00	0.025	0.050	0.100	0.200	0.300			SQP		X	K1		
26-Aug-05																
26-Aug-05	13:04:35	LI30_K1_S12_VH_034	38:17:00	0.025	0.050	0.100	0.200	0.300			CC	X		K1		
26-Aug-05	13:16:41	LI30_K1_S12_VI_035	43:49:00	0.010	0.005						CC	X		K1		
26-Aug-05																
26-Aug-05	14:38:21	PI30_CM_K1_VH_036	49:54:00	0.025	0.050	0.100	0.200	0.300			NQP			K1	9/10	video ann. Needs update
26-Aug-05	14:47:22	PI30_CM_K1_VL_037	55:26:00	0.010	0.005						NQP			K1	9/10	
26-Aug-05																
26-Aug-05	15:02:54	PI30_CH_K1_VH_038	Tape #2 0:00	0.025	0.050	0.100	0.200	0.300			NQP			K1	10/10	
26-Aug-05	15:12:31	PI30_CH_K1_VI_039	7:41:00	0.010	0.005						NQP			K1	10/10	
26-Aug-05																
26-Aug-05	16:00:02	PI30_CH_K1_VH_040	20:49:00	0.025	0.050	0.100	0.200	0.300			SQP			K1	8/10	
26-Aug-05		PI30_CH_K1_VI_041		0.010	0.005						SQP			K1	8/10	
26-Aug-05																RECALIBRATE QUALYSIS WITH BLACK SHROUD
26-Aug-05																WORKING BETTER
KULLUK9 (10MM)																
29-Aug-05	13:44:17	ZERO_RUN_042														SYSTEM CHECK
			TAPE#3													
29-Aug-05	14:26:28	LI10_K1_S20_VH_043	0:00:00	0.025	0.050	0.100	0.200	0.300			CC	X		K1		
29-Aug-05	14:38:33	LI10_K1_S20_VL_044	6:23:00	0.010	0.005						CC	X		K1		
29-Aug-05	15:12:39	ZERO_RUN_045														

ICE TANK **R, P, OL, and Ice Carriage Log** **Client:** **Client: IOT**

Proj 42_2019_26 **Project Name: Conical Structures in Ice** **Sub-Client**

Date	Data Acquisition Start Time or Time of Event	GDAC File Name	Video Start	Model Speed(m/s) v1	v2	v3	v4	V5	Open Water(Y/N)	Water Temp (ºC)	Ice Condition Quarter Point (CC or SQP)	Level Ice (thickness mm)	PRESAWN	SPRING	Pack Ice Conc.	Comments
29-Aug-05	15:39:05	PS10_K1_VH_046	17:30:00	0.050	0.100	0.200	0.300				SQP		X	K1		ABORT. NEEDS STAPLES
29-Aug-05	15:58:56	PS10_K1_VH_047	18:11:00	0.050	0.100	0.200	0.300							K1		
29-Aug-05	16:14:18	PS10_K1_VH_048	23:26:00	0.010	0.005									K1		video ann. Needs update
29-Aug-05																
29-Aug-05	16:50:12	LI10_K1_S12_VH_049	33:19:00	0.050	0.100	0.200	0.300				CC	X		K1		
29-Aug-05	17:01:49	LI10_K1_S12_VH_050		0.010	0.005						CC	X		K1		video ann. Needs update
29-Aug-05																
29-Aug-05	17:34:33	OW_K1_VL_051	TAPE #4	0.010	0.025	0.050			X		CC			K1		
29-Aug-05	17:46:52	OW_K1_VM_052	6:12:00	0.100	0.200				X		CC			K1		
29-Aug-05	17:59:13	OW_K1_V0P3_053		0P3					X		CC			K1		
29-Aug-05																
KULLUK10 (20MM)																
30-Aug-05	10:44:17	zero_run_054														
30-Aug-05	10:55:17	LI20_K1_S20_VH_055	15:22:00	0.050	0.100	0.200	0.300				CC			K1		
30-Aug-05	11:08:57	LI20_K1_S20_VL_056	21:13:00	0.010	0.005						CC			K1		
30-Aug-05	11:58:28	ZERO_RUN_057														
30-Aug-05	12:03:09	PS20_K1_VH_058	27:59:00	0.050	0.100	0.200	0.300				SQP			K1		
30-Aug-05	12:11:03	PS20_K1_VL_059	33:31:00	0.010	0.005						SQP			K1		
30-Aug-05	13:08:36	LI20_K1_S12_VH_060		0.050	0.100	0.200	0.300				CC			K1		
30-Aug-05	13:18:19	LI20_K1_S12_VL_061		0.010	0.005											
30-Aug-05	14:18:38	ZERO_RUN_062														
			TAPE #5													
30-Aug-05	14:27:55	PI20_CM_K1_VH_063	0:00:00	0.050	0.100	0.200	0.300				NQP			K1	9/10	
30-Aug-05	14:38:06	PI20_CM_K1_VL_064		0.010	0.005										9/10	
30-Aug-05	14:50:21	PI20_CH_K1_VH_065	10:14:00	0.050	0.100	0.200	0.300				NQP			K1	10/10	
30-Aug-05	15:05:05	PI20_CH_K1_VL_066		0.010	0.005						NQP			K1	10/10	
30-Aug-05	15:35:21	PI20_CL_K1_VL_067	24:56:00	0.050	0.100	0.200	0.300				SQP			K1	8/10	
30-Aug-05	15:42:39	PI20_CL_K1_VL_068	30:54:00	0.010	0.005						SQP			K1	8/10	
KULLUK11 (40MM)																

ICE TANK **R, P, OL, and Ice Carriage Log** **Client:** **Client: IOT**

Proj 42_2019_26 **Project Name: Conical Structures in Ice** **Sub-Client**

Date	Data Acquisition Start Time or Time of Event	GDAC File Name	Video Start	Model Speed(m/s) v1	v2	v3	v4	V5	Open Water(Y/N)	Water Temp (ºC)	Ice Condition Quarter Point (CC or SQP)	Level Ice (thickness mm)	PRESAWN	SPRING	Pack Ice Conc.	Comments
01-Sep-05	8:00:00															afb: ADDED LR F/V CONVERTER
01-Sep-05	8:40:51	ZERO_RUN_069														
01-Sep-05	9:11:55	EX_K1_070									CC	X		K1		0- PAN,5-35KG @ 5KG INC.
01-Sep-05	9:35:10	DECAY_K1_R_071														ROLL DECAY (3)
01-Sep-05	9:43:10	DECAY_K1_P_072														PITCH DECAY (3)
01-Sep-05	9:47:08	DECAY_K1_H_073														HEAVE DECAY (3)
01-Sep-05	10:02:01	LI40_K1_S20_VH_074	35:13:00	0.050	0.100	0.200	0.300				CC	X		K1		sat. on x,y,&z accels
01-Sep-05	10:20:54	LI40_K1_S20_VL_075		0.010	0.005						CC	X		K1		
01-Sep-05	11:23:11	ZERO_RUN_076														
01-Sep-05	11:27:08	PS40_K1_VH_077	46:17:00	0.050	0.100	0.200	0.300				SQP		X	K1		
01-Sep-05	11:43:41	PS40_K1_VL_078		0.010	0.005						SQP		X	K1		
			TAPE#6													
01-Sep-05	12:24:54	LI40_K1_S12_VH_079	0:00:00	0.050	0.100	0.200	0.300				CC	X		K1		STOPPED EARLY DUE TO SER.CAR. IN THE WAY
01-Sep-05	12:51:24	LI40_K1_S12_VL_080	5:33:00	0.010	0.005						CC	X		K1		
01-Sep-05	13:53:05	ZERO_RUN_081														
01-Sep-05	13:56:14	PI40_CM_K1_VH_082	15:41:00	0.050	0.100	0.200	0.300				NQP				9/10	
01-Sep-05	14:04:40	PI40_CM_K1_VL_083		0.010	0.005						NQP				9/10	
01-Sep-05	14:17:38	ZERO_RUN_084														
01-Sep-05	14:21:23	PI40_CH_K1_VH_085	20:57:00	0.050	0.100	0.200	0.300				NQP				10/10	
01-Sep-05	14:32:03	PI40_CH_K1_VL_086	34:30:00	0.010	0.005						NQP				10/10	
01-Sep-05	14:53:31	ZERO_RUN_087														
01-Sep-05	15:12:44	PI40_CL_K1_VH_088	42:07:00	0.050	0.100	0.200	0.300				SQP				8/10	
01-Sep-05	15:20:40	PI40_CL_K1_VL_089		0.010	0.005						SQP				8/10	
KULLUK12 (20MM)																
																REPEAT EXCURSION - QUALYSIS NOT WORKING
02-Sep-05	9:04:13	EX_K2_090														0- PAN,5-35KG @ 5KG INC.
02-Sep-05																
02-Sep-05	9:19:31	ZERO_RUN_091														K2 = 6.8LB SPRING
02-Sep-05			TAPE #7													
02-Sep-05	9:22:03	LI20_K2_S20_VH_092	0:00:00	0.050	0.100	0.200	0.300				CC	X		K2		
02-Sep-05		LI20_K2_S20_VL_093	5:37:00	0.010	0.005						CC	X		K2		

ICE TANK **R, P, OL, and Ice Carriage Log** **Client:** **Client: IOT**

Proj 42_2019_26 **Project Name: Conical Structures in Ice** **Sub-Client**

Date	Data Acquisition Start Time or Time of Event	GDAC File Name	Video Start	v1	v2	v3	v4	V5	Open Water(Y/N)	Water Temp (ºC)	Quarter Point (CC or SQP)	Level Ice (thickness mm)	PRESAWN	SPRING	Pack Ice Conc.	Comments
				Model Speed(m/s)					Open Wate		Ice Condition					
02-Sep-05																
02-Sep-05	10:29:05	ZERO_RUN_094												K2		
02-Sep-05																
02-Sep-05	10:33:44	PS20_K2_VH_095	15:17:00	0.050	0.100	0.200	0.300				SQP			K2		
02-Sep-05	10:45:21	PS20_K2_VL_096		0.010	0.005						SQP			K2		
02-Sep-05																
02-Sep-05	11:34:11	PI20_CM_K2_VH_097	31:17:00	0.050	0.100	0.200	0.300				NQP		X	K2	9/10	
02-Sep-05	11:47:54	PI20_CM_K2_VL_098		0.010	0.005						NQP		X	K2	9/10	
02-Sep-05																
02-Sep-05	11:59:04	ZERO_RUN_099														
02-Sep-05																
02-Sep-05	12:05:39	LI20_K2_S12_VH_100		0.050	0.100	0.200	0.300				CC	X				
02-Sep-05	12:14:36	LI20_K2_S12_VL_101	49:25:00	0.010	0.005						CC	X				
02-Sep-05																
	13:52:22	ZERO_RUN_102														
			TAPE #8													
02-Sep-05	13:56:19	PI20_CL_K2_VH_103	0:00:00	0.050	0.100	0.200	0.300				SQP					
02-Sep-05	14:04:09	PI20_CL_K2_VL_104		0.010	0.005						SQP				7/10	
02-Sep-05															7/10	
02-Sep-05	14:15:53	ZERO_RUN_105														
02-Sep-05																
02-Sep-05	14:24:44	PI20_CL_K2_VH_106	4:42:00	0.050	0.100	0.200	0.300				NQP				10/10	
06-Sep-05	8:51:40	ZERO_RUN_107														
		EX_K2_108														0- PAN,5-35KG @ 5KG INC.
06-Sep-05	9:06:34	EX_K2_109														0- PAN,5-35KG @ 5KG INC.
		QUALYSIS RECAL.														0
06-Sep-05	10:29:12	OW_K2_VM_110	10:13:00	0.050	0.100	0.200										
06-Sep-05	10:39:32	OW_K2_VL_111		0.010	0.025											
06-Sep-05	10:54:27	OW_K2_V0P3_112	15:40:00	0.300												
06-Sep-05	10:58:21	DECAY_K2_R_113														
06-Sep-05	11:03:26	DECAY_K2_P_114														
06-Sep-05	11:05:23	DECAY_K2_H_115														
																0- PAN,5-35KG @ 5KG INC. IN Y AXIS

ICE TANK | **R, P, OL, and Ice Carriage Log** | **Client:** | **Client: IOT**

Proj 42_2019_26 | **Project Name: Conical Structures in Ice** | **Sub-Client**

				Model Speed(m/s)					Open Wate		Ice Condition					Comments
Date	Data Acquisition Start Time or Time of Event	GDAC File Name	Video Start	v1	v2	v3	v4	V5	Open Water(Y/N)	Water Temp (ºC)	Quarter Point (CC or SQP)	Level Ice (thickness mm)	PRESAWN	SPRING	Pack Ice Conc.	
06-Sep-05	13:47:54	EX_Y_K2_116														
KULLUK13 (30MM)																
07-Sep-05																
07-Sep-05	8:41:15	ZERO_RUN_117														
07-Sep-05	8:55:05	EX_K2_118														0- PAN,5-35KG @ 5KG INC.
07-Sep-05	9:20:55	ZERO_RUN_119														
07-Sep-05	9:24:39	LI30_K2_S20_VH_120	17:00:00	0.050	0.100	0.200	0.300				CC	X		K2		
07-Sep-05	9:45:07	LI30_K2_S20_VL_121	22:33:00	0.010	0.005						CC	X		K2		
07-Sep-05	10:33:59	ZERO_RUN_122														
07-Sep-05	10:37:26	PS30_K2_VH_123	28:55:00	0.050	0.100	0.200	0.300				SQP		X	K2		
07-Sep-05	10:51:00	PS30_K2_VL_124		0.010	0.005						SQP		X	K2		
07-Sep-05	11:34:19	LI30_K2_S12_VH_125	41:22:00	0.050	0.100	0.200	0.300				CC	X		K2		
07-Sep-05	11:49:30	LI30_K2_S12_VL_126	46:54:00	0.010	0.005						CC	X		K2		
07-Sep-05	13:01:55	ZERO_RUN_127														
			TAPE #9													
07-Sep-05	13:05:48	PI30_CM_K2_VH_128	0:00:00	0.050	0.100	0.200	0.300				NQP			K2	9/10	
07-Sep-05	13:12:55	PI30_CM_K2_VL_129	5:26:00	0.010	0.005						NQP			K2	9/10	
07-Sep-05	13:25:55	ZERO_RUN_130														
07-Sep-05	13:28:50	PI30_CH_K2_VH_131	5:36:00	0.050	0.100	0.200	0.300				NQP			K2	10/10	
07-Sep-05	13:36:23	PI30_CH_K2_VL_132	11:08:00	0.010	0.005						NQP			K2	10/10	
07-Sep-05																
07-Sep-05	14:16:46	PI30_CL_K2_VH_133	16:22:00	0.050	0.100	0.200	0.300				SQP				8/10	
07-Sep-05	14:24:22	PI30_CL_K2_VL_134	21:49:00	0.010	0.005						SQP				8/10	
KULLUK 14(40)			TAPE#9													

ICE TANK			R, P, OL, and Ice Carriage Log								Client:					Client: IOT
Proj	42_2019_26		Project Name: Conical Structures in Ice													Sub-Client
				Model Speed(m/s)					Open Wate		Ice Condition					Comments
Date	Data Acquisition Start Time or Time of Event	GDAC File Name	Video Start	v1	v2	v3	v4	V5	Open Water(Y/N)	Water Temp (ºC)	Quarter Point (CC or SQP)	Level Ice (thickness mm)	PRESAWN	SPRING	Pack Ice Conc.	
09-Sep-05	9:20:02	ZERO_RUN_135														
09-Sep-05																
09-Sep-05	9:30:40	EX_K2_136														0- PAN,5-35KG @ 5KG INC.
09-Sep-05	9:51:12	ZERO_RUN_137														
09-Sep-05	9:58:54	LI40_K2_S20_VH_138	31:52:00	0.050	0.100	0.200	0.300				CC	X		K2		
09-Sep-05	10:12:58	LI40_K2_S20_VL_139	31:39:00	0.010	0.005						CC	X		K2		
09-Sep-05	11:15:20	ZERO_RUN_140														
09-Sep-05	11:18:36	PS40_K2_VH_141	45:45:00	0.050	0.100	0.200	0.300				SQP		X	K2		
09-Sep-05	11:27:22	PS40_K2_VL_142		0.010	0.005						SQP		X	K2		
			TAPE #10													
09-Sep-05	11:49:32	LI40_K2_S12_VH_143	0:00:00	0.050	0.100	0.200	0.300				CC					
09-Sep-05	12:01:08	L40_K2_S12_VL_144	6:12:00	0.010	0.005						CC					
09-Sep-05	13:05:54	PS40_DECAY_K2_P_V0P2_145		0.2							SQP			K2		
09-Sep-05	13:10:19	PS40_DECAY_K2_R_V0P2_146	15:18:00	0.2							SQP			K2		
09-Sep-05	13:15:04	PS40_DECAY_K2_H_V0P2_147		0.2										K2		
09-Sep-05	13:23:29	PS40_DECAY_K2_P_V0P01_148	16:56:00	0.01										K2		
09-Sep-05	13:26:51	PS40_DECAY_K2_P_149	18:27:00	0										K2		
09-Sep-05	13:30:07	PS40_DECAY_K2_R_V0P01_150	19:42:00	0.01										K2		
09-Sep-05	13:33:27	PS40_DECAY_K2_R_151	21:20:00	0										K2		NO VIDEO
09-Sep-05	13:36:33	PS40_DECAY_K2_H_V0P01_152	21:20:00	0.01										K2		
09-Sep-05	13:40:14	PS40_DECAY_K2_H_153	23:51:00	0										K2		
09-Sep-05	14:07:45	PS40_DECAY_K2_S_V0P2_154	25:52:00	0.2												not enough tank left
09-Sep-05	14:52:06	PI40_CM_K2_VH_155	26:24:00	0.050	0.100	0.200	0.300				NQP				9/10	
09-Sep-05	14:59:58	PI40_CM_K2_VL_156	32:00:00	0.010	0.005						NQP				9/10	
09-Sep-05	15:13:57	ZERO_RUN_157														

ICE TANK **R, P, OL, and Ice Carriage Log** **Client:** **Client: IOT**

Proj 42_2019_26 **Project Name: Conical Structures in Ice** **Sub-Client**

				Model Speed(m/s)					Open Wate		Ice Condition					Comments
Date	Data Acquisition Start Time or Time of Event	GDAC File Name	Video Start	v1	v2	v3	v4	V5	Open Water(Y/N)	Water Temp (ºC)	Quarter Point (CC or SQP)	Level Ice (thickness mm)	PRESAWN	SPRING	Pack Ice Conc.	
09-Sep-05	15:16:49	PI40_CH_K2_VH_158	40:29:00	0.050	0.100	0.200	0.300				NQP				10/10	
09-Sep-05	15:31:35	PI40_CH_K2_VL_159		0.010	0.005						SQP				10/10	
09-Sep-05	16:00:33	PI40_CL_K2_VH_151	54:34:00	0.050	0.100	0.200	0.300								8/10	
09-Sep-05	16:07:48	PI40_CL_K2_VL_152		0.010	0.005										8/10	NO VIDEO TAPES AVAILABLE
																*NOTE: LOSS POWER/CONTROL TO ICE DAS on sept 10th
																SPRINGS K3
12-Sep-05	14:27:05	ZERO_RUN_153														K3=3.5LBS
12-Sep-05	14:56:58	EX_K3_154												K3		0- PAN,5-35KG @ 5KG INC. pan bottomed out on 35kg.
KULLUK 15(30MM)			TAPE #11													
13-Sep-05																
13-Sep-05	8:33:29	ZERO_RUN_155												K3		
13-Sep-05																
13-Sep-05	9:00:07	EX_K3_156												K3		0- PAN,5-25KG @ 5KG INC.
13-Sep-05	9:16:35	EX_Y_K3_157												K3		0- PAN,5-25KG @ 5KG INC.
13-Sep-05	9:36:57	LI30_K3_S20_VH_158	0:00:00	0.050	0.100	0.200	0.300				CC	X		K3		
13-Sep-05	9:54:39	LI30_K3_S20_VL_159		0.010	0.005						CC	X		K3		
13-Sep-05	10:49:51	ZERO_RUN_160														
13-Sep-05	10:52:05	PS30_K3_VH_161	14:58:00	0.050	0.100	0.200	0.300				SQP		X	K3		
13-Sep-05	11:03:10	PS30_K3_VL_162	20:24:00	0.010	0.005						SQP		X	K3		
13-Sep-05	11:24:47	LI30_K3_S12_VH_163	26:00:00	0.050	0.100	0.200	0.300				CC	X		K3		
13-Sep-05	11:32:52	L30_K3_S12_VL_164	31:28:00	0.010	0.005						CC	X		K3		
13-Sep-05	12:35:42	ZERO_RUN_165														
13-Sep-05	12:40:59	PS30_DECAY_K3_P_V0P2_166	39:46:00	0.2							SQP		X	K3		
13-Sep-05	12:43:12	PS30_DECAY_K3_R_V0P2_167	40:25:00	0.2							SQP		X	K3		
13-Sep-05	12:45:15	PS30_DECAY_K3_H_V0P2_168		0.2							SQP		X	K3		poor heaving

ICE TANK | **R, P, OL, and Ice Carriage Log** | **Client:** | **Client: IOT**

Proj 42_2019_26 | **Project Name: Conical Structures in Ice** | **Sub-Client**

Date	Data Acquisition Start Time or Time of Event	GDAC File Name	Video Start	Model Speed(m/s) v1	v2	v3	v4	V5	Open Water(Y/N)	Water Temp (ºC)	Ice Condition Quarter Point (CC or SQP)	Level Ice (thickness mm)	PRESAWN	SPRING	Pack Ice Conc.	Comments
13-Sep-05	12:48:47	PS30_DECAY_K3_S_V0P2_169		0.2												
13-Sep-05		PS30_DECAY_K3_P_V0P01_170	43:04:00	0.01							SQP			K3		
13-Sep-05	13:02:23	PS30_DECAY_K3_P_171	45:12:00	0												
13-Sep-05	13:05:10	PS30_DECAY_K3_R_V0P01_172	46:23:00	0.01							SQP			K3		
13-Sep-05	13:08:14	PS30_DECAY_K3_R_173	48:19:00	0												
13-Sep-05	13:11:54	PS30_DECAY_K3_H_V0P01_174	49:34:00	0.01							SQP			K3		
13-Sep-05	13:14:49	PS30_DECAY_K3_H_175	51:31:00	0							SQP			K3		
	13:17:56	PS30_DECAY_K3_H_176	53:23:00													
13-Sep-05	13:55:33	ZERO_RUN_177														
13-Sep-05	13:57:11	PI30_CM_K3_VH_178	54:43:00	0.050	0.100	0.200	0.300				NQP			K3	9/10	
13-Sep-05	14:04:31	PI30_CM_K3_VL_179	????	0.010	0.005											no video available
13-Sep-05	14:19:08	ZERO_RUN_180														
13-Sep-05	14:23:10	PI30_CH_K3_VH_181	???	0.050	0.100	0.200	0.300				NQP			K3	10/10	no video available
13-Sep-05	14:29:48	PI30_CH_K3_VL_182	???	0.010	0.005											no video available
13-Sep-05		ZERO_RUN_183														
			TAPE #12													
13-Sep-05	15:05:21	PI30_CL_K3_VH_184	0:00:00	0.050	0.100	0.200	0.300				CC			K3	8/10	
13-Sep-05	15:12:13	PI30_CL_K3_VL_185	5:37:00	0.010	0.005											
KULLUK16(20MM)																
14-Sep-05		ZERO_RUN_186														
14-Sep-05		EX_K3_187														0- PAN,5-25KG @ 5KG INC.
14-Sep-05	9:36:43	LI20_K3_S20_VH_188	15:19:00	0.050	0.100	0.200	0.300									
14-Sep-05	9:51:27	LI20_K3_S20_VL_189	25:05:00	0.010	0.005											
14-Sep-05	10:40:23	ZERO_RUN_190														
14-Sep-05	10:44:55	PS30_K3_VH_191	34:58:00	0.050	0.100	0.200	0.300				SQP		X	K3		
14-Sep-05	10:57:00	PS30_K3_VL_192	40:35:00	0.010	0.005						SQP		X	K3		

ICE TANK | **R, P, OL, and Ice Carriage Log** | **Client:** | **Client: IOT**

Proj 42_2019_26 | **Project Name: Conical Structures in Ice** | **Sub-Client**

Date	Data Acquisition Start Time or Time of Event	GDAC File Name	Video Start	Model Speed(m/s) v1	v2	v3	v4	V5	Open Water(Y/N)	Water Temp (ºC)	Ice Condition: Quarter Point (CC or SQP)	Level Ice (thickness mm)	PRESAWN	SPRING	Pack Ice Conc.	Comments
14-Sep-05	11:17:49	LI30_K3_S12_VH_193	50:43:00	0.050	0.100	0.200	0.300				CC	X		K3		
14-Sep-05		L30_K3_S12_VL_194	56:10:00	0.010	0.005						CC	X		K3		
14-Sep-05	12:17:58	ZERO_RUN_195	TAPE #13													
14-Sep-05	12:28:33	PS20_DECAY_K3_P_V0P2_196	0:00:00	0.2							SQP		X	K3		
14-Sep-05	12:30:52	PS20_DECAY_K3_R_V0P2_197	1:00:00	0.2							SQP		X	K3		
14-Sep-05	13:39:16	PS20_DECAY_K3_H_V0P2_198	1:25:00	0.2							SQP		X	K3		
14-Sep-05	12:40:39	PS20_DECAY_K3_S_V0P2_199		0.2												
14-Sep-05	12:44:15	PS20_DECAY_K3_P_V0P01_200	1:56:00	0.01							SQP			K3		
14-Sep-05	12:47:49	PS20_DECAY_K3_P_201	3:49:00	0												
14-Sep-05	12:50:34	PS20_DECAY_K3_R_V0P01_202	3:49:00	0.01							SQP			K3		
14-Sep-05	12:54:47	PS20_DECAY_K3_R_203	6:10:00	0												
14-Sep-05	12:58:47	PS20_DECAY_K3_H_V0P01_204	8:04:00	0.01							SQP			K3		
14-Sep-05	13:03:21	PS20_DECAY_K3_H_205	10:25:00	0							SQP			K3		
14-Sep-05	13:24:07	ZERO_RUN_206														
14-Sep-05	13:46:33	PI20_CM_K3_VH_207	10:24:00	0.050	0.100	0.200	0.300				NQP			K3	9/10	
14-Sep-05	13:53:33	PI20_CM_K3_VL_208	17:04:00	0.010	0.005											
14-Sep-05	14:06:27	ZERO_RUN_209														
14-Sep-05	14:08:22	PI20_CH_K3_VH_210	21:28:00	0.050	0.100	0.200	0.300				NQP			K3	10/10	
14-Sep-05	14:15:29	PI20_CH_K3_VL_211	31:07:00	0.010	0.005											
14-Sep-05	14:59:11	ZERO_RUN_212														
14-Sep-05	15:02:01	PI20_CL_K3_VH_213	40:27:00	0.050	0.100	0.200	0.300				CC			K3	8/10	
14-Sep-05	15:08:26	PI20_CL_K3_VL_214	45:50:00	0.010	0.005											

ICE TANK **R, P, OL, and Ice Carriage Log** **Client:** **Client: IOT**

Proj 42_2019_26 **Project Name: Conical Structures in Ice** **Sub-Client**

				Model Speed(m/s)					Open Wate		Ice Condition					Comments
Date	Data Acquisition Start Time or Time of Event	GDAC File Name	Video Start	v1	v2	v3	v4	V5	Open Water(Y/N)	Water Temp (ºC)	Quarter Point (CC or SQP)	Level Ice (thickness mm)	PRESAWN	SPRING	Pack Ice Conc.	
KULLUK17(40MM)			TAPE #14													
16-Sep-05	9:14:17	ZERO_RUN_215														
16-Sep-05	9:16:35	EX_K3_216														0- PAN,5-25KG @ 5KG INC.
16-Sep-05	9:58:11	LI40_K3_S20_VH_217	0:00:00	0.050	0.100	0.200	0.300									
16-Sep-05	10:12:31	LI40_K3_S20_VL_218	6:07:00	0.010	0.005											
16-Sep-05		ZERO_RUN_219														
16-Sep-05	11:09:19	PS40_K3_VH_220	16:10:00	0.050	0.100	0.200	0.300				SQP		X	K3		ice rafted onto model
16-Sep-05	11:20:57	PS40_K3_VL_221	21:43:00	0.010	0.005						SQP		X	K3		
16-Sep-05	11:47:38	LI40_K3_S12_VH_222	31:07:00	0.050	0.100	0.200	0.300				CC	X		K3		
16-Sep-05	12:01:28	L40_K3_S12_VL_223	36:39:00	0.010	0.005						CC	X		K3		
16-Sep-05	12:51:09	ZERO_RUN_224														
16-Sep-05	13:01:38	PS40_DECAY_K3_P_V0P2_225	46:18:00	0.2							SQP		X	K3		
16-Sep-05	13:05:00	PS40_DECAY_K3_R_V0P2_226	46:49:00	0.2							SQP		X	K3		
16-Sep-05	13:08:16	PS40_DECAY_K3_H_V0P2_227	47:12:00	0.2							SQP		X	K3		
16-Sep-05	13:10:00	PS40_DECAY_K3_S_V0P2_228	47:40:00	0.2												
16-Sep-05	13:15:07	PS40_DECAY_K3_P_V0P01_229	48:20:00	0.01							SQP			K3		
16-Sep-05	13:18:47	PS40_DECAY_K3_P_230	50:27:00	0												
16-Sep-05		PS40_DECAY_K3_R_V0P01_231	51:44:00	0.01							SQP			K3		
16-Sep-05	13:25:29	PS40_DECAY_K3_R_232	53:50:00	0												
16-Sep-05	13:29:15	PS40_DECAY_K3_H_V0P01_233	55:18:00	0.01							SQP			K3		
16-Sep-05	13:33:09	PS40_DECAY_K3_H_234	57:38:00	0							SQP			K3		
16-Sep-05	14:09:59	ZERO_RUN_235	TAPE #15													
16-Sep-05	14:15:16	PI40_CM_K3_VH_236	0:00:00	0.050	0.100	0.200	0.300				NQP			K3	9/10	
16-Sep-05	14:22:43	PI40_CM_K3_VL_237	5:29:00	0.010	0.005											

ICE TANK **R, P, OL, and Ice Carriage Log** **Client:** **Client: IOT**

Proj 42_2019_26 **Project Name: Conical Structures in Ice** **Sub-Client**

				Model Speed(m/s)					Open Water		Ice Condition					Comments
Date	Data Acquisition Start Time or Time of Event	GDAC File Name	Video Start	v1	v2	v3	v4	V5	Open Water(Y/N)	Water Temp (ºC)	Quarter Point (CC or SQP)	Level Ice (thickness mm)	PRESAWN	SPRING	Pack Ice Conc.	
16-Sep-05	14:34:49	ZERO_RUN_238														
16-Sep-05	14:36:40	PI40_CH_K3_VH_239	15:09:00	0.050	0.100	0.200	0.300				NQP			K3	10/10	
16-Sep-05	14:46:54	PI40_CH_K3_VL_240	25:12:00	0.010	0.005											
16-Sep-05	15:25:17	ZERO_RUN_241														
16-Sep-05	15:28:22	PI40_CL_K3_VH_242	36:22:00	0.050	0.100	0.200	0.300				CC			K3	8/10	
16-Sep-05	15:38:03	PI40_CL_K3_VL_243	42:32:00	0.010	0.005											
17-Sep-05	14:02:06	ZERO_RUN_244														
	14:46:30	EX_K3_245														
	15:02:47	OW_K1_VM_246		0.050	0.100	0.200										
	15:09:52	OW_K1_VL_247		0.010	0.025											
	15:20:24	OW_K1_V0P3_248		0.3												
	15:27:21	DECAY_K2_R_249														
	15:29:03	DECAY_K2_P_250														
	15:31:42	DECAY_K2_H_251														

Appendix E
Video and Picture Documentation

The appendix contains:

- The directory for the video files created
- The directory for the picture that were taken

Set One
LI30_K1_BOW_1
LI30_K1_BOW_2
LI30_K1_S12_VH_034
LI30_K1_S12_VH_BOW_034
LI30_K1_S12_VH_UW_034
LI30_K1_S12_VL_035
LI30_K1_S12_VL_BOW_035
LI30_K1_S12_VL_UW_035
LI30_K1_Underwater
LI30_K1_Underwater_031
PI30_CH_K1_VH_BOW_036
PI30_CH_K1_VH_UW_036
PORT_SET1_KULLUK_LI3
PORT_SET!_KULLUK_LI30
PORT_SET1_KULLUK_PS30_032
PORT_SET1_KULLUK_PS30_033
PS30_CH_K1_VH_036
PS30_K1_VH_BOW_033
PS30_K1_VH_UW_032
STB_SET1_KULLUK_2005_LI
STB_SET1_KULLUK_LI_035
STB_SET1_KULLUK_LI
STB_SET1_KULLUK_PI30_036

Set Two
PI30_CH_K1_VH_BOW_038
PI30_CL_K1_VH_BOW_040
PI30_CL_K1_VL_BOW_041
PI30_CH_K1_VH_PORT_038
PI30_CL_K1_VH_PORT_040
PI30_CL_K1_VL_PORT_041
PI30_CH_K1_VH_UW_038
PI30_CL_K1_VH_UW_040
PI30_CL_K1_VL_UW_041
PI30_CH_K1_VH_STB_038
PI30_CL_K1_VH_STB_040
PI30_CL_K1_VL_STB_041

Set Three
LI10_K1_S20_VH_PORT_043
LI10_K1_S12_VH_PORT_050
LI10_K1_S20_VL_PORT_044
PS10_K1_VH_PORT_047
LI10_K1_S20_VH_BOW_043
LI10_K1_S12_VH_BOW_050
LI10_K1_S20_VL_BOW_044
PS10_K1_VH_BOW_047
LI10_K1_S20_VH_STB_043
LI10_K1_S12_VH_STB_050
LI10_K1_S20_VL_STB_044
PS10_K1_VH_STB_047
LI10_K1_S20_VH_UW_043
LI10_K1_S12_VH_UW_050
LI10_K1_S20_VL_UW_044
PS10_K1_VH_UW_047

Set Four
LI20_K1_S12_VH_PORT_060
LI20_K1_S20_VH_PORT_055
LI20_K1_S20_VL_PORT_056
OW_K1_VL_PORT_051
OW_K1_VL_V0P3_PORT_053
PS20_K1_VH_PORT_058
PS20_K1_VL_PORT_059
LI20_K1_S12_VH_BOW_060
LI20_K1_S20_VH_BOW_055
LI20_K1_S20_VL_BOW_056
OW_K1_VL_BOW_051
OW_K1_VL_V0P3_BOW_053
PS20_K1_VH_BOW_058
PS20_K1_VL_BOW_059
LI20_K1_S12_VH_STB_060
LI20_K1_S20_VH_STB_055
LI20_K1_S20_VL_STB_056
OW_K1_VL_STB_051
OW_K1_VL_V0P3_STB_053
PS20_K1_VH_STB_058
PS20_K1_VL_STB_059
LI20_K1_S12_VH_UW_060
LI20_K1_S20_VH_UW_055
LI20_K1_S20_VL_UW_056
OW_K1_VL_UW_051
OW_K1_VL_V0P3_UW_053
PS20_K1_VH_UW_058
PS20_K1_VL_UW_059

Set Five	Set Six
PI20_CL_K1_VH_PORT_063	LI40_K1_S12_VH_PORT_079
PI20_CM_K1_VL_PORT_064	LI40_K1_S12_VL_PORT_080
PI20_CH_K1_VL_PORT_065	PI40_CM_K1_VH_PORT_082
PI20_CL_K1_VH_PORT_067	PI40_CM_K1_VL_PORT_083
PI20_CL_K1_VL_PORT_068	PI40_CH_K1_VH_PORT_085
LI40_K1_S20_VH_PORT_070	PI40_CL_K1_VH_PORT_088
LI40_K1_S20_VL_PORT_071	PI40_CL_K1_VL_PORT_089
PI20_CM_K1_VH_PORT_077	LI40_K1_S12_VH_BOW_079
PS20_K1_VL_PORT_078	LI40_K1_S12_VL_BOW_080
PI20_CL_K1_VH_BOW_063	PI40_CM_K1_VH_BOW_082
PI20_CM_K1_VL_BOW_064	PI40_CM_K1_VL_BOW_083
PI20_CH_K1_VL_BOW_065	PI40_CH_K1_VH_BOW_085
PI20_CL_K1_VH_BOW_067	PI40_CL_K1_VH_BOW_088
PI20_CL_K1_VL_BOW_068	PI40_CL_K1_VL_BOW_089
LI40_K1_S20_VH_BOW_070	LI40_K1_S12_VH_STB_079
LI40_K1_S20_VL_BOW_071	LI40_K1_S12_VL_STB_080
PI20_CM_K1_VH_BOW_077	PI40_CM_K1_VH_STB_082
PS20_K1_VL_BOW_078	PI40_CM_K1_VL_STB_083
PI20_CL_K1_VH_STB_063	PI40_CH_K1_VH_STB_085
PI20_CM_K1_VL_STB_064	PI40_CL_K1_VH_STB_088
PI20_CH_K1_VL_STB_065	PI40_CL_K1_VL_STB_089
PI20_CL_K1_VH_STB_067	LI40_K1_S12_VH_UW_079
PI20_CL_K1_VL_STB_068	LI40_K1_S12_VL_UW_080
LI40_K1_S20_VH_STB_070	PI40_CM_K1_VH_UW_082
LI40_K1_S20_VL_STB_071	PI40_CM_K1_VL_UW_083
PI20_CM_K1_VH_STB_077	PI40_CH_K1_VH_UW_085
PS20_K1_VL_STB_078	PI40_CL_K1_VH_UW_088
PI20_CL_K1_VH_UW_063	PI40_CL_K1_VL_UW_089
PI20_CM_K1_VL_UW_064	
PI20_CH_K1_VL_UW_065	
PI20_CL_K1_VH_UW_067	
PI20_CL_K1_VL_UW_068	
LI40_K1_S20_VH_UW_070	
LI40_K1_S20_VL_UW_071	
PI20_CM_K1_VH_UW_077	
PS20_K1_VL_UW_078	

Set Seven	Set Eight
LI20_K2_S20_VH_BOW_092	PI20_CL_K2_VH_BOW_103
PS20_K2_VH_BOW_095	PI20_CH_K2_VH_BOW_106
PS20_K2_VL_BOW_096	LI30_K2_S20_VH_BOW_120
PI20_CM_K2_VH_BOW_097	LI30_K2_S20_VL_BOW_121
PI20_CM_K2_VL_BOW_098	PS30_K2_VH_BOW_123
LI20_K2_S12_VH_BOW_100	PS30_VL_BOW_124
LI20_K2_S12_VL_BOW_101	LI30_K2_S12_VH_BOW_125
PI20_CH_K2_VH_BOW_103	OW_BOW
LI20_K2_S20_VH_STB_092	PI20_CL_K2_VH_STB_103
PS20_K2_VH_STB_095	PI20_CH_K2_VH_STB_106
PS20_K2_VL_STB_096	LI30_K2_S20_VH_STB_120
PI20_CM_K2_VH_STB_097	LI30_K2_S20_VL_STB_121
PI20_CM_K2_VL_STB_098	PS30_K2_VH_STB_123
LI20_K2_S12_VH_STB_100	PS30_VL_STB_124
LI20_K2_S12_VL_STB_101	LI30_K2_S12_VH_STB_125
PI20_CH_K2_VH_STB_103	OW_STB
LI20_K2_S20_VH_UW_092	PI20_CL_K2_VH_UW_103
PS20_K2_VH_UW_095	PI20_CH_K2_VH_UW_106
PS20_K2_VL_UW_096	LI30_K2_S20_VH_UW_120
PI20_CM_K2_VH_UW_097	LI30_K2_S20_VL_UW_121
PI20_CM_K2_VL_UW_098	PS30_K2_VH_UW_123
LI20_K2_S12_VH_UW_100	PS30_VL_UW_124
LI20_K2_S12_VL_UW_101	LI30_K2_S12_VH_UW_125
PI20_CH_K2_VH_UW_103	OW_UW
LI20_K2_S20_VH_PORT_092	PI20_CL_K2_VH_PORT_103
PS20_K2_VH_PORT_095	PI20_CH_K2_VH_PORT_106
PS20_K2_VL_PORT_096	LI30_K2_S20_VH_PORT_120
PI20_CM_K2_VH_PORT_097	LI30_K2_S20_VL_PORT_121
PI20_CM_K2_VL_PORT_098	PS30_K2_VH_PORT_123
LI20_K2_S12_VH_PORT_100	PS30_VL_PORT_124
LI20_K2_S12_VL_PORT_101	LI30_K2_S12_VH_PORT_125
PI20_CH_K2_VH_PORT_103	OW_PORT

Set Nine
PI30_CM_K2_VH_BOW_128
PI30_CH_K2_VH_BOW_131
PI30_CH_K2_VL_BOW_132
PI30_CL_K2_VL_BOW_134
LI40_K2_S20_VH_BOW_138
LI40_K2_S20_VL_BOW_139
PS40_K2_VH_BOW_141
PI30_CM_K2_VH_STB_128
PI30_CH_K2_VH_STB_131
PI30_CH_K2_VL_STB_132
PI30_CL_K2_VL_STB_134
LI40_K2_S20_VH_STB_138
LI40_K2_S20_VL_STB_139
PS40_K2_VH_STB_141
PI30_CM_K2_VH_UW_128
PI30_CH_K2_VH_UW_131
PI30_CH_K2_VL_UW_132
PI30_CL_K2_VL_UW_134
LI40_K2_S20_VH_UW_138
LI40_K2_S20_VL_UW_139
PS40_K2_VH_UW_141
PI30_CM_K2_VH_PORT_128
PI30_CH_K2_VH_PORT_131
PI30_CH_K2_VL_PORT_132
PI30_CL_K2_VL_PORT_134
LI40_K2_S20_VH_PORT_138
LI40_K2_S20_VL_PORT_139
PS40_K2_VH_PORT_141

Set Ten
LI40_K2_S12_VH_BOW_143
LI40_K2_S12_VL_BOW_144
PI40_CH_K2_VH_BOW_158
PI40_CH_K2_VL_BOW_159
PI40_CL_K2_VH_BOW_160
PI40_CM_K2_VH_BOW_155
PI40_CM_K2_VL_BOW_156
PS_DECAY_K2_H_BOW_153
PS40_DECAY_K2_H_V0P01_BOW_148
PS40_DECAY_K2_H_V0P01_BOW_152
PS40_DECAY_K2_H_V0P2_BOW_147
PS40_DECAY_K2_P_V0P2_BOW_146
PS40_DECAY_K2_R_V0P01_BOW_150
PS40_DECAY_K2_S_V0P2_BOW_154
LI40_K2_S12_VH_STB_143
LI40_K2_S12_VL_STB_144
PI40_CH_K2_VH_STB_158
PI40_CH_K2_VL_STB_159
PI40_CL_K2_VH_STB_160
PI40_CM_K2_VH_STB_155
PI40_CM_K2_VL_STB_156
PS_DECAY_K2_H_STB_153
PS40_DECAY_K2_H_V0P01_STB_148
PS40_DECAY_K2_H_V0P01_STB_152
PS40_DECAY_K2_H_V0P2_STB_147
PS40_DECAY_K2_P_V0P2_STB_146
PS40_DECAY_K2_R_V0P01_STB_150
PS40_DECAY_K2_S_V0P2_STB_154
LI40_K2_S12_VH_UW_143
LI40_K2_S12_VL_UW_144
PI40_CH_K2_VH_UW_158
PI40_CH_K2_VL_UW_159
PI40_CL_K2_VH_UW_160
PI40_CM_K2_VH_UW_155
PI40_CM_K2_VL_UW_156
PS_DECAY_K2_H_UW_153
PS40_DECAY_K2_H_V0P01_UW_148
PS40_DECAY_K2_H_V0P01_UW_152
PS40_DECAY_K2_H_V0P2_UW_147
PS40_DECAY_K2_P_V0P2_UW_146
PS40_DECAY_K2_R_V0P01_UW_150
PS40_DECAY_K2_S_V0P2_UW_154
LI40_K2_S12_VH_PORT_143
LI40_K2_S12_VL_PORT_144
PI40_CH_K2_VH_PORT_158
PI40_CH_K2_VL_PORT_159
PI40_CL_K2_VH_PORT_160
PI40_CM_K2_VH_PORT_155
PI40_CM_K2_VL_PORT_156
PS_DECAY_K2_H_PORT_153
PS40_DECAY_K2_H_V0P01_PORT_148
PS40_DECAY_K2_H_V0P01_PORT_152
PS40_DECAY_K2_H_V0P2_PORT_147
PS40_DECAY_K2_P_V0P2_PORT_146
PS40_DECAY_K2_R_V0P01_PORT_150
PS40_DECAY_K2_S_V0P2_PORT_154

Set Eleven	PS30_DECAY_K3_H_V0P01_UW_174
LI30_K3_S20_VH_BOW_159	PI30_CM_K3_VH_UW_178
LI30_K3_S20_VL_BOW_160	PI30_CM_K3_VL_UW_179
PS30_K3_VH_BOW_161	LI30_K3_S20_VH_PORT_159
PS30_K3_VL_BOW_162	LI30_K3_S20_VL_PORT_160
LI30_K3_S12_VH_BOW_163	PS30_K3_VH_PORT_161
LI30_K3_S12_VL_BOW_164	PS30_K3_VL_PORT_162
PS30_DECAY_K3_P_V0P2_BOW_166	LI30_K3_S12_VH_PORT_163
PS30_DECAY_K3_R_V0P2_BOW_167	LI30_K3_S12_VL_PORT_164
PS30_DECAY_K3_H_V0P2_BOW_168	PS30_DECAY_K3_P_V0P2_PORT_166
PS30_DECAY_K3_S_V0P2_BOW_169	PS30_DECAY_K3_R_V0P2_PORT_167
PS30_DECAY_K3_P_V0P01_BOW_170	PS30_DECAY_K3_H_V0P2_PORT_168
PS30_DECAY_K3_R_V0P01_BOW_172	PS30_DECAY_K3_S_V0P2_PORT_169
PS30_DECAY_K3_R_BOW_173	PS30_DECAY_K3_P_V0P01_PORT_170
PS30_DECAY_K3_H_V0P01_BOW_174	PS30_DECAY_K3_R_V0P01_PORT_172
PI30_CM_K3_VH_BOW_178	PS30_DECAY_K3_R_PORT_173
PI30_CM_K3_VL_BOW_179	PS30_DECAY_K3_H_V0P01_PORT_174
LI30_K3_S20_VH_STB_159	PI30_CM_K3_VH_PORT_178
LI30_K3_S20_VL_STB_160	PI30_CM_K3_VL_PORT_179
PS30_K3_VH_STB_161	
PS30_K3_VL_STB_162	
LI30_K3_S12_VH_STB_163	
LI30_K3_S12_VL_STB_164	
PS30_DECAY_K3_P_V0P2_STB_166	
PS30_DECAY_K3_R_V0P2_STB_167	
PS30_DECAY_K3_H_V0P2_STB_168	
PS30_DECAY_K3_S_V0P2_STB_169	
PS30_DECAY_K3_P_V0P01_STB_170	
PS30_DECAY_K3_R_V0P01_STB_172	
PS30_DECAY_K3_R_STB_173	
PS30_DECAY_K3_H_V0P01_STB_174	
PI30_CM_K3_VH_STB_178	
PI30_CM_K3_VL_STB_179	
LI30_K3_S20_VH_UW_159	
LI30_K3_S20_VL_UW_160	
PS30_K3_VH_UW_161	
PS30_K3_VL_UW_162	
LI30_K3_S12_VH_UW_163	
LI30_K3_S12_VL_UW_164	
PS30_DECAY_K3_P_V0P2_UW_166	
PS30_DECAY_K3_R_V0P2_UW_167	
PS30_DECAY_K3_H_V0P2_UW_168	
PS30_DECAY_K3_S_V0P2_UW_169	
PS30_DECAY_K3_P_V0P01_UW_170	
PS30_DECAY_K3_R_V0P01_UW_172	
PS30_DECAY_K3_R_UW_173	

Set Twelve
PI30_CL_K3_VH_BOW_184
PI30_CL_K3_VL_BOW_185
LI20_K3_S20_VH_BOW_188
LI20_K3_S20_VL_BOW_189
PS20_K3_VH_BOW_191
PS20_K3_VL_BOW_192
LI20_K3_S12_VH_BOW_193
LI20_K3_S12_VL_BOW_194
PI30_CL_K3_VH_STB_184
PI30_CL_K3_VL_STB_185
LI20_K3_S20_VH_STB_188
LI20_K3_S20_VL_STB_189
PS20_K3_VH_STB_191
PS20_K3_VL_STB_192
LI20_K3_S12_VH_UW_193
LI20_K3_S12_VL_UW_194
PI30_CL_K3_VH_UW_184
PI30_CL_K3_VL_UW_185
LI20_K3_S20_VH_UW_188
LI20_K3_S20_VL_UW_189
PS20_K3_VH_UW_191
PS20_K3_VL_UW_192
LI20_K3_S12_VH_UW_193
LI20_K3_S12_VL_UW_194
PI30_CL_K3_VH_PORT_184
PI30_CL_K3_VL_PORT_185
LI20_K3_S20_VH_PORT_188
LI20_K3_S20_VL_PORT_189
PS20_K3_VH_PORT_191
PS20_K3_VL_PORT_192
LI20_K3_S12_VH_PORT_193
LI20_K3_S12_VL_PORT_194

Set Thirteen	PS20_DECAY_K3_H_V0P01_PORT_204
PS20_DECAY_K3_P_V0P2_BOW_196	PI20_CM_K3_VH_PORT_207
PS20_DECAY_K3_R_V0P2_BOW_197	PI20_CM_K3_VL_PORT_208
PS20_DECAY_K3_H_V0P2_BOW_198	PI20_CH_K3_VH_PORT_210
PS20_DECAY_K3_P_V0P01_BOW_200	PI20_CH_K3_VL_PORT_211
PS20_DECAY_K3_P_V0P01_BOW_202	PI20_CL_K3_VH_PORT_213
PS20_DECAY_K3_P_BOW_203	PI20_CL_K3_VL_PORT_214
PS20_DECAY_K3_H_V0P01_BOW_204	
PI20_CM_K3_VH_BOW_207	
PI20_CM_K3_VL_BOW_208	
PI20_CH_K3_VH_BOW_210	
PI20_CH_K3_VL_BOW_211	
PI20_CL_K3_VH_BOW_213	
PI20_CL_K3_VL_BOW_214	
PS20_DECAY_K3_P_V0P2_STB_196	
PS20_DECAY_K3_R_V0P2_STB_197	
PS20_DECAY_K3_H_V0P2_STB_198	
PS20_DECAY_K3_P_V0P01_STB_200	
PS20_DECAY_K3_P_V0P01_STB_202	
PS20_DECAY_K3_P_STB_203	
PS20_DECAY_K3_H_V0P01_STB_204	
PI20_CM_K3_VH_STB_207	
PI20_CM_K3_VL_STB_208	
PI20_CH_K3_VH_STB_210	
PI20_CH_K3_VL_STB_211	
PI20_CL_K3_VH_STB_213	
PI20_CL_K3_VL_STB_214	
PS20_DECAY_K3_P_V0P2_UW_196	
PS20_DECAY_K3_R_V0P2_UW_197	
PS20_DECAY_K3_H_V0P2_UW_198	
PS20_DECAY_K3_P_V0P01_UW_200	
PS20_DECAY_K3_P_V0P01_UW_202	
PS20_DECAY_K3_P_UW_203	
PS20_DECAY_K3_H_V0P01_UW_204	
PI20_CM_K3_VH_UW_207	
PI20_CM_K3_VL_UW_208	
PI20_CH_K3_VH_UW_210	
PI20_CH_K3_VL_UW_211	
PI20_CL_K3_VH_UW_213	
PI20_CL_K3_VL_UW_214	
PS20_DECAY_K3_P_V0P2_PORT_196	
PS20_DECAY_K3_R_V0P2_PORT_197	
PS20_DECAY_K3_H_V0P2_PORT_198	
PS20_DECAY_K3_P_V0P01_PORT_200	
PS20_DECAY_K3_P_V0P01_PORT_202	
PS20_DECAY_K3_P_PORT_203	

Set Fourteen	LI40_K3_S20_VH_PORT_217
LI40_K3_S20_VH_BOW_217	LI40_K3_S20_VL_PORT_218
LI40_K3_S20_VL_BOW_218	PS40_K3_VH_PORT_220
PS40_K3_VH_BOW_220	PS40_K3_VL_PORT_221
PS40_K3_VL_BOW_221	LI40_K3_S12_VH_PORT_222
LI40_K3_S12_VH_BOW_222	LI40_K3_S12_VL_PORT_223
LI40_K3_S12_VL_BOW_223	PS40_DECAY_K3_P_V0P2_PORT_225
PS40_DECAY_K3_P_V0P2_BOW_225	PS40_DECAY_K3_R_V0P2_PORT_226
PS40_DECAY_K3_R_V0P2_BOW_226	PS40_DECAY_K3_H_V0P2_PORT_227
PS40_DECAY_K3_H_V0P2_BOW_227	PS40_DECAY_K3_S_V0P2_PORT_228
PS40_DECAY_K3_S_V0P2_BOW_228	PS40_DECAY_K3_P_V0P01_PORT_229
PS40_DECAY_K3_P_V0P01_BOW_229	PS40_DECAY_K3_P_PORT_230
PS40_DECAY_K3_P_BOW_230	PS40_DECAY_K3_R_V0P01_PORT_231
PS40_DECAY_K3_R_V0P01_BOW_231	PS40_DECAY_K3_R_PORT_232_M
PS40_DECAY_K3_R_BOW_232_M	PS40_DECAY_K3_H_PORT_234
PS40_DECAY_K3_H_BOW_234	
LI40_K3_S20_VH_STB_217	
LI40_K3_S20_VL_STB_218	
PS40_K3_VH_STB_220	**Set Fifteen**
PS40_K3_VL_STB_221	PI40_CM_K3_VH_BOW_236
LI40_K3_S12_VH_STB_222	PI40_CM_K3_VL_BOW_237
LI40_K3_S12_VL_STB_223	PI40_CH_K3_VH_BOW_238
PS40_DECAY_K3_P_V0P2_STB_225	PI40_CH_K3_VL_BOW_240
PS40_DECAY_K3_R_V0P2_STB_226	PI40_CL_K3_VH_BOW_242
PS40_DECAY_K3_H_V0P2_STB_227	PI40_CM_K3_VH_UW_236
PS40_DECAY_K3_S_V0P2_STB_228	PI40_CM_K3_VL_UW_237
PS40_DECAY_K3_P_V0P01_STB_229	PI40_CH_K3_VH_UW_238
PS40_DECAY_K3_P_STB_230	PI40_CH_K3_VL_UW_240
PS40_DECAY_K3_R_V0P01_STB_231	PI40_CL_K3_VH_UW_242
PS40_DECAY_K3_R_STB_232_M	PI40_CM_K3_VH_PORT_236
PS40_DECAY_K3_H_STB_234	PI40_CM_K3_VL_PORT_237
LI40_K3_S20_VH_UW_217	PI40_CH_K3_VH_PORT_238
LI40_K3_S20_VL_UW_218	PI40_CH_K3_VL_PORT_240
PS40_K3_VH_UW_220	PI40_CL_K3_VH_PORT_242
PS40_K3_VL_UW_221	
LI40_K3_S12_VH_UW_222	
LI40_K3_S12_VL_UW_223	
PS40_DECAY_K3_P_V0P2_UW_225	
PS40_DECAY_K3_R_V0P2_UW_226	
PS40_DECAY_K3_H_V0P2_UW_227	
PS40_DECAY_K3_S_V0P2_UW_228	
PS40_DECAY_K3_P_V0P01_UW_229	
PS40_DECAY_K3_P_UW_230	
PS40_DECAY_K3_R_V0P01_UW_231	
PS40_DECAY_K3_R_UW_232_M	
PS40_DECAY_K3_H_UW_234	

Kulluk_Setup_Pictures
kulluk_decay
kulluk_exe_setup
kulluk_exe_setup2
kulluk_fullmodle_dry
kulluk_fullmodle_wet
kulluk_inforedcamera
kulluk_loadcell
kulluk_moorin_pole
kulluk_morrin_bottom
kulluk_morringpole
kulluk_motionpack
kulluk_plumbob
kulluk_plumbob_topview
kulluk_port_camera
kulluk_pretension_setup
kulluk_qualisistress
kulluk_qualisis_computer
kulluk_qualisis_testframe
kulluk_ron_setting_up_pole
kulluk_sidemodle_sideview_wet
kulluk_sidemodle_sideview2
kulluk_spring_mooring_pole
kulluk_topview_wet2
kulluk_trimming_block
kulluk_underwatercamera
kulluk_underwatercamera2

Kulluk_Aug_26_2005
10m_firsttime
20m_firsttime
30m_firsttime
40m_firsttime
50m_firsttime
60m_firsttime
70m_firsttime
10m_Secondtime
20m_Secondtime
30m_Secondtime
40m_Secondtime
50m_Secondtime
60m_Secondtime
70m_Secondtime
Ice_Tank
LI_backview
LI_backview2
LI_topview
LI_topview2
LI_frontview
LI_sideview
LI_sideview2
LI_ready_testing
Moduls_Elasticity_Equip.
LI_breaking_through

September_02_205_Kulluk
20mm_10m_firsttime
20mm_20m_firsttime
20mm_30m_firsttime
20mm_10m_secondtime
20mm_20m_secondtime
20mm_30m_secondtime
20mm_40m_secondtime
20mm_50m_secondtime
20mm_60m_secondtime
20mm_flatsheet_backview
20mm_flatsheet_backview1
20mm_flatsheet_frontview
20mm_flatsheet_frontview1
20mm_flatsheet_sideview
20mm_flatsheet_topview
20mm_LI_backview2
20mm_LI_frontview2
20mm_LI_sideview2
20mm_LI_topview2
20mm_PS_frontview

September _07_2005
LI_Topview
LI_topview_2
PI_topview
PI_frontview
PI_frontview_2
LI_Imprint
LI_Imprint_2
PS_topview
Sideview
Sideview_2

September_09_2005
LI_FrontView
LI_sideview
LI_sideview_2
LI_topview
LI_topview_2
LI_backview
LI_backview_2

August _30_2005_Kulluk
20mm_0m_firsttime
20mm_10m_firsttime
20mm_20m_firsttime
20mm_30m_firsttime
20mm_40m_firsttime
20mm_50m_firstime
20mm_60m_firsttime
20mm_10m_secondtime
20mm_20m_secondtime
20mm_30m_secondtime
20mm_40m_secondtime
20mm_50m_secondtime
20mm_60m_secondtime
Backview_flatsheet_20mm
Backview_flatsheet2_20mm
Topview_flatsheet_20mm

September_01_2005_Kulluk
40mm_flatsheet_backview
40mm_flatsheet_backview2
40mm_flatsheet_imprint
40mm_flatsheet_sideview
40mm_flatsheet_sideview2
40mm_flatsheet_topview
40mm_PS_backview
40mm_PS_frontview
40mm_PS_imprint
40mm_PS_sideview
40mm_PS_topview
40mm_PS_topview2
40mm_10m_firsttime
40mm_20m_firsttime
40mm_30m_firsttime
40mm_40m_firsttime
40mm_50m_firsttime
40mm_60m_firstime
40mm_70m_firsttime
40mm_10m_secondtime
40mm_20m_secondtime
40mm_30m_secondtime
40mm_40m_secondtime
40mm_50m_secondtime
40mm_60m_secondtime
40mm_70m_secondtime

September_16_2005
10m_firsttime
20m_firsttime
30m_firsttime
40m_firsttime
50m_firsttime
60m_firsttime
70m_firsttime
10m_Secondtime
20m_Secondtime
30m_Secondtime
40m_Secondtime
50m_Secondtime
60m_Secondtime
Sideview_LI
Sideview2_LI
Sideview3_LI
Sideview4_LI
Sideview5_LI
Sideview6_LI
Sideview7_LI
Sideview8_LI
Sideview9_LI
Sideview_PI
Sideview2_PI
Sideview3_PI
Decay
Frontview_LI
Frontview2_LI
Frontview3_LI
Frontview_OW
setup
ow

Setdown_Picture_Kulluk
kulluk_cracks
kulluk_cracks2
kulluk_cracks3
Kulluk_testingover
Kulluk_testingover2
model_takedown
model_takedown2
motionpak
motionpak_taken_off
qualysis
qualysis_on_kulluk

Appendix F
Spring Verification and Data

The appendix contains:

- The verification of the springs used
- The design criteria for mooring springs
- How to calibrate the springs (check spring constants)

K1 (Spring Numbers 6 - 10)

6						
Weight (g)	Lo (mm)	Lf (mm)	Delta L (mm)	K (KN/m)	Force (N)	Delta L (m)
4208	135	136	1	41.28048	41.28048	0.001
8721	135	151	16	5.347063	85.55301	0.016
12831	135	167	32	3.933503	125.8721	0.032
17070	135	185	50	3.349134	167.4567	0.05
20945	135	200	65	3.161084	205.4705	0.065
					K	2431

7						
Weight (g)	Lo (mm)	Lf (mm)	Delta L (mm)	K (KN/m)	Force (N)	Delta L (m)
4208	135	136	1	41.28048	41.28048	0.001
8721	134	151	17	5.03253	85.55301	0.017
12831	134	167	33	3.814306	125.8721	0.033
17070	134	184	50	3.349134	167.4567	0.05
20945	134	199	65	3.161084	205.4705	0.065
					K	2492.4

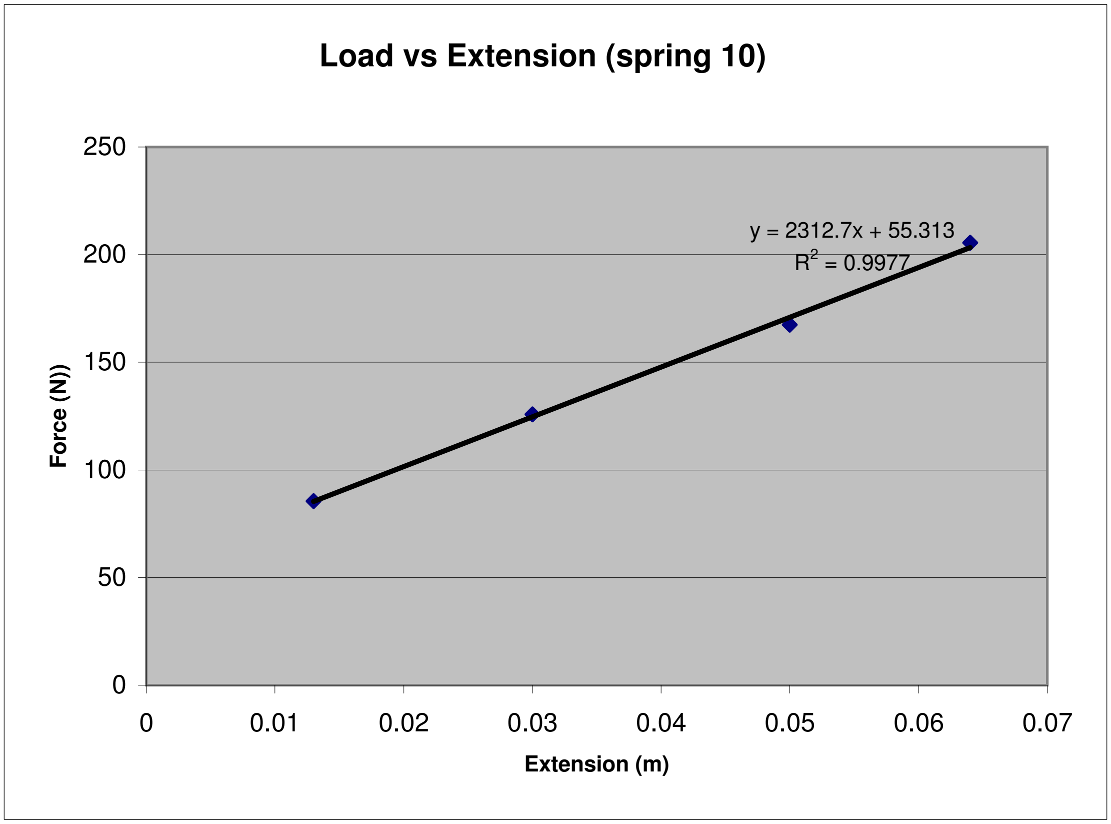
8						
Weight (g)	Lo (mm)	Lf (mm)	Delta L (mm)	K (KN/m)	Force (N)	Delta L (m)
4208	135	136	1	41.28048	41.28048	0.001
8721	136	150	14	6.110929	85.55301	0.014
12831	136	166	30	4.195737	125.8721	0.03
17070	136	186	50	3.349134	167.4567	0.05
20945	136	200	64	3.210476	205.4705	0.064
					K	2353.5

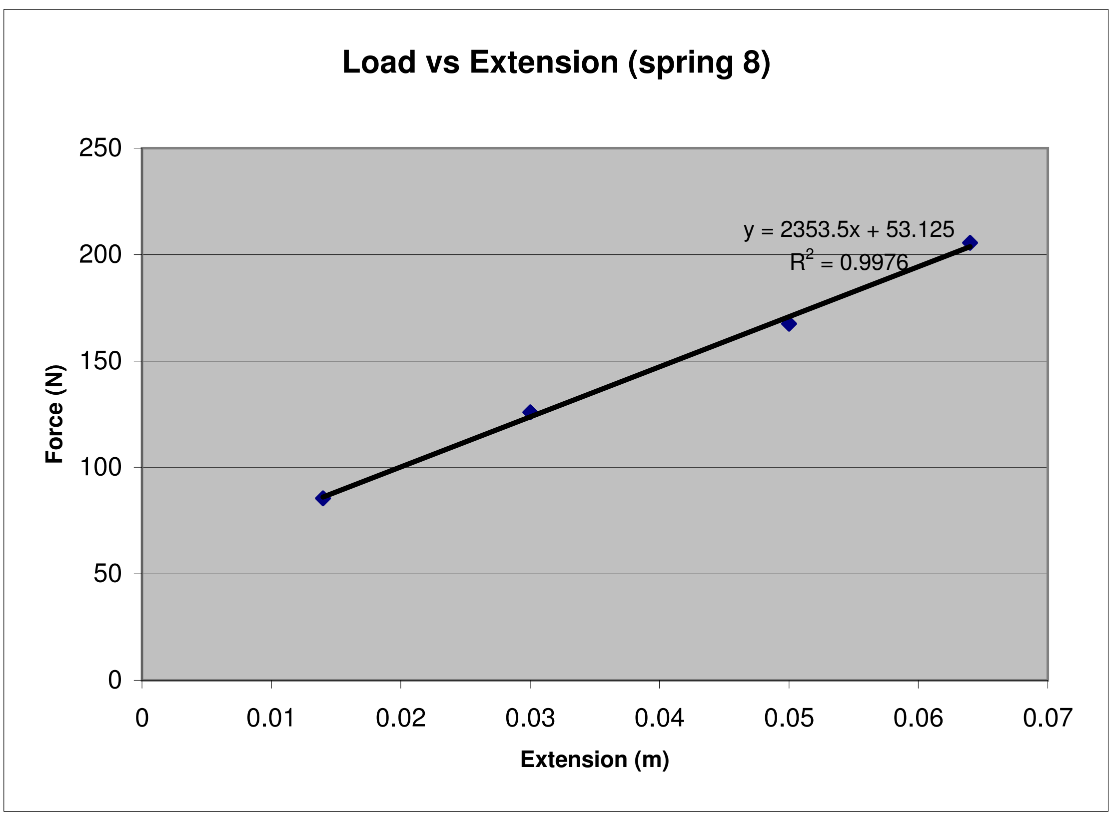
9						
Weight (g)	Lo (mm)	Lf (mm)	Delta L (mm	K (KN/m)	Force (N)	Delta L (m)
4208	135	136	1	41.28048	41.28048	0.001
8721	136	149	13	6.581001	85.55301	0.013
12831	136	165	29	4.340418	125.8721	0.029
17070	136	186	50	3.349134	167.4567	0.05
20945	136	200	64	3.210476	205.4705	0.064
					K	2396.8

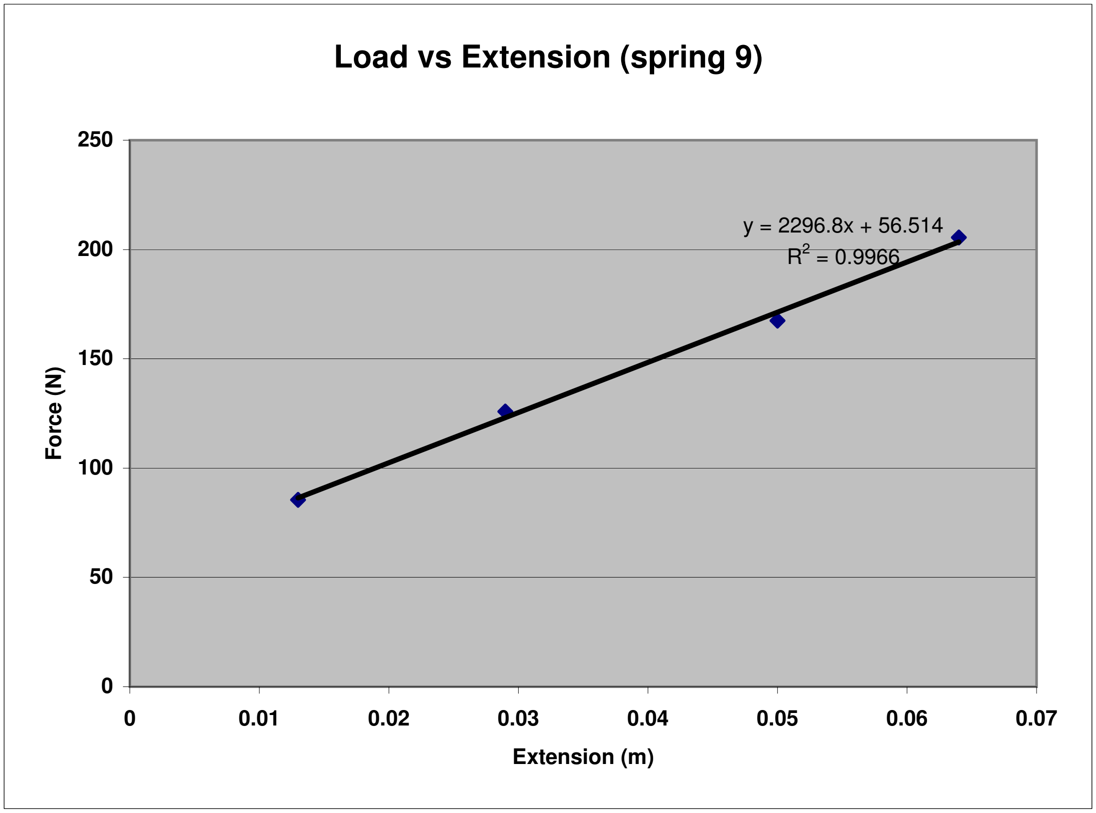
10						
Weight (g)	Lo (mm)	Lf (mm)	Delta L (mm	K (KN/m)	Force (N)	Delta L (m)
4208	135	136	1	41.28048	41.28048	0.001
8721	136	149	13	6.581001	85.55301	0.013
12831	136	166	30	4.195737	125.8721	0.03
17070	136	186	50	3.349134	167.4567	0.05
20945	136	200	64	3.210476	205.4705	0.064
					K	2312.7

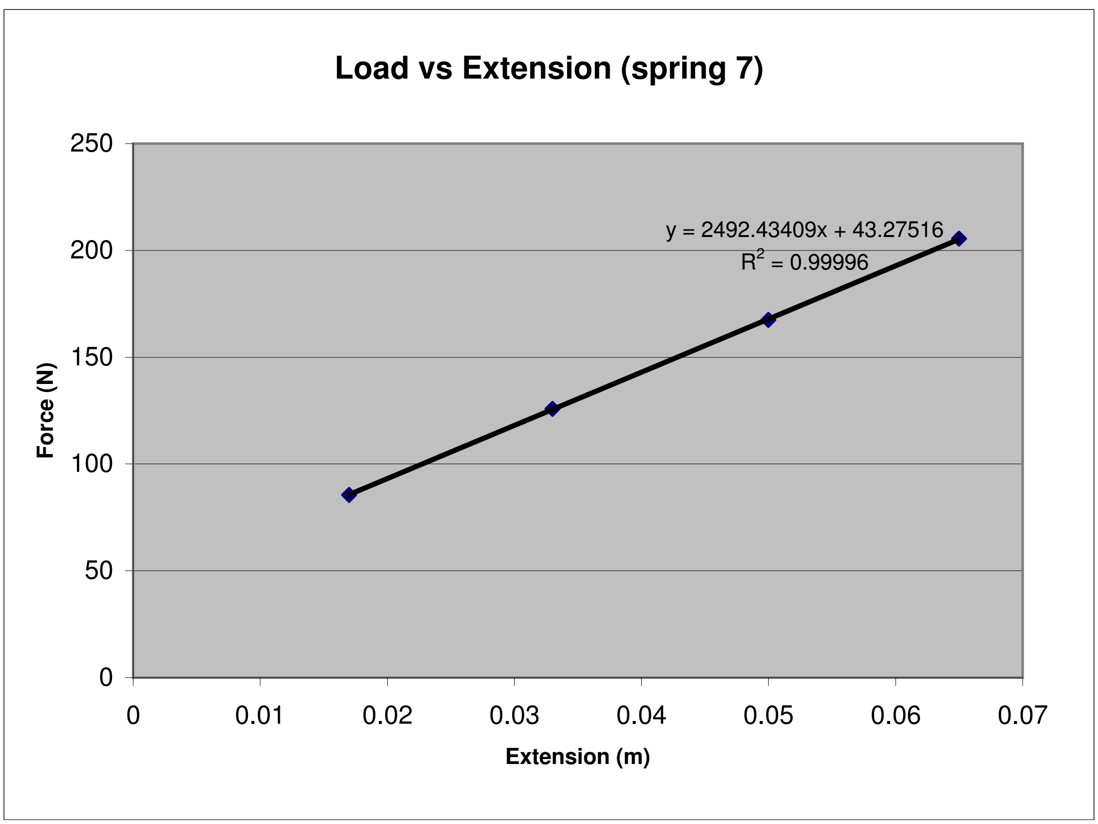
Kave	2397.28

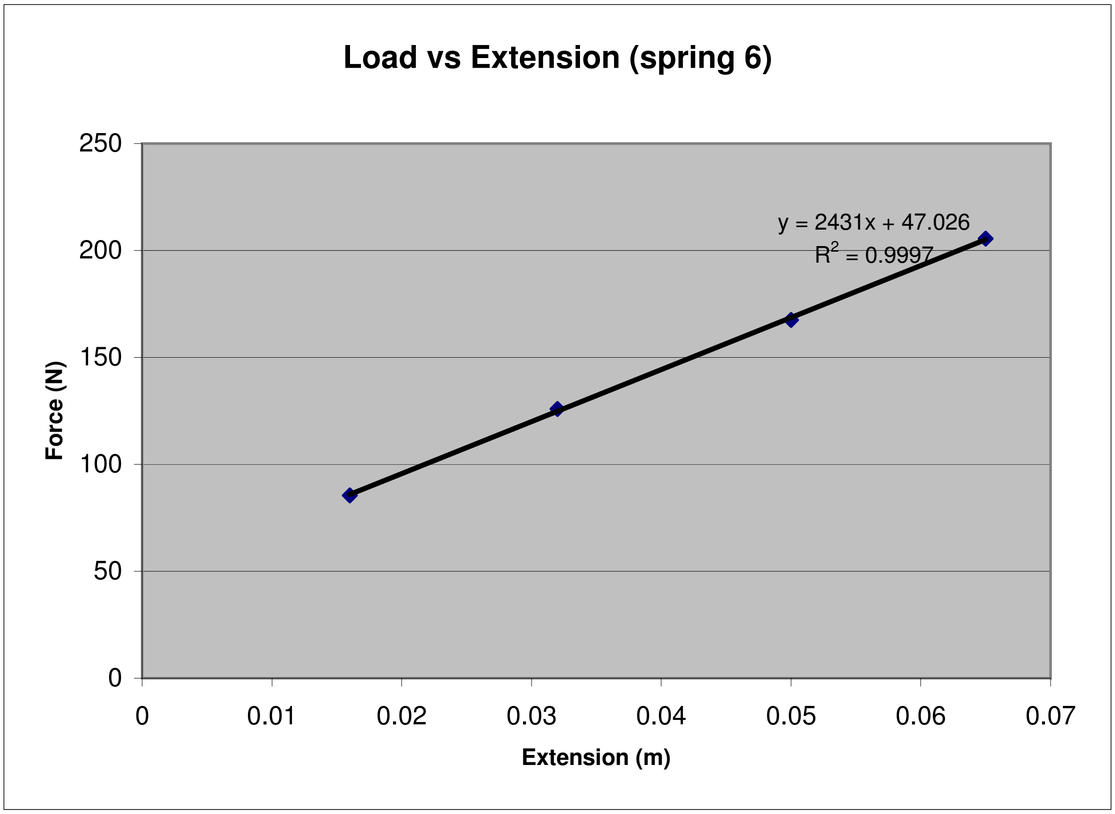
K1 (Spring Numbers 6 - 10)






Load vs Extension (spring 9)
y = 2296.8x + 56.514
R2 = 0.9966
Force (N)
Extension (m)
250
200
150
100
50
0
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07


Load vs Extension (spring 7)
y = 2492.43409x + 43.27516
R2 = 0.99996
Force (N)
Extension (m)
250
200
150
100
50
0
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07


Load vs Extension (spring 6)
y = 2431x + 47.026
R2 = 0.9997
Force (N)
250
200
150
100
50
0
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
Extension (m)

1						
Weight (g)	Lo (mm)	Lf (mm)	Delta L (mm	K (KN/m)	Force (N)	Delta L (m)
4208	113	118	5	8.256096	41.28048	0.005
8482	113	150	37	2.248876	83.20842	0.037
12831	113	187	74	1.700974	125.87211	0.074
17070	113	230	117	1.431254	167.4567	0.117
20945	113	262	149	1.378996	205.47045	0.149
					K	1075.5

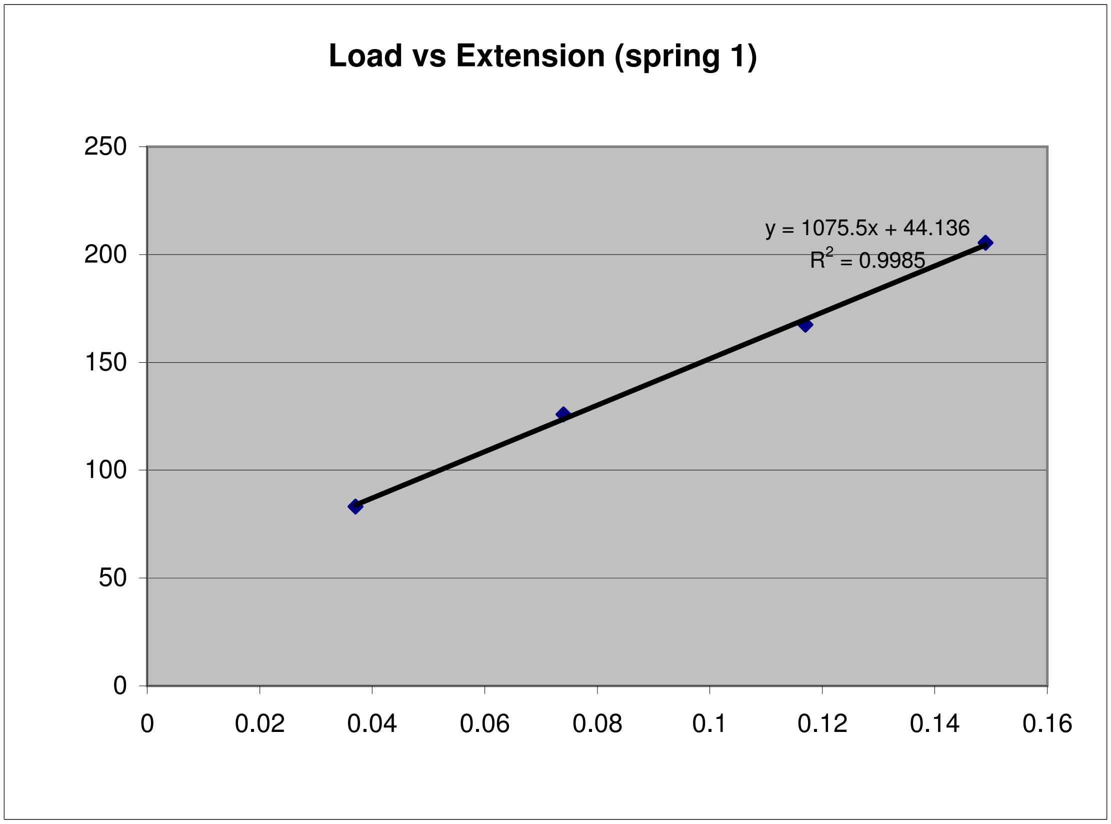
2						
Weight (g)	Lo (mm)	Lf (mm)	Delta L (mm	K (KN/m)	Force (N)	Delta L (m)
4208	113	119	6	6.88008	41.28048	0.006
8482	113	152	39	2.133549	83.20842	0.039
12831	113	190	77	1.634703	125.87211	0.077
17070	113	231	118	1.419125	167.4567	0.118
20945	113	264	151	1.360731	205.47045	0.151
					K	1082.3

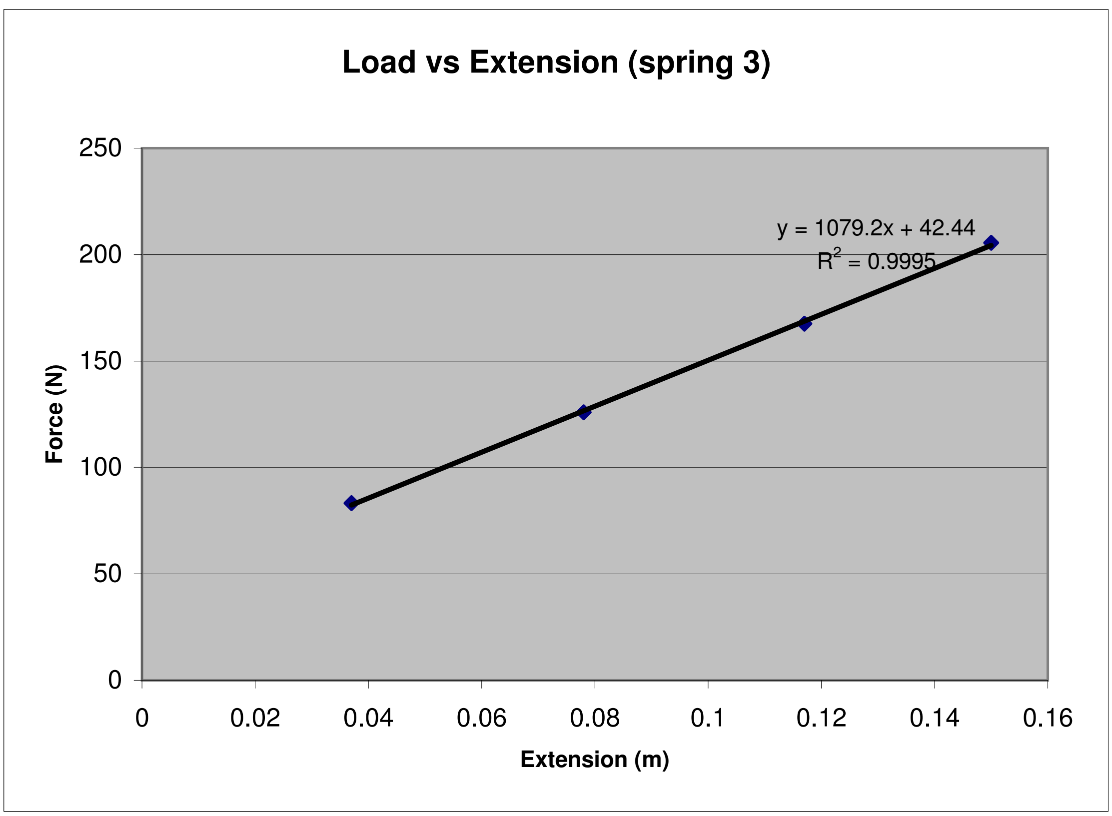
3						
Weight (g)	Lo (mm)	Lf (mm)	Delta L (mm	K (KN/m)	Force (N)	Delta L (m)
4208	113	120	7	5.897211	41.28048	0.007
8482	113	150	37	2.248876	83.20842	0.037
12831	113	191	78	1.613745	125.87211	0.078
17070	113	230	117	1.431254	167.4567	0.117
20945	113	263	150	1.369803	205.47045	0.15
					K	1079.2

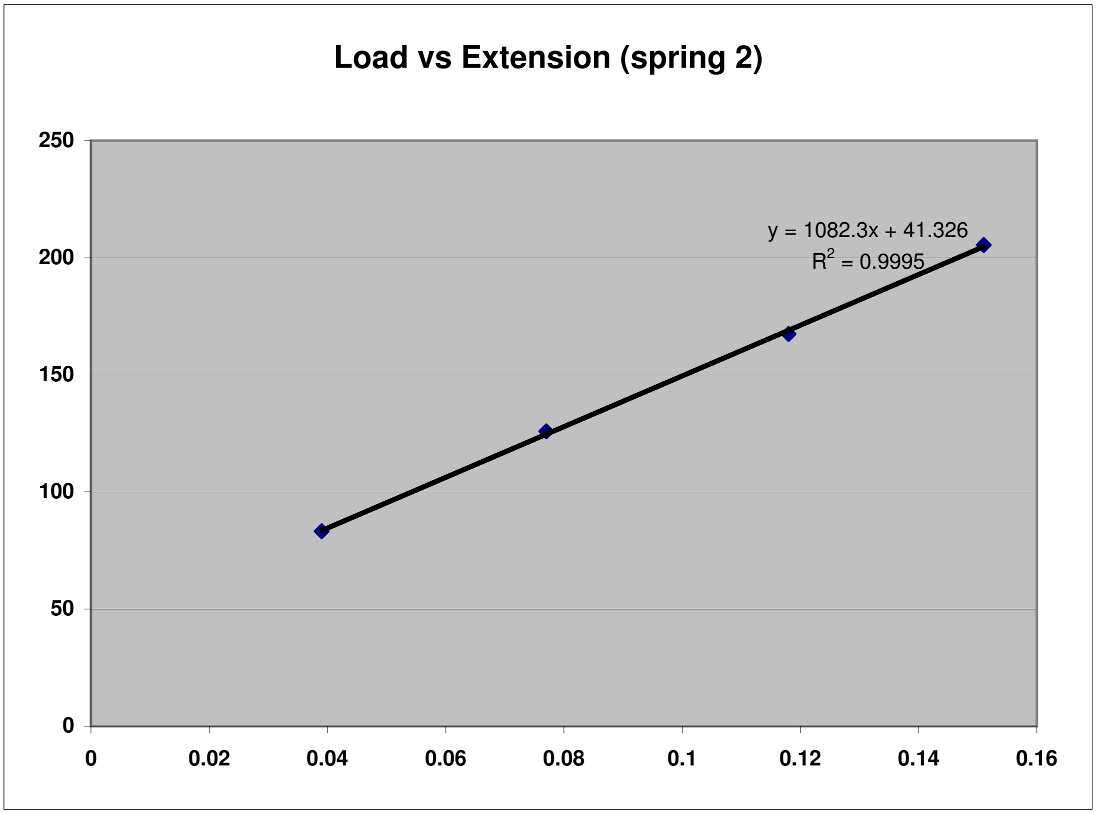
4						
Weight (g)	Lo (mm)	Lf (mm)	Delta L (mm	K (KN/m)	Force (N)	Delta L (m)
4208	113	116	3	13.76016	41.28048	0.003
8482	113	150	37	2.248876216	83.20842	0.037
12831	113	191	78	1.613745	125.8721	0.078
17070	113	230	117	1.431253846	167.4567	0.117
20945	113	263	150	1.369803	205.4705	0.15
					K	1079.2

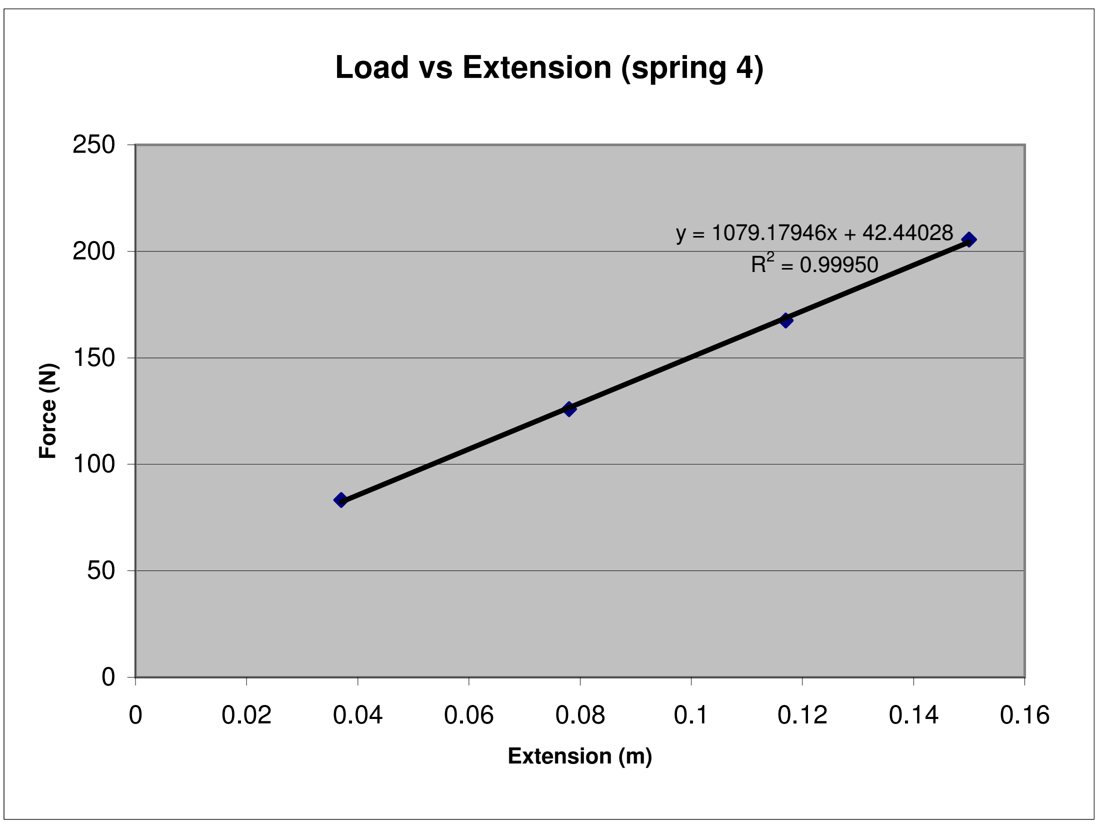
5						
Weight (g)	Lo (mm)	Lf (mm)	Delta L (mm	K (KN/m)	Force (N)	Delta L (m)
4208	113	117	4	10.32012	41.28048	0.004
8482	113	151	38	2.189695263	83.20842	0.038
12831	113	190	77	1.634702727	125.8721	0.077
17070	113	230	117	1.431253846	167.4567	0.117
20945	113	264	151	1.360731457	205.4705	0.151
					K	1077.1

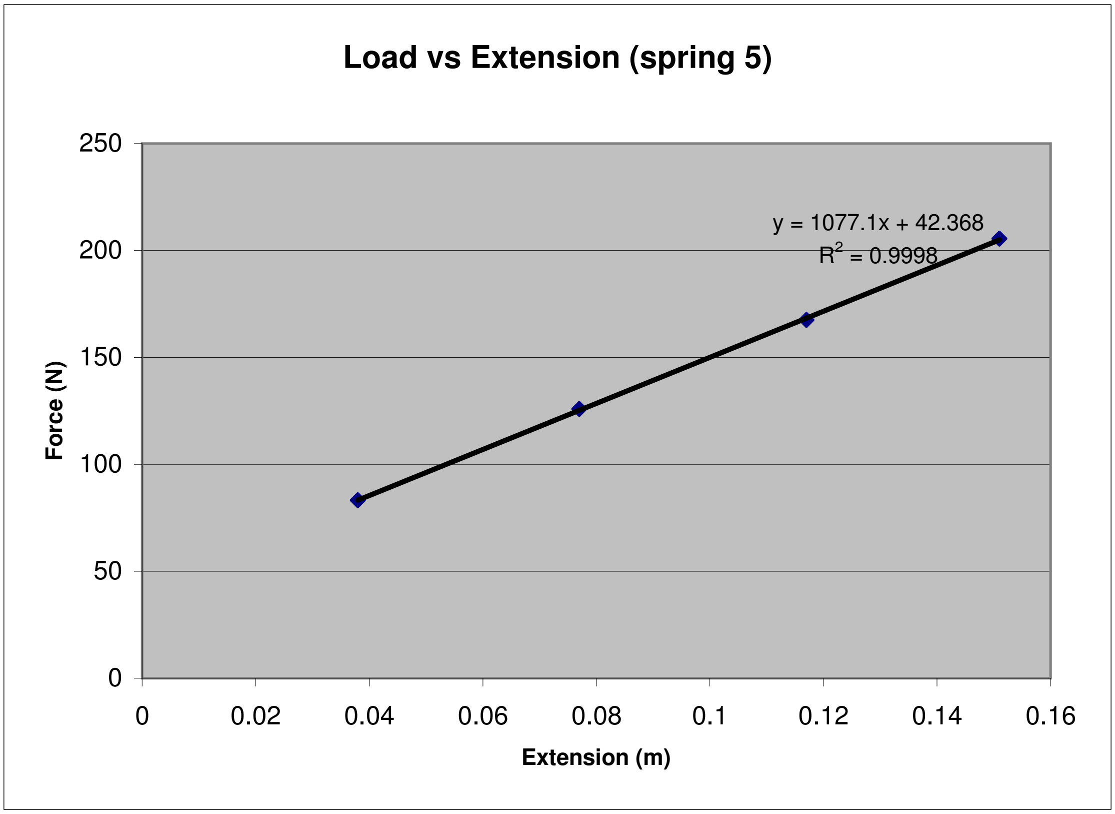
Kave	1078.66


Load vs Extension (spring 1)
y = 1075.5x + 44.136
R2 = 0.9985
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16


Load vs Extension (spring 3)
y = 1079.2x + 42.44
R2 = 0.9995
Force (N)
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
Extension (m)


Load vs Extension (spring 2)
y = 1082.3x + 41.326
R2 = 0.9995
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16


Load vs Extension (spring 4)
y = 1079.17946x + 42.44028
R2 = 0.99950
Force (N)
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
Extension (m)



Load vs Extension (spring 5)
y = 1077.1x + 42.368
R2 = 0.9998
Force (N)
Extension (m)
250
200
150
100
50
0
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16

K3 (Spring Numbers 11 - 15) (Note: Spring 14 is faluty)

11						
Weight (g)	Lo (mm)	Lf (mm)	Delta L (mm	K (KN/m)	Force (N)	Delta L (m)
4208	140	163	23	1.794803	41.28048	0.023
5655	140	185	45	1.23279	55.47555	0.045
9765	140	252	112	0.855309	95.79465	0.112
11220	140	276	136	0.809325	110.0682	0.136
15095	140	340	200	0.74041	148.082	0.2
					K	597.43

12						
Weight (g)	Lo (mm)	Lf (mm)	Delta L (mm	K (KN/m)	Force (N)	Delta L (m)
4208	136	161	25	1.651219	41.28048	0.025
5655	136	181	45	1.23279	55.47555	0.045
9765	136	247	111	0.863015	95.79465	0.111
11220	136	273	137	0.803418	110.0682	0.137
15095	136	336	200	0.74041	148.082	0.2
					K	596.17

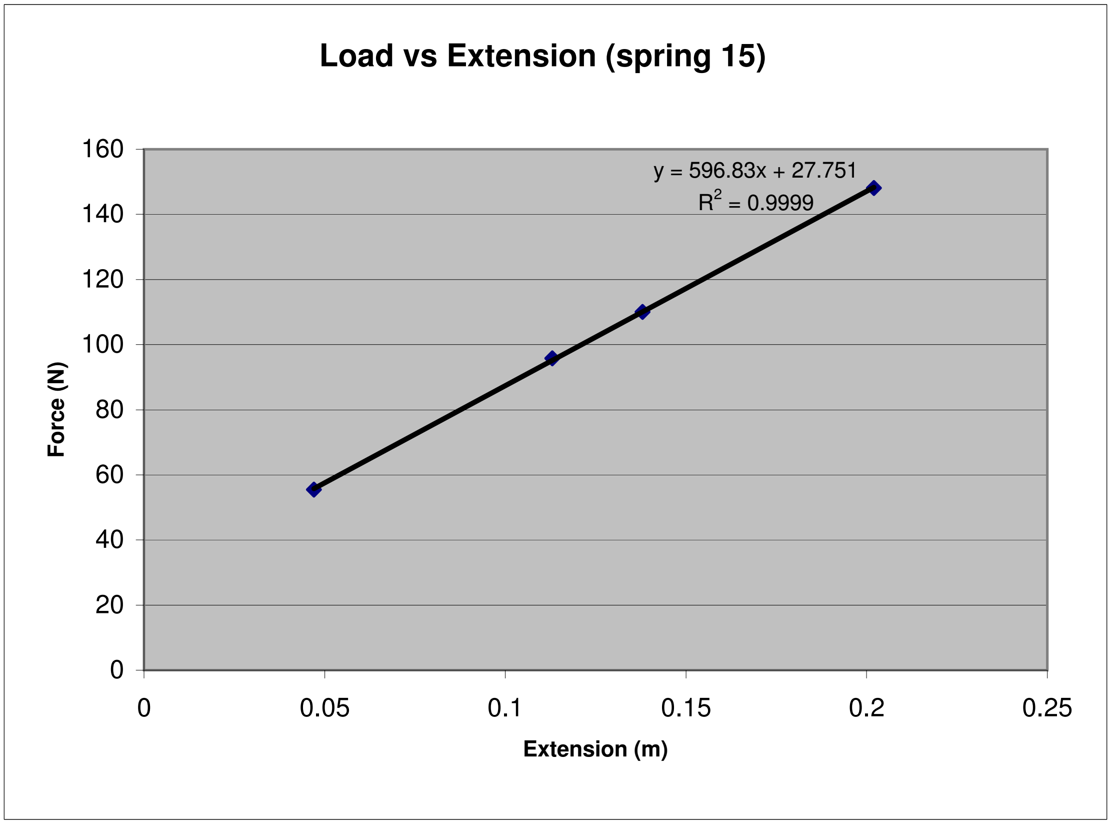
Kave	598.9825

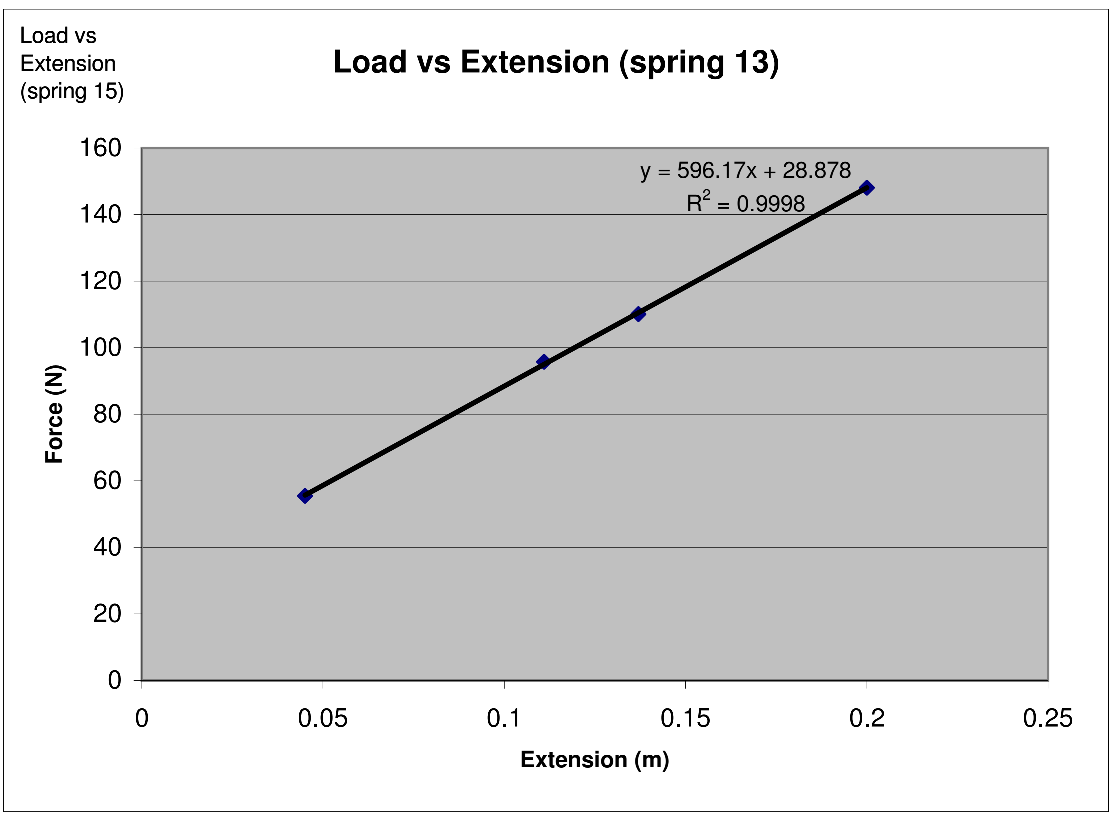
K3 (Spring Numbers 11 - 15) (Note: Spring 14 is faluty)

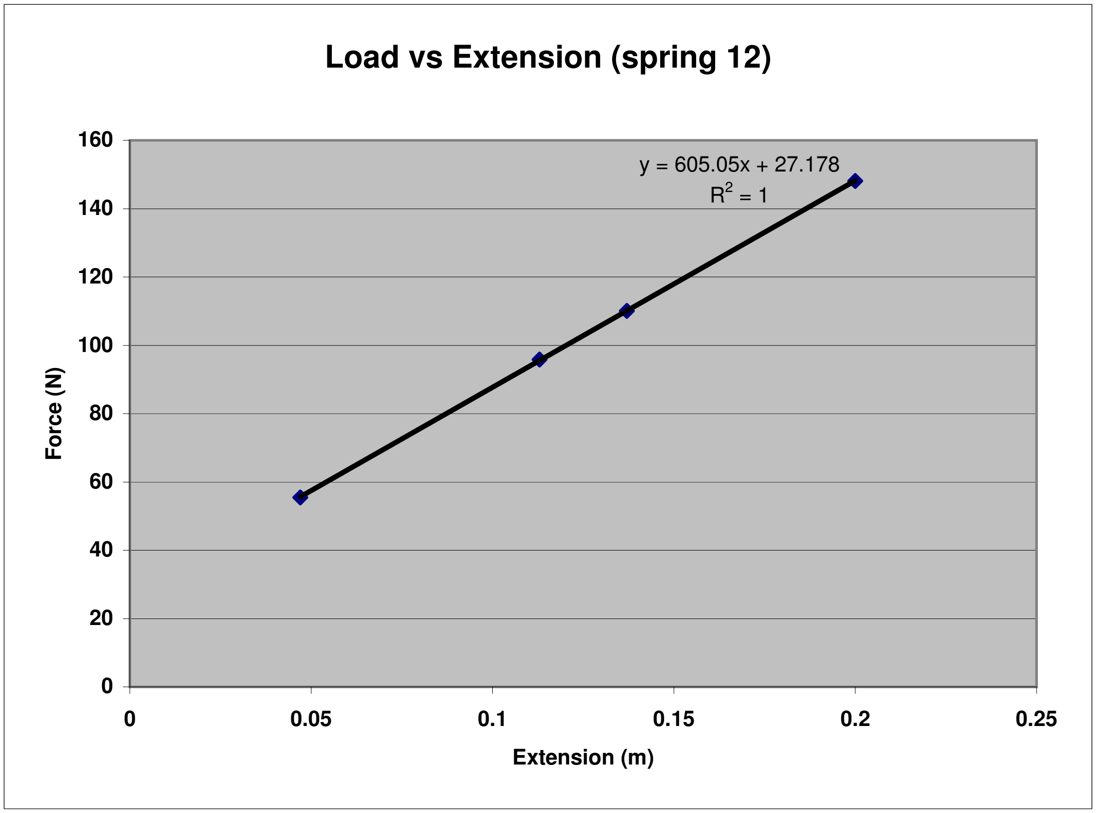
13						
Weight (g)	Lo (mm)	Lf (mm)	Delta L (mm	K (KN/m)	Force (N)	Delta L (m)
4208	136	161	25	1.6512192	41.28048	0.025
5655	136	183	47	1.180330851	55.47555	0.047
9765	136	249	113	0.847740265	95.79465	0.113
11220	136	273	137	0.803417518	110.0682	0.137
15095	136	336	200	0.74040975	148.082	0.2
					K	605.5

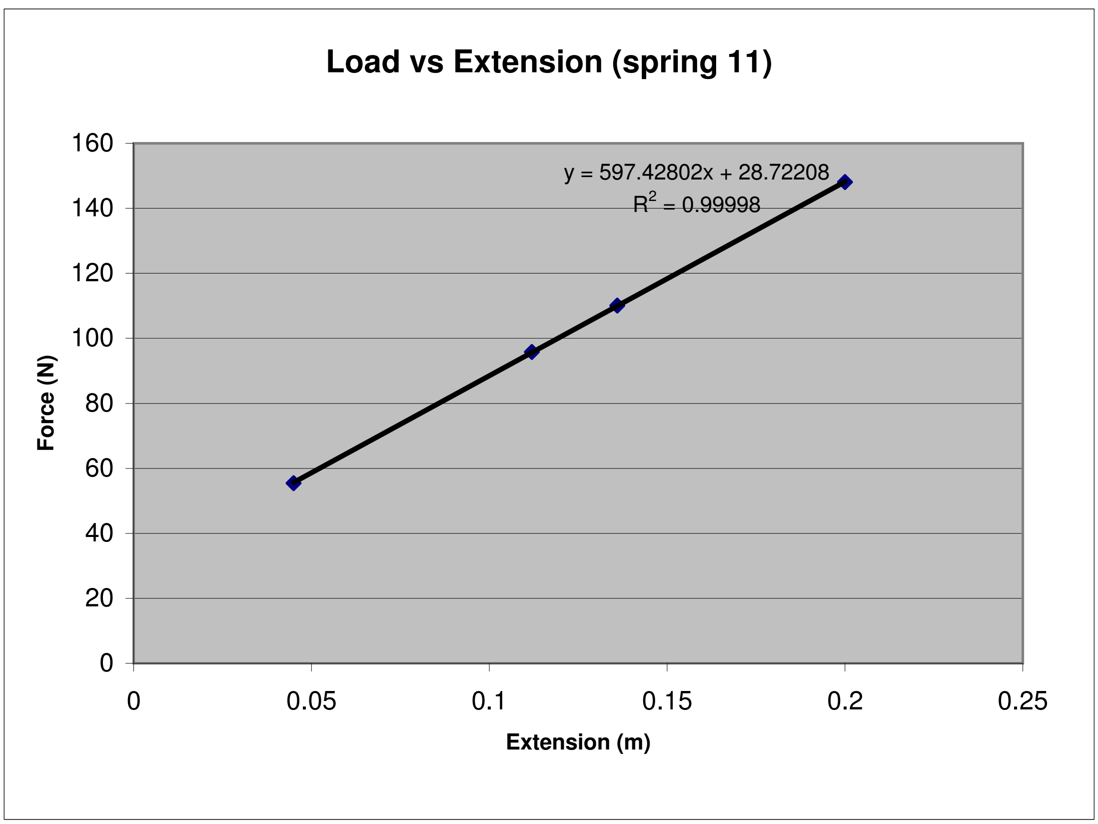
15						
Weight (g)	Lo (mm)	Lf (mm)	Delta L (mm	K (KN/m)	Force (N)	Delta L (m)
4208	140	163	23	1.794803478	41.28048	0.023
5655	140	187	47	1.180330851	55.47555	0.047
9765	140	253	113	0.847740265	95.79465	0.113
11220	140	278	138	0.797595652	110.0682	0.138
15095	140	342	202	0.73307896	148.082	0.202
					K	596.83

Note : Spring Number 14 was faulty

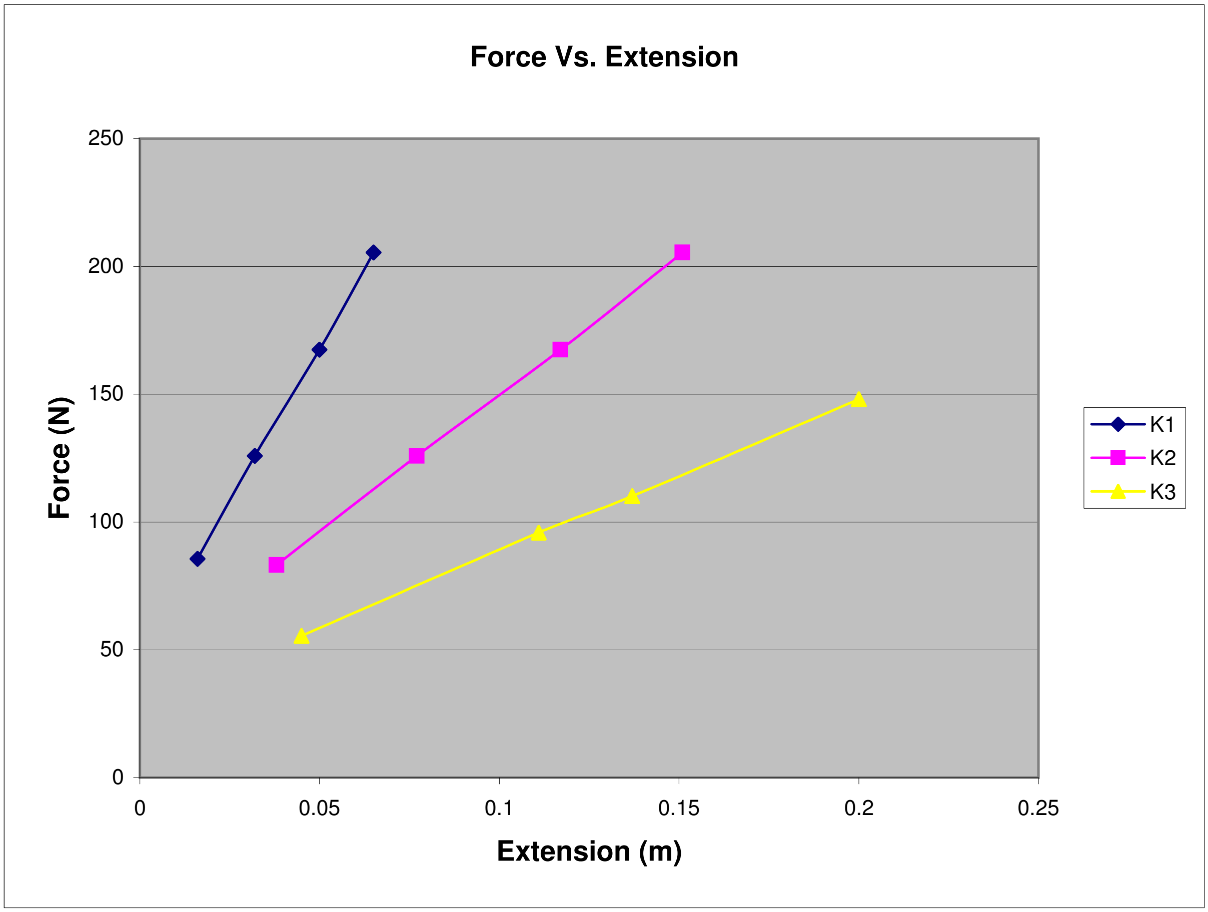

Load vs Extension (spring 15)
y = 596.83x + 27.751
R2 = 0.9999
Force (N)
Extension (m)
0
20
40
60
80
100
120
140
160
0
0.05
0.1
0.15
0.2
0.25


Load vs Extension (spring 15)
Load vs Extension (spring 13)
y = 596.17x + 28.878
R2 = 0.9998
Force (N)
Extension (m)
0
20
40
60
80
100
120
140
160
0
0.05
0.1
0.15
0.2
0.25


Load vs Extension (spring 12)
y = 605.05x + 27.178
R2 = 1
Force (N)
Extension (m)
160
140
120
100
80
60
40
20
0
0
0.05
0.1
0.15
0.2
0.25


Load vs Extension (spring 11)
y = 597.42802x + 28.72208
R2 = 0.99998
Force (N)
Extension (m)
160
140
120
100
80
60
40
20
0
0
0.05
0.1
0.15
0.2
0.25

F


Force Vs. Extension
250
200
150
100
50
0
Force (N)
0
0.05
0.1
0.15
0.2
0.25
Extension (m)
K1
K2
K3

Design Criteria for Soft mooring springs in Ice Tank

GLOBAL LOAD 4 Kn/m

Line Stiffness estimated 4 lines @ 45deg 4 kn/m / 2 = 2 Kn/m

Angle 0f 50deg

4 / 4 cos^2 (50) = 2.42 kn/m = 13.82 lbs/in

1st Design Load

2.42 Kn/m = 13.82 lbs/in
Excursion 35mm = 1.38 in

Spring selected Stock # 81176 $34.64US Each
Stiffness 14 lbs/in, length 8”, **min preload 10lbs**, max deflection 7.8in, max load 114 lbs, wire diameter .177in

2nd Design Load

1.21 Kn/m = 6.91 lbs/in
Excursion 70mm = 2.76 in

Spring selected Stock # 81166 $24.85Each
Stiffness 6.8 lbs/in, length 7
”, **min preload 6lbs**, max deflection 9.5in, max load 70 lbs, wire diameter .148in

3rd Design Load

.61 Kn/m = 3.46 lbs/in
Excursion 140mm = 5.52 in

Spring selected Stock # 81144 $23.09 Each
Stiffness 3.5 lbs/in, length 7.5”, **min preload 4lbs**, max deflection 13in, max load 51 lbs, wire diameter .125in

150mm global excursion = 2.704” change in spring length.

300mm global excursion = 6.370” change in spring length
Total cost $400.00 US plus Shipping

Calibration of Springs

To calibrate a spring (verify the spring constant), the follow must be done:

1. The spring is to be hung from a higher surface and left to hang. The distance from the top of the spring to the bottom of the spring is to be recorded as L_o.
2. A weight is to be hung from the spring; the new distance from the top of the spring to the bottom of the spring is to be recorded as L_f.
3. To find the value of the spring constant (k) we use the formula:
   k (N/m) = F (N)/ΔL (m) where:
      i. F is the force of the weight that is hung
      ii. ΔL is the difference between the distances
      iii. k is the spring constant

Appendix G
Decay Data

This appendix contains:

- The Damping data for decays
- Period and Offset data for decays

Decay Test Data Set 1

Test Name	Motion Pack				
	Damping			Mean	
	Linear	Equivalent B1	Equivalent B2	Offset	Period
DECAY_K1_H_012	0.07771	-0.001264	0.9651	-9.816	10.69
DECAY_K1_H_013	0.02305	-0.1071	2.206	-9.815	8.827
DECAY_K1_H_014	0.06678	-0.04258	0.731	-9.811	9.571
DECAY_K1_H_073	0.1813	0.1615	0.9919	-1	9.756
DECAY_K1_P_004	0.05531	0.03416	0.004799	0.02981	1.398
DECAY_K1_P_005	0.08996	0.09605	-0.001678	0.02673	1.351
DECAY_K1_P_006	0.07765	0.05195	0.003052	-0.1765	1.572
DECAY_K1_P_007	0.1007	0.09536	0.0006017	0.03178	1.333
DECAY_K1_P_008	0.09506	0.09421	0.00007933	0.0547	1.386
DECAY_K1_P_072	0.05689	0.03974	0.006205	-0.04432	1.396
DECAY_K1_R_009	0.07006	0.06359	0.008775	-0.00559	9.128
DECAY_K1_R_010	0.05715	0.03619	0.02988	-0.007912	9.082
DECAY_K1_R_011	0.09821	0.0972	0.0007764	-0.002638	9.208
DECAY_K1_R_071	0.03492	0.0392	-0.00645	-0.01969	9.308
DECAY_K2_H_115	0.1212	0.0471	6.118	-0.9994	8.707
DECAY_K2_P_114	0.04015	0.02654	0.004928	-0.01236	1.343
DECAY_K2_R_113	0.05705	0.06932	-0.02176	-0.006875	8.841
DECAY_K3_H_251	0.2104	0.2451	-1.67	-1	9.709
DECAY_K3_P_249	0.1127	0.1739	-0.01484	-0.07383	1.365
DECAY_K3_R_250	0.06078	0.02743	0.03251	0.1615	9.02
PS20_DECAY_K3_H_205	0.1487	0.07146	6.029	-0.999	8.417
PS20_DECAY_K3_H_V0P01_204	0.1517	0.08332	5.07	-1	9.15
PS20_DECAY_K3_H_V0P2_198	0.1925	0.1531	2.899	-1	8.833
PS20_DECAY_K3_P_201	0.1417	0.1652	-0.006509	0.04112	1.331
PS20_DECAY_K3_P_V0P01_200	0.2128	0.2573	-0.01884	0.001999	1.321
PS20_DECAY_K3_P_V0P2_196	0.1147	0.08214	0.00912	0.1164	1.261
PS20_DECAY_K3_R_203	0.1213	0.1147	0.009246	0.1435	8.243
PS20_DECAY_K3_R_V0P01_202	0.1409	0.1475	-0.009389	0.1398	8.087
PS20_DECAY_K3_R_V0P2_197	0.1214	0.1269	-0.00995	0.1551	8.221
PS20_DECAY_K3_S_V0P2_199					
PS30_DECAY_K3_H_0P01_174	0.08572	0.01568	8.127	-0.9998	8.33
PS30_DECAY_K3_H_175	0.09583	0.03978	6	-0.9999	9.609
PS30_DECAY_K3_H_176	0.1654	0.1047	5.713	-1	8.674
PS30_DECAY_K3_H_V0P2_168	0.1197	0.008728	11.82	-0.9997	8.647
PS30_DECAY_K3_P_171	0.1162	0.1308	-0.007211	0.02827	1.334
PS30_DECAY_K3_P_V0P01_170	0.04629	0.002138	0.01142	-0.03606	1.38
PS30_DECAY_K3_P_V0P2_166	0.117	0.06785	0.02983	0.09556	1.235
PS30_DECAY_K3_R_173	0.09255	0.0751	0.01978	0.1507	8.59
PS30_DECAY_K3_R_V0P01_172	0.101	0.09159	0.01412	0.152	8.388
PS30_DECAY_K3_R_V0P2_167	0.1645	0.1759	-0.01425	0.1617	8.349
PS30_DECAY_K3_S_V0P2_169					
PS40_DECAY_K2_H_V0P01_152	0.1423	-0.009561	33.48	-0.9998	8.628
PS40_DECAY_K2_H_V0P2_147					
PS40_DECAY_K2_P_149					
PS40_DECAY_K2_P_V0P01_148	0.2983	0.484	-0.05455	0.2988	1.202
PS40_DECAY_K2_P_V0P2_145	0.1382	0.02192	0.03656	-0.2539	1337
PS40_DECAY_K2_R_151	0.1973	0.1397	0.1707	0.1565	10.64
PS40_DECAY_K2_R_V0P01_150	0.1307	0.07316	0.1619	0.1534	10.47
PS40_DECAY_K2_R_V0P2_146	0.04639	-0.1611	0.7158	0.1243	6.99

Decay Test Data Set 1

Test Name	Motion Pack				
	Damping			Mean	
	Linear	Equivalent B1	Equivalent B2	Offset	Period
PS40_DECAY_K2_S_V0P2_154	0.1013	-4.15	268.4	-0.001549	15.17
PS40_DECAY_K3_H_234	0.2961	0.35	-4.88	-0.9995	12.36
PS40_DECAY_K3_H_V0P01_233	0.09103	-0.2822	150.8	-1	6.729
PS40_DECAY_K3_H_V0P2_227	0.1576	0.233	-3.301	-1.001	9.351
PS40_DECAY_K3_P_230	0.1782	0.2105	-0.005584	0.1244	1.323
PS40_DECAY_K3_P_V0P01_229	0.2542	0.4291	-0.03486	0.0325	1.406
PS40_DECAY_K3_P_V0P2_225	0.1484	0.5854	-0.1608	-0.4858	1.078
PS40_DECAY_K3_R_232	0.1382	0.05924	0.2954	0.1515	10.78
PS40_DECAY_K3_R_V0P01_231	0.15	0.1228	0.04339	0.1503	10.5
PS40_DECAY_K3_R_V0P2_226	0.1118	-0.05372	0.505	0.1788	7.163
PS40_DECAY_K3_S_V0P2_228	-0.07041	-0.5393	53.57	-0.000275	7.713
OW_K1_V0P3_017	0.06368	0.02975	0.6409	-0.02238	14.42
OW_K1_V0P3_021					
OW_K1_V0P3_053					
OW_K2_V0P3_112					
OW_K3_V0P3_248	0.07576	0.08179	-0.6325	-0.002702	28.15
PS10_K1_VH_046					
PS10_K1_VH_047	0.03771	-0.01283	2.018	0.02087	14.78
PS20_K1_VH_058					
PS20_K2_VH_095					
PS20_K3_VH_191					
PS30_K1_VH_033					
PS30_K2_VH_123	0.1808	0.05379	14.49	-0.000712	17.5
PS30_K3_VH_161					
PS40_K1_VH_077					
PS40_K2_VH_141					
PS40_K3_VH_220					
OW_K2_VL_111	0.09196	0.1317	-5.59	-0.000185	21.33

Means Insufficent data

Data not avaible for this run

Decay Test Data Set 1

Test Name	Qualysis				
	Damping			Mean	
	Linear	Equivalent B1	Equivalent B	Offset	Period
DECAY_K1_H_012	0.09831	-0.02383	0.000417	14.36	12.21
DECAY_K1_H_013	0.07617	-0.032	0.001134	-11.27	5.475
DECAY_K1_H_014	0.04771	-0.1517	0.000665	-7.723	9.807
DECAY_K1_H_073	0.02814	-0.1789	0.002551	-15.15	7.066
DECAY_K1_P_004	0.06624	0.04936	0.000275	0.5731	1.398
DECAY_K1_P_005	0.08069	0.09198	-0.000182	-2.438	1.405
DECAY_K1_P_006	0.08947	0.09816	-6.16E-05	3.592	1.535
DECAY_K1_P_007	0.09165	0.06566	0.000262	2.864	1.345
DECAY_K1_P_008	0.1042	0.1196	-0.000115	-1.881	1.399
DECAY_K1_P_072	0.06272	0.05021	0.000277	6.225	1.39
DECAY_K1_R_009	0.05296	0.005918	0.000462	-14.32	8.875
DECAY_K1_R_010	0.0765	0.03632	0.000342	-0.4699	9.008
DECAY_K1_R_011	0.08219	0.0401	0.000271	-11.25	9.139
DECAY_K1_R_071	0.06072	0.03249	0.00027	10.6	9.118
DECAY_K2_H_115	0.09882	-0.1114	0.001639	153.6	7.74
DECAY_K2_P_114	0.03906	0.01913	0.000535	4.311	1.331
DECAY_K2_R_113	0.07986	0.07787	2.36E-05	11.57	8.638
DECAY_K3_H_251	0.141	0.09916	0.000181	336.8	9.624
DECAY_K3_P_249	0.04918	-0.04508	0.002592	3.776	1.194
DECAY_K3_R_250	0.06729	0.03393	0.000327	15.15	9.009
PS20_DECAY_K3_H_205	0.09448	-0.1106	0.001669	-205	8.804
PS20_DECAY_K3_H_V0P01_204	0.06478	-0.02887	0.000489	-165.6	9.494
PS20_DECAY_K3_H_V0P2_198	0.107	-0.007642	0.000544	-182.9	8.565
PS20_DECAY_K3_P_201	0.09379	0.0549	0.001342	12.63	1.078
PS20_DECAY_K3_P_V0P01_200	0.05372	-0.04126	0.007158	1.303	0.8632
PS20_DECAY_K3_P_V0P2_196	0.1234	0.1691	-0.001048	16.33	1.239
PS20_DECAY_K3_R_203	0.0815	0.03944	0.000745	18.84	8.389
PS20_DECAY_K3_R_V0P01_202	0.07152	0.03223	0.000847	6.775	6.73
PS20_DECAY_K3_R_V0P2_197	0.1258	0.1468	-0.000313	13.05	8.744
PS20_DECAY_K3_S_V0P2_199	0.08069	0.01923	4.48E-05	-3801	29.14
PS30_DECAY_K3_H_0P01_174	0.1512	0.2497	-0.000727	32.81	13.2
PS30_DECAY_K3_H_175	0.1028	0.02786	0.000298	-19.44	9.278
PS30_DECAY_K3_H_176	0.1855	0.112	0.000286	-94.62	12.12
PS30_DECAY_K3_H_V0P2_168	0.203	0.1049	0.000323	-125.3	14.25
PS30_DECAY_K3_P_171	0.1091	0.1156	-0.000137	9.034	1.383
PS30_DECAY_K3_P_V0P01_170	0.1309	0.2179	-0.001404	11.27	1.32
PS30_DECAY_K3_P_V0P2_166	0.1048	0.02385	0.003769	20.28	1.238
PS30_DECAY_K3_R_173	0.09613	0.07111	0.000246	12.35	8.711
PS30_DECAY_K3_R_V0P01_172	0.1038	0.09246	0.000138	11.06	8.412
PS30_DECAY_K3_R_V0P2_167	0.1645	0.1759	-0.01425	0.1617	8.349
PS30_DECAY_K3_S_V0P2_169	0.07326	-0.2021	0.000104	-4050	32.87
PS40_DECAY_K2_H_V0P01_152					
PS40_DECAY_K2_H_V0P2_147					
PS40_DECAY_K2_P_149					
PS40_DECAY_K2_P_V0P01_148					
PS40_DECAY_K2_P_V0P2_145	0.001764	-0.2029	0.1423	5.037	0.09668
PS40_DECAY_K2_R_151					
PS40_DECAY_K2_R_V0P01_150					
PS40_DECAY_K2_R_V0P2_146					

Decay Test Data Set 1

Test Name	Qualysis				
	Damping			Mean	
	Linear	Equivalent B1	Equivalent B	Offset	Period
PS40_DECAY_K2_S_V0P2_154					
PS40_DECAY_K3_H_234	0.149	0.06267	0.000478	173.3	8.308
PS40_DECAY_K3_H_V0P01_233	0.1289	0.03245	0.000801	123.2	15.68
PS40_DECAY_K3_H_V0P2_227	0.08291	-0.06707	0.000945	122.6	11.1
PS40_DECAY_K3_P_230	0.2007	0.1871	0.000183	5.522	1.275
PS40_DECAY_K3_P_V0P01_229	0.1051	0.0388	0.002228	5.579	0.9696
PS40_DECAY_K3_P_V0P2_225	-0.004112	-0.3029	0.01166	-23.58	1.296
PS40_DECAY_K3_R_232	0.1476	0.06101	0.0022	20.02	10.97
PS40_DECAY_K3_R_V0P01_231	0.1388	0.1054	0.000652	19.04	10.23
PS40_DECAY_K3_R_V0P2_226	0.07263	-0.1054	0.005225	14.16	7.439
PS40_DECAY_K3_S_V0P2_228					
OW_K1_V0P3_017	0.0467	-0.005248	0.000211	-4163	14.61
OW_K1_V0P3_021	0.1056	0.1568	-0.000218	-4846	14.82
OW_K1_V0P3_053	0.07685	0.09864	-7.94E-05	104.9	15.3
OW_K2_V0P3_112					
OW_K3_V0P3_248	0.1042	0.157	-4.02E-05	-2602	27.85
PS10_K1_VH_046					
PS10_K1_VH_047	0.04163	0.03122	7.41E-05	73.25	14.63
PS20_K1_VH_058					
PS20_K2_VH_095	0.01555	-0.1567	0.000307	-1915	21.36
PS20_K3_VH_191	0.0572	-0.346	0.000727	-2364	24.34
PS30_K1_VH_033					
PS30_K2_VH_123					
PS30_K3_VH_161					
PS40_K1_VH_077					
PS40_K2_VH_141					
PS40_K3_VH_220	-0.01237	-0.5159	0.000249	-6054	32.41
OW_K2_VL_111	0.09427	0.1375	-6.52E-05	-1335	21.85

Means Insufficent data

Data not avaible for this run

Decay Test Data Set 2

Test Name	Motion Pack: Damping: Linear	Motion Pack: Damping: Equivalent B1	Motion Pack: Damping: Equivalent B2	Motion Pack: Mean: Offset	Motion Pack: Mean: Period
DECAY_K1_H_012	0.05793	-0.05899	1.162	-9.815	12.22
DECAY_K1_H_013	0.1302	0.05079	0.5535	-9.813	8.956
DECAY_K1_H_014	0.08331	-0.04417	0.7381	-9.811	9.421
DECAY_K1_H_073	0.158	0.1135	2.637	-1.001	9.84
DECAY_K1_P_004	0.07957	0.08023	-0.00008454	0.03779	1.39
DECAY_K1_P_005	0.07374	0.04768	0.002896	0.04576	1.366
DECAY_K1_P_006	0.09521	0.09338	0.0001111	-0.09398	1.427
DECAY_K1_P_007	0.08799	0.0783	0.00078	-0.010921	1.436
DECAY_K1_P_008	0.0976	0.105	-0.0005555	0.04717	1.38
DECAY_K1_P_072	0.0697	0.0828	-0.00218	-0.04033	1.385
DECAY_K1_R_009	0.07516	0.0624	0.009898	-0.01563	8.974
DECAY_K1_R_010	0.05832	0.02161	0.03044	-0.003907	9.025
DECAY_K1_R_011	0.09396	0.09485	-0.0005228	0.01876	9.125
DECAY_K1_R_071	0.02405	-0.02929	0.07348	-0.04623	9.042
DECAY_K2_H_115	0.1186	0.09206	1.206	-0.9993	9.179
DECAY_K2_P_114	0.03825	-0.0008999	0.01009	-0.02308	1.34
DECAY_K2_R_113	0.0662	0.08417	-0.04077	0.000295	8.708
DECAY_K3_H_251	0.112	0.02689	4.651	-1	8.881
DECAY_K3_P_249	0.1127	0.1739	-0.001157	-3.456	1.546
DECAY_K3_R_250	0.08791	0.04398	0.02788	0.1565	9.247
PS20_DECAY_K3_H_205	0.08572	-0.005484	8.375	-0.9999	9.041
PS20_DECAY_K3_H_V0P01_204	0.09913	0.02811	6.509	-0.9999	9.102
PS20_DECAY_K3_H_V0P2_198					
PS20_DECAY_K3_P_201	0.1365	0.1622	-0.006557	0.08837	1.352
PS20_DECAY_K3_P_V0P01_200	0.1625	0.2225	-0.01506	0.115	1.349
PS20_DECAY_K3_P_V0P2_196	0.121	0.2232	-0.02108	-0.1915	1.274
PS20_DECAY_K3_R_203	0.1384	0.1827	-0.0474	0.1585	8.774
PS20_DECAY_K3_R_V0P01_202	0.1525	0.2095	-0.06102	0.1556	8.791
PS20_DECAY_K3_R_V0P2_197	0.117	0.1218	-0.005539	0.1603	8.638
PS20_DECAY_K3_S_V0P2_199					
PS30_DECAY_K3_H_0P01_174	0.1925	0.1531	2.899	-1	8.833
PS30_DECAY_K3_H_175	0.1575	0.09926	4.056	-1	8.978
PS30_DECAY_K3_H_176	0.1614	0.08163	6.924	-1	9.157
PS30_DECAY_K3_H_V0P2_168					
PS30_DECAY_K3_P_171	0.1166	0.1327	-0.004354	0.03255	1.352
PS30_DECAY_K3_P_V0P01_170	0.1056	0.1188	-0.002364	-0.001122	1.336
PS30_DECAY_K3_P_V0P2_166	0.1353	0.05049	0.03516	-0.01608	1.357
PS30_DECAY_K3_R_173	0.07068	0.04211	0.03076	0.1497	8.751
PS30_DECAY_K3_R_V0P01_172	0.1082	0.1011	0.007407	0.1482	8.416
PS30_DECAY_K3_R_V0P2_167	0.1648	0.1788	-0.01469	0.1615	8.347
PS30_DECAY_K3_S_V0P2_169	-0.08695	-0.6016	266	0.006347	8.677
PS40_DECAY_K2_H_V0P01_152	0.162	0.09188	7.041	-1	8.665
PS40_DECAY_K2_H_V0P2_147	0.1631	0.06841	4.763	-1.001	8.821
PS40_DECAY_K2_P_149					
PS40_DECAY_K2_P_V0P01_148					
PS40_DECAY_K2_P_V0P2_145					
PS40_DECAY_K2_R_151	0.2043	0.1709	0.0732	0.164	10.81
PS40_DECAY_K2_R_V0P01_150	0.1527	0.1122	0.1002	0.1479	10.7
PS40_DECAY_K2_R_V0P2_146	0.1358	0.1198	0.01762	0.1733	9.469

Decay Test Data Set 2

Test Name	Motion Pack				
	Damping			Mean	
	Linear	Equivalent B1	Equivalent B2	Offset	Period
PS40_DECAY_K2_S_V0P2_154					
PS40_DECAY_K3_H_234					
PS40_DECAY_K3_H_V0P01_233					
PS40_DECAY_K3_H_V0P2_227					
PS40_DECAY_K3_P_230	0.1701	0.2066	-0.005483	-0.001082	1.33
PS40_DECAY_K3_P_V0P01_229	0.2643	0.308	-0.01448	-0.01568	1.458
PS40_DECAY_K3_P_V0P2_225					
PS40_DECAY_K3_R_232	0.2942	0.3587	-0.1536	0.1596	7.787
PS40_DECAY_K3_R_V0P01_231	0.2217	0.2396	-0.01673	0.1194	10.37
PS40_DECAY_K3_R_V0P2_226					
PS40_DECAY_K3_S_V0P2_228					
OW_K1_V0P3_017	0.06305	0.0007846	0.9488	-0.02475	14.48
OW_K1_V0P3_021					
OW_K1_V0P3_053					
OW_K2_V0P3_112					
OW_K3_V0P3_248	0.07295	0.06634	0.575	-0.002694	28.38
PS10_K1_VH_046					
PS10_K1_VH_047	0.02706	-0.1578	4.777	0.01908	14.98
PS20_K1_VH_058					
PS20_K2_VH_095					
PS20_K3_VH_191					
PS30_K1_VH_033					
PS30_K2_VH_123					
PS30_K3_VH_161					
PS40_K1_VH_077					
PS40_K2_VH_141					
PS40_K3_VH_220					
OW_K2_VL_111	0.07811	0.07148	0.7519	-0.001853	21.76

Means Insufficent data

Data not avaible for this run

Decay Test Data Set 2

Test Name	Qualysis				
	Damping			Mean	
	Linear	Equivalent B1	Equivalent B	Offset	Period
DECAY_K1_H_012	0.1816	0.1103	0.000174	9.868	10.06
DECAY_K1_H_013	0.1482	0.08413	0.000212	-3.492	8.298
DECAY_K1_H_014	0.1184	-0.161	0.000665	26.69	8.492
DECAY_K1_H_073	0.2079	0.1854	4.36E-05	-9.741	9.787
DECAY_K1_P_004	0.07143	0.00971	0.00066	3.137	1.399
DECAY_K1_P_005	0.08052	0.05121	0.000244	3.514	1.377
DECAY_K1_P_006	0.09771	0.09533	1.63E-05	3.959	1.409
DECAY_K1_P_007	0.08796	0.07252	8.96E-05	0.917	1.421
DECAY_K1_P_008	0.1003	0.1167	-8.21E-05	1.006	1.387
DECAY_K1_P_072	0.06382	5030	0.000155	4.212	1.383
DECAY_K1_R_009	0.06089	-0.01145	0.000462	-11.77	9.036
DECAY_K1_R_010	0.0829	0.0406	0.000249	-13.11	9.131
DECAY_K1_R_011	0.09982	0.05422	0.000213	-8.715	9.102
DECAY_K1_R_071	0.06274	0.005437	0.000379	12.41	9.144
DECAY_K2_H_115	0.126	0.08688	8.72E-05	195.1	9.225
DECAY_K2_P_114	0.05067	0.03782	0.000186	3.574	1.329
DECAY_K2_R_113	0.07865	0.06647	9.25E-05	12.61	8.708
DECAY_K3_H_251	0.09079	-0.02066	0.000275	365.6	9.42
DECAY_K3_P_249	0.08028	0.07516	5.22E-05	-1.265	1.341
DECAY_K3_R_250	0.06695	0.03197	0.00022	17.32	8.65
PS20_DECAY_K3_H_205	0.2054	0.223	-4.45E-05	-152.2	9.313
PS20_DECAY_K3_H_V0P01_204	0.2506	0.4096	-0.000365	-205	9.31
PS20_DECAY_K3_H_V0P2_198					
PS20_DECAY_K3_P_201	0.1291	0.1449	-0.00031	9.458	1.352
PS20_DECAY_K3_P_V0P01_200	0.1391	0.1723	-0.00047	11.08	1.361
PS20_DECAY_K3_P_V0P2_196	0.06684	0.07578	-0.00017	10.68	1.354
PS20_DECAY_K3_R_203	0.0792	0.03837	0.000653	15.63	8.328
PS20_DECAY_K3_R_V0P01_202	0.136	0.1677	-0.000366	10.08	8.851
PS20_DECAY_K3_R_V0P2_197	0.1263	0.1487	-0.000332	12.98	8.763
PS20_DECAY_K3_S_V0P2_199	0.0808	0.01924	4.48E-05	-3801	29.28
PS30_DECAY_K3_H_0P01_174	0.1856	0.007356	0.000387	23	13.69
PS30_DECAY_K3_H_175	0.2366	0.3284	-0.000186	-31.98	9.535
PS30_DECAY_K3_H_176	0.2276	0.2793	-0.000109	-104.8	9.898
PS30_DECAY_K3_H_V0P2_168	0.132	0.03047	0.000482	-126.9	11.96
PS30_DECAY_K3_P_171	0.109	0.1246	-0.000237	8.955	1.363
PS30_DECAY_K3_P_V0P01_170	0.09736	0.08544	0.000232	3.717	1.317
PS30_DECAY_K3_P_V0P2_166	0.1222	0.03526	0.002234	23.55	1.381
PS30_DECAY_K3_R_173	0.0947	0.06169	0.000295	12.97	8.604
PS30_DECAY_K3_R_V0P01_172	0.1334	0.2028	-0.000584	11.01	8.564
PS30_DECAY_K3_R_V0P2_167	0.1366	0.122	0.000394	12.43	8.312
PS30_DECAY_K3_S_V0P2_169					
PS40_DECAY_K2_H_V0P01_152					
PS40_DECAY_K2_H_V0P2_147					
PS40_DECAY_K2_P_149					
PS40_DECAY_K2_P_V0P01_148					
PS40_DECAY_K2_P_V0P2_145					
PS40_DECAY_K2_R_151					
PS40_DECAY_K2_R_V0P01_150					
PS40_DECAY_K2_R_V0P2_146					

Decay Test Data Set 2

Test Name	Qualysis				
	Damping			Mean	
	Linear	Equivalent B1	Equivalent B	Offset	Period
PS40_DECAY_K2_S_V0P2_154					
PS40_DECAY_K3_H_234	0.1645	0.05906	0.000424	171.9	14.47
PS40_DECAY_K3_H_V0P01_233	0.2328	0.2559	-6.32E-05	121.4	12.96
PS40_DECAY_K3_H_V0P2_227	0.1573	0.09702	0.000188	131.5	8.519
PS40_DECAY_K3_P_230	0.1646	0.1966	-0.000323	2.651	1.344
PS40_DECAY_K3_P_V0P01_229	0.2682	0.3114	-0.000879	-18.99	1.582
PS40_DECAY_K3_P_V0P2_225					
PS40_DECAY_K3_R_232	0.1902	0.1386	0.000896	17.39	11.12
PS40_DECAY_K3_R_V0P01_231	0.1077	0.04341	0.001263	13.42	8.185
PS40_DECAY_K3_R_V0P2_226					
PS40_DECAY_K3_S_V0P2_228					
OW_K1_V0P3_017	0.04635	-0.006333	0.000214	-4164	14.59
OW_K1_V0P3_021	0.08227	0.1042	-7.5E-05	-4841	14.56
OW_K1_V0P3_053	0.08995	0.1755	-0.000282	95.29	15.26
OW_K2_V0P3_112					
OW_K3_V0P3_248	0.1043	0.1568	-4.01E-05	-2601	27.99
PS10_K1_VH_046					
PS10_K1_VH_047	0.05802	0.03726	7.09E-05	84.45	15.27
PS20_K1_VH_058	0.1927	0.3855	-0.000312	-431.5	12.06
PS20_K2_VH_095	0.05144	0.1818	-0.000108	-2088	22.09
PS20_K3_VH_191	0.06246	-0.5829	0.000605	-2712	28.18
PS30_K1_VH_033	0.1071	-0.1553	0.000562	-959.9	21.5
PS30_K2_VH_123	0.1004	0.2112	-0.000144	-2385	21.78
PS30_K3_VH_161	-0.2378	-0.4879	0.000309	-4538	24.71
PS40_K1_VH_077					
PS40_K2_VH_141					
PS40_K3_VH_220	0.04825	-0.3131	0.000172	-6541	31
OW_K2_VL_111	0.109	0.1706	-0.000103	-1326	21.46

Means Insufficent data

Data not avaible for this run

Decay Test Data Set 3

Test Name	Motion Pack				
	Damping			Mean	
	Linear	Equivalent B1	Equivalent B2	Offset	Period
DECAY_K1_H_012	0.2628	0.3345	-0.3333	-9.806	9.823
DECAY_K1_H_013	0.2209	0.3056	-0.3602	-9.819	9.768
DECAY_K1_H_014	0.07556	-0.02282	39485	-9.807	9.344
DECAY_K1_H_073	0.04305	-0.05597	12.24	-1.001	8.812
DECAY_K1_P_004					
DECAY_K1_P_005	0.06758	0.0544	0.00221	0.03189	1.362
DECAY_K1_P_006	0.04598	0.01862	0.004253	0.00594	1.433
DECAY_K1_P_007	0.07822	0.05105	0.002823	0.08938	1.495
DECAY_K1_P_008					
DECAY_K1_P_072	0.07744	0.09507	-0.004714	-0.06109	1.346
DECAY_K1_R_009	0.1173	0.1584	-0.02968	0.000254	9.026
DECAY_K1_R_010	0.07384	0.06758	0.003686	0.004009	9.185
DECAY_K1_R_011	0.05023	0.1013	-0.5492	-0.007621	9.199
DECAY_K1_R_071	0.02521	0.1802	-0.3212	-0.003441	9.091
DECAY_K2_H_115	0.1328	0.04537	5.171	-0.9994	8.861
DECAY_K2_P_114	0.06562	0.05909	0.002308	-0.02651	1.299
DECAY_K2_R_113	0.04295	0.01728	0.05213	-0.004933	8.471
DECAY_K3_H_251	0.05213	-0.02917	6.316	-1	9.143
DECAY_K3_P_249	0.08566	0.09067	-0.0009426	-0.02975	1.318
DECAY_K3_R_250	0.06871	0.07158	-0.003005	0.1596	8.628
PS20_DECAY_K3_H_205	0.08886	0.03425	6.829	-0.9999	8.697
PS20_DECAY_K3_H_V0P01_204	0.114	0.06236	5.897	-0.9999	8.779
PS20_DECAY_K3_H_V0P2_198					
PS20_DECAY_K3_P_201	0.161	0.2044	-0.01513	0.05681	1.353
PS20_DECAY_K3_P_V0P01_200	0.1515	0.1882	-0.009018	-0.006297	1.335
PS20_DECAY_K3_P_V0P2_196					
PS20_DECAY_K3_R_203	0.134	0.1426	-0.01021	0.1412	8.289
PS20_DECAY_K3_R_V0P01_202	0.1341	0.1285	0.007693	0.1376	8.149
PS20_DECAY_K3_R_V0P2_197					
PS20_DECAY_K3_S_V0P2_199					
PS30_DECAY_K3_H_0P01_174	0.1503	0.1186	3.007	-0.9998	8.889
PS30_DECAY_K3_H_175	0.09031	0.02872	6.196	-0.9998	9.476
PS30_DECAY_K3_H_176	0.1334	0.08669	4.7	-0.9999	8.923
PS30_DECAY_K3_H_V0P2_168					
PS30_DECAY_K3_P_171	0.1236	0.142	-0.006932	0.01227	1.35
PS30_DECAY_K3_P_V0P01_170	0.151	0.1559	-0.002043	-0.03088	1.314
PS30_DECAY_K3_P_V0P2_166					
PS30_DECAY_K3_R_173	0.07244	0.05622	0.01814	0.155	8.769
PS30_DECAY_K3_R_V0P01_172	0.1046	0.07779	0.03214	0.1561	8.45
PS30_DECAY_K3_R_V0P2_167	0.07689	0.03156	0.09945	0.1489	8.41
PS30_DECAY_K3_S_V0P2_169					
PS40_DECAY_K2_H_V0P01_152	0.1106	0.01669	37.02	-0.9996	9.338
PS40_DECAY_K2_H_V0P2_147	0.04601	-0.0591	11.34	-1	7.918
PS40_DECAY_K2_P_149	0.1877	0.1209	0.1051	0.07303	1.738
PS40_DECAY_K2_P_V0P01_148	0.1541	0.1024	0.02752	0.06877	1.634
PS40_DECAY_K2_P_V0P2_145	0.09845	0.03458	0.0452	0.00784	1.564
PS40_DECAY_K2_R_151	0.1295	0.07494	0.1279	0.1494	10.28
PS40_DECAY_K2_R_V0P01_150	0.09674	0.04338	0.1484	0.1549	11.38
PS40_DECAY_K2_R_V0P2_146	0.06151	0.00664	0.1306	0.162	8.073

Decay Test Data Set 3

Test Name	Motion Pack				
	Damping			Mean	
	Linear	Equivalent B1	Equivalent B2	Offset	Period
PS40_DECAY_K2_S_V0P2_154					
PS40_DECAY_K3_H_234	0.07123	-0.009864	26.99	-1	11.37
PS40_DECAY_K3_H_V0P01_233	0.185	0.1681	1.938	-1	13.92
PS40_DECAY_K3_H_V0P2_227					
PS40_DECAY_K3_P_230	0.1651	0.2061	-0.005824	0.02337	1.346
PS40_DECAY_K3_P_V0P01_229	0.1805	0.1217	0.03455	-0.016	1.964
PS40_DECAY_K3_P_V0P2_225					
PS40_DECAY_K3_R_232	0.07795	0.01951	0.2866	0.1671	8.885
PS40_DECAY_K3_R_V0P01_231	0.1031	0.05965	0.169	0.1501	7.743
PS40_DECAY_K3_R_V0P2_226	0.1135	0.06181	0.09619	0.1806	9.195
PS40_DECAY_K3_S_V0P2_228					
OW_K1_V0P3_017					
OW_K1_V0P3_021					
OW_K1_V0P3_053					
OW_K2_V0P3_112					
OW_K3_V0P3_248					
PS10_K1_VH_046					
PS10_K1_VH_047	0.07188	0.04229	0.4286	0.02444	15.27
PS20_K1_VH_058					
PS20_K2_VH_095					
PS20_K3_VH_191					
PS30_K1_VH_033					
PS30_K2_VH_123					
PS30_K3_VH_161					
PS40_K1_VH_077					
PS40_K2_VH_141					
PS40_K3_VH_220					
OW_K2_VL_111					

Decay Test Data Set 3

Test Name	Qualysis				
	Damping			Mean	
	Linear	Equivalent B	Equivalent B	Offset	Period
DECAY_K1_H_012	0.04127	-0.1226	0.00064	86.69	9.05
DECAY_K1_H_013	0.089	0.023	0.000209	-8.834	10.06
DECAY_K1_H_014	0.07084	-0.04676	0.000506	-13.83	6.937
DECAY_K1_H_073	0.1751	0.1376	0.000114	-9.748	8.156
DECAY_K1_P_004					
DECAY_K1_P_005	0.06491	0.02487	0.000461	7.64	1.353
DECAY_K1_P_006	0.03988	0.01143	0.000369	0.5568	1.423
DECAY_K1_P_007	0.07359	0.05299	0.000197	1.454	1.523
DECAY_K1_P_008					
DECAY_K1_P_072	0.07228	0.07808	-8.62E-05	3.185	1.358
DECAY_K1_R_009					
DECAY_K1_R_010	0.06042	0.02199	0.000237	-10.35	9.217
DECAY_K1_R_011	0.04026	-0.01192	0.000638	-10.46	9.291
DECAY_K1_R_071	0.04466	0.001088	0.000378	8.113	9.325
DECAY_K2_H_115	0.1517	0.09648	0.000158	212.8	9.739
DECAY_K2_P_114	0.06297	0.05233	0.000249	4.332	1.339
DECAY_K2_R_113	0.06186	0.04607	0.000204	12.31	8.443
DECAY_K3_H_251	0.1268	0.009848	0.000246	475.2	9.031
DECAY_K3_P_249	0.08108	0.08032	1.16E-05	0.05021	1.29
DECAY_K3_R_250	0.05494	0.01927	0.000272	14.3	8.772
PS20_DECAY_K3_H_205	0.08761	-0.02886	0.000526	-159.7	8.884
PS20_DECAY_K3_H_V0P01_204	0.1599	-0.004972	0.001426	-215.8	8.68
PS20_DECAY_K3_H_V0P2_198					
PS20_DECAY_K3_P_201	0.1514	0.2293	-0.00192	9.211	1.347
PS20_DECAY_K3_P_V0P01_200	0.1386	0.1685	-0.000425	10.83	1.362
PS20_DECAY_K3_P_V0P2_196					
PS20_DECAY_K3_R_203	0.0708	0.01317	0.000944	16.28	6.37
PS20_DECAY_K3_R_V0P01_202	0.08175	0.04296	0.000658	11.09	8.384
PS20_DECAY_K3_R_V0P2_197					
PS20_DECAY_K3_S_V0P2_199					
PS30_DECAY_K3_H_0P01_174	0.06745	-0.01725	0.000469	17.63	12.09
PS30_DECAY_K3_H_175	0.142	0.05759	0.000277	-40.52	9.161
PS30_DECAY_K3_H_176	0.1424	0.04391	0.000672	-63.55	8.28
PS30_DECAY_K3_H_V0P2_168					
PS30_DECAY_K3_P_171	0.09975	0.09369	0.00013	6.883	1.344
PS30_DECAY_K3_P_V0P01_170	0.1486	0.1791	-0.000587	3.326	1.309
PS30_DECAY_K3_P_V0P2_166					
PS30_DECAY_K3_R_173	0.06968	0.04965	0.000282	12.96	9.23
PS30_DECAY_K3_R_V0P01_172	0.1063	0.08295	0.000325	9.172	8.431
PS30_DECAY_K3_R_V0P2_167	0.08102	0.02557	0.001079	12.45	8.245
PS30_DECAY_K3_S_V0P2_169					
PS40_DECAY_K2_H_V0P01_152					
PS40_DECAY_K2_H_V0P2_147					
PS40_DECAY_K2_P_149					
PS40_DECAY_K2_P_V0P01_148					
PS40_DECAY_K2_P_V0P2_145					
PS40_DECAY_K2_R_151					
PS40_DECAY_K2_R_V0P01_150					
PS40_DECAY_K2_R_V0P2_146					

Decay Test Data Set 3

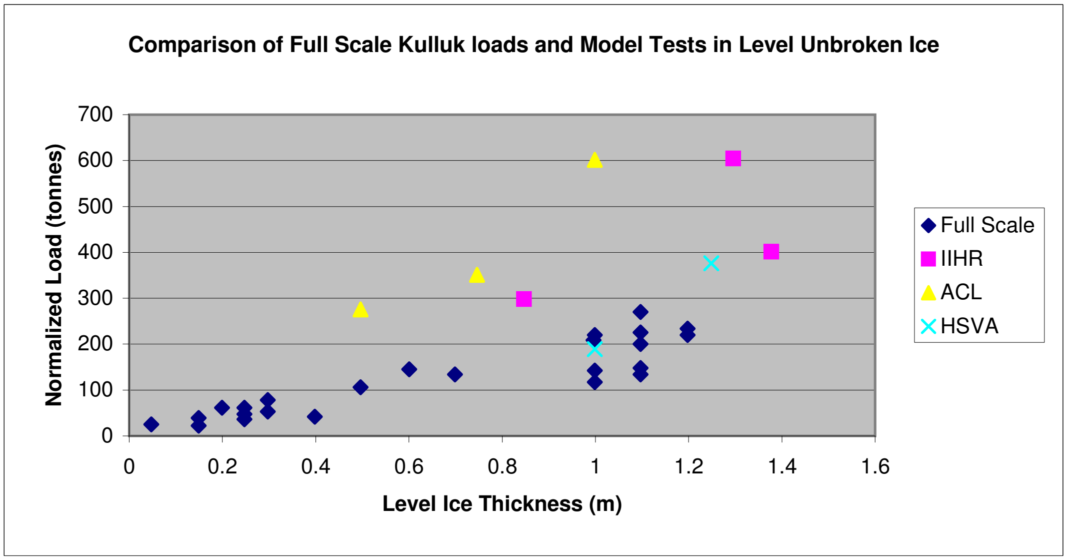
Test Name	Qualysis				
	Damping			Mean	
	Linear	quivalent B	quivalent B	Offset	Period
PS40_DECAY_K2_S_V0P2_154					
PS40_DECAY_K3_H_234	0.09561	0.03468	0.000425	135.1	10.71
PS40_DECAY_K3_H_V0P01_233	0.1474	0.0978	0.000313	168.4	10.5
PS40_DECAY_K3_H_V0P2_227					
PS40_DECAY_K3_P_230	0.1613	0.1771	-0.000184	2.397	1.379
PS40_DECAY_K3_P_V0P01_229	0.1395	0.03815	0.002481	-21.94	1.813
PS40_DECAY_K3_P_V0P2_225					
PS40_DECAY_K3_R_232	0.1033	0.02494	0.0021	18.55	10.84
PS40_DECAY_K3_R_V0P01_231	0.07476	0.000817	0.002206	17.38	6.015
PS40_DECAY_K3_R_V0P2_226	0.122	0.06431	0.000632	13.86	12.09
PS40_DECAY_K3_S_V0P2_228					
OW_K1_V0P3_017					
OW_K1_V0P3_021					
OW_K1_V0P3_053					
OW_K2_V0P3_112					
OW_K3_V0P3_248					
PS10_K1_VH_046					
PS10_K1_VH_047	0.101	0.1324	-9.51E-05	-65.97	15.02
PS20_K1_VH_058	0.07393	-0.03078	0.000117	-601	15.2
PS20_K2_VH_095	0.05456	-0.1013	0.000404	-2367	16.21
PS20_K3_VH_191	-0.0433	-0.6291	0.001148	-3377	28.47
PS30_K1_VH_033					
PS30_K2_VH_123	0.1007	0.2124	-0.000145	-2384	21.81
PS30_K3_VH_161	0.0865	0.01729	3.36E-05	-4068	29.75
PS40_K1_VH_077					
PS40_K2_VH_141					
PS40_K3_VH_220					
OW_K2_VL_111					

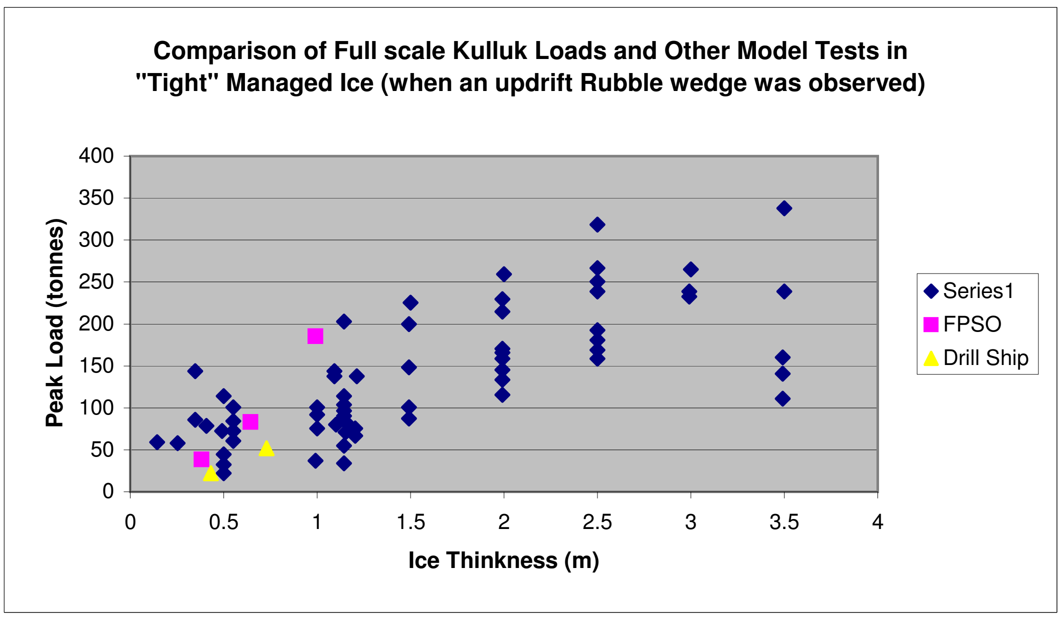
Note: Means Insufficent data
Data not avaible for this run

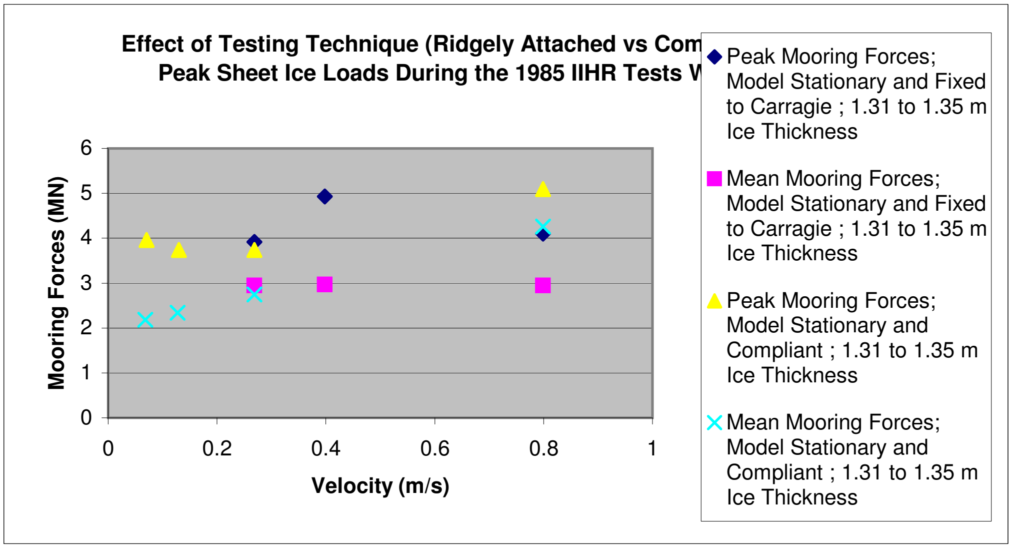
Appendix H
Data From Previous Test Series

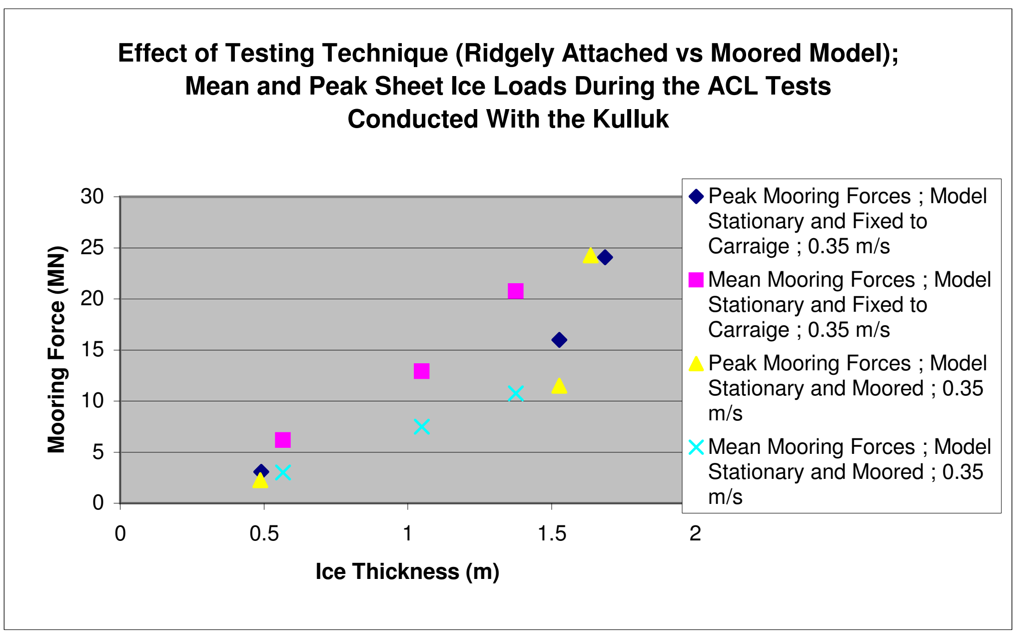
This appendix contains:

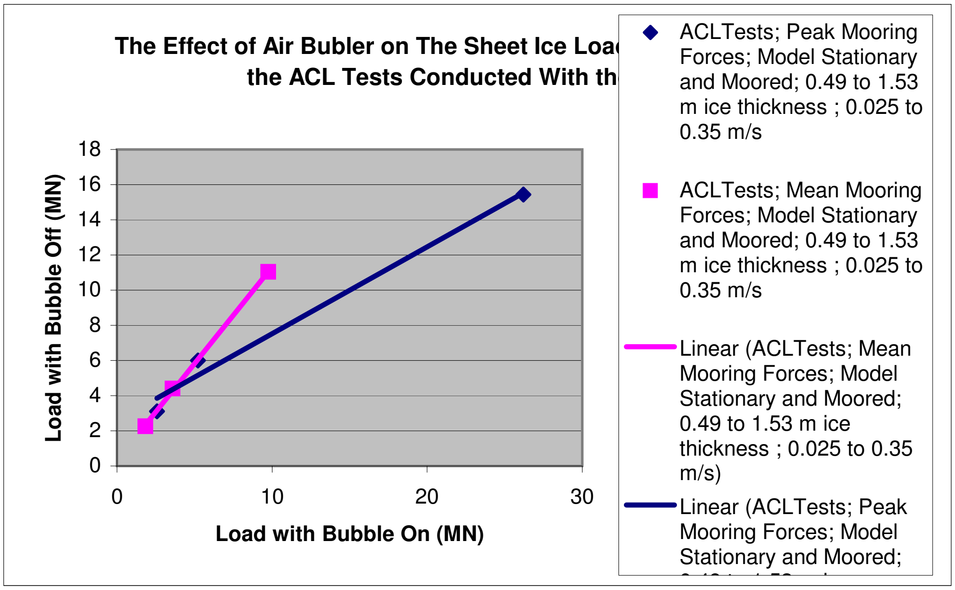
- Graphs from previous test series

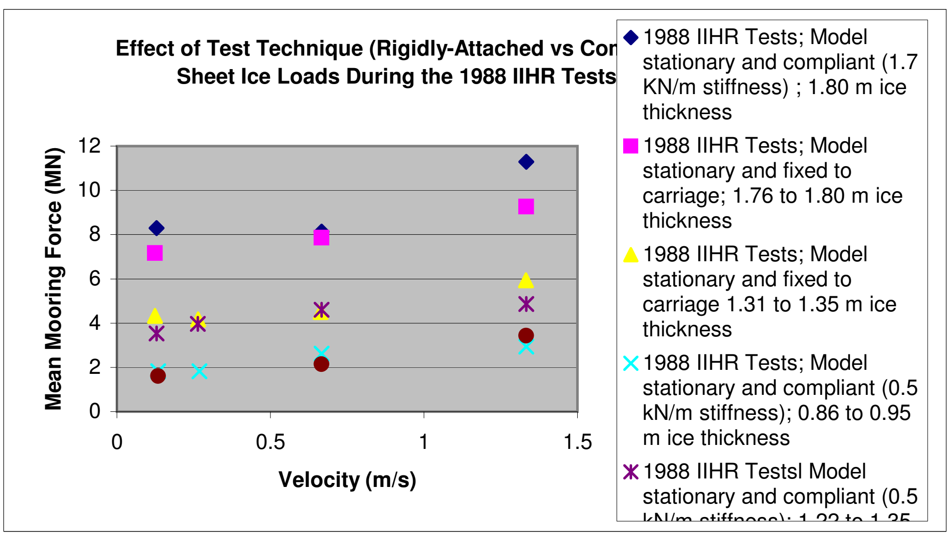

Comparison of Full Scale Kulluk loads and Model Tests in Level Unbroken Ice
Normalized Load (tonnes)
700
600
500
400
300
200
100
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
Level Ice Thickness (m)
Full Scale
IIHR
ACL
HSVA

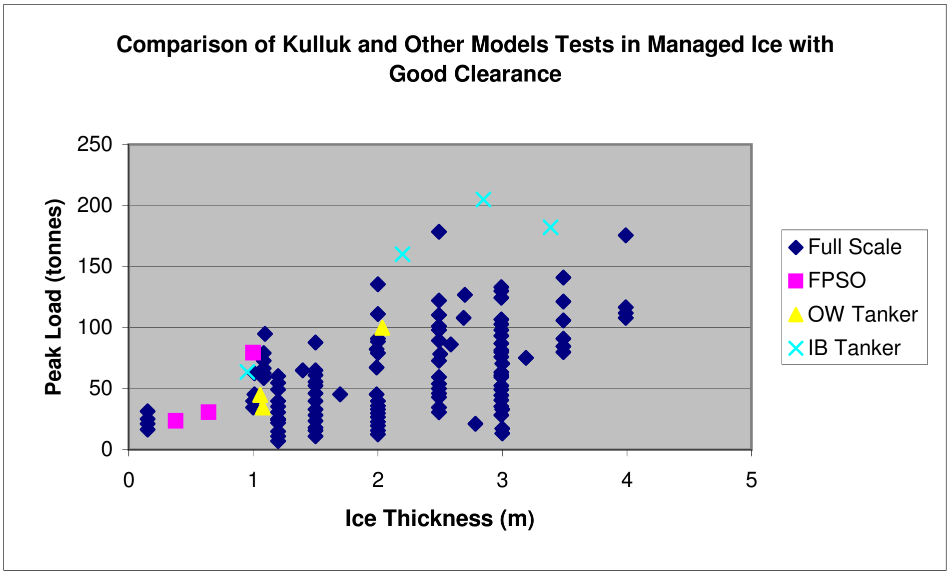

Comparison of Full scale Kulluk Loads and Other Model Tests in "Tight" Managed Ice (when an updrift Rubble wedge was observed)
Peak Load (tonnes)
400
350
300
250
200
150
100
50
0
0
0.5
1
1.5
2
2.5
3
3.5
4
Ice Thinkness (m)
Series1
FPSO
Drill Ship


Effect of Testing Technique (Ridgely Attached vs Com
Peak Sheet Ice Loads During the 1985 IIHR Tests W
Mooring Forces (MN)
Velocity (m/s)
0
0.2
0.4
0.6
0.8
1
1
2
3
4
5
6
Peak Mooring Forces; Model Stationary and Fixed to Carragie ; 1.31 to 1.35 m Ice Thickness
Mean Mooring Forces; Model Stationary and Fixed to Carragie ; 1.31 to 1.35 m Ice Thickness
Peak Mooring Forces; Model Stationary and Compliant ; 1.31 to 1.35 m Ice Thickness
Mean Mooring Forces; Model Stationary and Compliant ; 1.31 to 1.35 m Ice Thickness

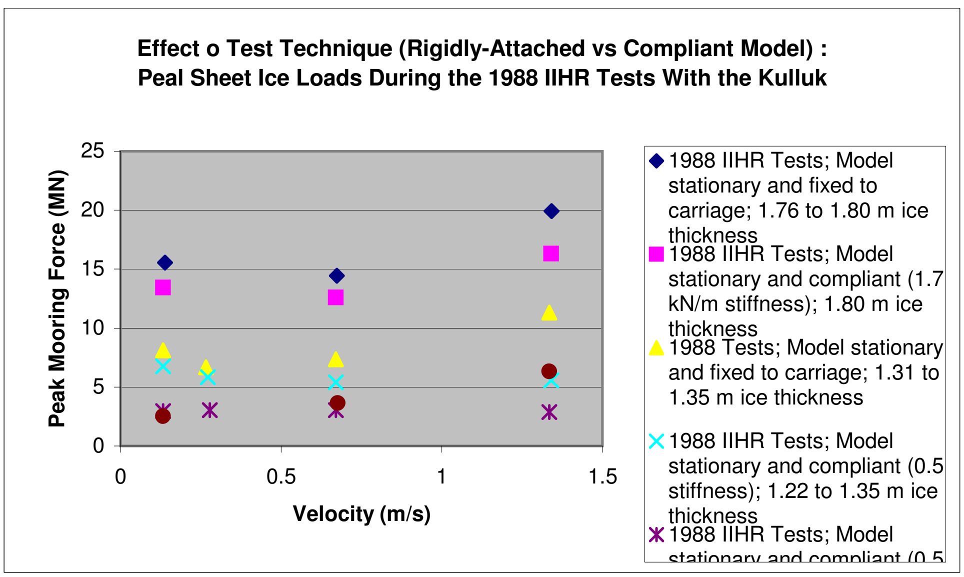

Effect of Testing Technique (Ridgely Attached vs Moored Model);
Mean and Peak Sheet Ice Loads During the ACL Tests
Conducted With the Kulluk
Mooring Force (MN)
Ice Thickness (m)
0
0.5
1
1.5
2
5
10
15
20
25
30
Peak Mooring Forces ; Model Stationary and Fixed to Carraige ; 0.35 m/s
Mean Mooring Forces ; Model Stationary and Fixed to Carraige ; 0.35 m/s
Peak Mooring Forces ; Model Stationary and Moored ; 0.35 m/s
Mean Mooring Forces ; Model Stationary and Moored ; 0.35 m/s


The Effect of Air Bubler on The Sheet Ice Loa
the ACL Tests Conducted With th
Load with Bubble Off (MN)
Load with Bubble On (MN)
18
16
14
12
10
8
6
4
2
0
0
10
20
30
ACLTests; Peak Mooring Forces; Model Stationary and Moored; 0.49 to 1.53 m ice thickness ; 0.025 to 0.35 m/s
ACLTests; Mean Mooring Forces; Model Stationary and Moored; 0.49 to 1.53 m ice thickness ; 0.025 to 0.35 m/s
Linear (ACLTests; Mean Mooring Forces; Model Stationary and Moored; 0.49 to 1.53 m ice thickness ; 0.025 to 0.35 m/s)
Linear (ACLTests; Peak Mooring Forces; Model Stationary and Moored;

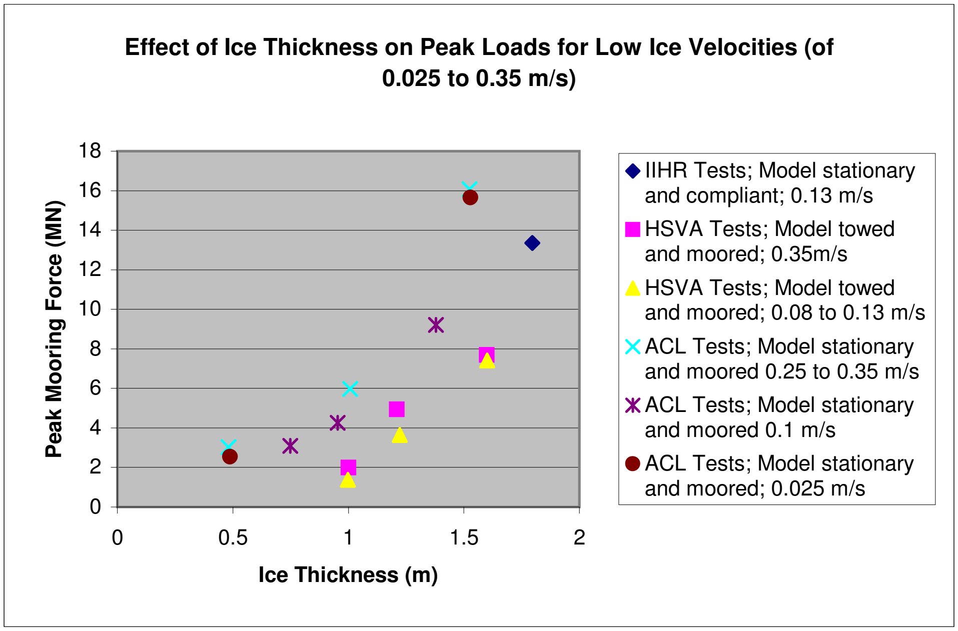

Effect of Test Technique (Rigidly-Attached vs Co
Sheet Ice Loads During the 1988 IIHR Tests
Mean Mooring Force (MN)
Velocity (m/s)
12
10
8
6
4
2
0
0
0.5
1
1.5
1988 IIHR Tests; Model stationary and compliant (1.7 KN/m stiffness) ; 1.80 m ice thickness
1988 IIHR Tests; Model stationary and fixed to carriage; 1.76 to 1.80 m ice thickness
1988 IIHR Tests; Model stationary and fixed to carriage 1.31 to 1.35 m ice thickness
1988 IIHR Tests; Model stationary and compliant (0.5 kN/m stiffness); 0.86 to 0.95 m ice thickness
1988 IIHR Testsl Model stationary and compliant (0.5

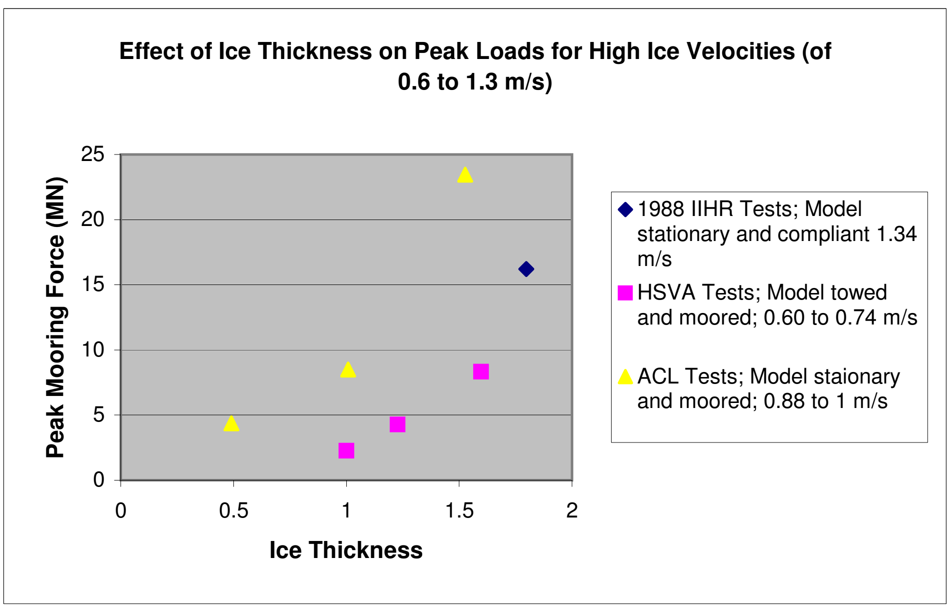


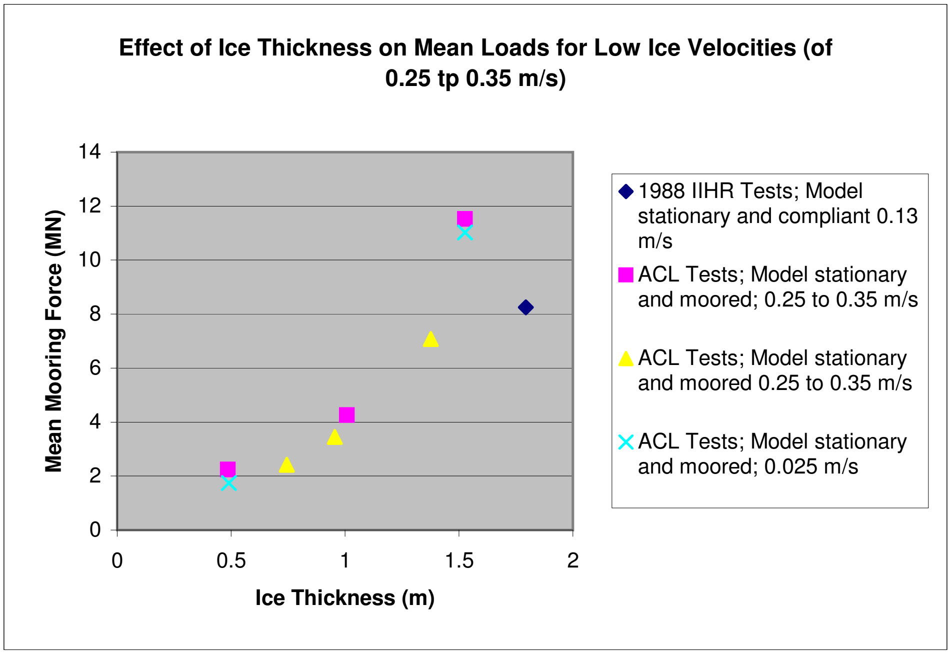
Comparison of Kulluk and Other Models Tests in Managed Ice with Good Clearance
Peak Load (tonnes)
250
200
150
100
50
0
0
1
2
3
4
5
Ice Thickness (m)
Full Scale
FPSO
OW Tanker
IB Tanker



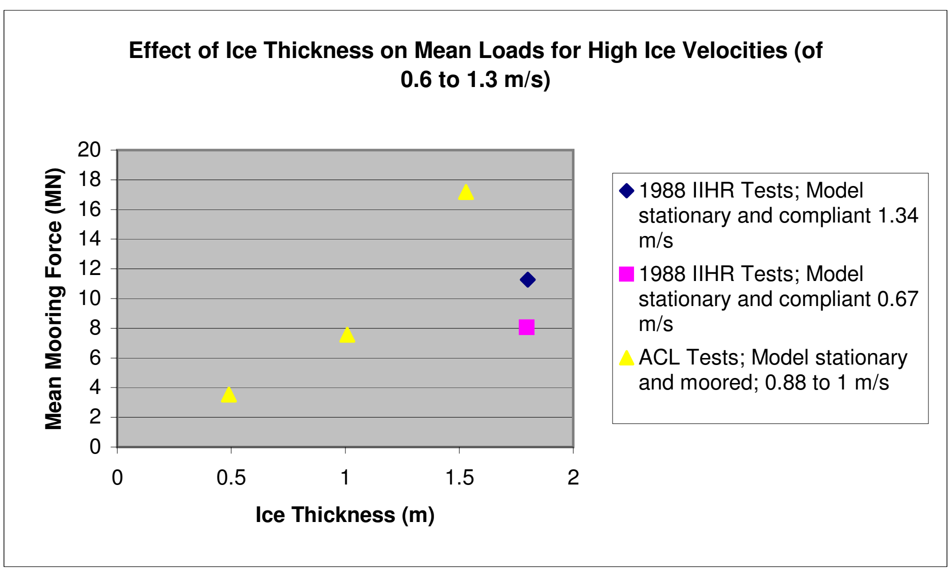
Effect o Test Technique (Rigidly-Attached vs Compliant Model) :
Peal Sheet Ice Loads During the 1988 IIHR Tests With the Kulluk
Peak Mooring Force (MN)
25
20
15
10
5
0
0
0.5
1
1.5
Velocity (m/s)
1988 IIHR Tests; Model stationary and fixed to carriage; 1.76 to 1.80 m ice thickness
1988 IIHR Tests; Model stationary and compliant (1.7 kN/m stiffness); 1.80 m ice thickness
1988 Tests; Model stationary and fixed to carriage; 1.31 to 1.35 m ice thickness
1988 IIHR Tests; Model stationary and compliant (0.5 stiffness); 1.22 to 1.35 m ice thickness
1988 IIHR Tests; Model


Effect of Ice Thickness on Peak Loads for Low Ice Velocities (of 0.025 to 0.35 m/s)
Peak Mooring Force (MN)
0
2
4
6
8
10
12
14
16
18
0
0.5
1
1.5
2
Ice Thickness (m)
IIHR Tests; Model stationary and compliant; 0.13 m/s
HSVA Tests; Model towed and moored; 0.35m/s
HSVA Tests; Model towed and moored; 0.08 to 0.13 m/s
ACL Tests; Model stationary and moored 0.25 to 0.35 m/s
ACL Tests; Model stationary and moored 0.1 m/s
ACL Tests; Model stationary and moored; 0.025 m/s

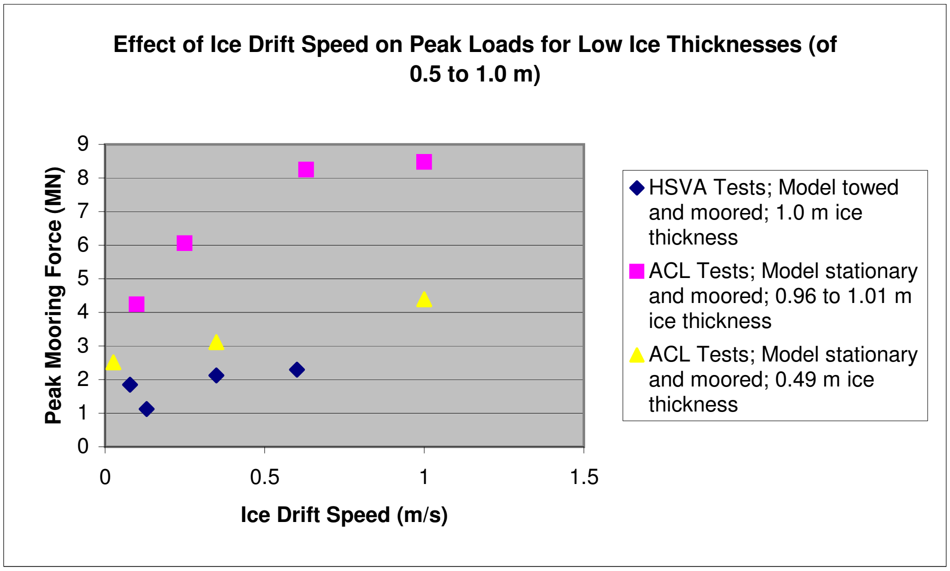

Effect of Ice Thickness on Peak Loads for High Ice Velocities (of 0.6 to 1.3 m/s)
Peak Mooring Force (MN)
0
5
10
15
20
25
0
0.5
1
1.5
2
Ice Thickness
1988 IIHR Tests; Model stationary and compliant 1.34 m/s
HSVA Tests; Model towed and moored; 0.60 to 0.74 m/s
ACL Tests; Model staionary and moored; 0.88 to 1 m/s

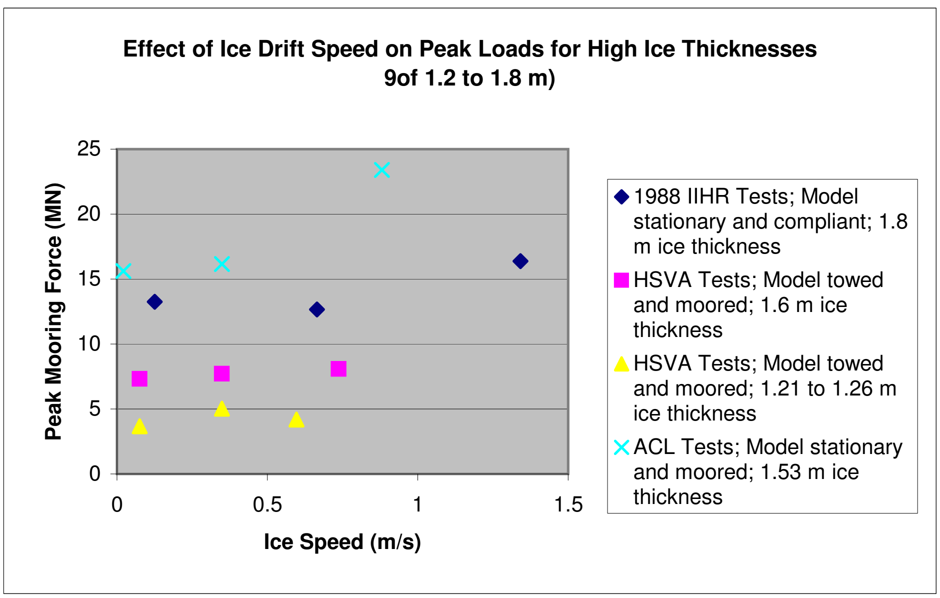


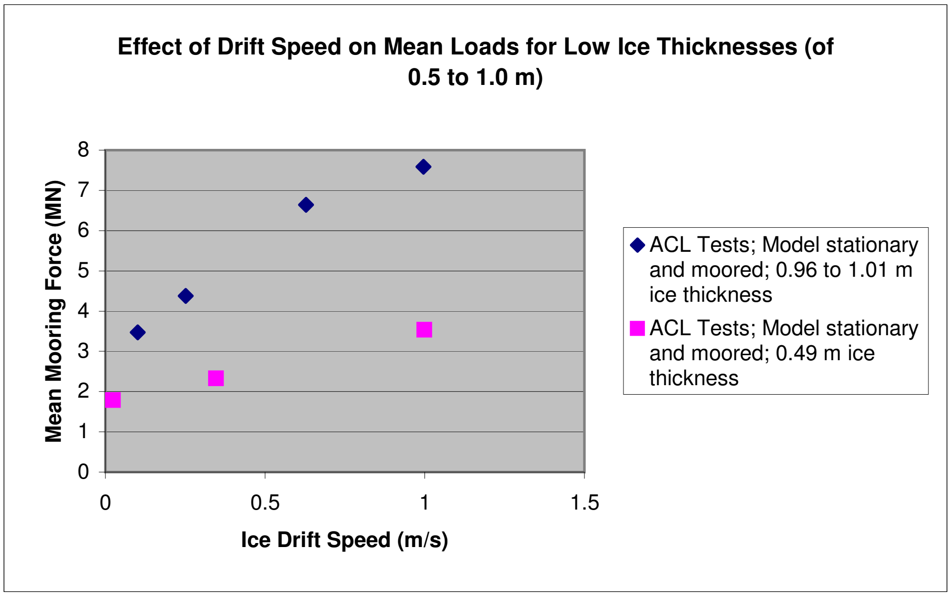
Effect of Ice Thickness on Mean Loads for Low Ice Velocities (of 0.25 tp 0.35 m/s)
Mean Mooring Force (MN)
14
12
10
8
6
4
2
0
0
0.5
1
1.5
2
Ice Thickness (m)
1988 IIHR Tests; Model stationary and compliant 0.13 m/s
ACL Tests; Model stationary and moored; 0.25 to 0.35 m/s
ACL Tests; Model stationary and moored 0.25 to 0.35 m/s
ACL Tests; Model stationary and moored; 0.025 m/s



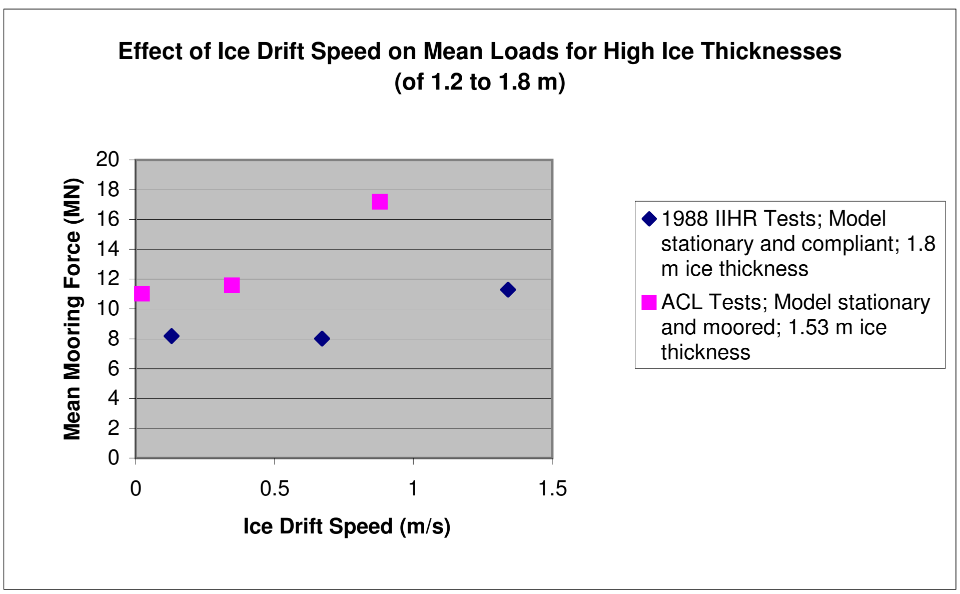
Effect of Ice Thickness on Mean Loads for High Ice Velocities (of 0.6 to 1.3 m/s)
Mean Mooring Force (MN)
20
18
16
14
12
10
8
6
4
2
0
0
0.5
1
1.5
2
Ice Thickness (m)
1988 IIHR Tests; Model stationary and compliant 1.34 m/s
1988 IIHR Tests; Model stationary and compliant 0.67 m/s
ACL Tests; Model stationary and moored; 0.88 to 1 m/s


Effect of Ice Drift Speed on Peak Loads for Low Ice Thicknesses (of 0.5 to 1.0 m)
Peak Mooring Force (MN)
0
1
2
3
4
5
6
7
8
9
0
0.5
1
1.5
Ice Drift Speed (m/s)
HSVA Tests; Model towed and moored; 1.0 m ice thickness
ACL Tests; Model stationary and moored; 0.96 to 1.01 m ice thickness
ACL Tests; Model stationary and moored; 0.49 m ice thickness

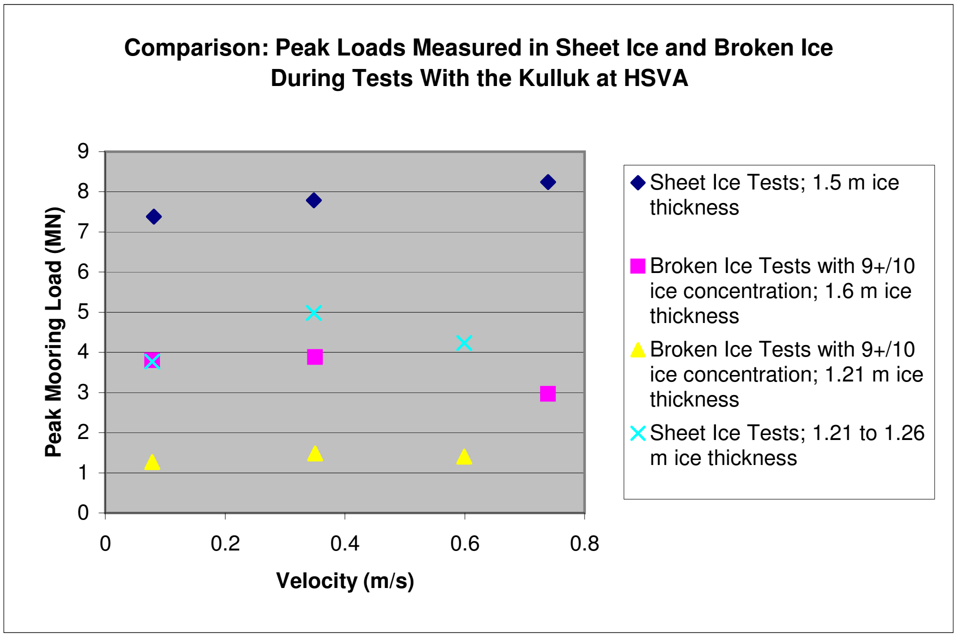

Effect of Ice Drift Speed on Peak Loads for High Ice Thicknesses 9of 1.2 to 1.8 m)
Peak Mooring Force (MN)
0
5
10
15
20
25
0
0.5
1
1.5
Ice Speed (m/s)
1988 IIHR Tests; Model stationary and compliant; 1.8 m ice thickness
HSVA Tests; Model towed and moored; 1.6 m ice thickness
HSVA Tests; Model towed and moored; 1.21 to 1.26 m ice thickness
ACL Tests; Model stationary and moored; 1.53 m ice thickness

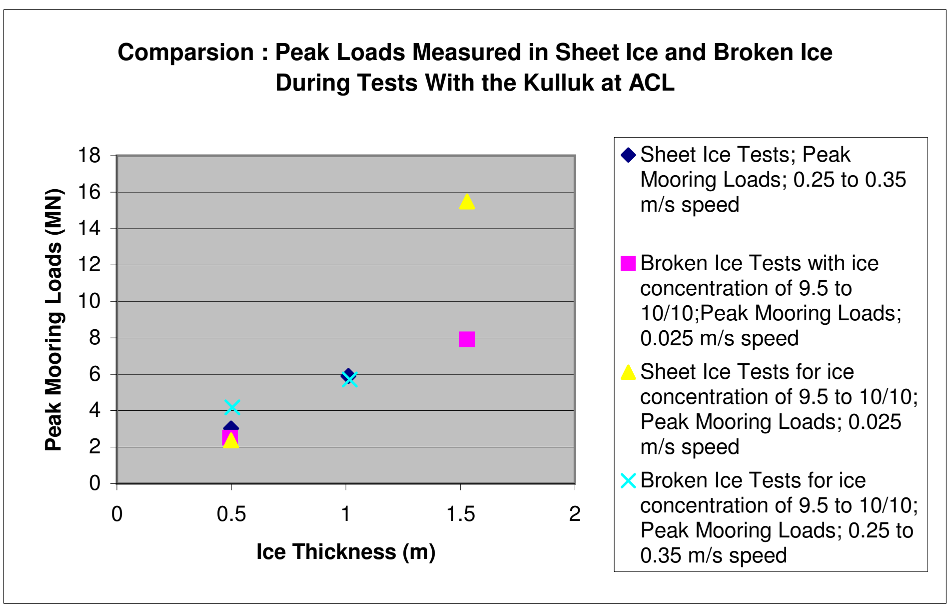


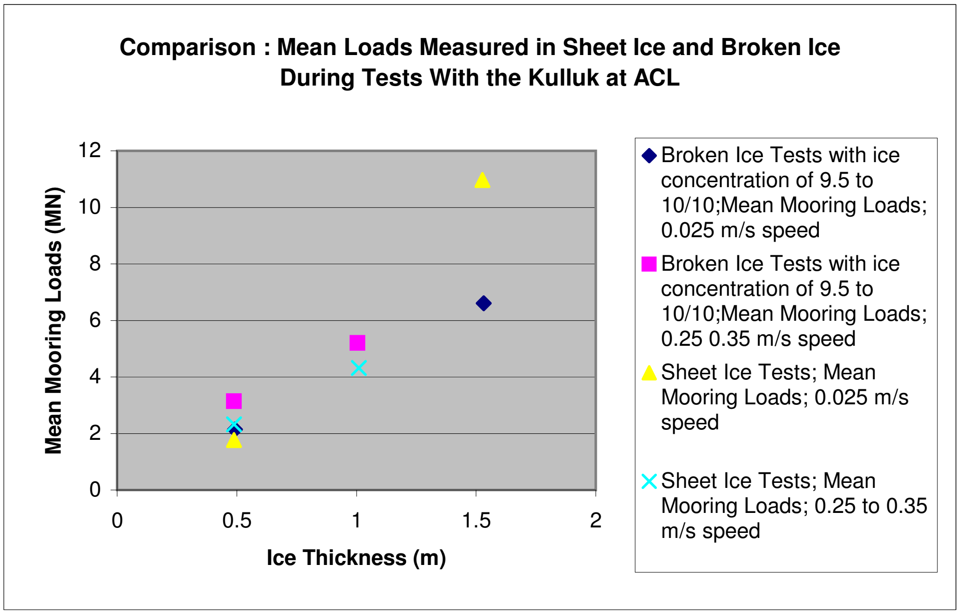
Effect of Drift Speed on Mean Loads for Low Ice Thicknesses (of 0.5 to 1.0 m)
Mean Mooring Force (MN)
8
7
6
5
4
3
2
1
0
0
0.5
1
1.5
Ice Drift Speed (m/s)
ACL Tests; Model stationary and moored; 0.96 to 1.01 m ice thickness
ACL Tests; Model stationary and moored; 0.49 m ice thickness

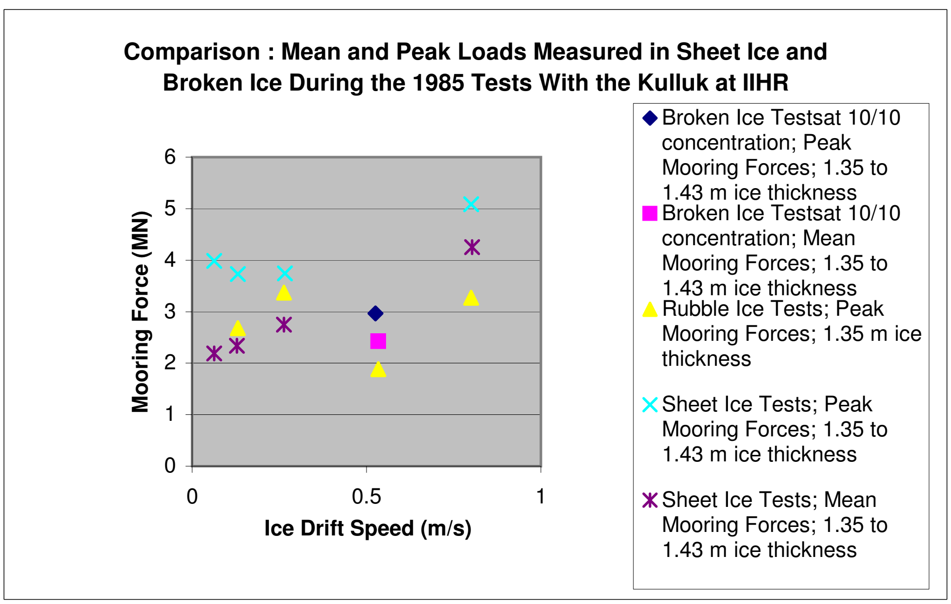


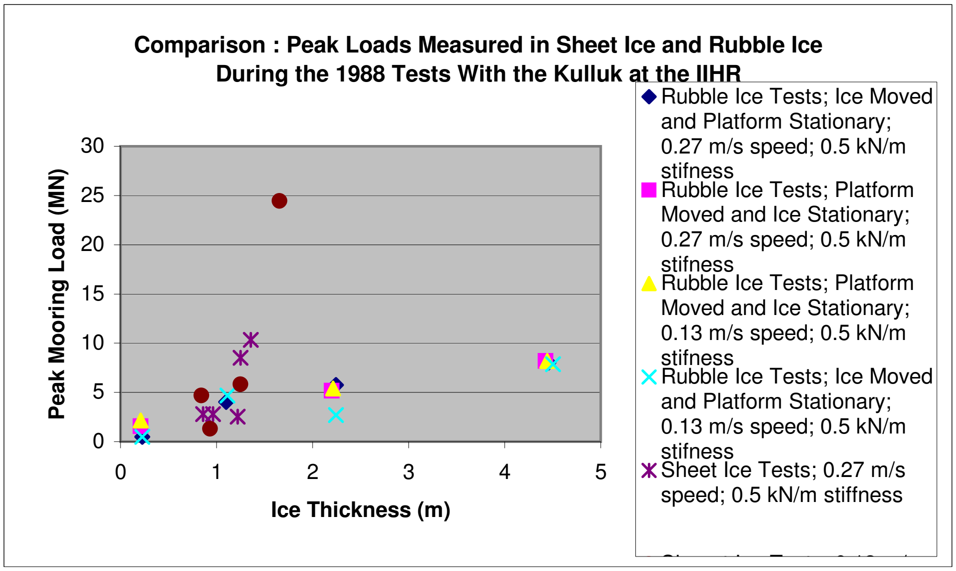
Effect of Ice Drift Speed on Mean Loads for High Ice Thicknesses (of 1.2 to 1.8 m)
Mean Mooring Force (MN)
20
18
16
14
12
10
8
6
4
2
0
0
0.5
1
1.5
Ice Drift Speed (m/s)
1988 IIHR Tests; Model stationary and compliant; 1.8 m ice thickness
ACL Tests; Model stationary and moored; 1.53 m ice thickness


Comparison: Peak Loads Measured in Sheet Ice and Broken Ice
During Tests With the Kulluk at HSVA
Peak Mooring Load (MN)
0
1
2
3
4
5
6
7
8
9
Velocity (m/s)
0
0.2
0.4
0.6
0.8
Sheet Ice Tests; 1.5 m ice thickness
Broken Ice Tests with 9+/10 ice concentration; 1.6 m ice thickness
Broken Ice Tests with 9+/10 ice concentration; 1.21 m ice thickness
Sheet Ice Tests; 1.21 to 1.26 m ice thickness

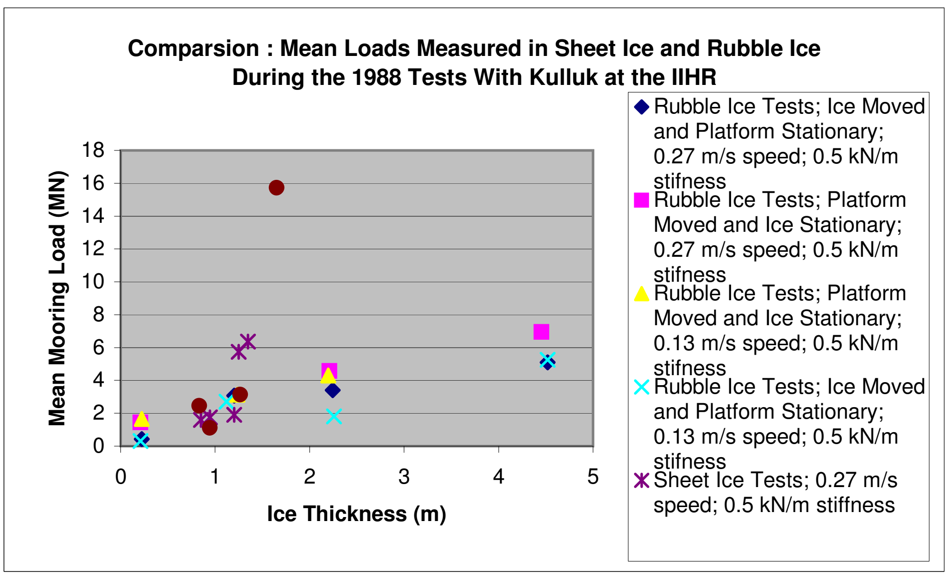

Comparsion : Peak Loads Measured in Sheet Ice and Broken Ice
During Tests With the Kulluk at ACL
Peak Mooring Loads (MN)
0
2
4
6
8
10
12
14
16
18
Ice Thickness (m)
0
0.5
1
1.5
2
Sheet Ice Tests; Peak Mooring Loads; 0.25 to 0.35 m/s speed
Broken Ice Tests with ice concentration of 9.5 to 10/10;Peak Mooring Loads; 0.025 m/s speed
Sheet Ice Tests for ice concentration of 9.5 to 10/10; Peak Mooring Loads; 0.025 m/s speed
Broken Ice Tests for ice concentration of 9.5 to 10/10; Peak Mooring Loads; 0.25 to 0.35 m/s speed


Comparison : Mean Loads Measured in Sheet Ice and Broken Ice During Tests With the Kulluk at ACL
Mean Mooring Loads (MN)
12
10
8
6
4
2
0
0
0.5
1
1.5
2
Ice Thickness (m)
Broken Ice Tests with ice concentration of 9.5 to 10/10;Mean Mooring Loads; 0.025 m/s speed
Broken Ice Tests with ice concentration of 9.5 to 10/10;Mean Mooring Loads; 0.25 0.35 m/s speed
Sheet Ice Tests; Mean Mooring Loads; 0.025 m/s speed
Sheet Ice Tests; Mean Mooring Loads; 0.25 to 0.35 m/s speed


Comparison : Mean and Peak Loads Measured in Sheet Ice and Broken Ice During the 1985 Tests With the Kulluk at IIHR
Mooring Force (MN)
6
5
4
3
2
1
0
0
0.5
1
Ice Drift Speed (m/s)
Broken Ice Testsat 10/10 concentration; Peak Mooring Forces; 1.35 to 1.43 m ice thickness
Broken Ice Testsat 10/10 concentration; Mean Mooring Forces; 1.35 to 1.43 m ice thickness
Rubble Ice Tests; Peak Mooring Forces; 1.35 m ice thickness
Sheet Ice Tests; Peak Mooring Forces; 1.35 to 1.43 m ice thickness
Sheet Ice Tests; Mean Mooring Forces; 1.35 to 1.43 m ice thickness



Comparison : Peak Loads Measured in Sheet Ice and Rubble Ice
During the 1988 Tests With the Kulluk at the IIHR
Peak Mooring Load (MN)
0
5
10
15
20
25
30
0
1
2
3
4
5
Ice Thickness (m)
Rubble Ice Tests; Ice Moved and Platform Stationary; 0.27 m/s speed; 0.5 kN/m stifness
Rubble Ice Tests; Platform Moved and Ice Stationary; 0.27 m/s speed; 0.5 kN/m stifness
Rubble Ice Tests; Platform Moved and Ice Stationary; 0.13 m/s speed; 0.5 kN/m stifness
Rubble Ice Tests; Ice Moved and Platform Stationary; 0.13 m/s speed; 0.5 kN/m stifness
Sheet Ice Tests; 0.27 m/s speed; 0.5 kN/m stiffness

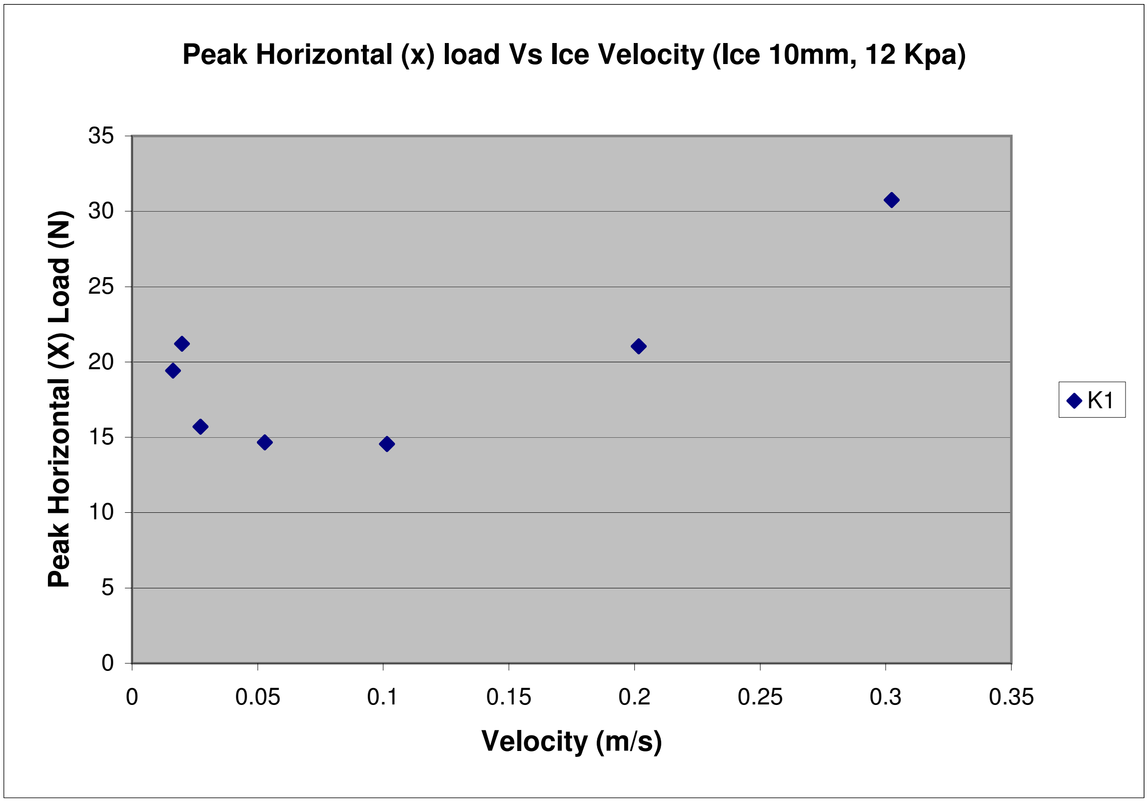


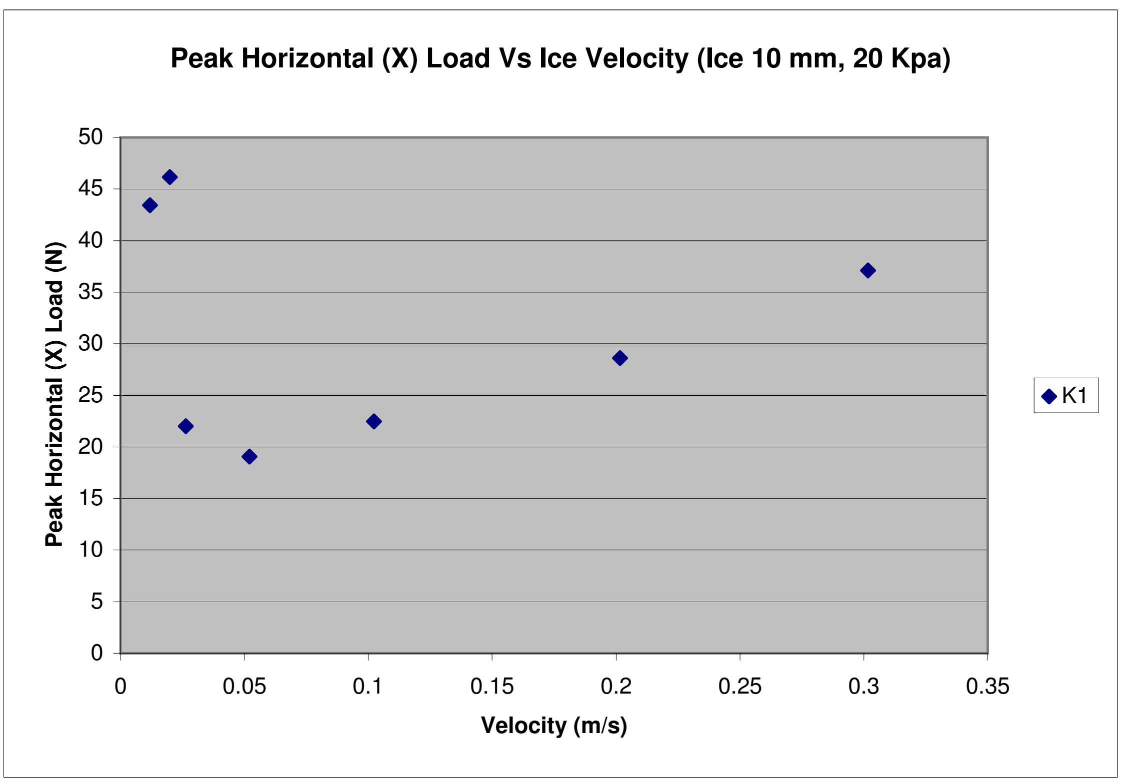
Comparsion : Mean Loads Measured in Sheet Ice and Rubble Ice
During the 1988 Tests With Kulluk at the IIHR
Mean Mooring Load (MN)
0
2
4
6
8
10
12
14
16
18
0
1
2
3
4
5
Ice Thickness (m)
Rubble Ice Tests; Ice Moved and Platform Stationary; 0.27 m/s speed; 0.5 kN/m stifness
Rubble Ice Tests; Platform Moved and Ice Stationary; 0.27 m/s speed; 0.5 kN/m stifness
Rubble Ice Tests; Platform Moved and Ice Stationary; 0.13 m/s speed; 0.5 kN/m stifness
Rubble Ice Tests; Ice Moved and Platform Stationary; 0.13 m/s speed; 0.5 kN/m stifness
Sheet Ice Tests; 0.27 m/s speed; 0.5 kN/m stiffness

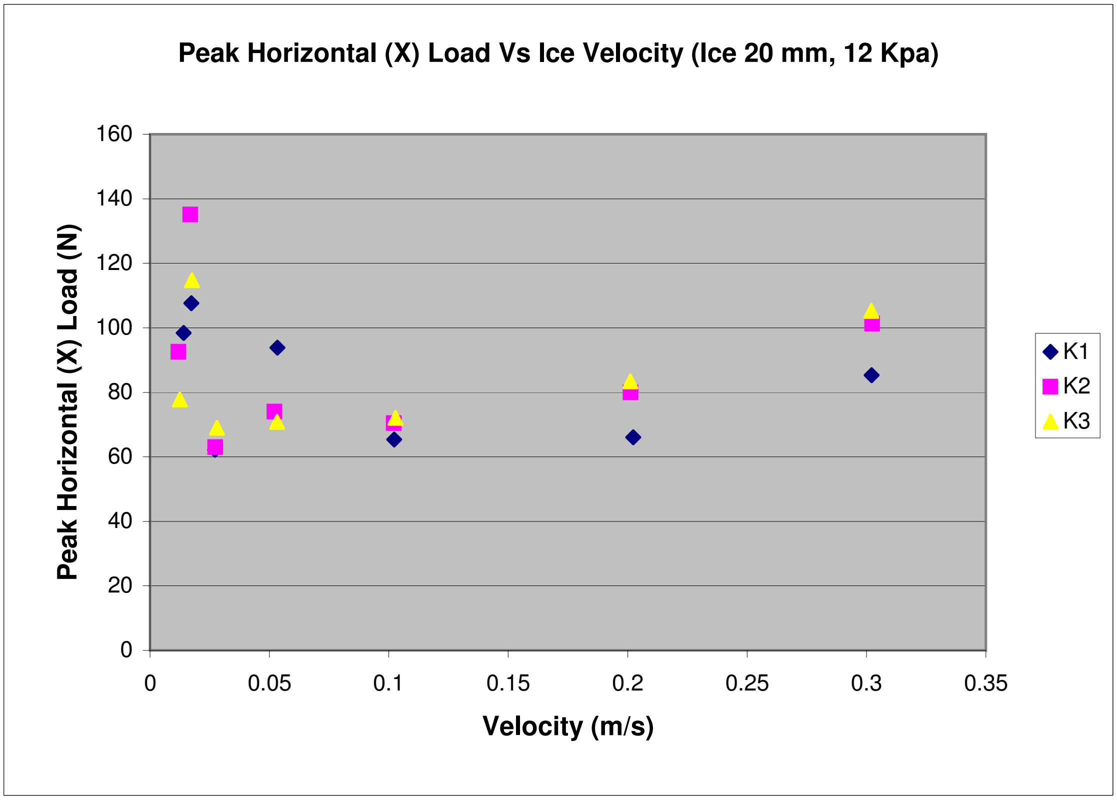
Appendix I
Preliminary Test Results (Graphs)

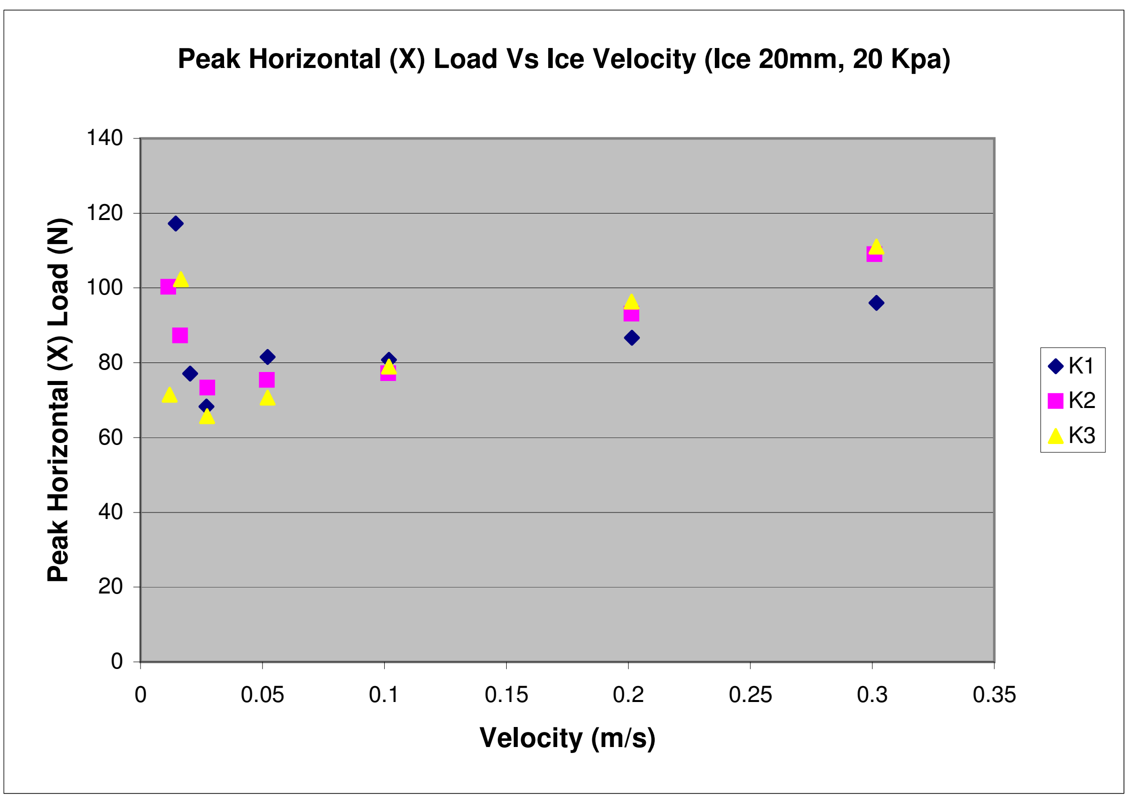
This appendix contains:

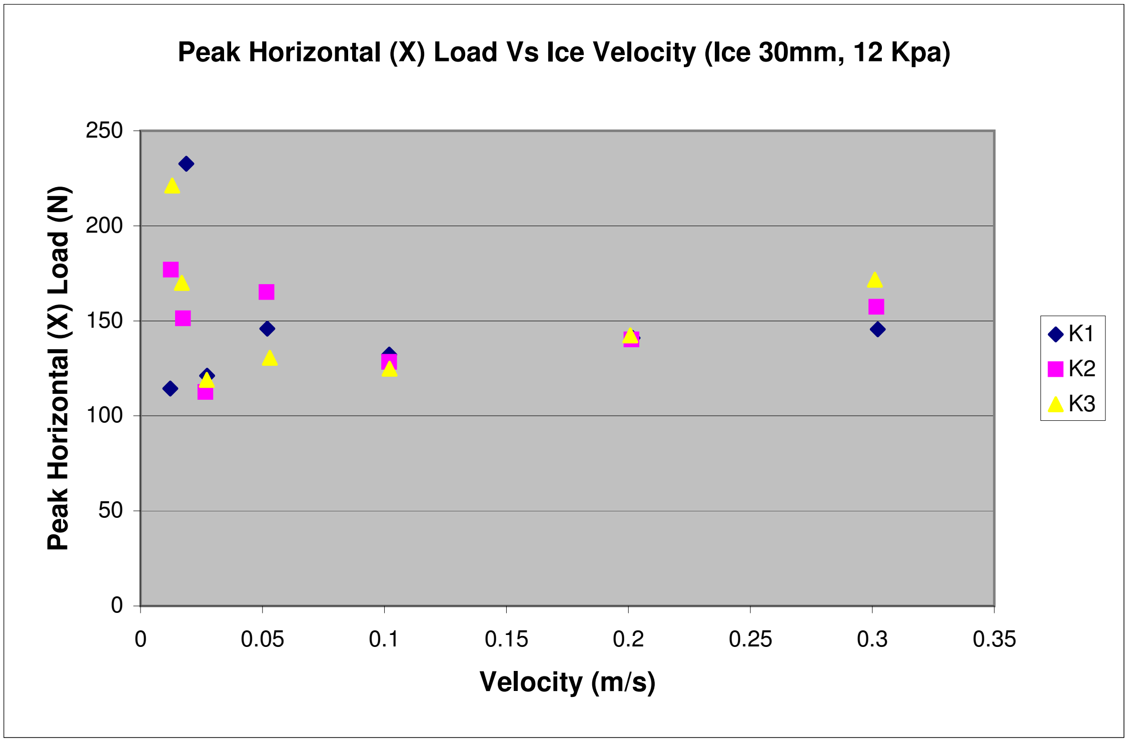
- Typical test results for Level Ice


Peak Horizontal (x) load Vs Ice Velocity (Ice 10mm, 12 Kpa)
Peak Horizontal (X) Load (N)
35
30
25
20
15
10
5
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
Velocity (m/s)
K1

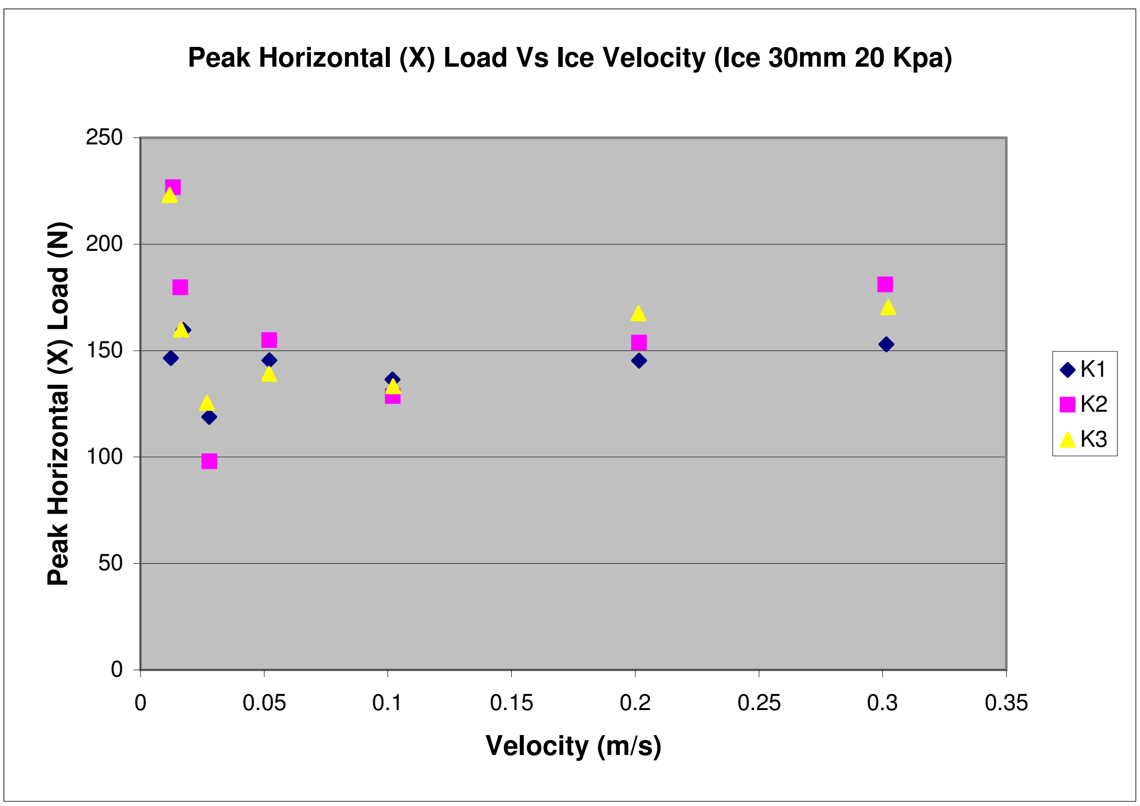

Peak Horizontal (X) Load Vs Ice Velocity (Ice 10 mm, 20 Kpa)
Peak Horizontal (X) Load (N)
50
45
40
35
30
25
20
15
10
5
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
Velocity (m/s)
K1


Peak Horizontal (X) Load Vs Ice Velocity (Ice 20 mm, 12 Kpa)
Peak Horizontal (X) Load (N)
160
140
120
100
80
60
40
20
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
Velocity (m/s)
K1
K2
K3

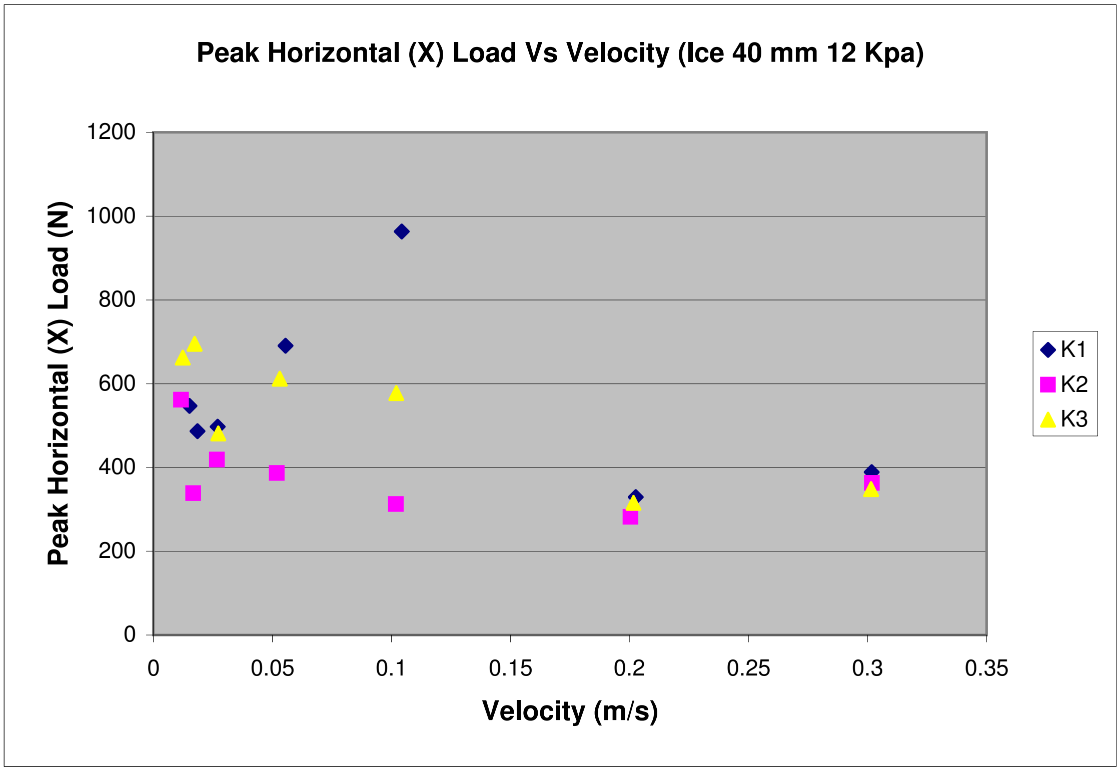

Peak Horizontal (X) Load Vs Ice Velocity (Ice 20mm, 20 Kpa)
Peak Horizontal (X) Load (N)
140
120
100
80
60
40
20
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
Velocity (m/s)
K1
K2
K3

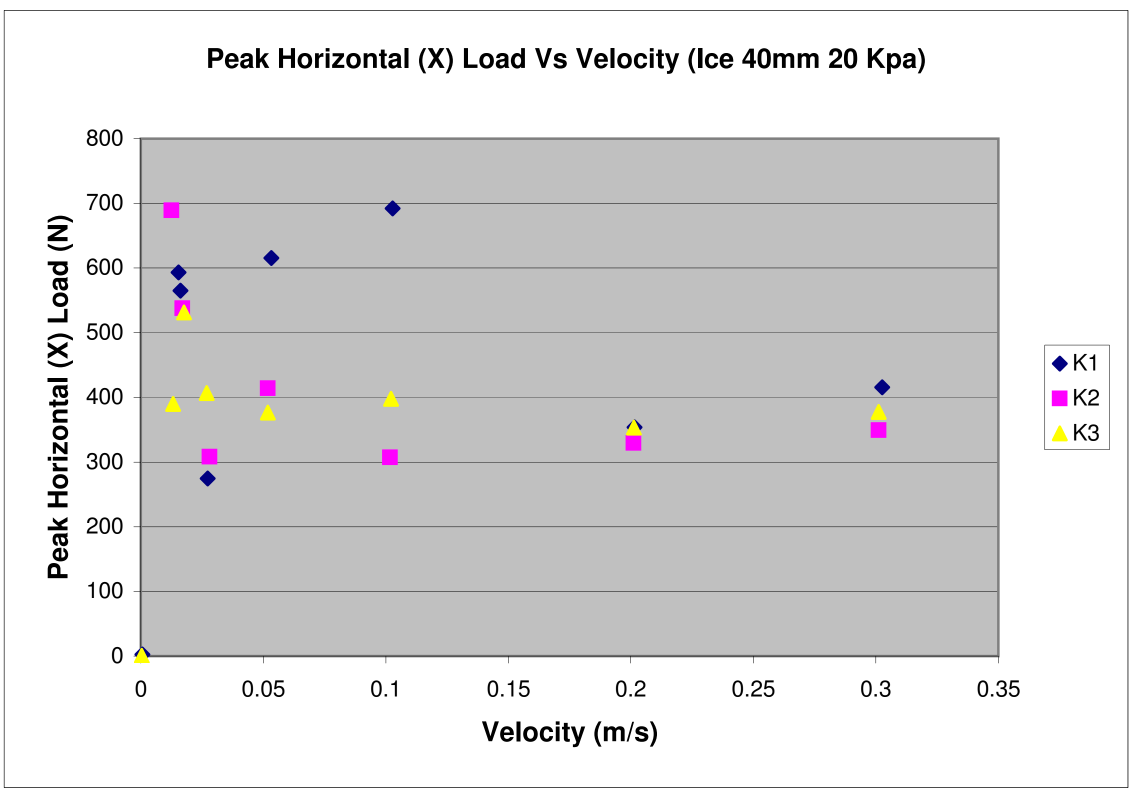


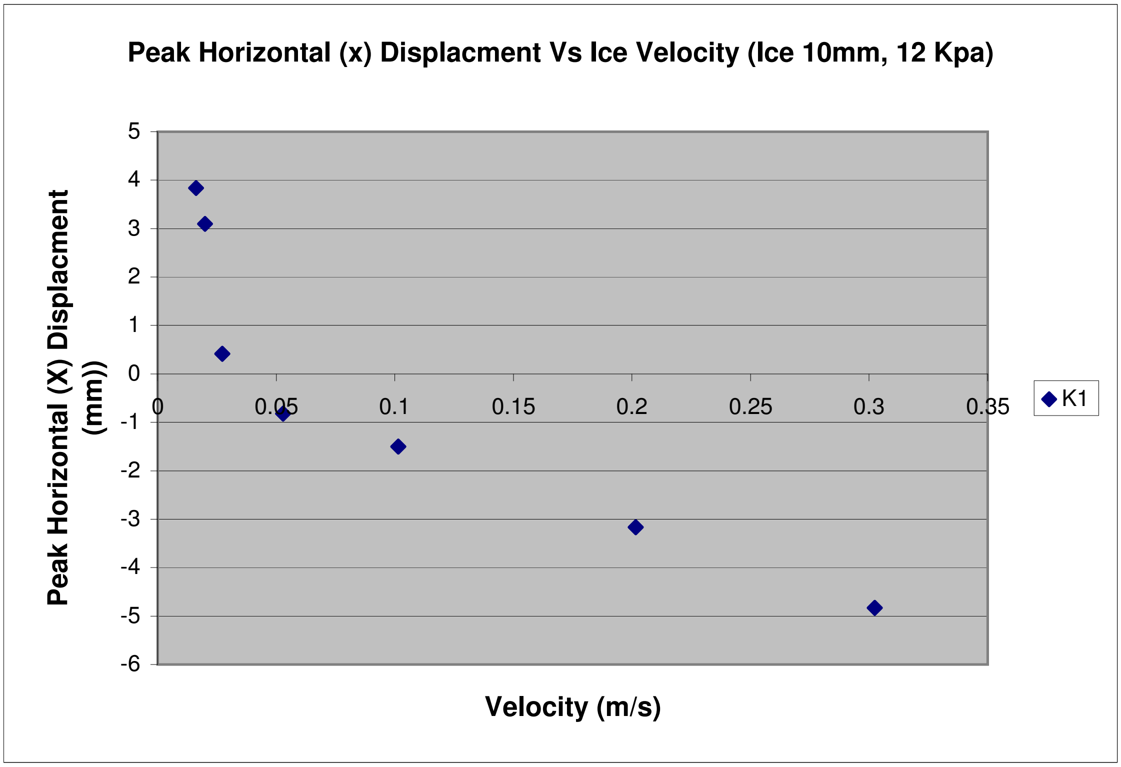
Peak Horizontal (X) Load Vs Ice Velocity (Ice 30mm, 12 Kpa)
Peak Horizontal (X) Load (N)
250
200
150
100
50
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
Velocity (m/s)
K1
K2
K3

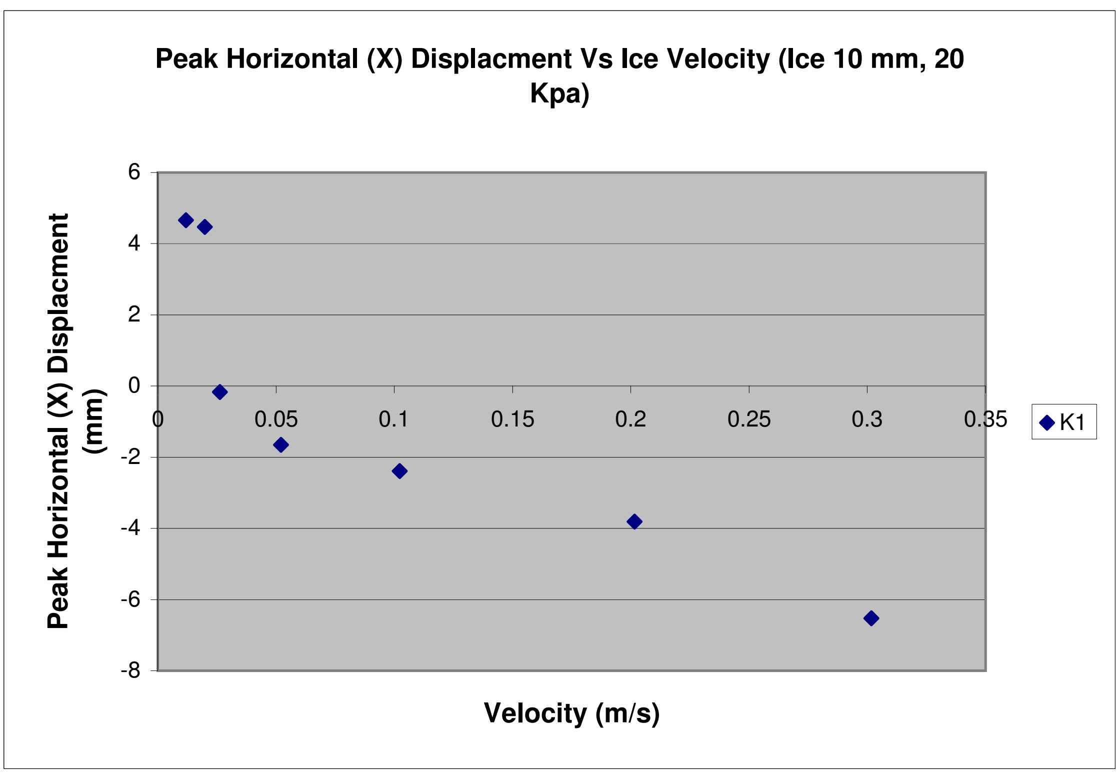


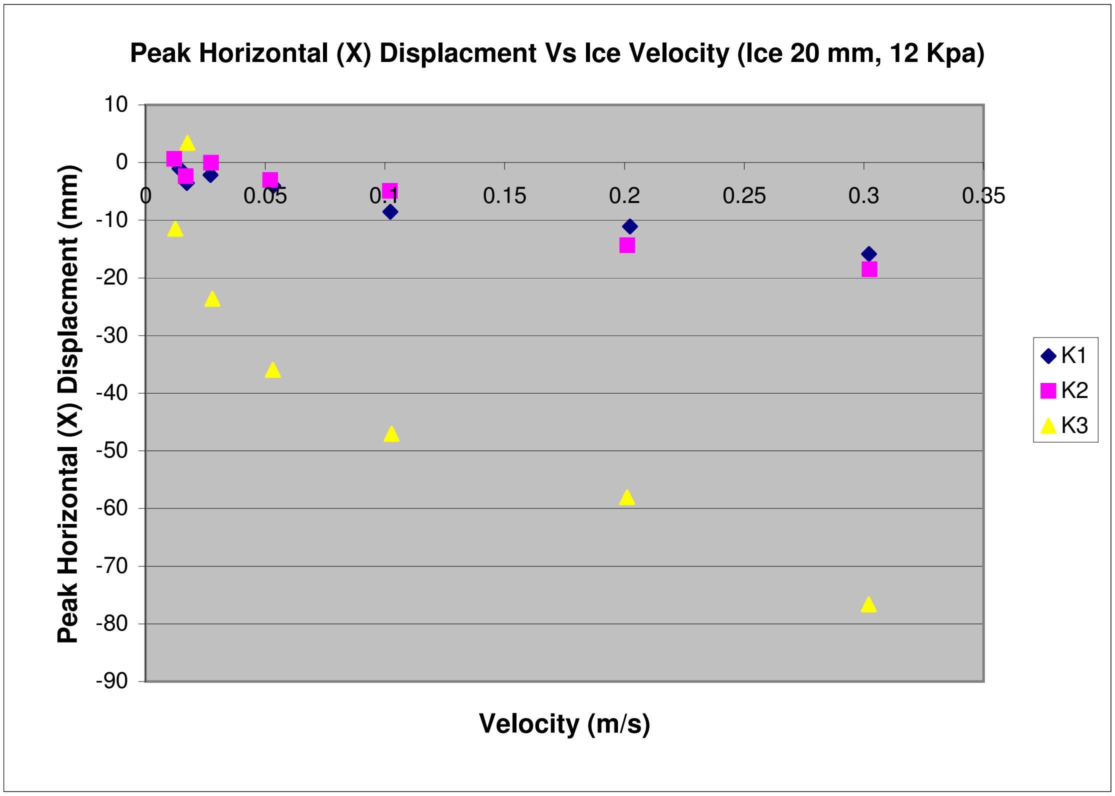
Peak Horizontal (X) Load Vs Ice Velocity (Ice 30mm 20 Kpa)
Peak Horizontal (X) Load (N)
250
200
150
100
50
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
Velocity (m/s)
K1
K2
K3

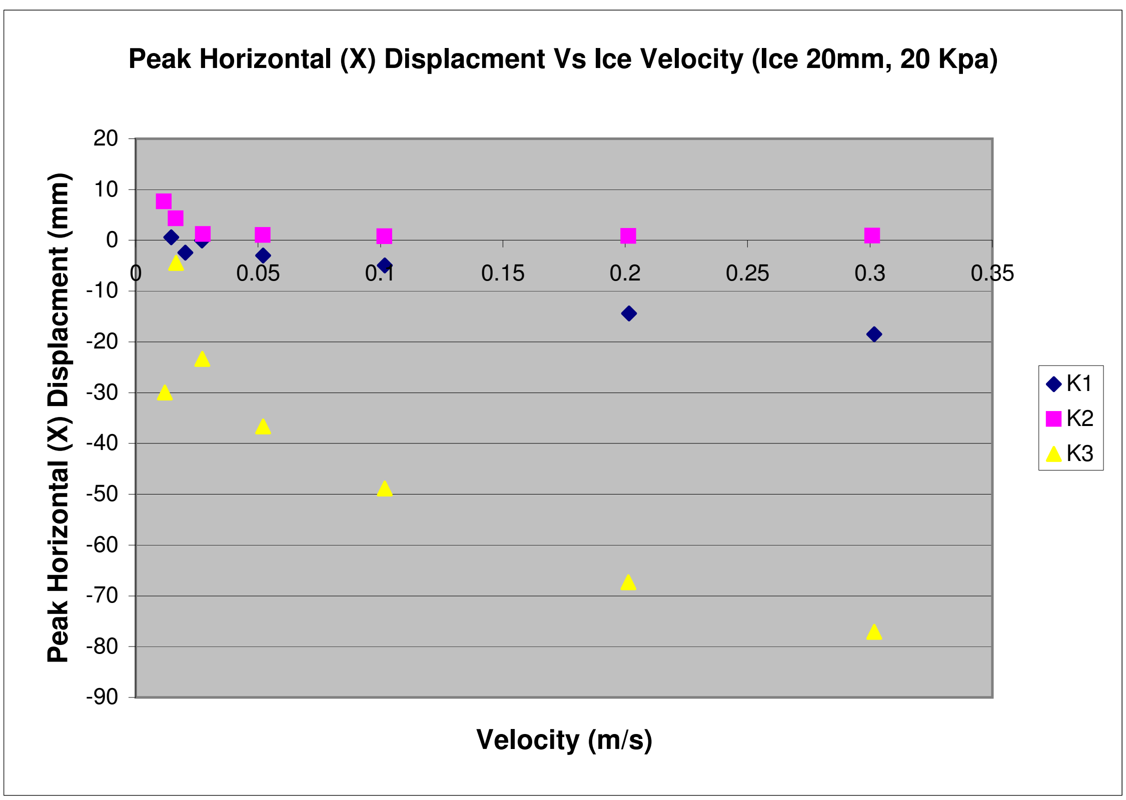

Peak Horizontal (X) Load Vs Velocity (Ice 40 mm 12 Kpa)
Peak Horizontal (X) Load (N)
Velocity (m/s)
0
200
400
600
800
1000
1200
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
K1
K2
K3

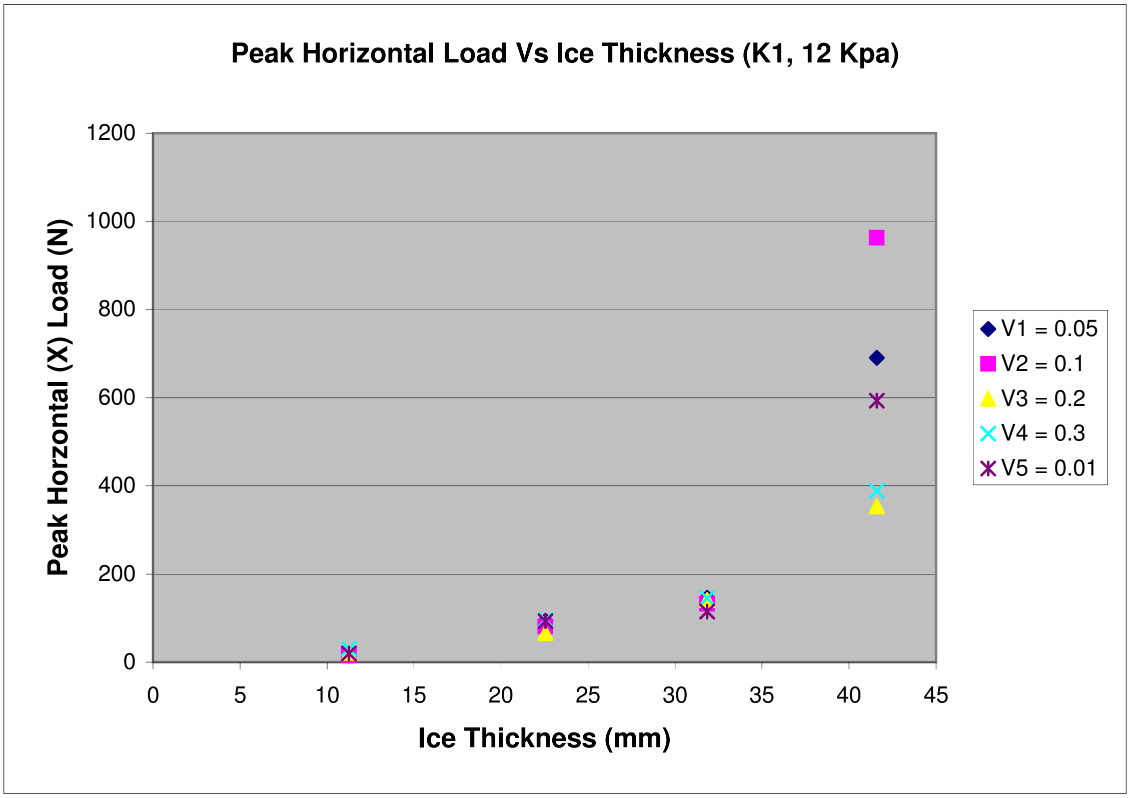

Peak Horizontal (X) Load Vs Velocity (Ice 40mm 20 Kpa)
Peak Horizontal (X) Load (N)
Velocity (m/s)
0
100
200
300
400
500
600
700
800
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
K1
K2
K3

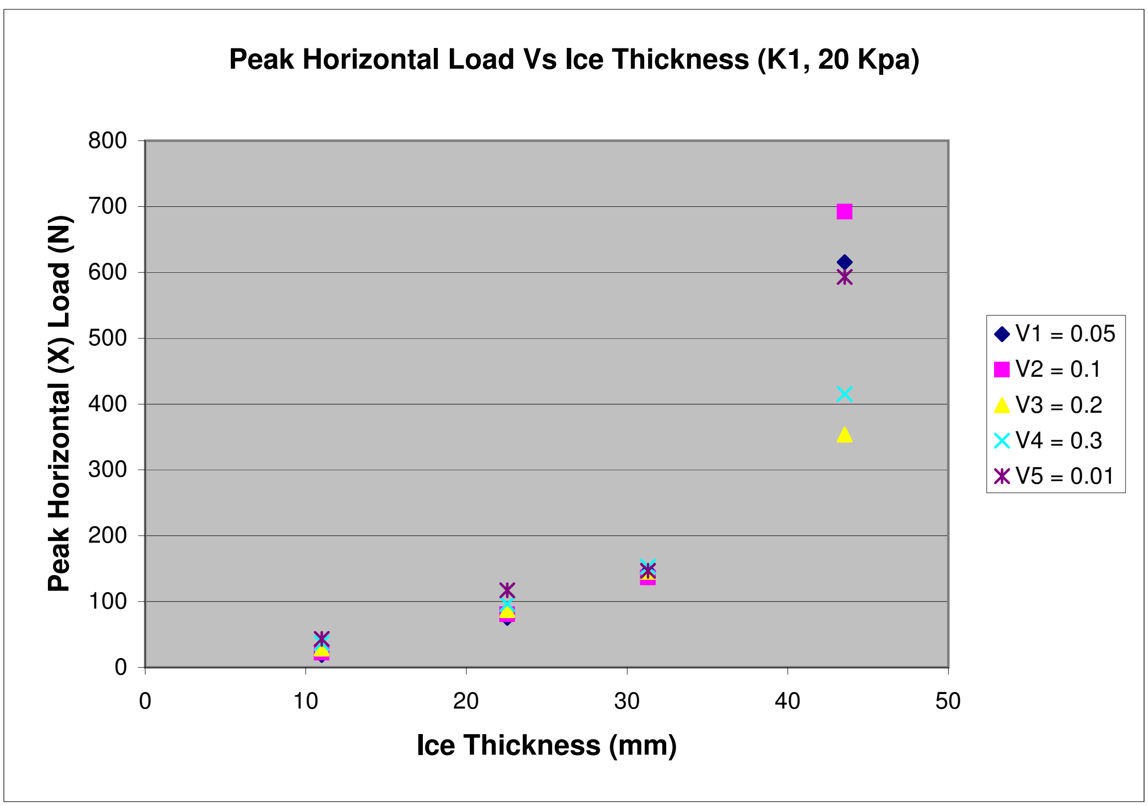

Peak Horizontal (x) Displacment Vs Ice Velocity (Ice 10mm, 12 Kpa)
Peak Horizontal (X) Displacment (mm))
Velocity (m/s)
K1
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35

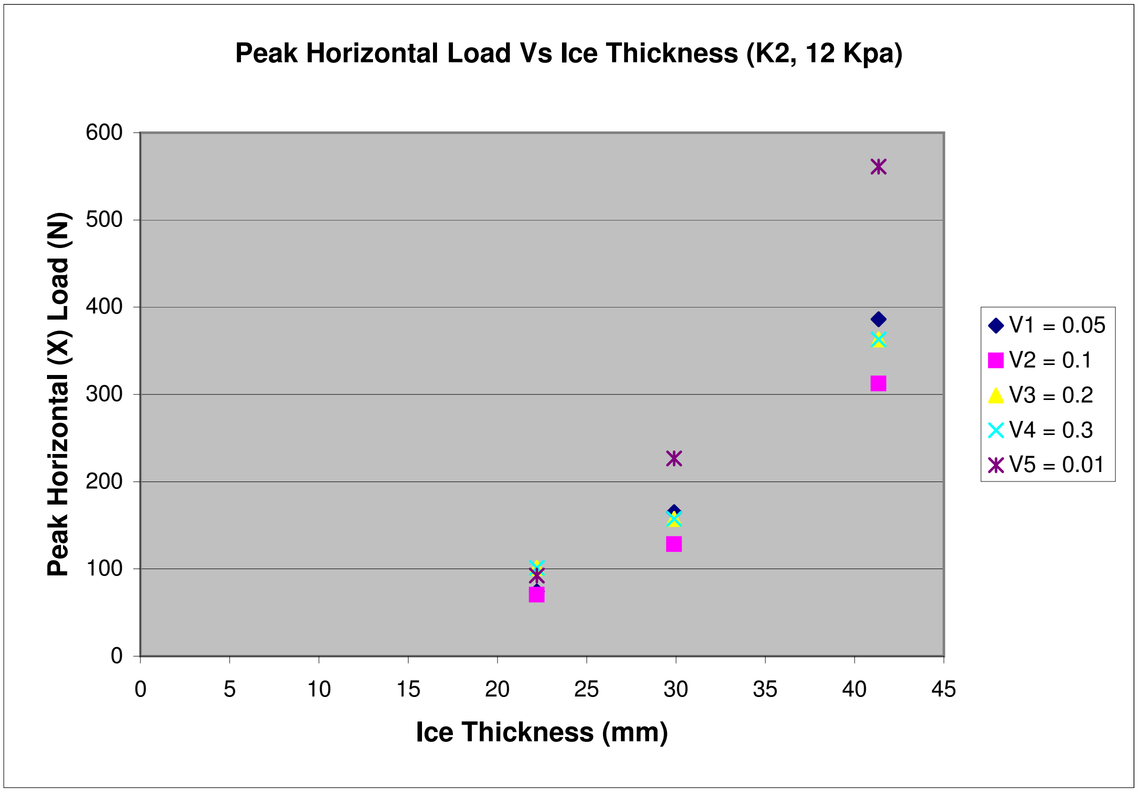

Peak Horizontal (X) Displacment Vs Ice Velocity (Ice 10 mm, 20 Kpa)
Peak Horizontal (X) Displacment (mm)
Velocity (m/s)
K1
6
4
2
0
-2
-4
-6
-8
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35

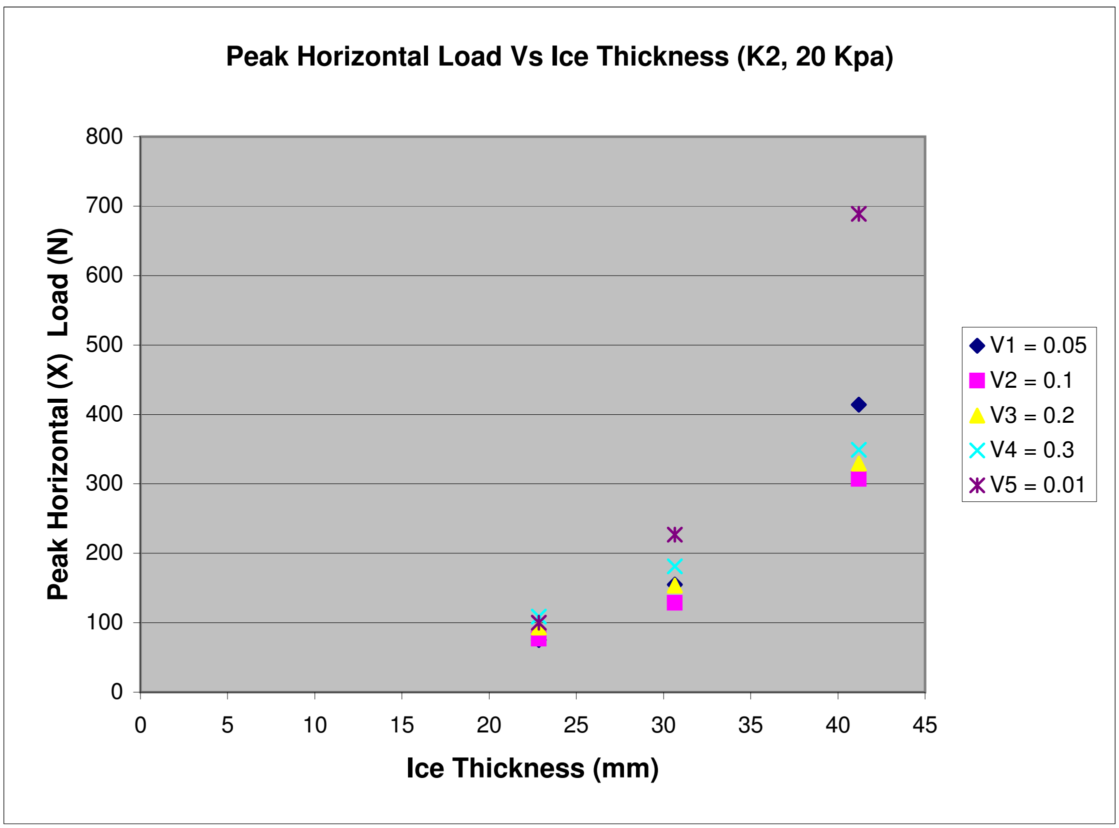

Peak Horizontal (X) Displacment Vs Ice Velocity (Ice 20 mm, 12 Kpa)
Peak Horizontal (X) Displacment (mm)
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
Velocity (m/s)
K1
K2
K3

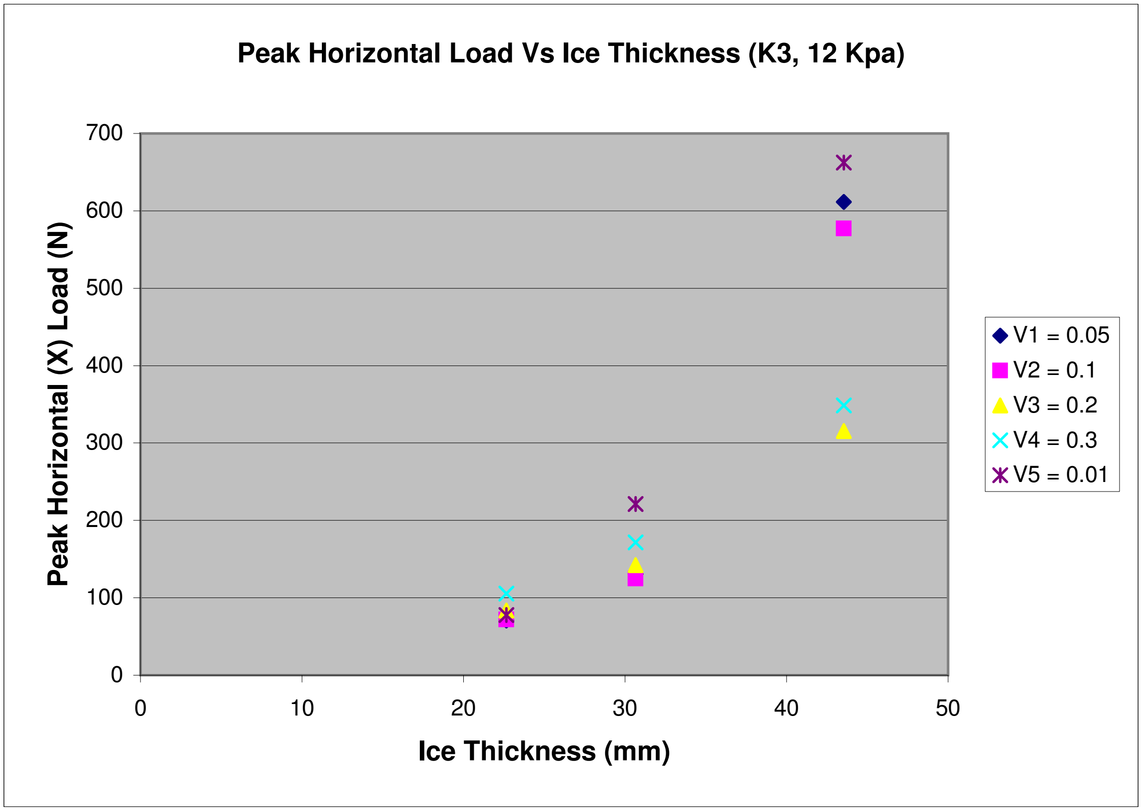

Peak Horizontal (X) Displacment Vs Ice Velocity (Ice 20mm, 20 Kpa)
Peak Horizontal (X) Displacment (mm)
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
Velocity (m/s)
K1
K2
K3

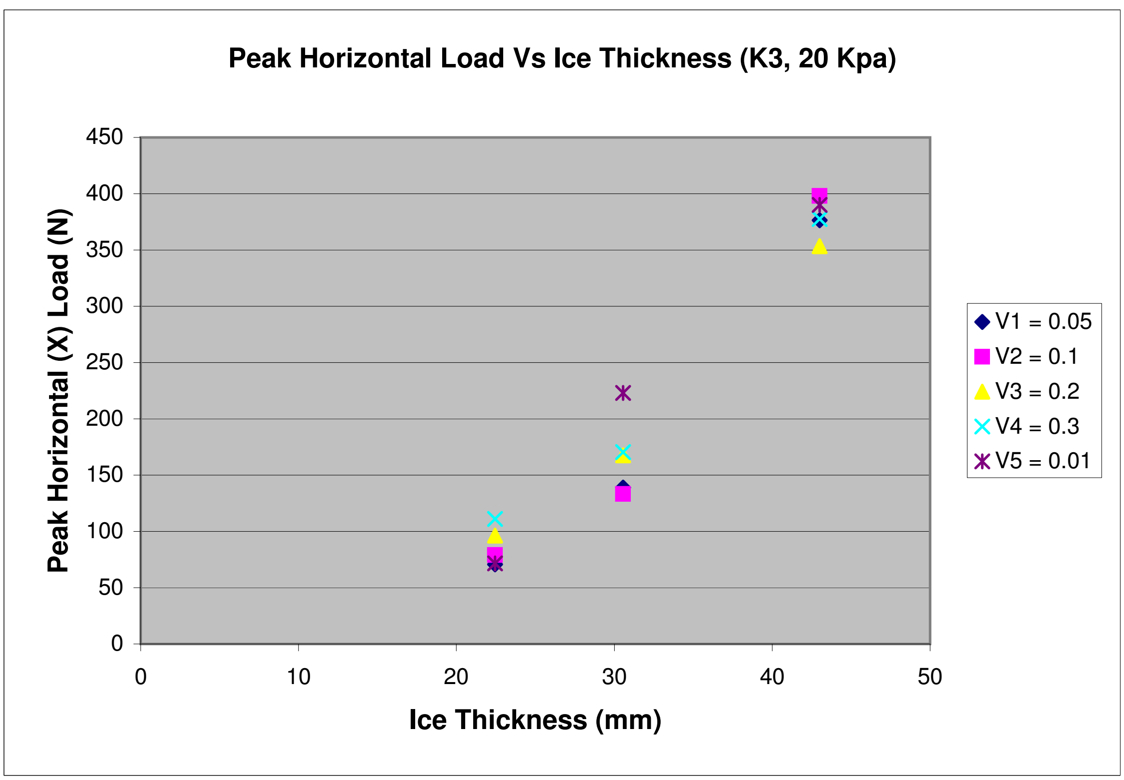

Peak Horizontal Load Vs Ice Thickness (K1, 12 Kpa)
Peak Horizontal (X) Load (N)
1200
1000
800
600
400
200
0
0
5
10
15
20
25
30
35
40
45
Ice Thickness (mm)
V1 = 0.05
V2 = 0.1
V3 = 0.2
V4 = 0.3
V5 = 0.01

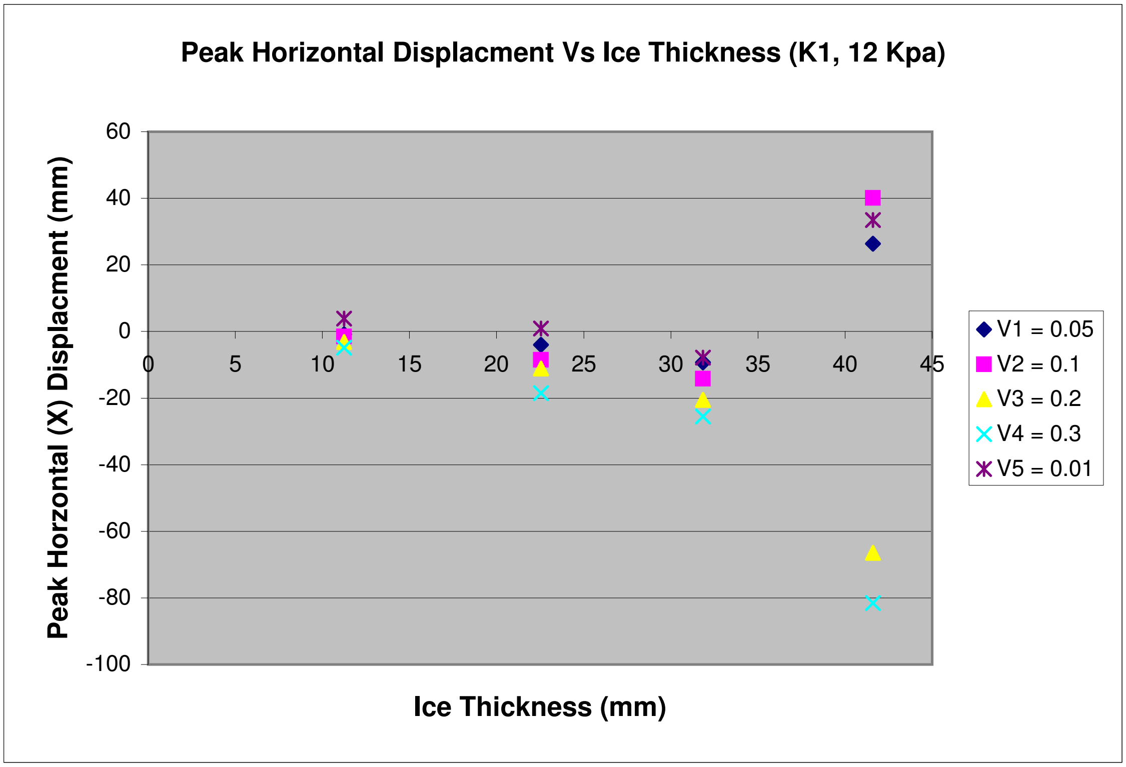

Peak Horizontal Load Vs Ice Thickness (K1, 20 Kpa)
Peak Horizontal (X) Load (N)
800
700
600
500
400
300
200
100
0
0
10
20
30
40
50
Ice Thickness (mm)
V1 = 0.05
V2 = 0.1
V3 = 0.2
V4 = 0.3
V5 = 0.01

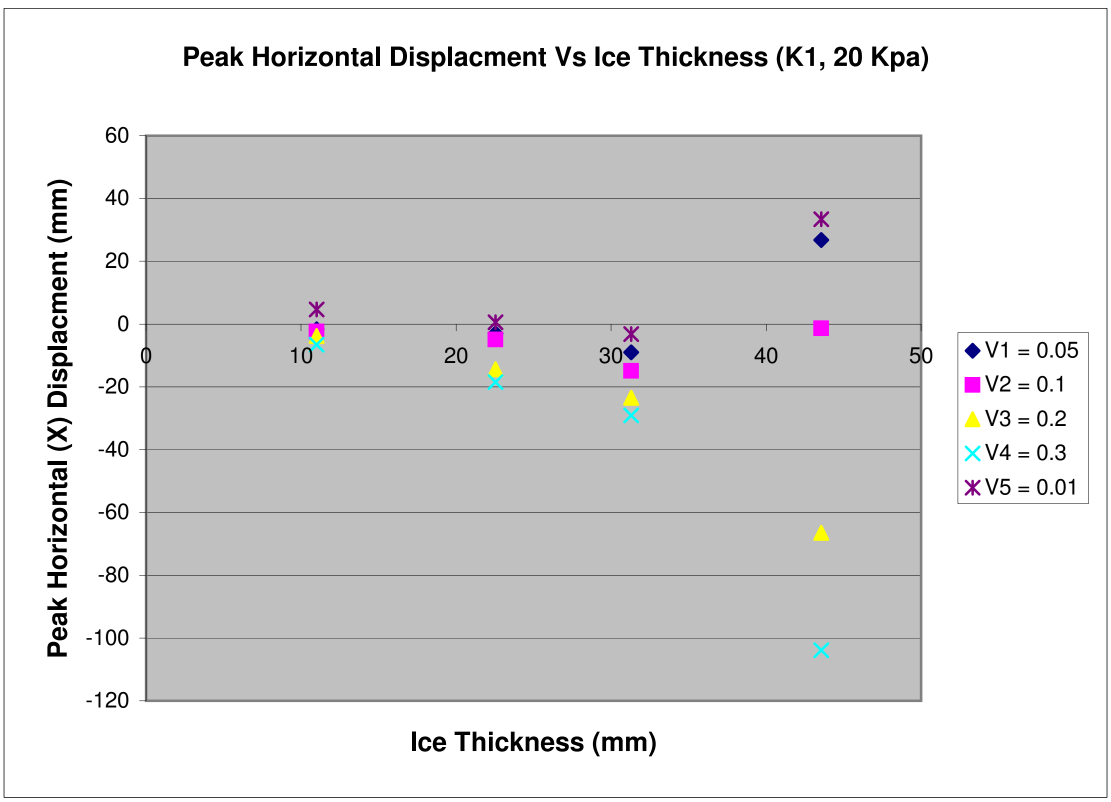

Peak Horizontal Load Vs Ice Thickness (K2, 12 Kpa)
Peak Horizontal (X) Load (N)
Ice Thickness (mm)
0
100
200
300
400
500
600
0
5
10
15
20
25
30
35
40
45
V1 = 0.05
V2 = 0.1
V3 = 0.2
V4 = 0.3
V5 = 0.01

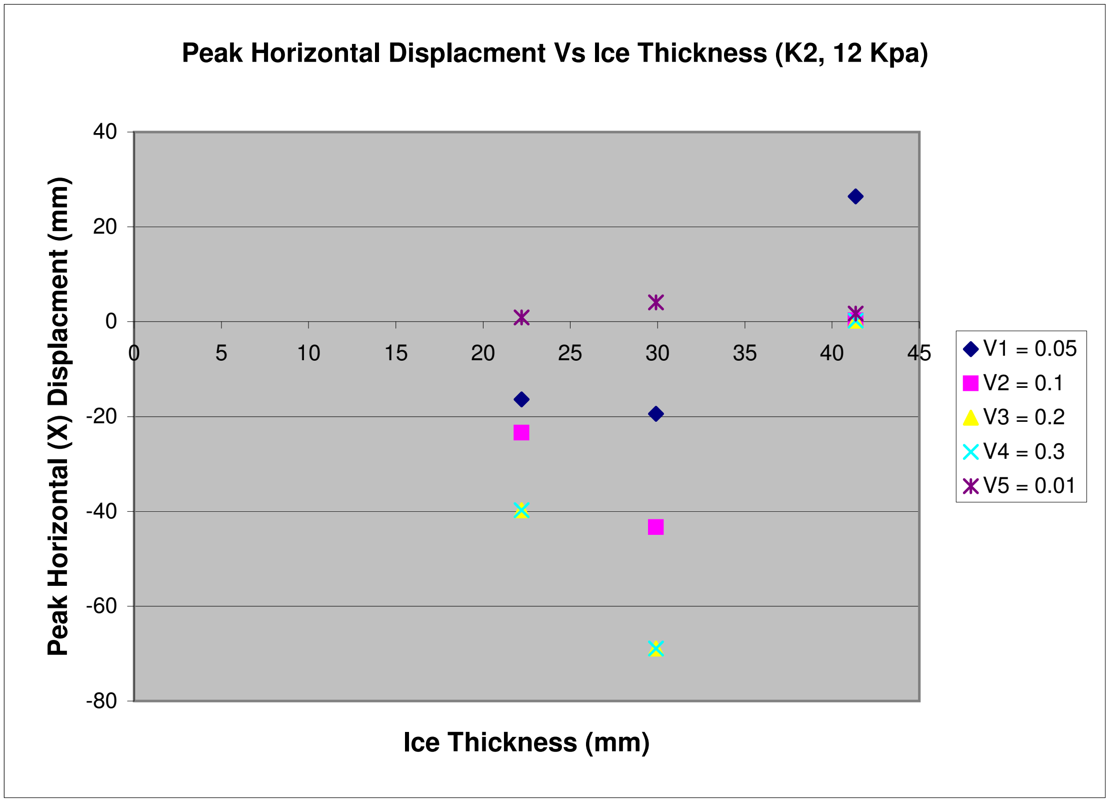

Peak Horizontal Load Vs Ice Thickness (K2, 20 Kpa)
Peak Horizontal (X) Load (N)
Ice Thickness (mm)
0
100
200
300
400
500
600
700
800
0
5
10
15
20
25
30
35
40
45
V1 = 0.05
V2 = 0.1
V3 = 0.2
V4 = 0.3
V5 = 0.01


Peak Horizontal Load Vs Ice Thickness (K3, 12 Kpa)
Peak Horizontal (X) Load (N)
Ice Thickness (mm)
0
100
200
300
400
500
600
700
0
10
20
30
40
50
V1 = 0.05
V2 = 0.1
V3 = 0.2
V4 = 0.3
V5 = 0.01

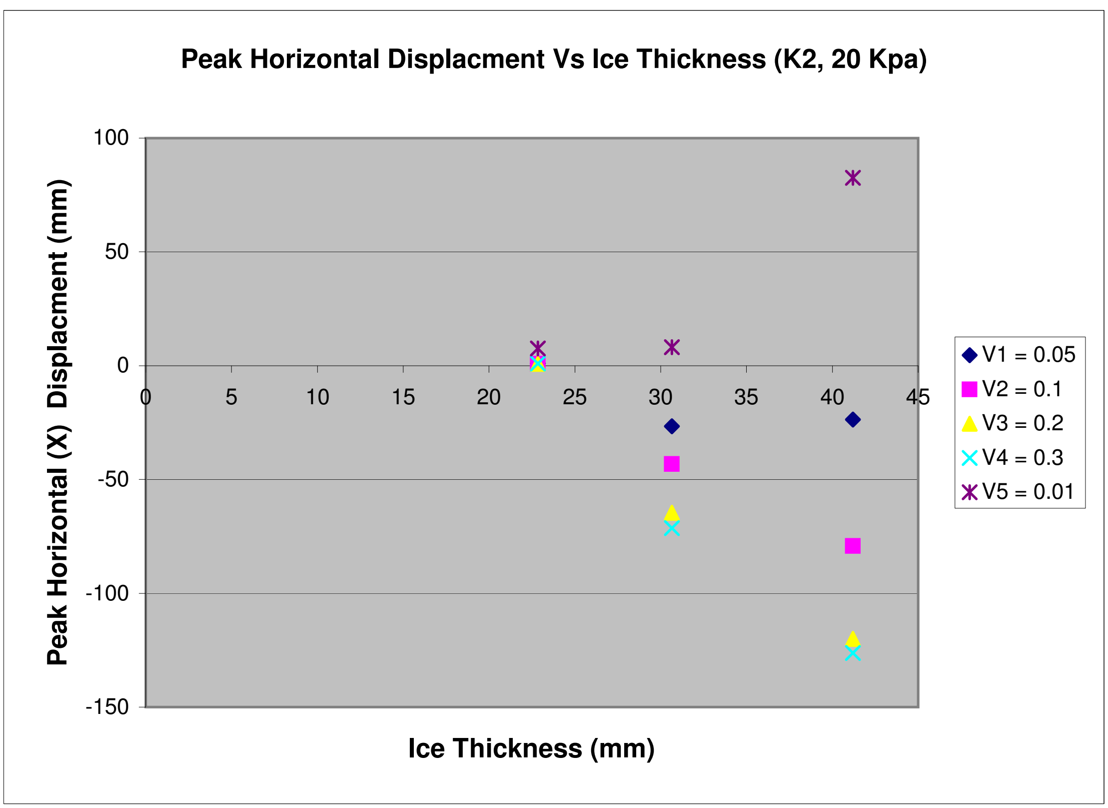

Peak Horizontal Load Vs Ice Thickness (K3, 20 Kpa)
Peak Horizontal (X) Load (N)
Ice Thickness (mm)
0
50
100
150
200
250
300
350
400
450
0
10
20
30
40
50
V1 = 0.05
V2 = 0.1
V3 = 0.2
V4 = 0.3
V5 = 0.01


Peak Horizontal Displacment Vs Ice Thickness (K1, 12 Kpa)
Peak Horzontal (X) Displacment (mm)
60
40
20
0
-20
-40
-60
-80
-100
0
5
10
15
20
25
30
35
40
45
Ice Thickness (mm)
V1 = 0.05
V2 = 0.1
V3 = 0.2
V4 = 0.3
V5 = 0.01

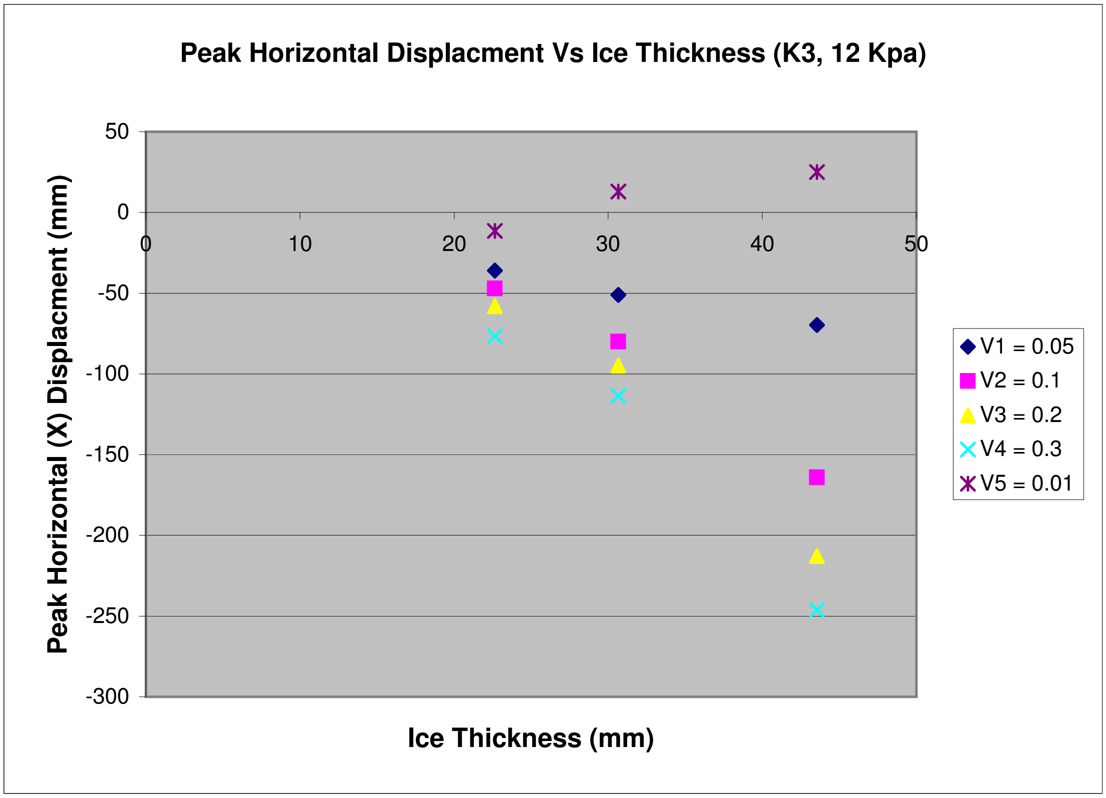

Peak Horizontal Displacment Vs Ice Thickness (K1, 20 Kpa)
Peak Horizontal (X) Displacment (mm)
60
40
20
0
-20
-40
-60
-80
-100
-120
0
10
20
30
40
50
Ice Thickness (mm)
V1 = 0.05
V2 = 0.1
V3 = 0.2
V4 = 0.3
V5 = 0.01

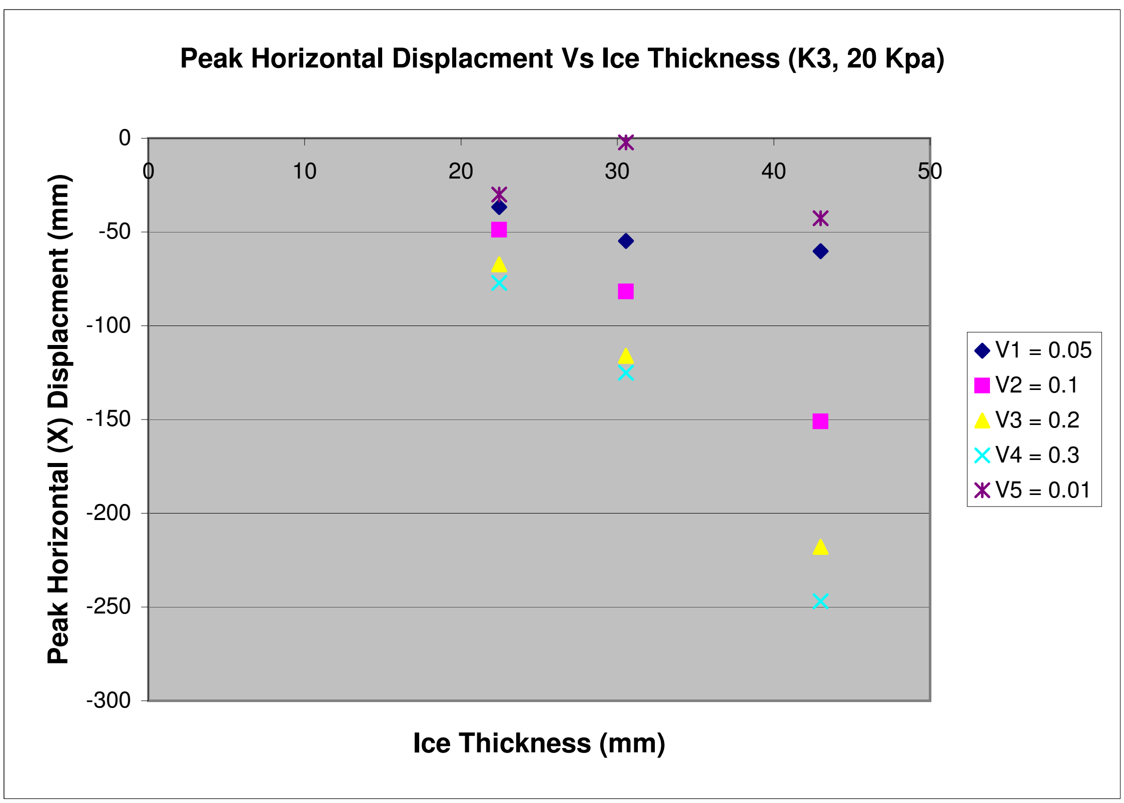


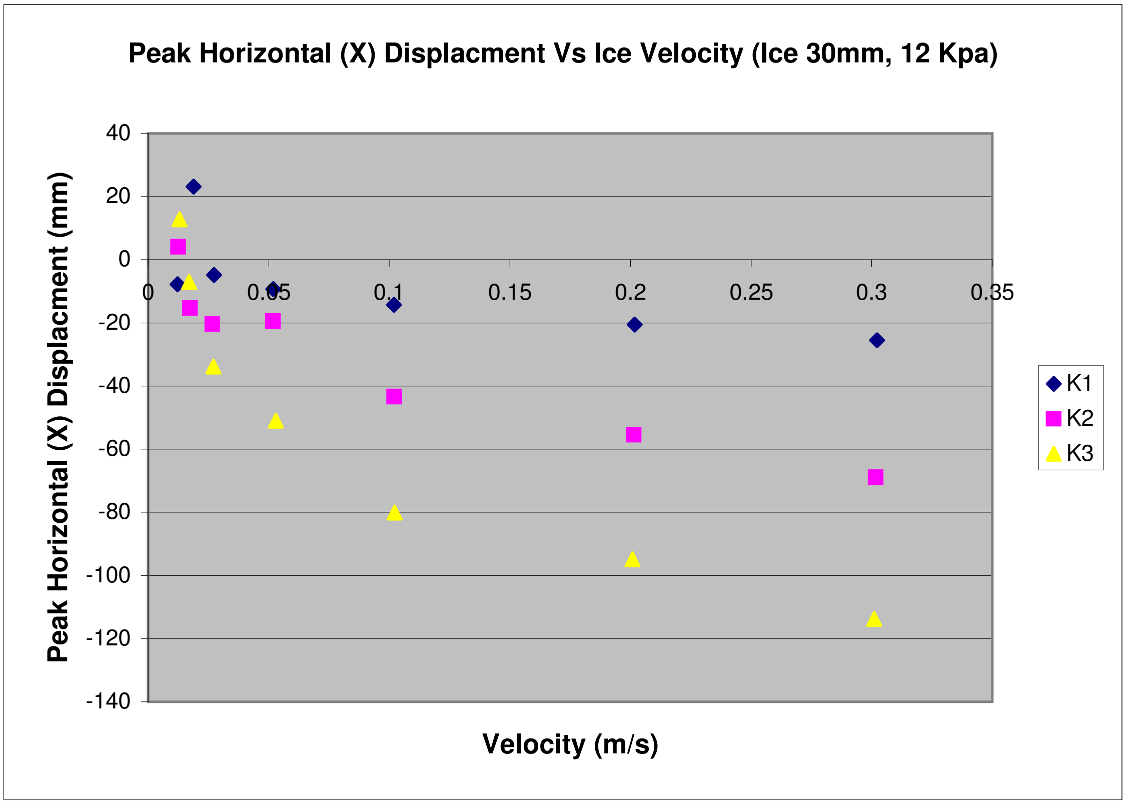
Peak Horizontal Displacment Vs Ice Thickness (K2, 12 Kpa)
40
20
0
-20
-40
-60
-80
0
5
10
15
20
25
30
35
40
45
Peak Horizontal (X) Displacment (mm)
Ice Thickness (mm)
V1 = 0.05
V2 = 0.1
V3 = 0.2
V4 = 0.3
V5 = 0.01

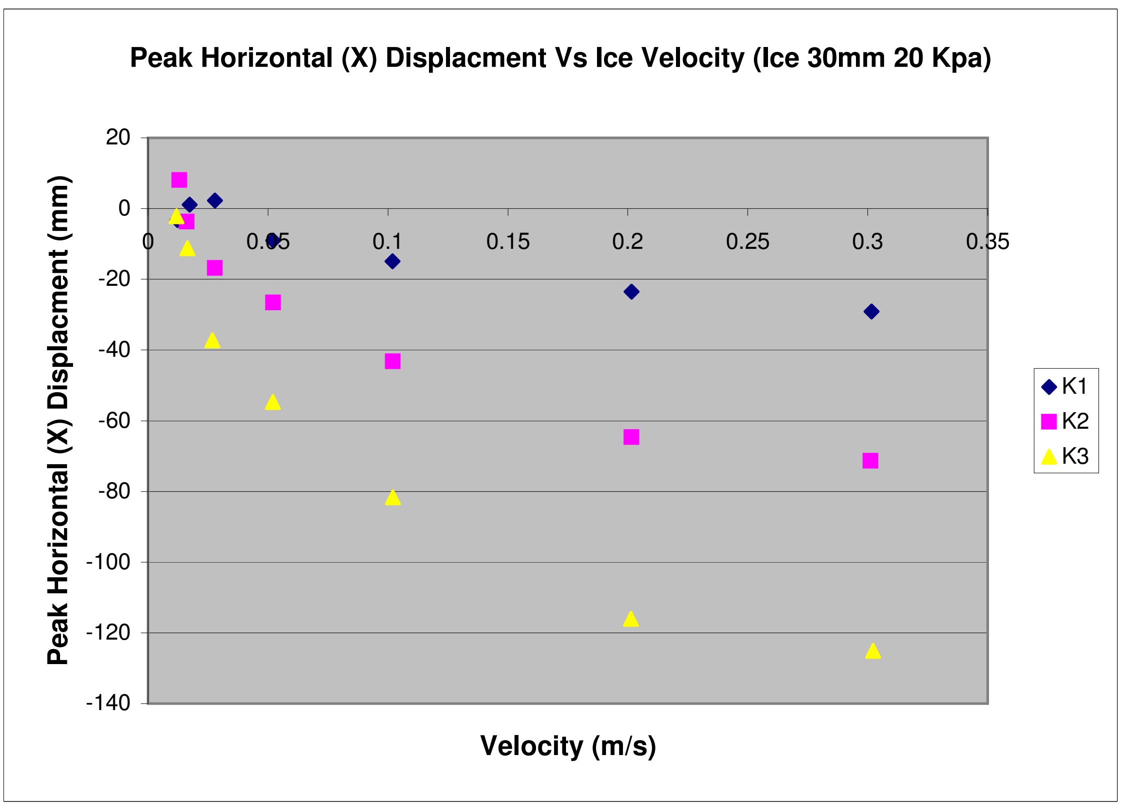


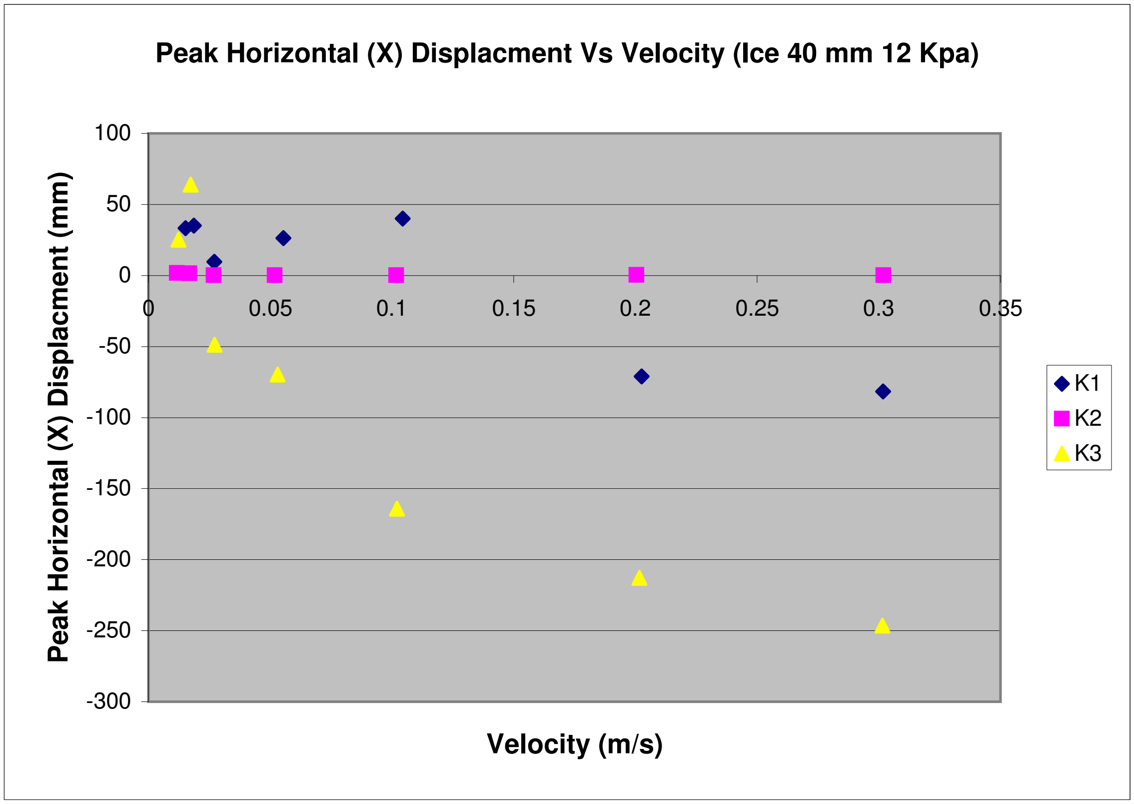
Peak Horizontal Displacment Vs Ice Thickness (K2, 20 Kpa)
100
50
0
-50
-100
-150
0
5
10
15
20
25
30
35
40
45
Peak Horizontal (X) Displacment (mm)
Ice Thickness (mm)
V1 = 0.05
V2 = 0.1
V3 = 0.2
V4 = 0.3
V5 = 0.01

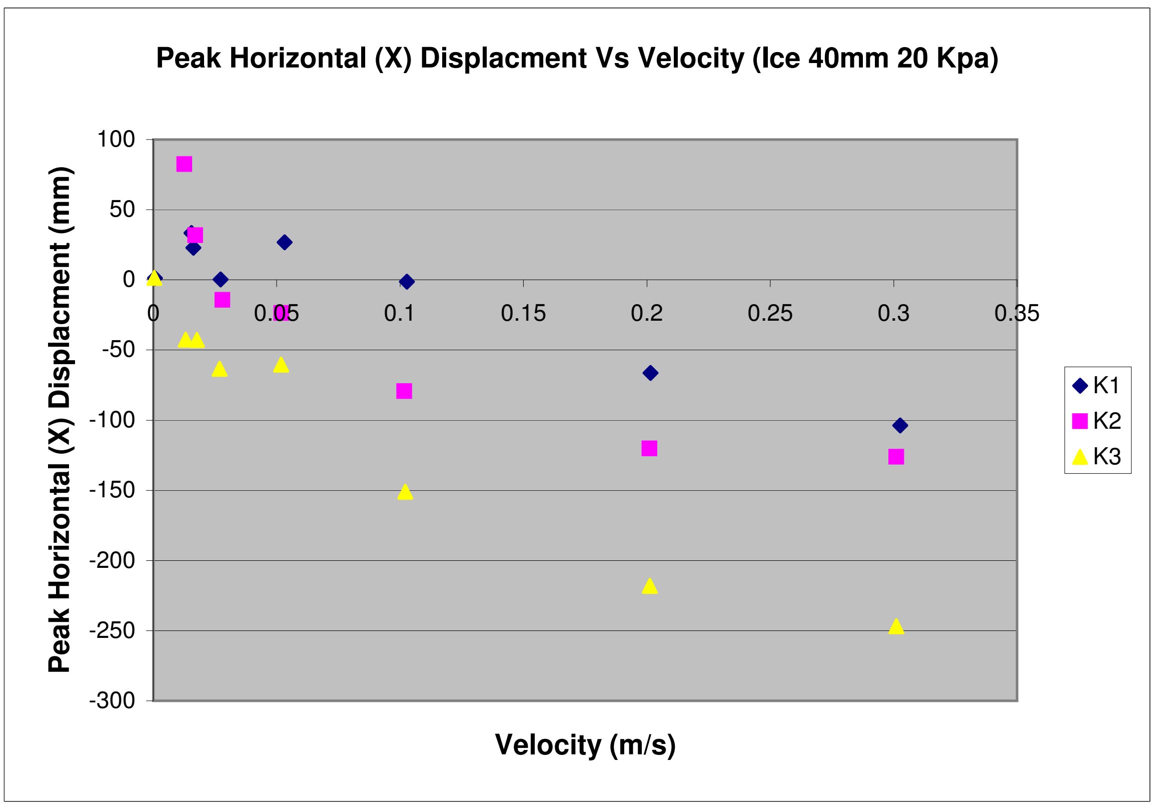

Peak Horizontal Displacment Vs Ice Thickness (K3, 12 Kpa)
Peak Horizontal (X) Displacment (mm)
Ice Thickness (mm)
50
0
-50
-100
-150
-200
-250
-300
0
10
20
30
40
50
V1 = 0.05
V2 = 0.1
V3 = 0.2
V4 = 0.3
V5 = 0.01


Peak Horizontal Displacment Vs Ice Thickness (K3, 20 Kpa)
Peak Horizontal (X) Displacment (mm)
Ice Thickness (mm)
0
-50
-100
-150
-200
-250
-300
0
10
20
30
40
50
V1 = 0.05
V2 = 0.1
V3 = 0.2
V4 = 0.3
V5 = 0.01


Peak Horizontal (X) Displacment Vs Ice Velocity (Ice 30mm, 12 Kpa)
Peak Horizontal (X) Displacment (mm)
40
20
0
-20
-40
-60
-80
-100
-120
-140
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
Velocity (m/s)
K1
K2
K3


Peak Horizontal (X) Displacment Vs Ice Velocity (Ice 30mm 20 Kpa)
Peak Horizontal (X) Displacment (mm)
20
0
-20
-40
-60
-80
-100
-120
-140
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
Velocity (m/s)
K1
K2
K3


Peak Horizontal (X) Displacment Vs Velocity (Ice 40 mm 12 Kpa)
Peak Horizontal (X) Displacment (mm)
100
50
0
-50
-100
-150
-200
-250
-300
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
Velocity (m/s)
K1
K2
K3


Peak Horizontal (X) Displacment Vs Velocity (Ice 40mm 20 Kpa)
Peak Horizontal (X) Displacment (mm)
100
50
0
-50
-100
-150
-200
-250
-300
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
Velocity (m/s)
K1
K2
K3