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Cumming, D.; Hopkins, D.; Barrett, D.

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<p>SUMMARY</p> <p>This report describes seakeeping experiments carried out on the 45 ft. (13.72 m) fishing vessel CCGA Nautical Twilight off St. John's, NL November 20, 2003. Collaborators involved in the fishing vessel sea trials include the Institute for Ocean Technology (IOT), Memorial University of Newfoundland (MUN), Oceanic Consulting Corp. (OCC), Canadian Coast Guard (CCG), the Offshore Safety and Survival Centre (OSSC) of the Marine Institute and SafetyNet – a Community Research Alliance on Health and Safety in Marine and Coastal Work. Primary financial support for the project is provided from federal funding sources including the Search & Rescue (SAR), New Initiatives Fund (NIF) and the Canadian Institutes of Health and Research (CIHR) in addition to significant in-kind contributions from the many participants. The objective of the project is to acquire quality full scale motions data on fishing vessels to validate physical model methodology as well as numerical simulation models under development. Eventually, tools will be developed and validated to evaluate the number of Motion Induced Interrupts (MIIs), induced by sudden ship motions, and their impact on crew accidents to develop criteria to reduce MIIs.</p> <p>This document describes the CCGA Nautical Twilight, the trials instrumentation package, data acquisition system, test program, data analysis procedure and presents the results. Unfortunately there was a failure of the directional wave buoy deployed during the trial and no valid wave information data was acquired. Thus although a series of short runs were completed for the benefit of research underway by MUN Kinesiology staff, this trial cannot be considered a success and this report merely documents effort carried out. There may be an opportunity to repeat the trial on the 'Nautical Twilight' or equivalent vessel in the future.</p>			
<p>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</p>			



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DESCRIPTION OF SEAKEEPING TRIAL CARRIED OUT ON CCGA NAUTICAL TWILIGHT – NOVEMBER 2003

TR-2004-02

D. Cumming, D. Hopkins, J. Barrett

January 2004

TABLE OF CONTENTS

List of Tables	ii
List of Figures	ii
List of Abbreviations.....	iii
1.0 INTRODUCTION.....	1
2.0 BACKGROUND	1
3.0 DESCRIPTION OF THE CCGA NAUTICAL TWILIGHT.....	3
4.0 DESCRIPTION OF INSTRUMENTATION	4
4.1 Data Acquisition System (DAS).....	4
4.2 Rudder Angle Measurement.....	5
4.3 Ship's Motion Instrumentation	5
4.4 Differential Global Positioning System Data	6
4.5 Directional Wave Buoy/Mooring Arrangement.....	7
4.6 Propeller Shaft Speed.....	9
4.7 Wind Anemometer	9
4.8 Sea Water Temperature/Density Measurement	9
4.9 Electrical Power	10
4.10 Signal Cabling	10
5.0 TRIALS DESCRIPTION	10
6.0 DESCRIPTION OF ONLINE DATA ANALYSIS	11
7.0 DESCRIPTION OF OFFLINE DATA ANALYSIS.....	11
7.1 Interpreting the Raw Data.....	12
7.2 Validation of MotionPak Software and Instrumentation	12
7.3 Ship Motion Analysis	12
7.4 Roll and Pitch Frequency Analysis	13
8.0 DISCUSSION & RECOMMENDATIONS	13
9.0 ACKNOWLEDGEMENTS	15
10.0 REFERENCES.....	15

APPENDIX A: Inclining Experiment Report

APPENDIX B: Instrumentation Plan

APPENDIX C: Calibration Information

APPENDIX D: Wave Buoy Specifications and Typical Output File

APPENDIX E: Seakeeping Trials Run Log

APPENDIX F: Tables of Basic Information and Statistics for Each Trial Run

LIST OF TABLES

	Table
MotionPak Validation	1
Standard Deviations of Motions	2

LIST OF FIGURES

	Figure
Photographs of CCGA Nautical Twilight	1
Photographs of Data Acquisition System (DAS)	2
Photograph of Rudder Angle Measurement.....	3
Photographs of MotionPak Installation.....	4
Photograph of Orthogonal Linear Accelerometers	5
Photographs of GPS Antenna.....	6
Photograph of Directional Wave Buoy	7
Photograph of Wind Anemometer Installation.....	8
Photograph of Instrumentation Used for Water Density Assessment	9
Example Online Data Analysis.....	10
Offline Analysis – Standard Deviation vs. Heading	11

LIST OF ABBREVIATIONS

CCG	Canadian Coast Guard
CCGA	Canadian Coast Guard Auxiliary
CG	Center of Gravity
CIHR	Canadian Institutes of Health and Research
cm	centimeter(s)
COG	Course Over Ground
DAS	Data Acquisition System
DC	Direct Current
deg.	degree(s)
DGPS	Differential Global Positioning System
FP	forward perpendicular
ft	foot, feet
Fwd	forward
F/V	frequency/voltage
g	acceleration due to gravity
GM_T	Transverse Metacentric Height
GPS	Global Positioning System
HF	High Frequency
h, hr	hour(s)
Hz	Hertz
in	inch(es)
IOT	Institute for Ocean Technology
kg	kilogram(s)
kHz	kiloHertz
km	kilometre(s)
KM_L	longitudinal metacentric height above keel
kt(s)	knot(s)

LIST OF ABBREVIATIONS (CONT'D)

kW	kiloWatt(s)
l	litre(s)
lb(s)	pound(s)
m	metre(s)
mHz	megaHertz
MII(s)	Motion Induced Interrupt(s)
MUN	Memorial University of Newfoundland
NIF	New Initiatives Fund
nm	nautical mile(s)
NMEA	National Marine Electronics Association
NSERC	Natural Sciences and Engineering Research Council of Canada
OCC	Oceanic Consulting Corporation
OEB	Offshore Engineering Basin
OSSC	Offshore Safety and Survival Centre
PPT	Parts Per Thousand
RF	Radio Frequency
RPM	Revolutions Per Minute
s, sec.	second(s)
SAR	Search And Rescue
SNAME	Society of Naval Architects and Marine Engineers
SOG	Speed Over Ground
St. Dev.	standard deviation
t	tonne(s)
UHF	Ultra High Frequency
UNESCO	United Nations Educational, Scientific and Cultural Organization
UPS	Uninterruptible Power Supply
V	volt(s)
VHF	very high frequency

1.0 INTRODUCTION

This report describes seakeeping experiments carried out on the 45 ft. (13.72 m) long inshore fishing vessel 'Nautical Twilight' off St. John's, NL November 20, 2003. Collaborators involved in the fishing vessel sea trials include the Institute for Ocean Technology (IOT), Memorial University of Newfoundland (MUN), Oceanic Consulting Corp. (OCC), Canadian Coast Guard (CCG), the Offshore Safety and Survival Centre (OSSC) of the Marine Institute and SafetyNet – a Community Research Alliance on Health and Safety in Marine and Coastal Work. Primary financial support for the project is provided from federal funding sources including the Search & Rescue (SAR), New Initiatives Fund (NIF) and the Canadian Institutes of Health and Research (CIHR) in addition to significant in-kind contributions from the many participants. The objective of the project is to acquire quality full scale motions data on fishing vessels to validate physical model methodology as well as numerical simulation models under development. Eventually, tools will be developed and validated to evaluate the number of Motion Induced Interrupts (MIIs), induced by sudden ship motions, and their impact on crew accidents to develop criteria to reduce MIIs. Although the priority was to collect seakeeping data, a manoeuvring test program was also available in the event that calm seas prevailed.

This document describes the CCGA Nautical Twilight, the trials instrumentation package, data acquisition system, test program, data analysis procedure and presents the results. Unfortunately there was a failure of the directional wave buoy deployed during the trial and no valid wave information data was acquired. Thus although a series of short runs were completed for the benefit of research underway by MUN Kinesiology staff, this trial cannot be considered a success and this report merely documents effort carried out. There may be an opportunity to repeat the trial on the 'Nautical Twilight' or equivalent vessel in the future.

2.0 BACKGROUND

The Fishing Vessel Safety Project is just a small component of the overall SafetyNet initiative to understand and mitigate the health and safety risks associated with employment in a marine environment. SafetyNet is the first federally funded research program investigating occupational health and safety in historically high risk Atlantic Canada marine, coastal and offshore industries. The Fishing Vessel Safety Project is conducting research on the occupational health and safety of seafood harvesters. Fishing is the most dangerous occupation in Newfoundland and Labrador and is increasingly so: over the past ten years, the rates of reported injuries and fatalities nearly doubled. These trends have the effect of reducing the sustainability of the fishery, increasing health care and compensation costs, and straining the available SAR resources. The development of effective solutions, to prevent or mitigate injury, fatality or SAR events, has been seriously hindered by the scarcity of the research needed

to understand the factors that influence seafood harvester occupational health and safety.

The Fishing Vessel Safety project is a multi-disciplinary, inter-departmental and inter-sectorial research project. The broad-based and multi-factorial approach in investigating the inter-related factors that influence fishing safety including: fishery policy and vessel regulations, vessel safety design and modeling, human relationships on vessels and health and safety program development, implementation and evaluation. The Fishing Vessel Safety project is composed of six integrated components:

- 1) Longitudinal Analysis: A statistical analysis of all fishing injuries, fatalities and SAR incidents from 1989 to 2000 to determine trends and influencing factors of seafood harvester occupational health and safety;
- 2) Perceptions of Risk: An interview-based study, conducted with seafood harvesters, on the perceptions of causes of accidents and near-misses - and the effectiveness of existing accident prevention programs;
- 3) Motion Induced Interruptions: Sea trials, physical and numerical modeling of the effects of MIIs, sudden vessel motions induced by wave action, on crew accidents and development of criteria to reduce MIIs;
- 4) Delayed Return to Work: an interview-based study on the psychological and social factors that delay previously injured seafood harvesters from returning to work;
- 5) Education Program: The development of an interactive, community-based occupational safety education program for seafood harvesters; and
- 6) Comparative Analysis: A comparative analysis of accident and fatality rates, and regulatory regimes for fisheries management and fishing vessel safety in Canada, the United States, Iceland, Norway, Denmark, France and Australia.

Several of the project components will yield results that can be directly used by stakeholder organizations for designing and implementing injury and fatality prevention programs. The applied nature of the overall project will be represented by a series of recommendations that will provide accessible and applicable information needed to make informed decisions. Additional information on SafetyNet may be found by visiting their web site (Reference 1).

The effort described in this report is part of Component #3 of the overall Fishing Vessel Research project. The tentative plan involves carrying out seakeeping trials on a total of five Newfoundland based fishing vessels ranging in lengths from 35 ft. to 75 ft. (10.67 m to 22.86 m) over two years. Data will be acquired on some of the vessels with and without roll damping devices deployed. Standard seakeeping parameters such as ship motions, speed and heading angle will be recorded along with data on the ambient environmental conditions (wave height/direction, wind speed/direction). Physical models of three of the vessels (tentatively the 35, 45 and 65 ft. vessels) suitable for free-running operation in the

IOT Offshore Engineering Basin (OEB) will be fabricated and tested by IOT over three years in environmental conditions emulating the full scale conditions. Project participants at the MUN Faculty of Engineering will derive numerical models of all five hull forms and run simulations using their non-linear time domain ship motion prediction codes. Validated simulation tools will then be used to predict the expected level of MIIs for different fishing vessel designs.

Additional information on human factors in ship design is provided in References 2 to 5.

3.0 DESCRIPTION OF THE CCGA NAUTICAL TWILIGHT

The CCGA Nautical Twilight (see Figure 1) is a typical 45' fiberglass fishing vessel and was built by Jackson's Boatyard of Whiteway, NL in 2003 to a design furnished by TriNav Consultants Inc of St. John's, NL. The vessel primarily participates in the inshore snow crab fishery, but has the ability to harvest other species using a gillnetting setup, such as codfish and capelin, when the stocks are available. The vessel is based in Catalina, Trinity Bay but operates out of different ports around the island to exploit various Newfoundland fishing grounds.

Nominal Principal Particulars:

Length Overall:	44 ' 11 " (13.69 m)
Beam:	23' (7.01 m)
Draft:	10' (3.05 m)
Installed Power:	475 HP (354.2 kW)
Displacement:	77 L. Tons (78,235.2 kg)
Fuel Capacity:	2500 gal. (9463.5 l)
Fresh Water Capacity:	350 gal. (1325 l)
Fish Hold Volume:	2000 ft ³ (57 m ³)
Accommodations:	7 berths

One of the goals of this experiment is to measure the motions of the vessel while it is harvesting its catch, therefore a "half loaded" displacement condition was simulated by adding some 6 tons of flake ice to an existing estimated 6 tons of flake ice in the fish hold. Once the vessel was ballasted and most of the outfit items installed, an inclining experiment was performed on November 19th by TriNav Consultants Inc. to identify key hydrostatic properties for the trials condition.

The inclining experiment was carried out using standard procedures whereby two pendulums (aft pendulum was 2.286 m long in the fish hold, forward pendulum was 1.632 m long in the galley/mess area) suspended with the weights in an oil bath were deployed to measure roll angle. Static roll angles were induced by the shifting of two 45 gal. steel drums filled with fresh water, weighing a total of 0.4661 LT (474 kg), laterally to various locations on the main deck.

The following is a summary of results:

Draft:	10.69 ft @ AP (3.258 m Aft) 5.29 ft @ FP (1.612 m Fwd.)
Displacement:	79.991 Long Tons (81,274 kg)
Longitudinal Center of Buoyancy (LCG):	19.651 feet (5.990 m) Fwd. of AP
Vertical Center of Buoyancy (VCG):	11.792 feet (3.594 m) above base plane
Transverse Metacentric Height (GM_T):	7.982 feet (2.433 m) above base plane
Longitudinal Metacentric Height (KM_L):	76.2 feet (23.23 m) above base plane

The inclining report delivered by the contractor is included in Appendix A.

The 'Nautical Twilight' is a round bilge, single screw (fixed pitch propeller), single flat plate rudder vessel with a very large centerline skeg and no dedicated anti-roll device. The vessel has a normal suite of navigation/ communications electronics including radar, GPS, VHF radio, depth sounder and electronic chart information as well as a Robertson Model AP35 autopilot. The vessel is fitted with a seven person Ovatek life boat capsule however the lifesaving equipment was augmented with a four person inflatable life raft and floater suits on loan from the CCG for the trials period.

4.0 DESCRIPTION OF INSTRUMENTATION

IOT was tasked to provide the trials technical support, primary on-board instrumentation, and a data acquisition system with limited online data analysis capability for all the trials. The instrumentation plan is provided in Appendix B while the analog channel calibration information is provided in Appendix C. Note that all analog channel calibrations were verified after completion of the trial. The instrumentation, signal cabling, and data acquisition system used along with the calibration method employed for each parameter is described in this section. The standard IOT sign convention is provided in Reference 6.

4.1 Data Acquisition System (DAS)

The Data Acquisition System (DAS) used in the 'Nautical Twilight' was mounted on the galley table of the vessel (Figure 2). The software package designed for these trials were run on two ruggedized Panasonic notebook computers, which had the following software attributes:

Off-the-shelf Software:

- Windows 2000 – operating system
- WinZip 8.0 – data compression software
- Excel 2000 – spreadsheet software
- Daqview 2000 – for viewing the data graphically

Hardware:

- Daqboard 2000

Additional Devices:

- CompassPoint 2200 GPS – provides position along with heading, rate of turn, etc.
- IOTech Daqbook 2000 – provides analog-to-digital conversion for analog signals including rudder angle, MotionPak, accelerometers and inclinometers.
- Signal Conditioning and interfacing hardware for analog channels.
- Uninterruptible Power Supply (UPS)

Custom Software:

- FishingVesselLogger – the primary program used to acquire the analog data (data rate was generally 50 Hz for each of 16 analog channels).
- CompassPointGPS – a slave process to the FishingVesselLogger program. It receives data from the DGPS unit and also logs all the GPS data.
- FishingVesselCal – used to post-calibrate the acquired data.
- CompassPointNMEA Parser – used to post-parse the NMEA data stream from the CompassPoint 2200 GPS unit and save the resulting parsed data to ASCII.

4.2 Rudder Angle Measurement

The rudder angle was measured by winding the cable, with wax string extension, from a 10 inch yo-yo type potentiometer linear displacement transducer around a groove cut in a circular ½ inch (1.27 cm) thick Plexiglas plate. The plate was machined with a steel clamp at its center so that it could be adjusted to any size rudderpost (Figure 3). The transducer was clamped to a convenient vertical frame attached to the aft starboard fuel tank in the steering compartment.

Rudder angle was calibrated with respect to the rudder indicator on the Bridge.

4.3 Ship's Motion Instrumentation

For the seakeeping trials carried out on November 20th, a MotionPak I was used to measure ship motions with six degrees of freedom. The MotionPak was mounted on a steel bracket fixed to a lateral frame in the forward compartment of the vessel's fish hold (Figure 4) and outputs the following motion channels:

Roll Rate	Surge Acceleration
Pitch Rate	Sway Acceleration
Yaw Rate	Heave Acceleration

From these six signals, dedicated MotionPak software was available to derive the following 18 channels in either an earth or body co-ordinate system, and move the motions to any point on the rigid platform:

Roll Angle/Rate/Acceleration	Surge Displacement/Velocity/Acceleration
Pitch Angle/Rate/Acceleration	Sway Displacement/Velocity/Acceleration
Yaw Angle/Rate/Acceleration	Heave Displacement/Velocity/Acceleration

The MotionPak angular rate channels were calibrated using manufacturer's specifications while the acceleration channels were physically calibrated by placing the sensors on a set of precision wedges and computing the acceleration. The accelerometers output zero m/s^2 when placed on a horizontal plane and -9.808 m/s^2 (-1 g) when oriented with the measuring axis vertical. The intermediate accelerations are computed as follows:

$$\text{Acceleration} = -9.808 \text{ m/s}^2 * \sin(\text{angle of inclination})$$

In addition, orthogonal linear accelerations (sway, surge and heave, Figure 5) were measured on the Bridge, behind the central circuit breakers and physically calibrated using the same procedure as was used for the MotionPak accelerometers. These instruments were used primarily to validate data collected by the MotionPak.

Two inclinometers used in the measurement of the pitch and roll angle were also mounted near the DAS and physically calibrated using the series of precision wedges. It should be noted that the inclinometers have a relatively low response rate and were fitted primarily to measure angular motion in the event that manoeuvring trials in calm water were carried out.

4.4 Differential Global Positioning System Data

The Global Positioning System (GPS) is a satellite based navigation system operated and maintained by the US Department of Defense. GPS consists of a constellation of 24 satellites providing world-wide, 24 hour, three-dimensional position coverage. Although originally conceived to satisfy military requirements, GPS now has a broad array of civilian applications including becoming the standard tool for marine navigation.

GPS is currently the most accurate navigation technology available to the public. The GPS receiver computes the distance to a minimum of three GPS satellites orbiting the earth to accurately derive the ship's position. GPS receivers also output precise time, speed of the ship over the ground (SOG) as well as course over ground (COG) measurements. Additional general information on the operation of a GPS system is provided in Reference 7.

Differential GPS (DGPS) provides greater positioning accuracy than standard GPS since error corrections can be included using a GPS signal transmitted via HF from a receiver established at a known location on land. To acquire a DGPS correction, IOT installed a CompassPoint 2200 GPS (a rectangular antenna with dimensions 60 cm x 16 cm x 18 cm) with a fixed based mounting, which was clamped to a lateral beam above the deckhouse (Figure 6). Once the antenna was visually aligned parallel to the ship's longitudinal centerline, the system software was initiated by having the vessel perform multiple 360 degree rotations in the harbour.

The DGPS correction signal was acquired from a CCG broadcast at a frequency of 315 kHz from Cape Race, NL. Using DGPS, absolute position accuracies between 3 and 10 m can be achieved along with velocity accuracies within 0.1 knots.

The following digital data channels were acquired using the DGPS receiver in standard National Marine Electronics Association (NMEA) format:

Course Over Ground (COG) – degrees TRUE
Speed Over Ground (SOG) – km/hr
Latitude/Longitude - degrees/minutes/seconds

4.5 Directional Wave Buoy/Mooring Arrangement

A small (0.75 m diameter, 15.7 kg) discus shaped directional wave buoy manufactured by Neptune Sciences, Inc. of Slidell, Louisiana and procured by MUN for previous sea trials using NSERC funding was used to acquire information on the wave conditions during the seakeeping trials.

The wave buoy was configured to acquire data for 17.07 minutes (1024 s) every half hour, process and store the data in an ASCII format file on an internal non-volatile flash disk. A radio modem was used to communicate between a base station on the 'Nautical Twilight' and the buoy over line of sight range using a spread spectrum device operating in the UHF 902-928 MHz frequency band. The buoy assembly is composed of the following components:

Instrument Housing: composed of a sealed aluminum cylinder with connections for the antenna and on/off plug on top. The housing contains the instrumentation package, onboard computer and onboard radio modem. All components of motion required to transform the buoy-fixed accelerations into an earth-fixed coordinate system (vertical, east-west and north-south) are measured using sensors mounted in the instrument package. Earth-fixed accelerations enable determination of non-directional wave information (wave heights, periods, and non-directional spectra) as well as directional wave information (wave directions and directional spectra) with all required computations executed within the onboard computer.

Battery Housing: comprises a smaller sealed aluminum cylinder fitted below the instrument housing and contains the battery pack composed of 27 disposable D-cell alkaline batteries providing a 1 to 2 week lifetime with the buoy configured for data collection every ½ hour.

Floatation Assembly: a rugged urethane foam and aluminum cage designed to provide the appropriate buoyancy for the instrument and battery housing. The floatation assembly was designed such that the instrument and battery housing combination can be removed and replaced without disturbing the mooring or recovering the entire system.

On Shore Modem: An RF modem with dedicated power supply and antenna is used to communicate from a ship based laptop computer to the wave buoy. A dedicated windows based, user friendly software package is supplied by the buoy manufacturer to facilitate the communication between the ship board computer and the wave buoy. The data can also be retrieved using an umbilical connection to the buoy after the buoy has been recovered.

Mooring Assembly: A mooring for the wave buoy system was designed for a 165 m depth of water by personnel from the MUN Physical Oceanography Group after discussions with the buoy manufacturer. The small CCG launch CG 206 deployed the wave buoy as well as radar reflector buoy on November 19th by manually lifting them over the side into the water. The mooring is described as follows:

Between buoy and anchor:

1. Neptune Wave Buoy with light floating tether
2. 4 meter half inch nylon cord in parallel with 3 meter shock cord
3. 1/2" stainless steel shackle, stainless steel swivel, 1/2" stainless steel shackle
4. 55 meters of 1/4" jacketed wire rope and shackle
5. 1/2 meter galvanized chain and shackle
6. 183 meters of 1/2" polypropylene rope
7. 3 meters 1/2" galvanized chain
8. 50 lb grapnel anchor

A separate reflective guard buoy was used to help locate the wave buoy using radar. It consisted of:

1. 18" diameter Polyform buoy with radar reflector, tether, weight and Scotty flash lamp
2. Short length of polypropylene rope to 15" Polyform float
3. 183 meters of 1/2" polypropylene rope
4. 7 meters of 1/2" galvanized chain
5. 10 lb Danforth anchor

A photograph of the deployed wave buoy and radar reflector float is provided in Figure 7. Additional information on the buoy including detailed operating instructions, data interpretation and visualization are presented in Reference 8. The specifications for the buoy and typical output file are provided in Appendix D.

4.6 Propeller Shaft Speed

Propeller shaft speed was measured using an optical sensor acting on a piece of reflective tape on the shaft in the engine room. The pulse train from the optical pickup was fed to an IOT designed and built frequency-to-voltage (F/V) circuit that converts the digital pulse train to a linear DC voltage proportional to shaft RPM. This instrumentation was calibrated using a laser tachometer that acted on the reflective target, which was then verified using the vessel's RPM gauge.

4.7 Wind Anemometer

A MUN "Weather Wizard III", manufactured by Davis Instruments, provides monitoring and logging of essential weather conditions such as temperature, wind direction, wind speed and wind chill (Figure 8). This instrument was fixed to an aluminum mast furnished by IOT, which was in turn attached to a guard rail aft port side of the deck house. At dockside the directional indicator was aligned with the bow of the vessel. Wind speed and direction were logged by hand.

4.8 Sea Water Temperature/Density Measurement

To determine whether there are any large variations in water density (which would ultimately change the draft of the vessel) between St. John's harbour where the ship's draft is recorded and the trials area, a YSI model 30 battery powered hand-held salinity, conductivity and temperature meter was used to measure the parameters required to determine ambient water density. The YSI 30 unit, manufactured by YSI of Yellow Springs, Ohio, consists of a hand held display device and a weighted probe with 25 feet of cable connecting the two (Figure 9). The required information, i.e. temperature and salinity, is collected by the probe and presented on the hand held display with an accuracy of $\pm 2\%$ or ± 0.1 PPT (parts per thousand) for salinity and $\pm 0.1^\circ\text{C}$ for the temperature. The instruments range for salinity and temperature is 0 to 80 PPT and -5° to $+95^\circ\text{C}$ respectively.

To obtain a mean density of the sea water, the probe tested the water at about half the draft ~ 2 m. The density is then calculated using the Equation of State of Seawater given in Reference 9, which provided density as a function of temperature, salinity, and pressure. Additional information on the YSI instrument is provided in Reference 10.

4.9 Electrical Power

Acquiring quality 120 V electrical power was not a problem on the 'Nautical Twilight'. IOT filtered all power used for IOT equipment through a UPS, however, to ensure that no power glitches or spikes impaired the data.

4.10 Signal Cabling

Belden 8723 two pair individually shielded cable was used to conduct signals from the MotionPak, accelerometers and inclinometers to the DAS. The inclinometers were located within the unit designed to accommodate the DAS therefore the distance for cable connection was short. The cable for the accelerometers extended from the DAS along the galley deckhead forward, up the stairway to the Bridge, behind the central circuit panel, slightly port of centerline. The cable to the MotionPak was fed from the DAS through an aft window adjacent to the dining table in the galley, then down through the open fish hold hatch into the fish hold.

In addition, one cable was installed to accommodate the yo-yo potentiometer used to measure the rudder angle. This cable was run from the tiller flat forward to the fish hold penetrating the aft fish hold transverse bulkhead through a gland in a Plexiglas access hatch fabricated by IOT to replace the existing aluminum access hatch normally in place. This cable was simply secured to the transverse beams strengthening the top of the hold and, bundled together with the cable for the MotionPak, was passed through the open hatch cover and finally through an aft window adjacent to the dining table in the galley where the DAS was located. The cable for the shaft RPM signal extended from the DAS along the galley deckhead forward and down the starboard stairway into the engine room. This cable was run through existing cable trays along the engine room deckhead to the aft transverse bulkhead separating the engine room from the fish hold where it dropped down to the location of the shaft RPM instrumentation.

The DGPS antenna and the wind anemometer were both located on top of the deckhouse of the vessel. Cabling was simply extended from the DAS through an aft window adjacent to the dining table in the galley up to the top of the deckhouse.

5.0 TRIALS DESCRIPTION

Prior to proceeding to the trials area, a 10 minute zero speed run was carried out in St. John's harbour in an effort to determine the ship motion natural periods. The seakeeping trials were completed on November 20, 2003 approximately 10 nm due east of St. John's. Prior to departure, all instrumentation was inspected to ensure all sensors were functioning properly. The draft of the vessel was then measured at the bow and stern of the vessel, before departing for the wave buoy located at 47 34.042 North and 52 26.200 West.

Upon arrival at the wave buoy location, the sea conditions were found to be very favorable for the experiment. The significant wave height was visually estimated at approximately 1.5 - 2 m. Unfortunately, radio communication with the wave buoy was unsuccessful. The wave buoy electronics canister was removed from the buoyancy chamber to attempt a hard wire link between the base station and the buoy however this was also unsuccessful. The electronics canister was retained on the 'Nautical Twilight' for further troubleshooting back in St. John's while the moorings for the buoyancy chamber and radar reflector buoy remained deployed.

After recovering the wave buoy electronics canister, the 'Nautical Twilight' executed a total of five short (~ 5 minute) forward speed runs at nominally 7 - 8 knots in head, following, bow, beam and quartering seas to collect data in support of research being carried out by MUN Kinesiology staff. Note that all runs were carried out with the vessel on autopilot control. The log of the trials events can be found in Appendix E.

6.0 DESCRIPTION OF ONLINE DATA ANALYSIS

The purpose of performing an online analysis during the trials is to ensure that all the instrumentation is working properly to identify potential problems with the various sensors that may lead to invalid results.

A network of two laptop computers was used in the Data Acquisition System. One computer logged the raw data from the data stream and, using the custom software FishingVesselCal, converted the data into a usable format stored with the appropriate physical units. The second computer was used to analyze the data from the previous acquired run to assess its integrity as well as communicate with the wave buoy. This was done to avoid overloading the computer logging the data, which could have led to program failure and potentially resulted in incomplete data files or even lost data.

Columns of acquired data were converted to MicroSoft EXCEL¹ format and standard EXCEL plotting utilities were used to view the data in the time domain. An example time series plot of heave acceleration along with pitch and roll angle experienced during the 8 knots beam seas run is provided in Figure 10.

7.0 DESCRIPTION OF OFFLINE DATA ANALYSIS

Once the trial was complete, ASCII data files were compiled for transfer to MUN Kinesiology staff and basic statistics were computed.

¹ © MicroSoft Corp.

7.1 Interpreting the Raw Data

The data received by all the various instruments onboard the vessel was initially recorded as an analog DC voltage. A calibration file was then applied to the raw data using the custom software program FishingVesselCal. The calibration file included a five point linear regression curve and instrument offsets for each instrument. A summary of the calibration file along with the regression equations is provided in Appendix C.

7.2 Validation of MotionPak Software and Instrumentation

Within the software used to analyze MotionPak data, there is the capability to translate the accelerations recorded to any position onboard the vessel. To verify the ship motions data acquired, the motions were moved from the location of the MotionPak to the accelerometers located in the wheelhouse (3.302 m Fwd, 0.457 m Port, and 2.286 m above) and then analyzed in the “Body” fixed coordinate system. During this verification process, the installation of the tri-mounted accelerometers was noticed to be incorrect by 90 degrees, see Figure 5. Therefore, the surge and sway accelerometers had to be re-calibrated.

Table 1 shows the comparison between the data from MotionPak and the linear accelerometers in beam seas. From the values of standard deviation computed, it is demonstrated that the accelerations recorded were very similar.

Instrument	Parameter	Unit	Mean	St. Dev.	Min.	Max.
Accelerometer	Surge Accel.	(m/s ²)	0.449	0.483	-1.764	2.231
MotionPak	Surge Accel.	(m/s ²)	0.019	0.519	-2.325	1.940
Accelerometer	Sway Accel.	(m/s ²)	0.010	1.733	-6.189	5.787
MotionPak	Sway Accel.	(m/s ²)	-0.127	1.759	-5.885	6.193
Accelerometer	Heave Accel.	(m/s ²)	-0.137	1.044	-4.876	3.646
MotionPak	Heave Accel.	(m/s ²)	0.143	1.052	-3.667	4.860

Table 1: MotionPak Validation

Note that a comparison between the MotionPak angular data and the inclinometer data was not considered valid for data collected in a seaway due to the inherently low response rate of the inclinometers.

7.3 Ship Motion Analysis

As part of this seakeeping experiment, ship motions were measured at two locations on the vessel, the forward compartment of the fish hold using the MotionPak and behind the central circuit panel on the Bridge with the tri-mounted accelerometers.

As mentioned above, the MotionPak software is capable of translating the accelerations recorded to any position on the vessel. This provided the ability to generate motions data for the location required for the research that was carried out by the MUN Kinesiology² staff. The Kinesiology experiments consisted of measuring various parameters on an instrumented student while the student performed tasks primarily consisting of lifting and moving known weights on the quarterdeck. The approximate position of the Kinesiology research relative to the MotionPak was as follows: 2.438 m aft, 0.914 m starboard, and 0.889 m above.

The following table is a summary of standard deviations of ship motions data at the Kinesiology research location obtained from the experiment. Tables of detailed basic information and statistics (average, standard deviation, minimum and maximum) for each run are provided in Appendix F.

Speed (kts)	Heading	Roll Angle (deg)	Pitch Angle (deg)	Yaw Angle (deg)	Surge Accel. (m/s ²)	Sway Accel. (m/s ²)	Heave Accel. (m/s ²)
7	Head	1.680	3.734	1.738	0.914	0.485	1.176
7	Bow	5.221	2.621	3.153	0.664	1.285	1.225
7	Beam	6.274	2.046	16.091	0.387	1.446	0.631
7	Quartering	4.476	1.775	2.669	0.200	0.960	0.354
7	Following	1.682	1.748	4.683	0.138	0.350	0.221

Table 2: Standard Deviation of Motions

A plot of roll angle, pitch angle and heave acceleration standard deviation vs. heading is provided in Figure 11.

7.4 Roll and Pitch Frequency Analysis

A variance spectral density analysis was carried out on the roll rate and pitch rate data for the zero speed run carried out in St. John's harbour prior to the trial in an effort to determine the roll and pitch period. The following values of the spectral peak were output:

Roll Period: 3.8870 s

Pitch Period: 3.1368 s

8.0 DISCUSSION & RECOMMENDATIONS

The following is a series comments on how the trial was executed with recommendations on how to improve the quality of data collected.

Ballasting Effort:

Procuring several tons of flake ice (at \$50/ton) locally in St. John's and loading it into the fish hold of the 'Nautical Twilight' proved to be a convenient method of ballasting the vessel to the desired trials displacement. Removing the ice in a

² Dr. Scott MacKinnon, Assistant Professor, MUN Human Kinetics Faculty

timely matter may be somewhat problematic however. The ice must be removed manually or it will freeze into a solid mass over time. Melting the ice using hot water is a possible alternative strategy however the energy required is not insignificant. Of course, if there are plans by the vessel's operators to use the ice after the trial during fishing activity, removal of the ice is not an issue.

Wave Buoy Issues:

Failure of the wave buoy was a disappointment since without valid directional wave data measured during the trial; this trial cannot be considered a success. Operation of the wave buoy was verified on shore prior to deployment and seemed to be collecting data after deployment on November 19th. A review of the data stored in the buoy computer memory carried out ashore after recovery of the electronics canister indicated that no data had been collected since deployment when there should have been several files accumulated over the period. The canister was sent back to the buoy manufacturer for a complete replacement of all the electronic components. In future, it is recommended that the buoy be deployed and recovered the same day as the trial - and verified operational during the trial. Also, if a secondary means of measuring directional wave information can be derived perhaps using a second buoy, then serious consideration should be given to pursuing this. The Neptune buoy has several advantages over other buoys on the market in terms of size and ease of deployment from a small vessel however this instrumentation has not proven very reliable during use on several trials to date. Retaining a vessel for a dedicated sea trial is always an expensive, relatively high risk endeavor and failure to collect quality data represents a loss of precious research resources.

Overall Outfit:

Overall the outfit of the 'Nautical Twilight' went well with few complications. Not having to install a portable generator to power IOT electronics certainly reduces the complexity of the outfit and operational risks. Since the vessel was less than a year old, it afforded a clean, attractive work environment. Accessing the tiller flat for a rudder angle signal was the biggest single outfit issue. The decision to temporarily replace the existing aluminum access hatch in the aft fish hold bulkhead with an IOT fabricated Plexiglass hatch with integral cable gland rather than install a gland in the aluminum hatch to be sealed up after the trial was made to minimize damage to the ship.

Draft Measurement:

The transom of the 'Nautical Twilight' was covered with aluminum plate obscuring the aft draft marks complicating the measurement of the draft. The draft aft had to be determined from a freeboard measurement port and starboard – and related to a profile drawing.

Tri-Mounted Accelerometers:

During the motion verification stage, it was noticed that the measured surge and sway accelerations was not the same as the predicted motions produced from the Motionpak. With the help of photographs that were taken of the equipment, it was realized that the tri-mount was positioned incorrectly by 90 degrees. In the future, it should become standard practice to have all equipment double-checked for proper installation and photographed for future referencing.

Yaw Motions:

The 'Nautical Twilight' exhibited high yaw motion deviations during the beam sea run even with the vessel on autopilot control and the forward speed was ~ 7 knots. The data implies that the vessel has poor steering control when subjected to beam seas.

9.0 ACKNOWLEDGEMENTS

The authors would like to thank Capt. Delton McGrath and the crew of the CCGA Nautical Twilight for their enthusiastic support during the trial, the CCG for the loan of survival equipment and permission to berth the 'Nautical Twilight' at the Coast Guard Base (St. John's), Jack Foley of MUN Oceanography for assistance designing the wave buoy mooring, and IOT technical staff for their efforts throughout the planning and execution of the trial. Support from the crew of the Coast Guard vessel CG 206 to deploy the wave buoy, Oceanic Consulting Corp. for transport support and the Offshore Safety and Survival Centre (OSSC) for Marine Emergency Duty (MED) survival training for IOT staff was much appreciated. Funding support from the Search & Rescue (SAR) New Initiatives Fund (NIF) and the Canadian Institutes of Health and Research (CIHR) is gratefully acknowledged.

10.0 REFERENCES

- 1) "SafetyNet – a Community Research Alliance on Health and Safety in Marine and Coastal Work", www.SafetyNet.MUN.ca, December 2003.
- 2) Stevens, S.C., Parsons, M.G., "Effects of Motion at Sea on Crew Performance: A Survey", SNAME Publication Marine Technology, Vol. 39, No. 1, January 2002, pp. 29 – 47.
- 3) Boccadamo, G., Cassella, P., Scamardella, A., "Stability, Operability and Working Conditions Onboard Fishing Vessels", 7th International Conference on Stability of Ships and Ocean Vehicles, Launceston, Tasmania, Australia, February 7-11, 2000.

- 4) Crossland, P., Rich, K.J.N.C., "A Method for Deriving MII Criteria", Conference on Human Factors in Ship Design and Operation, London, UK, September 27 – 29, 2000.
- 5) Graham, R., "Motion-Induced Interruptions as Ship Operability Criteria", Naval Engineers Journal, March 1990.
- 6) Model Test Co-ordinate System & Units of Measure, IOT Standard Test Methods GM-5, V3.0, February 14, 2001.
- 7) Hofmann-Wellenhof, B., "Global Positioning System: Theory and Practice", Wein: Springer, 2001.
- 8) Sentry Wave Buoy Operation Manual, Neptune Sciences, Inc., Slidell, Louisiana, USA.
- 9) Fofonoff, P., Millard Jr., R.C., "Algorithms for Computation of Fundamental Properties of Seawater", UNESCO Technical Papers in Marine Science, 1983, pp. 44-53.
- 10) YSI Model 30/YSI Model 30M Handheld Salinity, Conductivity and Temperature System Operations Manual, YSI Inc., Yellow Springs, Ohio, DRW #A30136D, May 1998.

Figures



Figure 1: CCGA Nautical Twilight

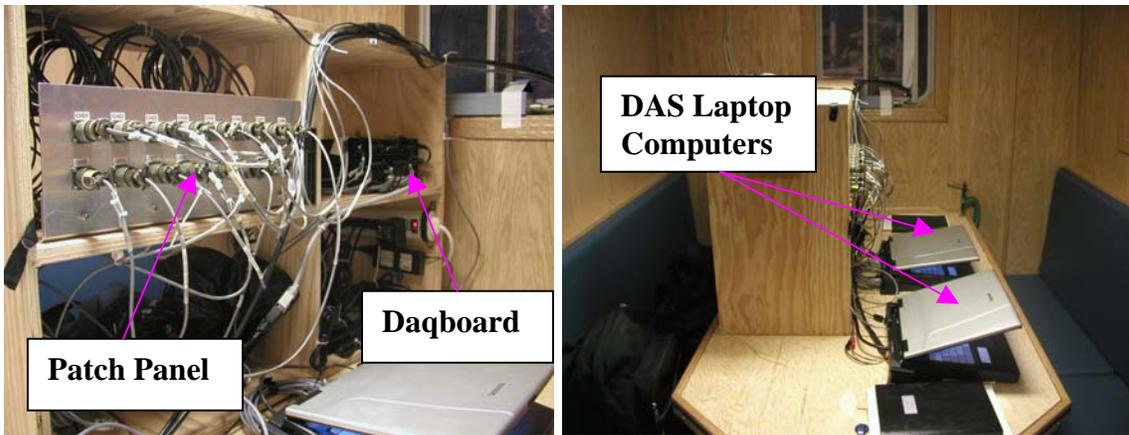


Figure 2: Data Acquisition System

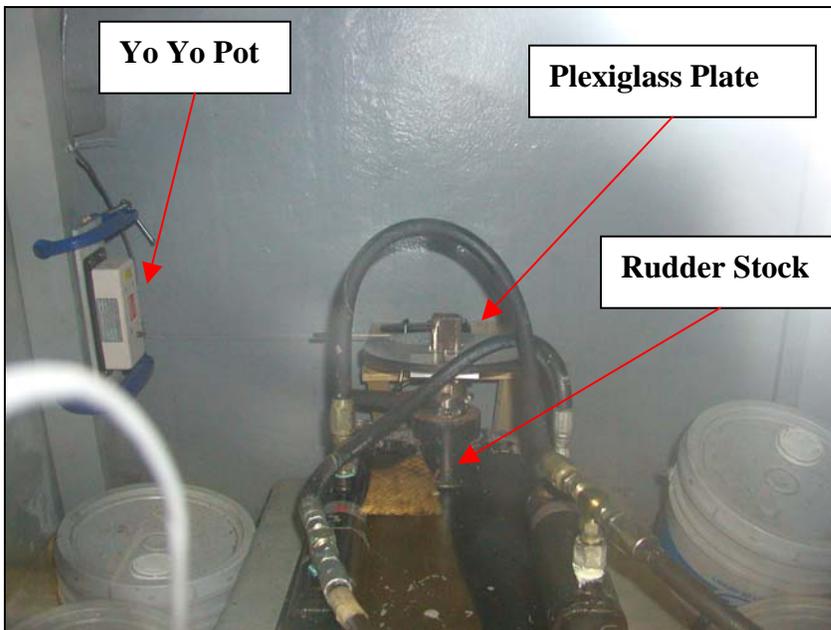


Figure 3: Rudder Angle Measurement



Figure 4: MotionPak Installation in Fish Hold



Figure 5: Orthogonal Linear Accelerometers on Bridge



GPS Antenna Mounting

Figure 6: GPS Antenna



Figure 7: Directional Wave Buoy

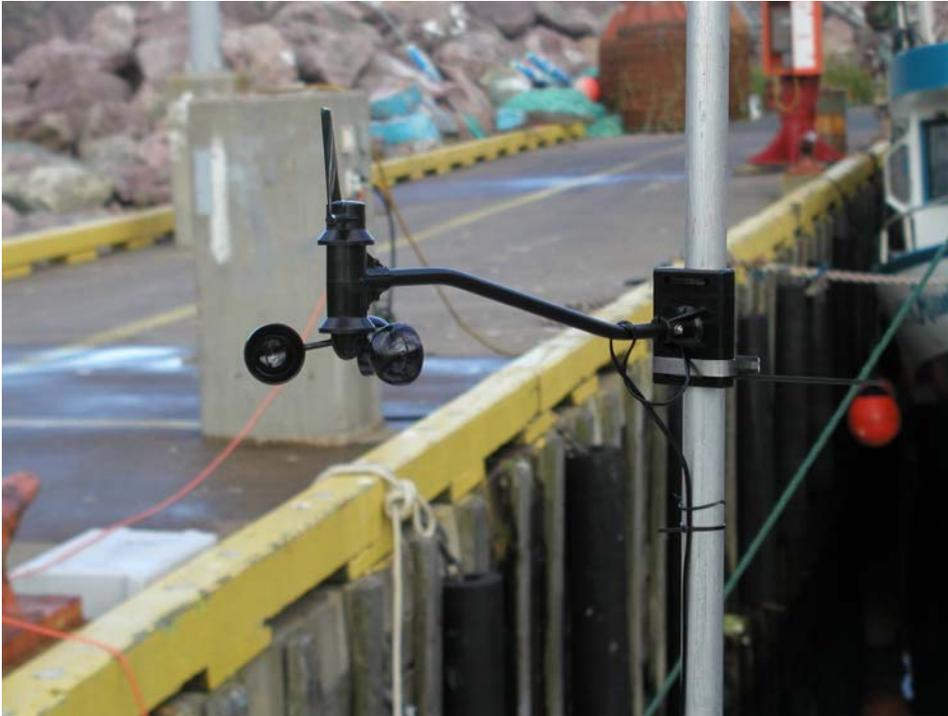


Figure 8: Wind Anemometer



Figure 9: Instrumentation Used for Water Density Assessment

Example Online Data Analysis - 7 knots Beam Seas

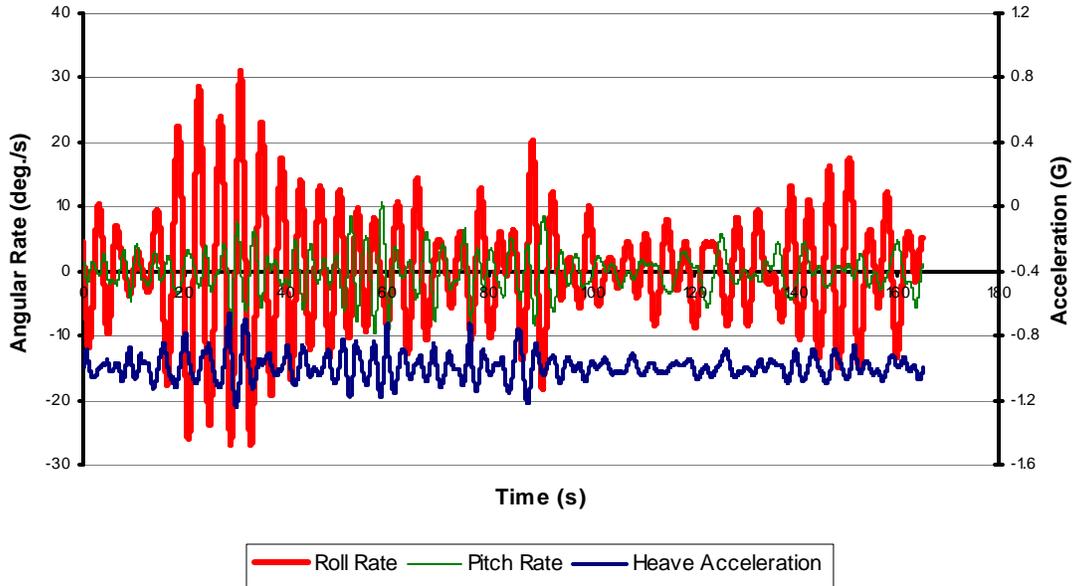


Figure 10: Example Online Data Analysis

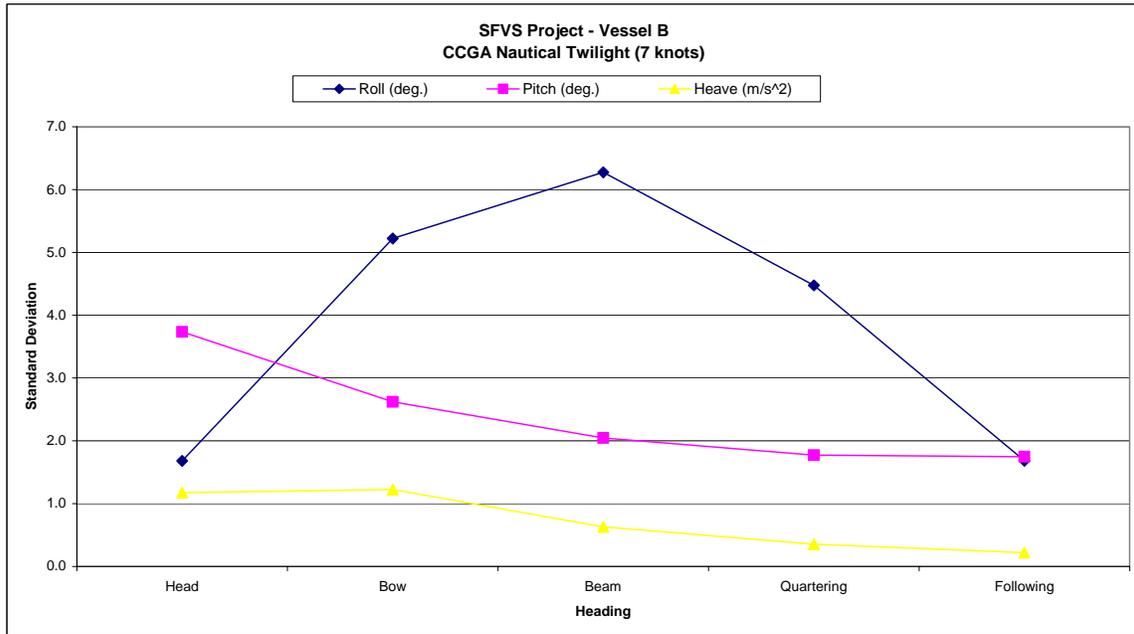
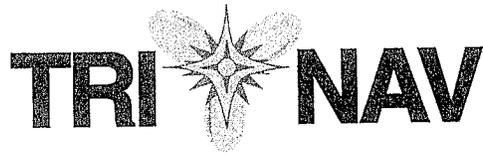


Figure 11: Standard Deviation vs. Heading

Appendix A
Inclining Experiment Report



Naval Architecture

Fisheries Consulting

Marine Brokerage

**INCLINE REPORT
FOR THE SMALL FISHING VESSEL**

**“NAUTICAL TWILIGHT”
- PORT DEPARTURE CONDITION**

COMPLETED BY: TRINAV CONSULTANTS INC.

NOVEMBER, 2003

TriNav Consultants Inc.

Correspondence: P.O. Box 29126, St. John's, NL, A1A 5B5

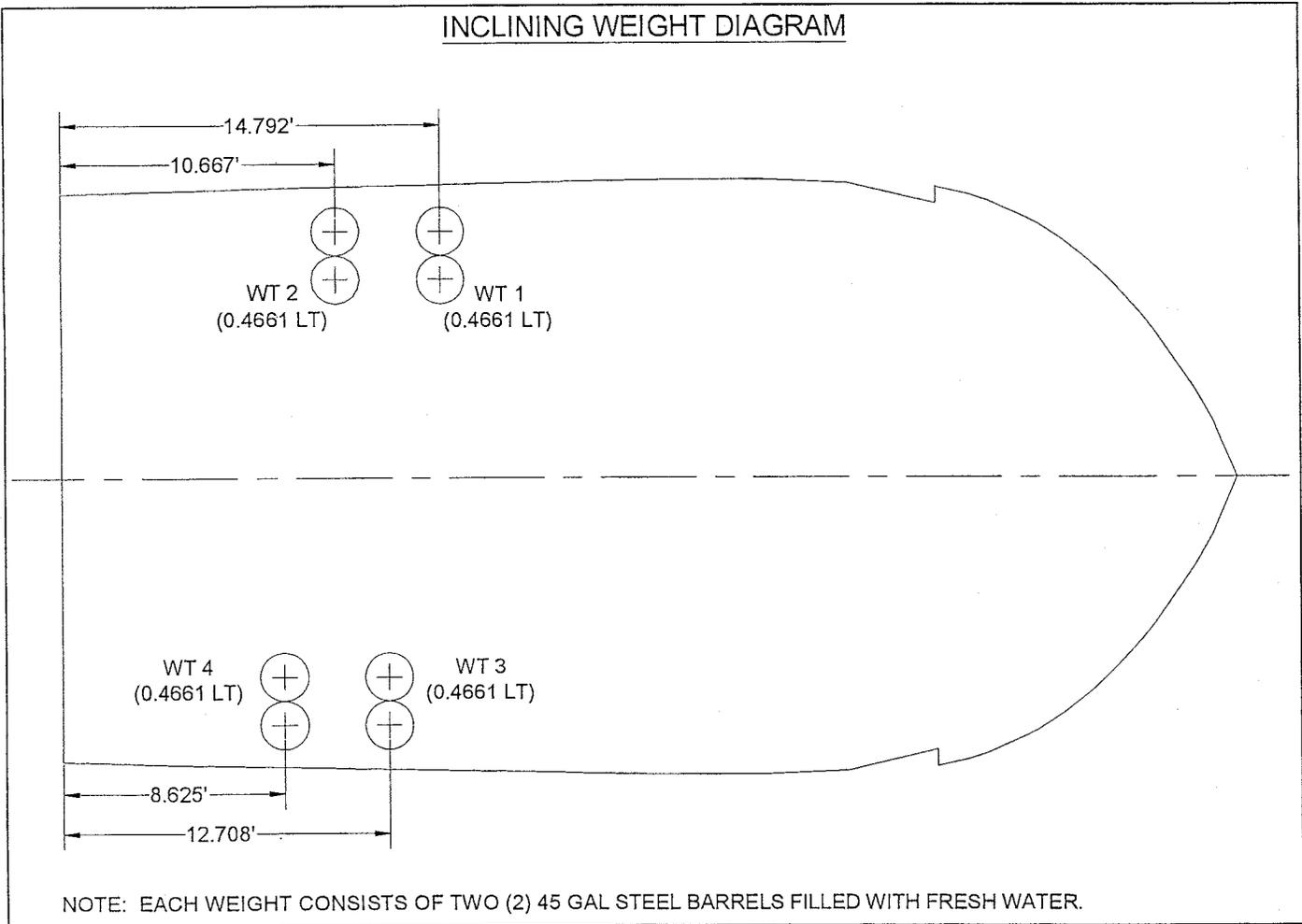
Location Address: 197 Majors Path, St. John's, NL, A1A 5A1

Telephone: (709) 754-7060 Fax: (709) 754-6171 e-mail: admin@trinav.com

Toll Free: 866 754 7060 Website: www.trinav.com

VESSEL:	Nautical Twilight
CONSTRUCTION MATERAIL:	GRP
DATE OF INCLINING EXPERIMENT:	November 19/2003
EXPERIMENT CONDUCTED AT:	St. John's, Newfoundland
WEATHER CONDITIONS:	Overcast - Wind 5 Knots on Stern.
DATUM LINE:	Baseline
SPECIFIC GRAVITY OF WATER:	1.020
NUMBER OF PERSONS ONBOARD	5
CONDITION OF VESSEL	Port Departure w/Flake Ice In Hold.

INCLINING WEIGHT DIAGRAM





Inclining Experiment Drafts: (see Appendix A)

Draft aft - 10.69 ft. @ A.P. (based on freeboard measurements)
Draft fwd - 5.29 ft. @ F.P.

Length of Pendulums:

Aft pendulum - 7.750 ft., fish hold
Fwd pendulum - 5.354 ft., galley/mess

Weight per shift-

0.4661 Lt (2 x 45 Gal Steel Drum Filled with Fresh Water)

CALCULATION OF GM BASED ON PENDULUM RESULTS

FWD PENDULUM DEFLECTIONS

SHIFT NO.	DISTANCE (ft.)	WEIGHT (Lt.)	DEFLECTION (ft.)
1	17.146	0.4661	0.0607
2	16.667	0.4661	0.0623
3	16.667	0.4661	0.0591
4	17.146	0.4661	0.0640
5	16.813	0.4661	0.0656
6	16.313	0.4661	0.0607
7	16.313	0.4661	0.0607
8	16.813	0.4661	0.0656
AVERAGE	16.735	0.4661	0.0623

$$GM = wdl/Wx$$

$$= \frac{0.4661 \times 16.735 \times 5.354}{(81.90) (0.0623)}$$

$$= 8.185 \text{ ft}$$

$$w = 0.4661 \text{ Lt}$$

$$d = 16.735 \text{ ft}$$

$$l = 5.354 \text{ ft}$$

$$W = 81.90 \text{ Lt (See Appendix B)}$$

$$x = 0.0623 \text{ ft}$$

AFT PENDULUM DEFLECTIONS

SHIFT NO.	DISTANCE (ft.)	WEIGHT (Lt.)	DEFLECTION (ft.)
1	17.146	0.4661	0.0968
2	16.667	0.4661	0.0935
3	16.667	0.4661	0.0951
4	17.146	0.4661	0.0951
5	16.813	0.4661	0.0951
6	16.313	0.4661	0.0951
7	16.313	0.4661	0.0935
8	16.813	0.4661	0.0951
AVERAGE	16.735	0.4661	0.0949

GM = wdl/Wx	w =	0.4661 Lt
= $\frac{0.4661 \times 16.735 \times 7.750}{(81.90) \times (0.0949)}$	d =	16.735 ft
= 7.778 ft	l =	7.750 ft
	W =	81.90 Lt
	x =	0.0949 ft

CALCULATION OF VCG

INCLINED GM (solid) = GM from fwd pend. Results + GM from aft pend. Results / 2

$$= 8.185 \text{ ft} + 7.778 \text{ ft} / 2$$

$$= 7.982 \text{ ft}$$

VCG = KM(from hydrostatics) - GM (solid)

$$= 19.57 \text{ ft} - 7.982 \text{ ft}$$

$$= 11.792 \text{ ft}$$

WEIGHTS TO REMOVE

	Mass (Lt)	VCG (ft.)	VMOM (Lt ft)	LCG (ft)	LMOM (Lt ft)
WT 1	-0.4661	14.541	-6.777	-14.792	6.894
WT 2	-0.4661	14.729	-6.865	-10.667	4.972
WT 3	-0.4661	14.627	-6.817	-12.708	5.923
WT 4	-0.4661	14.848	-6.920	-8.625	4.020
Incl. Equip	-0.0223	10.531	-0.235	-26.144	0.584
Trolley	-0.0223	13.752	-0.307	-11.826	0.264
TOTAL	-1.909		-27.921		22.656

WEIGHTS TO ADD

	Mass (Lt)	VCG (ft.)	VMOM (Lt ft)	LCG (ft)	LMOM (Lt ft)
Nil	0.000	0.000	0.000	0.000	0.000
TOTAL	0.000		0.000		0.000

NOTE: - VCG is measured above baseline in feet
- LCG is measured forward of AP in feet

LIGHTSHIP CALCULATION

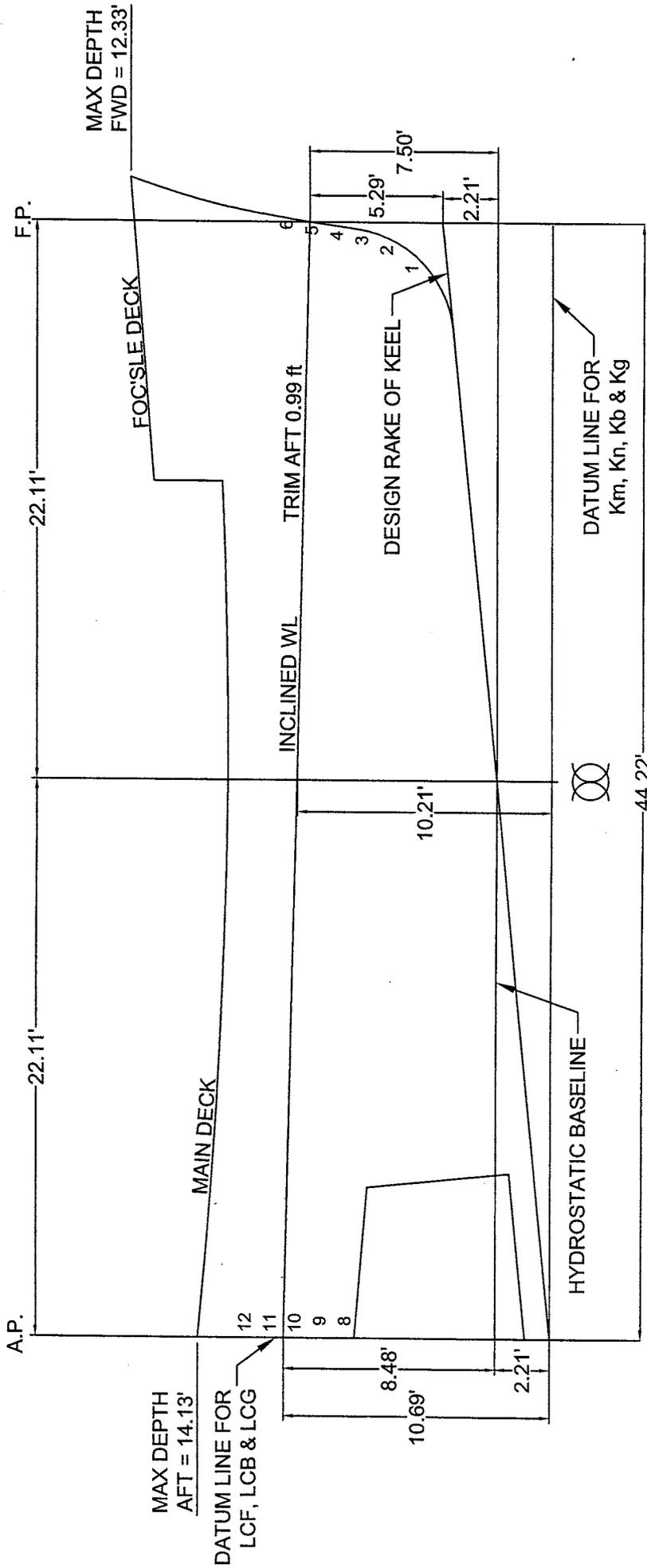
	Mass (Lt)	VCG (ft.)	VMOM (Lt ft)	LCG (ft)	LMOM (Lt ft)
Loaded vessel	81.900	11.792	965.765	-19.470	-1594.593
Weights to Remove	-1.909	14.627	-27.921	11.868	22.656
Weights to Add	0.000	0.000	0.000	0.000	0.000
Total	79.991		937.844		-1571.937

LIGHTSHIP MASS = 79.991 Lt
LIGHTSHIP VCG = 11.724 ft. above Baseline.
LCG = 19.651 forward of A.P.

APPENDIX A

DATUM LINE DIAGRAM

DATUM LINE FOR THE FISHING VESSEL "NAUTICAL TWILIGHT"



NOTE:

1. VESSEL INCLINED WITH 0.22 DEGREES STARBOARD HEEL.
2. DRAFT READINGS:
 - FWD; 5'-3 $\frac{1}{2}$ "
 - AFT; DRAFT MARKS NOT VISABLE; FREEBOARDS TAKEN.
 - FREEBOARD STBD - 40.75"
 - FREEBOARD PORT - 41.75"

APPENDIX B

INCLINED HYDROSTATICS AND CROSS CURVES

INCLINED HYDROSTATICS

HYDROSTATIC PROPERTIES

Trim: Aft 0.99/44.22, No Heel, VCG = 0.00

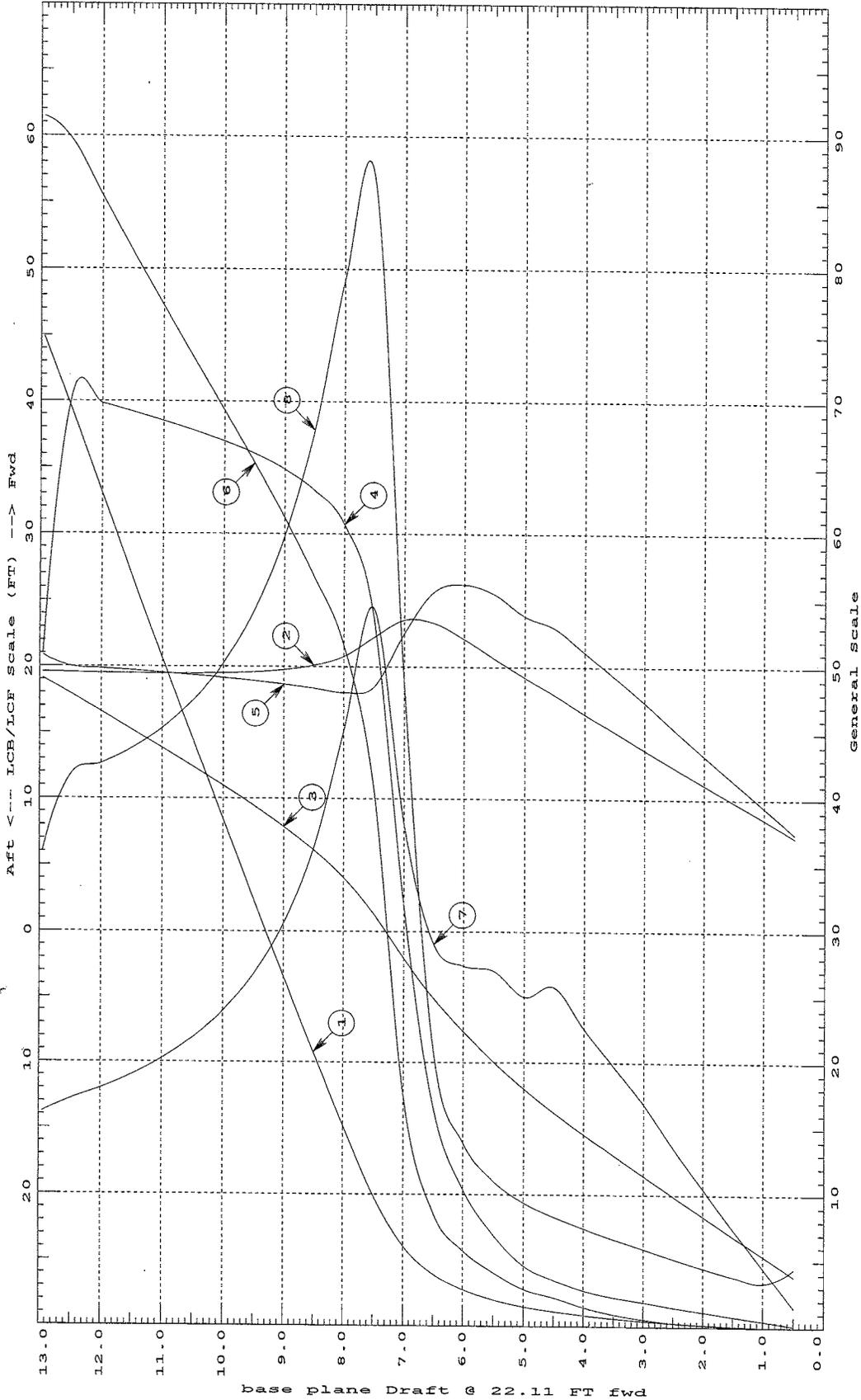
Draft@	Displacement	Buoyancy-Ctr.		Weight/	Moment/			
22.11f	Weight (LT)	LCB	VCB	Inch	LCF	IN trim	KML	KMT
0.500	0.00	7.14f	0.77	0.00	7.40f	0.00	3.0	1.77
1.000	0.06	8.50f	1.08	0.01	9.41f	0.00	8.9	1.34
1.500	0.17	9.80f	1.38	0.02	11.36f	0.00	14.8	1.53
2.000	0.35	11.11f	1.68	0.03	13.33f	0.01	20.9	1.78
2.500	0.58	12.42f	1.98	0.04	15.32f	0.03	27.1	2.07
3.000	0.88	13.77f	2.29	0.06	17.37f	0.06	33.7	2.36
3.500	1.25	15.11f	2.60	0.07	19.27f	0.09	39.4	2.66
4.000	1.70	16.46f	2.91	0.08	21.12f	0.14	45.2	2.97
4.500	2.25	17.90f	3.24	0.10	22.95f	0.22	51.5	3.33
5.000	2.97	19.22f	3.60	0.14	23.86f	0.28	50.0	3.75
5.500	3.99	20.63f	4.01	0.21	25.50f	0.41	54.0	4.41
6.000	5.52	22.12f	4.47	0.31	26.23f	0.57	54.8	5.55
6.500	7.86	23.32f	4.98	0.50	25.70f	0.86	58.1	8.33
7.000	12.10	23.56f	5.59	0.96	22.55f	1.74	76.2	19.50
7.500	19.89	22.24f	6.27	1.61	18.46f	4.08	108.8	34.68
8.000	30.36	20.79f	6.81	1.82	18.04f	5.16	90.2	31.67
8.500	41.53	20.09f	7.22	1.90	18.36f	5.68	72.5	27.14
9.000	53.07	19.75f	7.57	1.95	18.66f	6.12	61.2	23.92
9.500	64.86	19.58f	7.89	1.98	18.92f	6.53	53.4	21.68
10.000	76.83	19.49f	8.19	2.01	19.15f	6.93	47.9	20.10
10.210	81.90	19.47f	8.31	2.02	19.23f	7.10	46.0	19.57
10.500	88.95	19.46f	8.48	2.03	19.35f	7.33	43.7	18.96
11.000	101.22	19.46f	8.76	2.06	19.52f	7.72	40.5	18.12
11.500	113.61	19.47f	9.04	2.08	19.69f	8.13	38.0	17.51
12.000	126.11	19.50f	9.31	2.09	19.85f	8.54	35.9	17.05
12.500	138.73	19.54f	9.59	2.11	20.00f	8.97	34.3	16.71
12.950	149.86	19.58f	9.82	1.53	20.87f	9.15	32.4	14.42

Distances in FEET.-----Specific Gravity = 1.020.-----Moment in Ft-LT.
Trim is per 44.22Ft

Draft is from base plane.

INCLINED HYDROSTATICS

HYDROSTATIC PROPERTIES AT 0.99 FT AFT TRIM



- ① Displacement 1=2 LT
- ② LCB (use top scale)
- ③ VCB (KB) 1=.2 FT
- ④ Immersion 1=.03 LT/IN
- ④ WPA 1=12.7 Sq.FT
- ⑤ LCF (use top scale)
- ⑥ Moment/Trim 1=.1 FT-LT/IN
- ⑦ KML 1=2 FT
- ⑧ KMT 1=.4 FT

Specific Gravity = 1.020 Assumed KG = 0.00 FT
Trim is per 44.22 FT "K" = base plane

AS INCLINED CROSS CURVES OF STABILITY

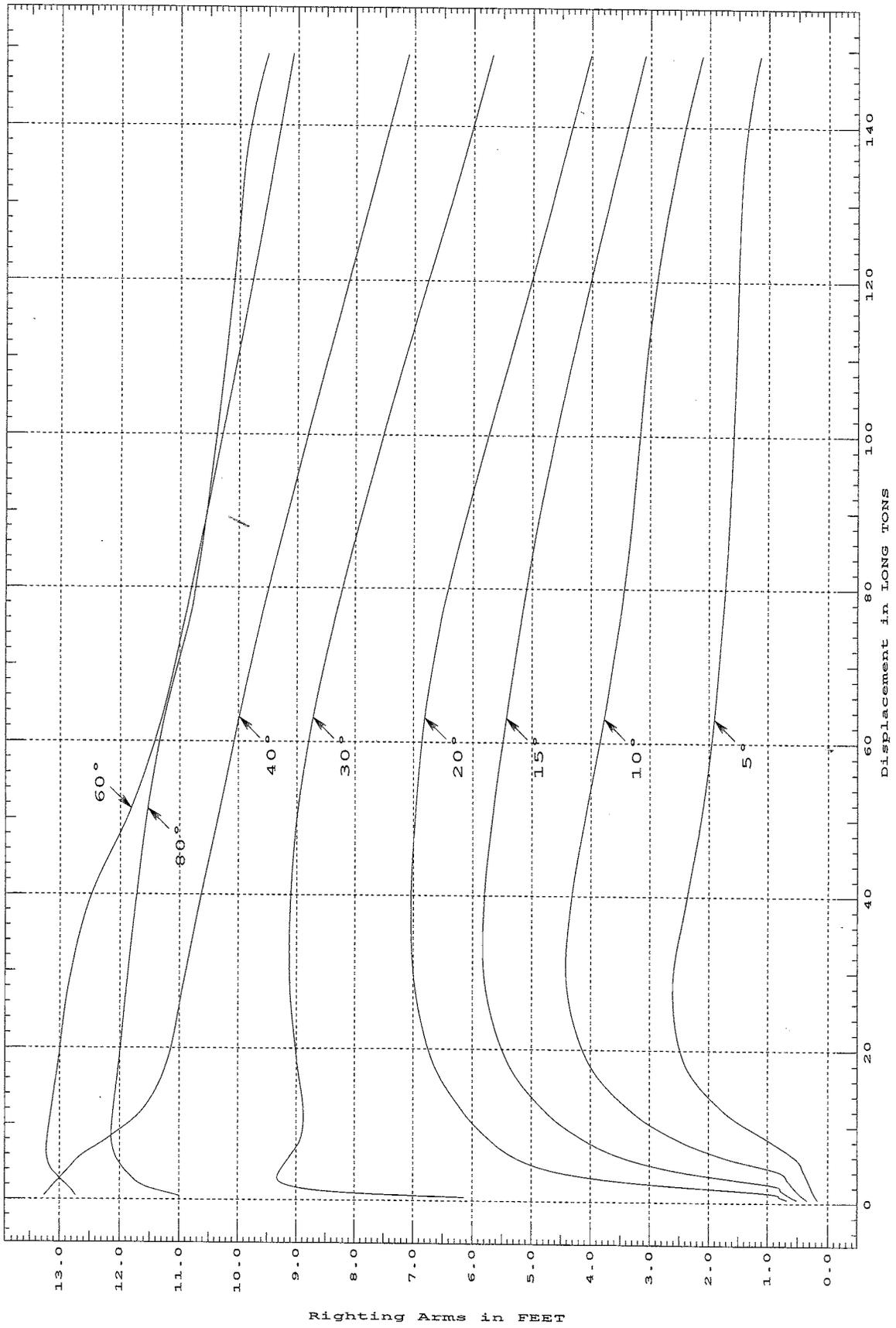
Showing righting arms in heel at VCG = 0.00
 Trim: Aft 0.99/44.22 at zero heel (trim righting arm held at zero)

Displacement LONG TONS	Heel Angles in Degrees							
	5.00s	10.00s	15.00s	20.00s	30.00s	40.00s	60.00s	80.00s
0.50	0.18s	0.35s	0.52s	0.69s	6.15s	13.26s	12.73s	11.00s
0.81	0.21s	0.41s	0.61s	0.80s	7.66s	13.22s	12.76s	11.16s
1.20	0.24s	0.47s	0.69s	0.92s	8.52s	13.18s	12.80s	11.36s
1.67	0.27s	0.53s	0.78s	1.67s	9.01s	13.13s	12.86s	11.56s
2.28	0.30s	0.59s	0.88s	2.89s	9.26s	13.06s	12.94s	11.71s
3.04	0.34s	0.67s	1.57s	3.90s	9.33s	12.97s	13.03s	11.81s
4.19	0.41s	0.84s	2.59s	4.74s	9.25s	12.84s	13.16s	11.95s
5.88	0.53s	1.70s	3.47s	5.31s	9.11s	12.63s	13.22s	12.08s
8.31	0.99s	2.53s	4.14s	5.74s	8.92s	12.17s	13.21s	12.14s
12.19	1.76s	3.34s	4.81s	6.20s	8.88s	11.59s	13.13s	12.10s
18.51	2.42s	4.05s	5.42s	6.68s	9.00s	11.20s	13.02s	12.01s
28.36	2.61s	4.41s	5.79s	6.98s	9.12s	10.93s	12.85s	11.89s
39.60	2.38s	4.33s	5.81s	7.04s	9.11s	10.64s	12.49s	11.73s
51.25	2.11s	4.07s	5.65s	6.96s	8.98s	10.31s	11.81s	11.54s
63.14	1.91s	3.78s	5.43s	6.81s	8.72s	9.99s	11.30s	11.26s
75.21	1.77s	3.52s	5.19s	6.55s	8.37s	9.63s	10.94s	10.85s
80.33	1.72s	3.44s	5.09s	6.41s	8.21s	9.47s	10.80s	10.73s
87.43	1.67s	3.33s	4.93s	6.19s	7.97s	9.24s	10.61s	10.59s
99.78	1.59s	3.18s	4.61s	5.76s	7.53s	8.83s	10.29s	10.38s
112.25	1.53s	3.03s	4.25s	5.30s	7.06s	8.39s	9.97s	10.20s
124.83	1.49s	2.80s	3.87s	4.85s	6.58s	7.95s	9.66s	10.02s
137.52	1.39s	2.48s	3.47s	4.42s	6.10s	7.50s	9.35s	9.86s
149.20	1.14s	2.12s	3.09s	4.02s	5.68s	7.10s	9.08s	9.51s

Distances in FEET.-----Specific Gravity = 1.020.-----

AS INCLINED CROSS CURVES OF STABILITY

CROSS CURVES OF STABILITY with - Stbd Heel
at 0.99 FT AFT TRIM (initial)



Specific Gravity = 1.020 Assumed KG = 0.00 FT
"K" = base plane

**Appendix B
Instrumentation Plan**

Instrumentation Plan for Fishing Vessel Trials

See Proj PIP for additional info on instrumentation requirement

Proj. 2017

Sept. 11, 2003

V2.0

Signal	Device	Calibrated Range	Units	Comments
Vertical Acceleration	MotionPak	+/- 20	m/s ²	
Lateral Acceleration	MotionPak	+/- 20	m/s ²	
Longitudinal Acceleration	MotionPak	+/- 20	m/s ²	
Yaw Rate	MotionPak	+/- 50	deg./s	
Roll Rate	MotionPak	+/- 50	deg./s	
Pitch Rate	MotionPak	+/- 50	deg./s	
Vertical Acceleration	Linear accelerometer	+/- 20	m/s ²	
Lateral Acceleration	Linear accelerometer	+/- 20	m/s ²	
Longitudinal Acceleration	Linear accelerometer	+/- 20	m/s ²	
Roll Angle	Inclinometer	+/- 30	deg.	only required in manoeuvring trials are to be carried out
Pitch Angle	Inclinometer	+/- 20	deg.	low critical parameter
Forward Speed	DGPS	0-20	knots	
Heading Angle	DGPS	0-360	deg. TRUE	
Planar Position	DGPS	-	m	
Rudder Angle	yo-yo potentiometer	+/- 45	deg.	required if manoeuvring trials to be carried out,
Shaft RPM	freq./volt. convertor	0 - 1000	RPM	otherwise measure if convenient low critical parameter

NOTES: Sampling rate is 50 Hz (filter 10 Hz) for all analog channels

Forward Speed as measured by the DGPS is Speed Over the Ground (SOG).

Heading Angle measured using DGPS is Course Over Ground (COG).

Heading Angle as measured by DGPS is Heading True.

Antenna alignment and set up for the new GPS unit is going to be more complex than previous experience.

Even though Selective Availability (SA) has been shut down on GPS by the US Government, an HF correction signal is still broadcast via HF radio by the CCG and DGPS correction signal will be accessed for increased accuracy.

UPS will be required for all trials.

An algorithm is available to move acceleration motions to any other point on the rigid body.
Mount MotionPak as close to ship's CG as possible.
Inclinometers used to record roll and pitch angle for a calm water manoeuvring trial only as response rate is inadequate for seakeeping data.
Three linear accelerometers will fitted in orthogonal tri-axial mount in wheelhouse.
Instrumentation on ship to be used to manually record wind speed/direction or install MUN supplied instrument.
Record shaft RPM from ship's instrumentation or with IOT frequency/voltage based inst. if possible.
IOT to bring hand held instrumentation to determine sea water temperature/density. To be measured roughly mid-draft, amidships.
Wave height/direction to be measured recorded using MUN directional wave buoy or a leased Datawell buoy from Oceans Ltd.
Note wave direction from buoy is deg. Magnetic.

Offline analysis software is available to derive the following additional motions from the rate/accel. (MotionPak)
data assuming the stimulation freq. is high enough:

- Roll/Pitch/Yaw Angle
- Roll/Pitch/Yaw Angular Accel.
- Surge/Sway/Heave Displacement
- Surge/Sway/Heave Velocity

Appendix C
Calibration Information

Summary of Analog Channel Calibrations

CCGA Nautical Twilight

Nov. 2003

Fishing Vessel Research Project (Proj. 2017)

Channel Number	Channel Description	Units	Slope	Offset
1	MotionPak X-accel, SURGE	g	0.4357	0.0153
2	MotionPak Y-accel, SWAY	g	0.4194	-0.0045
3	MotionPak Z-accel, HEAVE	g	0.6259	-0.0037
4	MotionPak ROLL RATE	deg/s	10.8763	0.0073
5	MotionPak PITCH RATE	deg/s	10.8681	-0.0036
6	MotionPak YAW RATE	deg/s	10.9010	0.0091
7	MotionPak TEMP OUTPUT	deg C	71.9424	-272.8058
8	Linear Accel, X-SURGE	g	0.5022	0.0004
9	Linear Accel, Y-SWAY	g	0.4971	-0.0005
10	Linear Accel, Z-HEAVE	g	0.7419	-0.0029
11	Rudder Angle, Yo-yo Pot	deg	49.9020	-109.3473
12	Roll Angle, Jewell Inclinator	deg	5.8303	0.2667
13	Pitch Angle, Jewell Inclinator	deg	5.8332	0.1114
14	Shaft RPM	rpm	399.6410	-1.7484

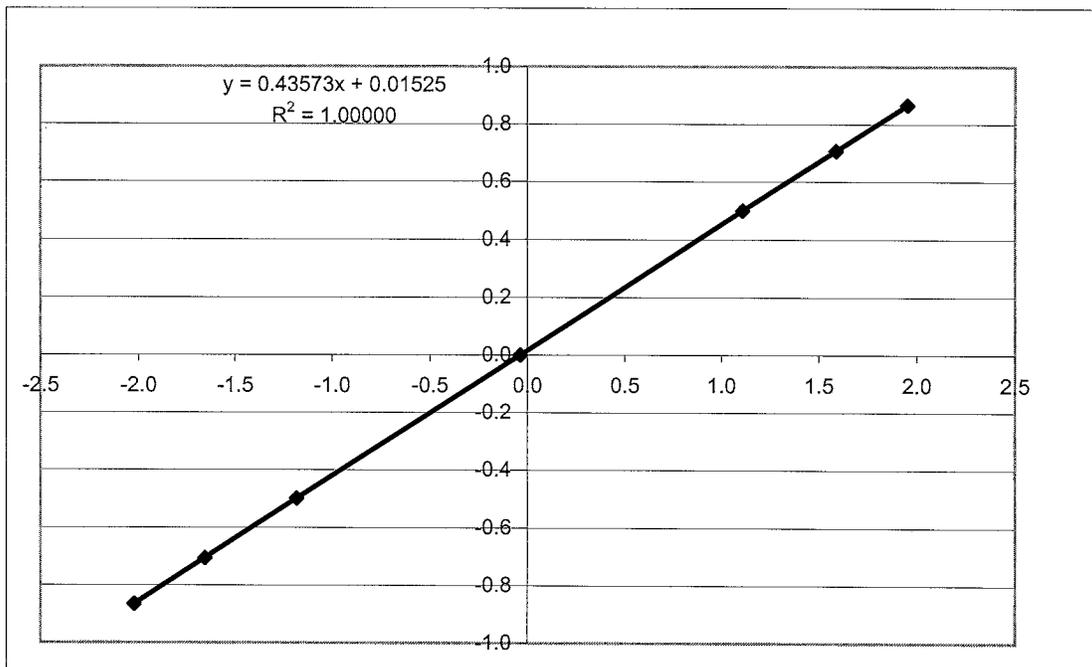
Ch. 01
X Accel, Motion Pak
 S/N 0326

Gravity

1

Angle	Sin(angle)	Acceleration	Voltage
0	0	0.0000	-0.036
29.994	0.499909307	0.4999	1.111
45.016	0.707304215	0.7073	1.588
59.9	0.865151421	0.8652	1.952
-59.9	-0.865151421	-0.8652	-2.022
-45.016	-0.707304215	-0.7073	-1.656
-29.994	-0.499909307	-0.4999	-1.182

slope	offset
0.4357	0.0153



CCGA Nautical Twilight Seakeeping Trials

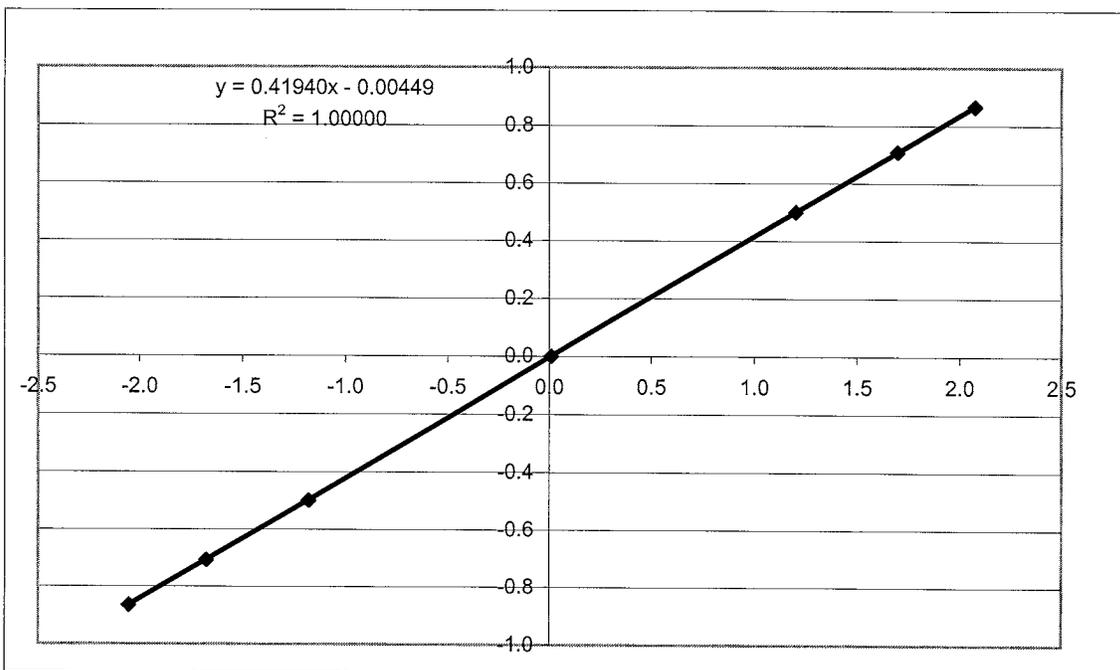
Ch 02
Y Accel, Motion Pak
 S/N 0326

Gravity

1

Angle	Sin(angle)	Acceleration	Voltage
0	0	0.0000	0.01
29.994	0.499909307	0.4999	1.201
45.016	0.707304215	0.7073	1.696
59.9	0.865151421	0.8652	2.076
-59.9	-0.865151421	-0.8652	-2.053
-45.016	-0.707304215	-0.7073	-1.675
-29.994	-0.499909307	-0.4999	-1.18

slope	offset
0.4194	-0.0045



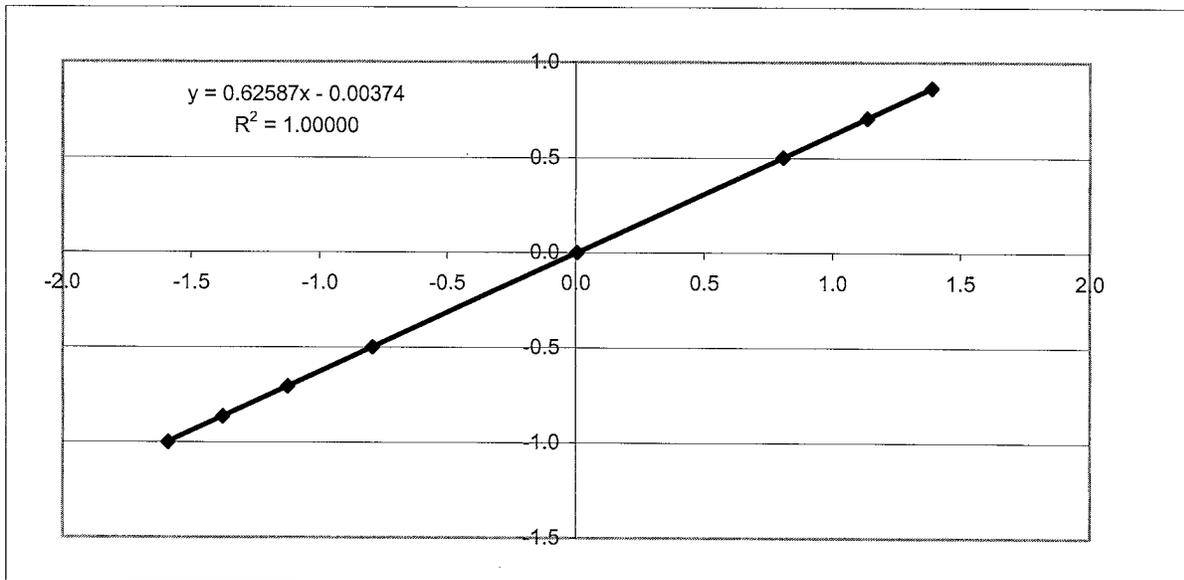
CCGA Nautical Twilight Seakeeping Trials

Ch 03
Z Accel, Motion Pak
 S/N 0326

Gravity 1

wedge	Angle	-Sin(angle)	Acceleration	Voltage
0	90	-1	-1.0000	-1.591
29.994	60.006	-0.866077759	-0.8661	-1.378
45.016	44.984	-0.706909292	-0.7069	-1.125
59.9	30.1	-0.501510737	-0.5015	-0.794
90	0	0	0.0000	0.005
-59.9	-30.1	0.501510737	0.5015	0.807
-45.016	-44.984	0.706909292	0.7069	1.137
-29.994	-60.006	0.866077759	0.8661	1.389

slope	offset
0.6259	-0.0037



CCGA Nautical Twilight Seakeeping Trials

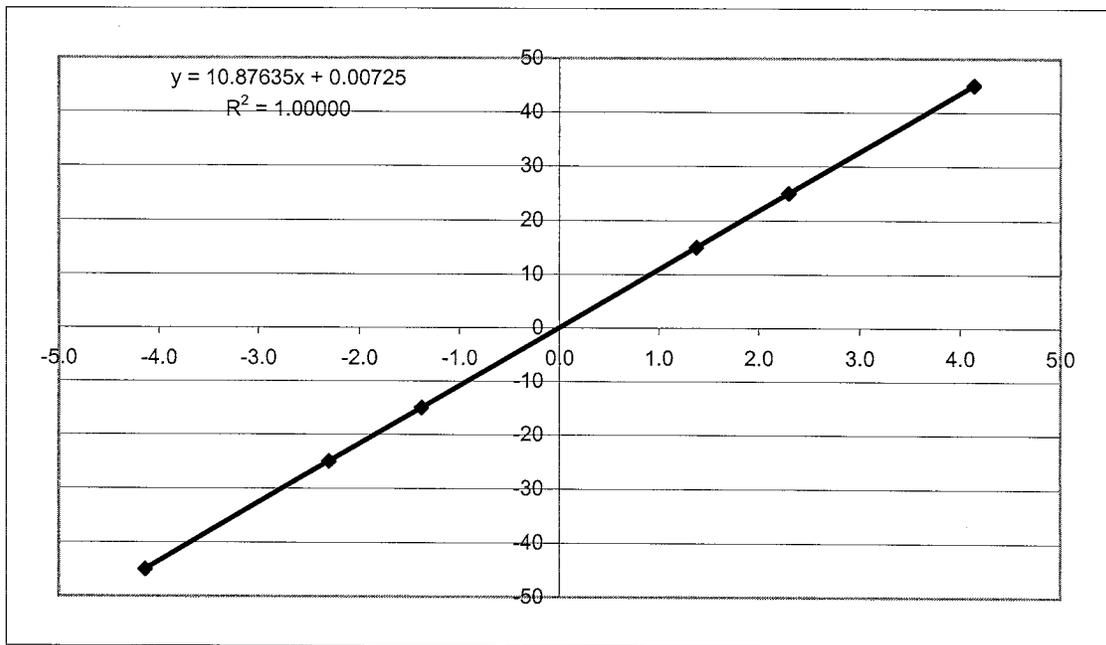
Ch. 04
X Rate, Motion Pak
S/N 0326

Scale Factor 50.213 mV/deg/s

Universal Source 169644

Deg/second	injected voltage Volts	Output, Volts
45	2.2596	4.137
25	1.2553	2.298
15	0.7532	1.378
-15	-0.7532	-1.380
-25	-1.2553	-2.299
-45	-2.2596	-4.138

slope	offset
10.8763	0.0073



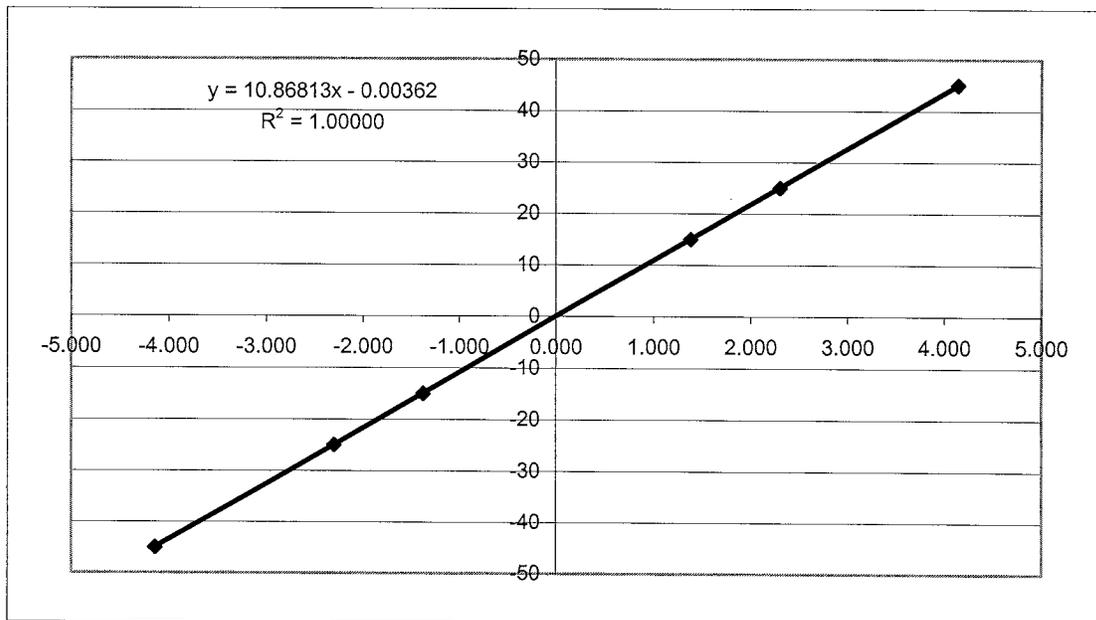
Ch. 05
Y Rate, Motion Pak
 S/N 0326

Scale Factor 49.916 mV/deg/s

Universal Source 169644

Deg/second	injected voltage, V	Output, Volts
45	2.2462	4.141
25	1.2479	2.301
15	0.7487	1.380
-15	-0.7487	-1.380
-25	-1.2479	-2.300
-45	-2.2462	-4.140

slope	offset
10.8681	-0.0036



CCGA Nautical Twilight Seakeeping Trials

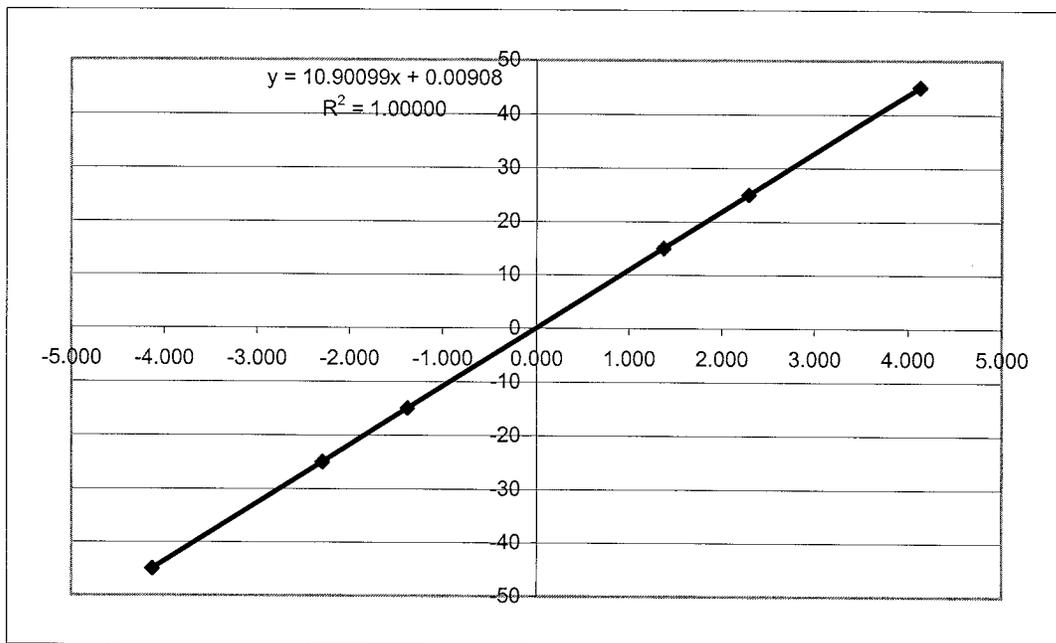
Ch. 06
Z Rate, Motion Pak
S/N 0326

Scale Factor 49.889 mV/deg/s

Universal Source 169644

Deg/second	injected voltage	Output, Volts
45	2.2450	4.127
25	1.2472	2.293
15	0.7483	1.375
-15	-0.7483	-1.377
-25	-1.2472	-2.294
-45	-2.2450	-4.129

slope	offset
10.9010	0.0091



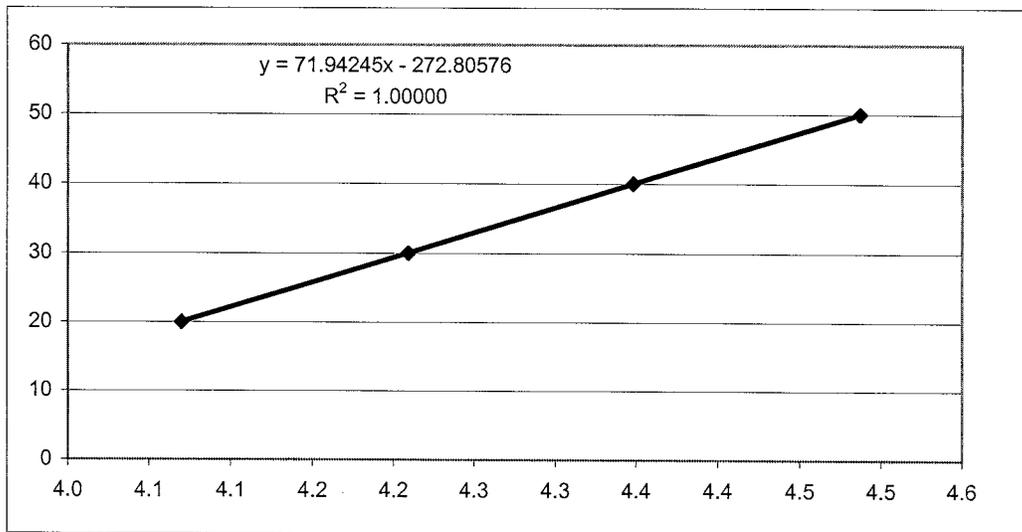
CCGA Nautical Twilight Seakeeping Trials

Ch. 07
Temperature, Motion Pak
S/N 0326

1.00E-06 A/°K
13.91 Kohms

Temperature Celsius	injected voltage V	Output, Volts Volts
-10	3.660	3.653
0	3.800	3.793
20	4.078	4.070
30	4.217	4.209
40	4.356	4.348
50	4.495	4.487

slope	offset
71.9424	-272.8058



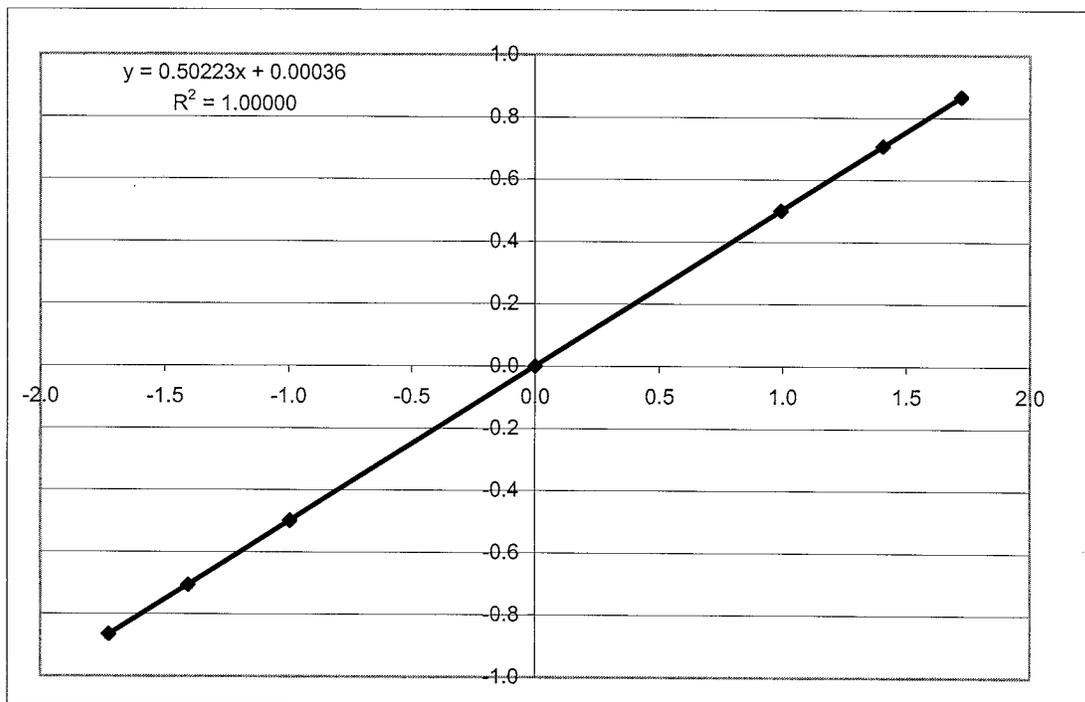
CCGA Nautical Twilight Seakeeping Trials

Ch 08
X Accel (Surge)

Model QA700
serial # 132702

Gravity	1		
Angle	Sin(angle)	Acceleration	Voltage
0.000	0.0000	0.0000	0
29.994	0.4999	0.4999	0.994
45.016	0.7073	0.7073	1.406
59.900	0.8652	0.8652	1.723
-59.900	-0.8652	-0.8652	-1.726
-45.016	-0.7073	-0.7073	-1.408
-29.994	-0.4999	-0.4999	-0.994

slope	offset
0.5022	0.0004



CCGA Nautical Twilight Seakeeping Trials

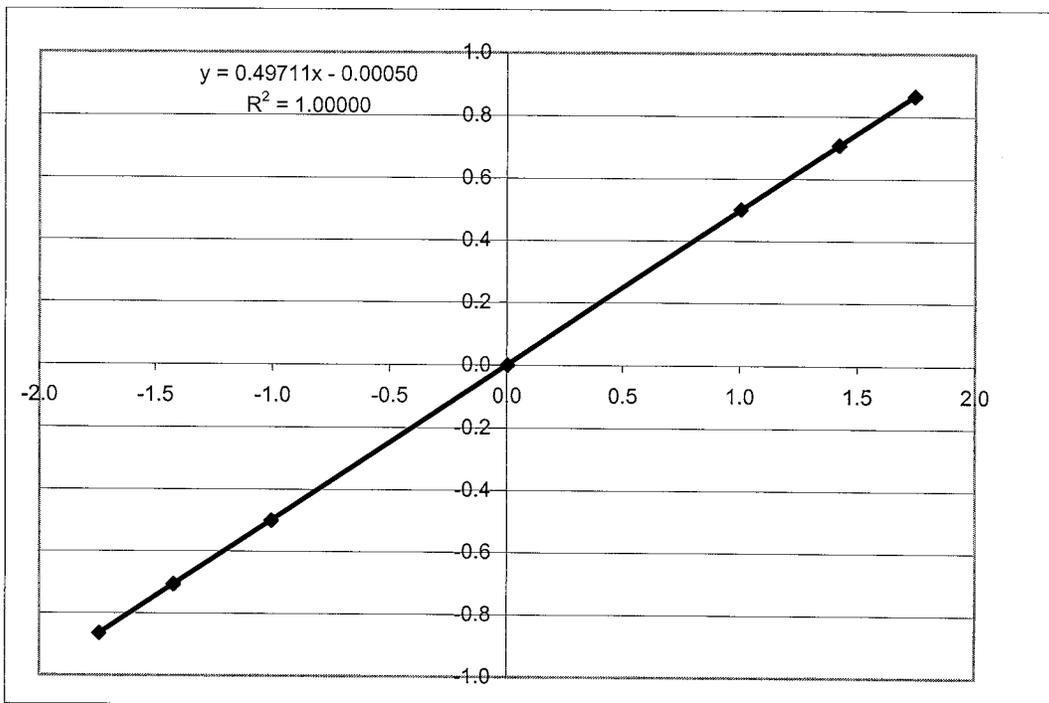
Ch 09
Y Accel (Sway)

Model QA1400
serial # 8710/942

Gravity 1

Angle	Sin(angle)	Acceleration	Voltage
0.000	0.0000	0.0000	0.003
29.994	0.4999	0.4999	1.004
45.016	0.7073	0.7073	1.423
59.900	0.8652	0.8652	1.743
-59.900	-0.8652	-0.8652	-1.741
-45.016	-0.7073	-0.7073	-1.421
-29.994	-0.4999	-0.4999	-1.004

slope	offset
0.4971	-0.0005



CCGA Nautical Twilight Seakeeping Trials

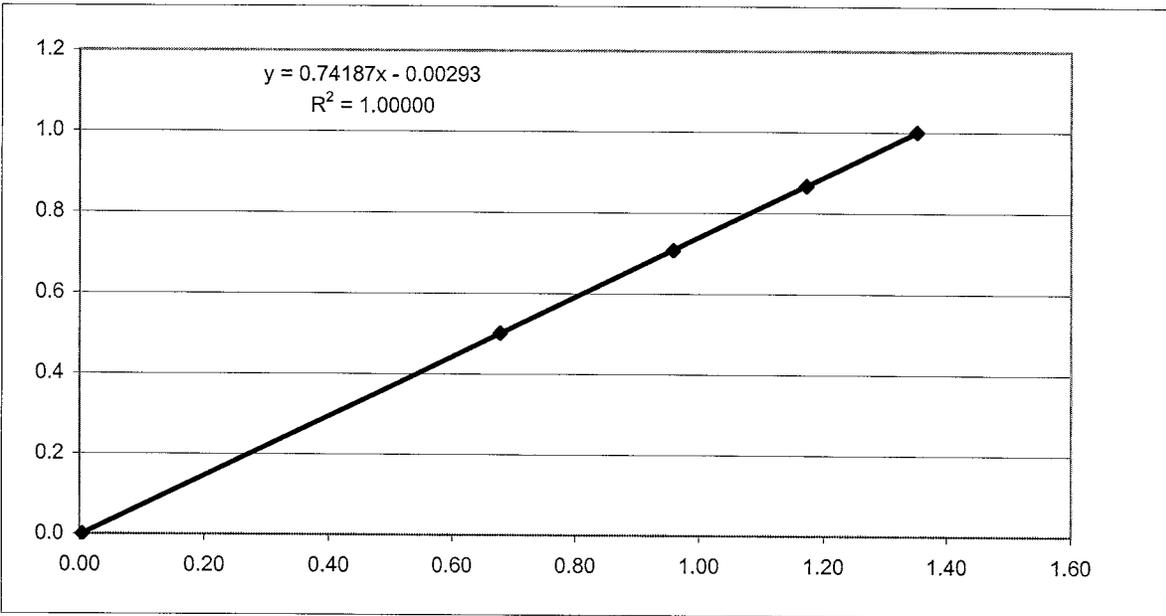
Ch 10
Z Accel (Heave)

Model QA1400
serial # 149

Gravity 1

wedge	Angle	SIN(angle)	Acceleration	Voltage
0	90	1.0000	1.0000	1.351
29.994	60.006	0.8661	0.8661	1.172
45.016	44.984	0.7069	0.7069	0.958
59.9	30.1	0.5015	0.5015	0.679
90	0	0.0000	0.0000	0.004

slope	offset
0.7419	-0.0029



CCGA Nautical Twilight Seakeeping Trials

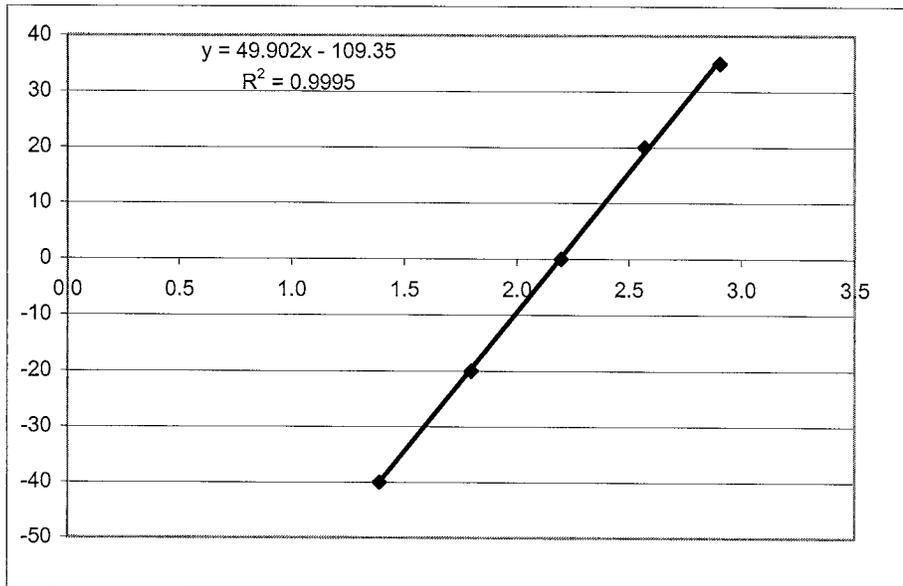
Ch 11
Rudder Angle

Model serial # PT101-0025-111-1110
A10806

Gravity 1

Angle	Voltage
35	2.906
20	2.57
0	2.195
-20	1.797
-40	1.388

slope	Intercept
49.9020	-109.3473



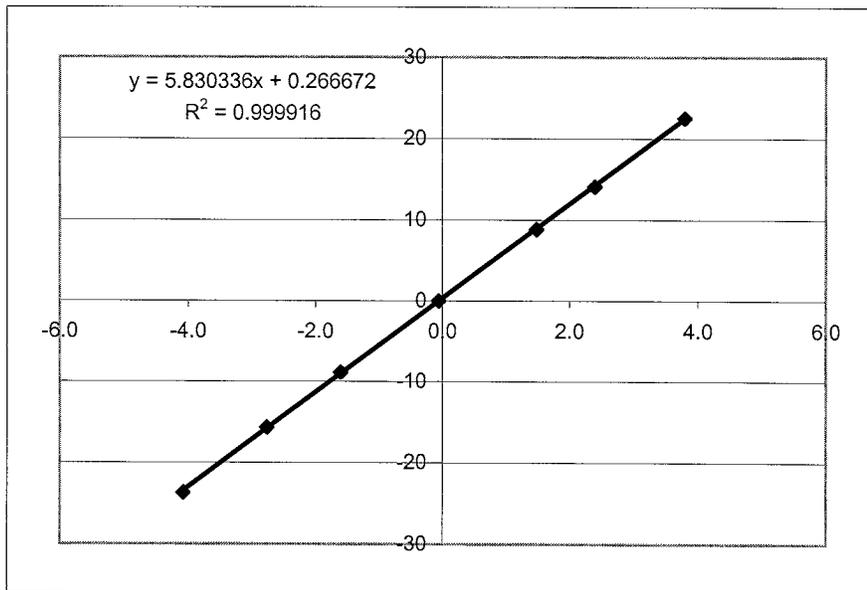
CCGA Nautical Twilight Seakeeping Trials

Ch 12
Roll Angle

Model serial # LSOC-30 52732

Angle	Voltage
22.5	3.797
14.1	2.397
8.83	1.487
-0.03	-0.056
-8.92	-1.606
-15.7	-2.765
-23.7	-4.075

slope	offset
5.8303	0.2667



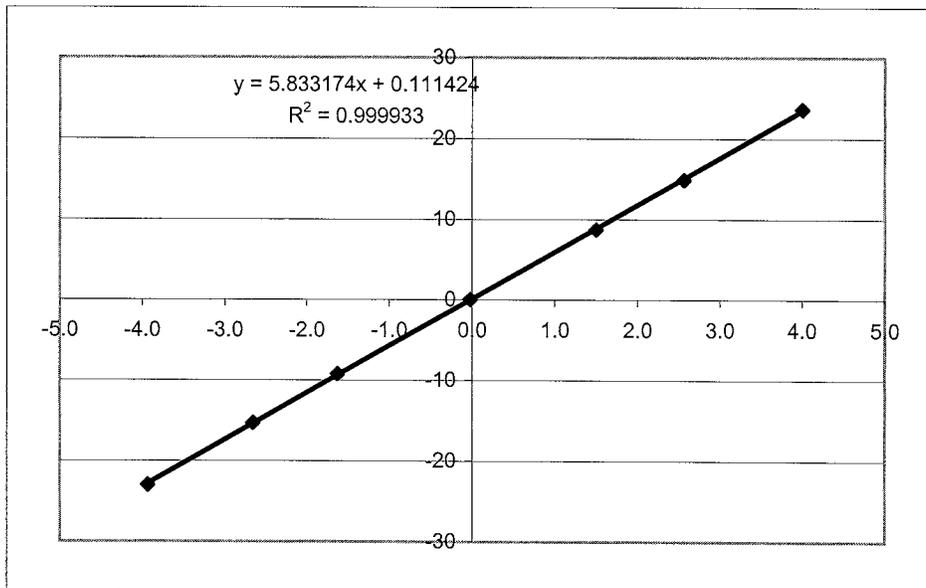
CCGA Nautical Twilight Seakeeping Trials

Ch 13
Pitch Angle

Model serial # LSOC-30 52734

Gravity 1
Angle Voltage
23.60 4.004
14.90 2.563
8.73 1.499
0.03 -0.024
-9.23 -1.625
-15.30 -2.660
-23.00 -3.937

slope	Offset
5.8332	0.1114



CCGA Nautical Twilight Seakeeping Trials

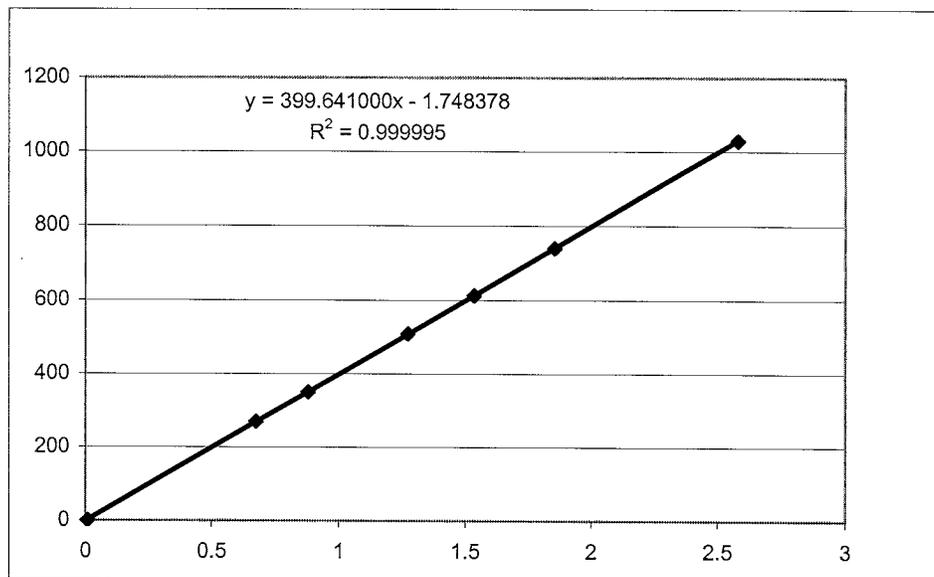
Ch 14
Shaft RPM

Model serial # IMD RPM to voltage converter

Note: Model 198 lasetach ser no. 9509281, nrc # 018585 used as a reference

rpm	Voltage Out
0	0.007
269	0.676
350	0.879
508	1.273
612	1.536
739	1.855
1029	2.58

slope	Offset
399.6410	-1.7484



Appendix D
Wave Buoy Specifications and Typical Output File

Sentry Wave Buoy Specifications

Physical

- Weight in air with batteries 15.7 kg (42 lb.)
- Mooring varies with location and deployment duration
- Hull size, 0.75 m (2.5 ft.) diameter
- Housing Material, PVC and aluminum
- Discus Hull, Urethane foam collar
- O-ring waterproof seal on battery and instrument housing

Power / Batteries

27 Alkaline D cells provide an approximately 2-3 week lifetime with hourly data collection and processing. When not deployed, the buoy may be powered optionally by an external connector.

Operating Temperature Range

0°C to 60°C (32°F to 140°F)

Sensors

- Accelerations along antenna vertical, bow, starboard axes
- Magnetic field along vertical, bow, starboard axes
- Water Temperature (internal hull-contacting thermistor)
- Leak detector
- Sampling rate, 4.0 Hz.

SENTRY WAVE BUOY

- Record length, 4096 samples (17.1 min)

Onboard Computer

Embedded 32-bit processor

Radio Frequency

Spread spectrum, 902-928 MHz

Outputs

- Nondirectional wave spectra
- Directional wave spectra
- Wave parameters: Significant wave height, dominant wave period, average wave period, dominant wave direction
- Data Quality Assurance (DQA) parameters: for measured time series, buoy internal temperature, leak detector

Accuracies and Ranges

- Significant Wave Height ± 0.03 m, 0-9 m (± 0.10 ft., 0-30 ft.)
- Dominant and average wave period: ± 0.5 s, 0 - 25 s
- Dominant wave direction: $\pm 2^\circ$, 0° - 360°
- Nondirectional and directional spectra are limited by statistical confidence related to record length rather than the instrumentation.

TYPICAL WAVE BUOY OUTPUT FILE

NSI-Neptune Sciences, Inc - Wave Sentry Data Processing Software Version 1.23

Sat Oct 4 06:00:00 2003

VBat = 11.69, Leak = DRY, Temp = 12.1

Significant wave height = 1.80 m

Dominant and average frequency = 0.15 Hz 0.17 Hz

Dominant and average period = 6.87 s 6.06 s

Wave directions are compass headings from which waves approach.

Dominant wave direction = 169.5 deg magnetic

Average wave direction = -155.9 deg magnetic

bnd	cfrq	c11	r1	r2	0	alpha1	alpha2
1	0.038	0	999.9	999.9	0	999.9	999.9
2	0.049	0	999.9	999.9	0	999.9	999.9
3	0.06	0	999.9	999.9	0	999.9	999.9
4	0.07	0.3299	0.3885	0.971	0	260.2	262.2
5	0.081	0.2955	0.2683	0.9643	0	264	257.6
6	0.092	0.7882	0.4297	0.9042	0	255.2	260.2
7	0.103	1.7148	0.5875	0.8518	0	253.3	258.1
8	0.113	1.7287	0.4883	0.6261	0	237.2	246.7
9	0.124	1.5661	0.5122	0.6453	0	237.5	258.2
10	0.135	2.4357	0.5449	0.3036	0	211.5	266.8
11	0.146	3.9363	0.6942	0.2545	0	169.5	144.1
12	0.156	1.5108	0.6213	0.2223	0	157.5	124
13	0.167	0.9978	0.5497	0.3311	0	175.9	123.5
14	0.178	0.728	0.7948	0.5252	0	154.9	145.7
15	0.188	0.4663	0.658	0.1558	0	177	150.7
16	0.199	0.2908	0.4939	0.4529	0	179.2	114.2
17	0.21	0.2432	0.655	0.0769	0	186	153.5
18	0.221	0.3348	0.574	0.1752	0	182.4	223.7
19	0.231	0.1682	0.5771	0.1029	0	182	259.4
20	0.242	0.087	0.3815	0.3539	0	187.9	223.2
21	0.253	0.077	0.3235	0.344	0	243.7	312.5
22	0.264	0.0982	0.3959	0.3716	0	173	251.2
23	0.274	0.1038	0.4363	0.2483	0	221.5	218
24	0.285	0.078	0.2909	0.2366	0	243.7	253.8
25	0.296	0.0455	0.1663	0.2141	0	277.9	210.2
26	0.307	0.048	0.6041	0.0958	0	249	285.1
27	0.317	0.0512	0.347	0.3337	0	356.2	6.1
28	0.328	0.0229	0.2707	0.33	0	74.7	84
29	0.339	0.0345	0.3802	0.3252	0	327.8	3.6
30	0.35	0.0402	0.3815	0.4623	0	351.6	325.5
31	0.36	0.0499	0.6504	0.4888	0	353.3	337.8
32	0.371	0.0401	0.7294	0.6016	0	345.2	338.1
33	0.382	0.0238	0.6276	0.2962	0	9.9	172.3
34	0.393	0.0755	0.7679	0.5661	0	356.4	349.7
35	0.403	0.0764	0.7529	0.6579	0	1.5	175.7
36	0.414	0.0471	0.7464	0.3066	0	357.4	7.6
37	0.425	0.0609	0.8191	0.5963	0	5.6	177.4
38	0.436	0.0444	0.855	0.7432	0	357.4	355.1
39	0.446	0.0256	0.6421	0.5067	0	11.8	1.7
40	0.457	0.031	0.7415	0.2536	0	13	8.1
41	0.468	0.0184	0.5676	0.1889	0	9.6	76.6
42	0.479	0.0232	0.7684	0.4595	0	13.2	15.6
43	0.489	0.0089	0.5808	0.1072	0	7.7	163.1
44	0.5	0.0183	0.7482	0.2797	0	17	16.2

Mean, min, max acc (g) = 0.02 -0.47 0.59

Mean, min, max pitch (deg) = 0.0 -20.1 25.6

Mean, min, max roll (deg) = -0.0 -15.9 16.0

Maximum tilt (deg) = 26.2

Appendix E
Seakeeping Trials Run Log

Run Log for Seakeeping Trial on CCGA Nautical Twilight - Vessel 'B'

Fishing Vessel Research Project - Proj. 2017

Date: November 20, 2003

Run #	File Name	Start Finish Time	Course Relative to Incident Waves	Location Start/Finish		Nominal SWH (m)	SOG (kts.)	COG (Deg. TRUE)	Wind Speed (kts.)	Wind Direction (Deg. Rel.)	Engine Rpm	Shaft Rpm	Comments: Heavy vessel movement, slamming, spray, water accumulation, maintaining balance/seasickness.
				Latitude	Long.								
1	fol_20031120092544_CAL.CSV	9:25 9:34	Following	47 58 19 47 59 73	52 42 01 52 40 91	1.5 - 2	7.3	25.73	N/A	N/A	N/A	337	
2	head_20031120093759_CAL.CSV	9:37 9:44	Head	47 59 50 47 58 27	52 40 85 52 41 10	1.5 - 2	7.3	186.99	N/A	N/A	N/A	305	
3	bow_20031120094525_CAL.CSV	9:45 9:51	Bow	47 58 05 47 56 99	52 41 05 52 40 00	1.5 - 2	7.5	145.97	N/A	N/A	N/A	305	
4	beam_20031120095346_CAL.CSV	9:53 9:56	Beam	47 56 85 47 56 96	52 40 39 52 41 07	1.5 - 2	7.1	282.96	N/A	N/A	N/A	323	run could not be completed as roll amplitude was severe - ~ 30 deg.
5	quart_20031120095702_CAL.CSV	9:57 10:01	Quartering	47 57 03 47 57 55	52 41 19 52 42 28	1.5 - 2	7.1	305.44	N/A	N/A	N/A	323	

NOTES: Wind speed/direction is provided relative to the ship's course. The Anemometer was aligned to Magnetic north.

SOG - Speed Over Ground COG - Course Over Ground SWH - Significant Wave Height

Wave Buoy failed - no valid wave data acquired during this trial. Wave Buoy location: 47 34.042 N 52 26.200 W

Short runs (5 min.) were acquired specifically for S. Mackinnon/MUN Kinesiology. Nominal wave height listed is a visual estimate.

Nominal Speed for all runs was 7 knots.

Appendix F
Tables of Basic Information and Statistics for Each Trial Run

CCGA Nautical Twilight Seakeeping Trials

File Name: scott_head_20031120093759

Date: November 20, 2003

NF Time: 9:38

Dockside

Location: Pier 31, St. John's Harbour

Nominal Draft FP: 2.29 m Nominal Draft AP: 3.26 m

Water Temperature: 5.4 °C Water Density: 1021.7 kg/m³

Static Stability Info - GM_T(Fluid): 2.49 m

Closest Stability Booklet Condition: At Grounds, 50% Consumables, Half Load Capelin

Trials Site:

Trials Location: 10 nautical miles East of St. John's

Duration of Run: 375 s Number of Samples: 18737

Peak Response Frequency: Roll Angle: 0.2520 Hz

Pitch Angle: 0.3113 Hz

Heave Accel: 0.3262 Hz

Channel		Average	St. Dev.	Minimum	Maximum
DGPS Antenna					
COG	(deg. True)	187.0	1.907	181.4	192.2
SOG	(m/s)	3.746	0.231	3.117	4.225
SOG	(knots)	7.281	0.450	6.059	8.213
Shaft Speed	(RPM)	305.3	1.946	301.8	320.3
Computed for the Lifting Position from the MotionPak					
Roll Angle	(deg.)	0.610	1.680	-4.664	6.591
Pitch Angle	(deg.)	0.571	3.734	-12.095	13.061
Yaw Angle	(deg.)	-0.075	1.738	-3.422	5.695
Surge Displacement	(m)	-0.001	0.218	-0.666	0.738
Sway Displacement	(m)	0.000	0.151	-0.479	0.545
Heave Displacement	(m)	0.000	0.305	-0.949	0.990
Surge Acceleration	(m/s ²)	0.092	0.914	-3.033	2.410
Sway Acceleration	(m/s ²)	-0.105	0.485	-1.826	1.453
Heave Acceleration	(m/s ²)	0.048	1.176	-3.439	4.412

CCGA Nautical Twilight Seakeeping Trials

File Name: scott_head_20031120093759

Date: November 20, 2003

NF Time: 9:38

Channel		Average	St. Dev.	Minimum	Maximum
Output from Tri-Mounted Accelerometer positioned near DAS					
Surge Acceleration	(m/s ²)	0.420	1.281	-3.733	3.769
Sway Acceleration	(m/s ²)	-0.011	0.656	-2.117	2.567
Heave Acceleration	(m/s ²)	-0.081	2.167	-7.415	5.816
Computed for the Accelerometers position from the MotionPak					
Surge Displacement	(m)	-0.001	0.310	-1.012	1.024
Sway Displacement	(m)	0.000	0.200	-0.619	0.722
Heave Displacement	(m)	-0.002	0.507	-1.679	1.699
Surge Acceleration	(m/s ²)	-0.005	1.295	-4.271	3.468
Sway Acceleration	(m/s ²)	-0.100	0.670	-2.823	2.141
Heave Acceleration	(m/s ²)	0.081	2.081	-5.685	7.457

Notes:

- The draft is referenced to the datum baseline.
- The Surge and Sway channels had to be switched during the offline analysis because the tri-mounted accelerometers was installed incorrectly.
- The motions of the vessel were calculated using the body fixed coordinate system.
- The sign convention for Accelerometer is:

x : '+' forward	y : '+' starboard	z : '-' downwards
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- The sign convention for MotionPak is:

x : '+' forward	y : '+' starboard	z : '+' downwards
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- The distance to Lifting Position from the MotionPak:

Δx :	-2.438 m	Δy :	0.914 m	Δz :	-0.889 m
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- The distance to Accelerometers position from the MotionPak:

Δx :	3.302 m	Δy :	-0.457 m	Δz :	-2.286 m
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CCGA Nautical Twilight Seakeeping Trials

File Name: scott_bow_20031120094525

Date: November 20, 2003

NF Time: 9:45

Dockside

Location: Pier 31, St. John's Harbour

Nominal Draft FP: 2.29 m Nominal Draft AP: 3.26 m

Water Temperature: 5.4 °C Water Density: 1021.7 kg/m³

Static Stability Info - GM_T(Fluid): 2.49 m

Closest Stability Booklet Condition: At Grounds, 50% Consumables, Half Load Capelin

Trials Site:

Trials Location: 10 nautical miles East of St. John's

Duration of Run: 377 s Number of Samples: 18833

Peak Response Frequency: Roll Angle: 0.2508 Hz

Pitch Angle: 0.3098 Hz

Heave Accel: 0.3098 Hz

Channel		Average	St. Dev.	Minimum	Maximum
DGPS Antenna					
COG	(deg. True)	146.0	3.525	137.6	154.7
SOG	(m/s)	3.850	0.113	3.569	4.094
SOG	(knots)	7.484	0.220	6.939	7.960
Shaft Speed	(RPM)	305.0	0.665	302.3	308.0
Computed for the Lifting Position from the MotionPak					
Roll Angle	(deg.)	0.073	5.221	-16.881	16.782
Pitch Angle	(deg.)	0.419	2.621	-6.686	7.160
Yaw Angle	(deg.)	-0.110	3.153	-7.950	8.104
Surge Displacement	(m)	0.000	0.154	-0.385	0.428
Sway Displacement	(m)	0.000	0.472	-1.512	1.525
Heave Displacement	(m)	0.000	0.364	-1.033	1.073
Surge Acceleration	(m/s ²)	0.065	0.664	-1.901	1.698
Sway Acceleration	(m/s ²)	-0.088	1.285	-4.131	3.479
Heave Acceleration	(m/s ²)	0.093	1.225	-3.068	3.819

CCGA Nautical Twilight Seakeeping Trials

File Name: scott_bow_20031120094525

Date: November 20, 2003

NF Time: 9:45

Channel		Average	St. Dev.	Minimum	Maximum
Output from Tri-Mounted Accelerometer positioned near DAS					
Surge Acceleration	(m/s ²)	0.438	0.946	-2.266	2.731
Sway Acceleration	(m/s ²)	-0.058	1.674	-4.649	5.211
Heave Acceleration	(m/s ²)	-0.145	1.657	-5.493	3.795
Computed for the Accelerometers position from the MotionPak					
Surge Displacement	(m)	0.000	0.220	-0.563	0.630
Sway Displacement	(m)	0.000	0.613	-1.935	1.960
Heave Displacement	(m)	0.001	0.397	-1.031	1.019
Surge Acceleration	(m/s ²)	0.013	0.956	-2.814	2.412
Sway Acceleration	(m/s ²)	-0.058	1.692	-5.416	4.519
Heave Acceleration	(m/s ²)	0.138	1.614	-3.846	5.427

Notes:

- The draft is referenced to the datum baseline.
- The Surge and Sway channels had to be switched during the offline analysis because the tri-mounted accelerometers was installed incorrectly.
- The motions of the vessel were calculated using the body fixed coordinate system.
- The sign convention for Accelerometer is:

x : '+' forward	y : '+' starboard	z : '-' downwards
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- The sign convention for MotionPak is:

x : '+' forward	y : '+' starboard	z : '+' downwards
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- The distance to Lifting Position from the MotionPak:

Δx :	-2.438 m	Δy :	0.914 m	Δz :	-0.889 m
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- The distance to Accelerometers position from the MotionPak:

Δx :	3.302 m	Δy :	-0.457 m	Δz :	-2.286 m
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CCGA Nautical Twilight Seakeeping Trials

File Name: scott_beam_20031120095346

Date: November 20, 2003

NF Time: 9:53

Dockside

Location: Pier 31, St. John's Harbour

Nominal Draft FP: 2.29 m Nominal Draft AP: 3.26 m

Water Temperature: 5.4 °C Water Density: 1021.7 kg/m³

Static Stability Info - GM_T(Fluid): 2.49 m

Closest Stability Booklet Condition: At Grounds, 50% Consumables, Half Load Capelin

Trials Site:

Trials Location: 10 nautical miles East of St. John's

Duration of Run: 165 s Number of Samples: 8260

Peak Response Frequency: Roll Angle: 0.2421 Hz

Pitch Angle: 0.1345 Hz

Heave Accel: 0.2959 Hz

Channel		Average	St. Dev.	Minimum	Maximum
DGPS Antenna					
COG	(deg. True)	283.0	26.759	253.4	324.6
SOG	(m/s)	3.667	0.152	3.292	4.017
SOG	(knots)	7.128	0.295	6.399	7.808
Shaft Speed	(RPM)	322.9	1.033	319.5	326.2
Computed for the Lifting Position from the MotionPak					
Roll Angle	(deg.)	1.044	6.274	-17.302	20.788
Pitch Angle	(deg.)	0.146	2.046	-5.871	5.397
Yaw Angle	(deg.)	0.147	16.091	-20.355	32.952
Surge Displacement	(m)	-0.003	0.186	-0.487	0.444
Sway Displacement	(m)	-0.006	0.850	-2.422	2.234
Heave Displacement	(m)	0.008	0.424	-1.145	1.170
Surge Acceleration	(m/s ²)	0.038	0.387	-1.771	1.372
Sway Acceleration	(m/s ²)	-0.153	1.446	-4.616	4.787
Heave Acceleration	(m/s ²)	0.102	0.631	-1.911	2.836

CCGA Nautical Twilight Seakeeping Trials

File Name: scott_beam_20031120095346

Date: November 20, 2003

NF Time: 9:53

Channel		Average	St. Dev.	Minimum	Maximum
Output from Tri-Mounted Accelerometer positioned near DAS					
Surge Acceleration	(m/s ²)	0.449	0.483	-1.764	2.231
Sway Acceleration	(m/s ²)	0.010	1.733	-6.189	5.787
Heave Acceleration	(m/s ²)	-0.137	1.044	-4.876	3.646
Computed for the Accelerometers position from the MotionPak					
Surge Displacement	(m)	0.000	0.231	-0.525	0.626
Sway Displacement	(m)	-0.004	0.978	-3.204	2.877
Heave Displacement	(m)	0.006	0.515	-1.632	1.473
Surge Acceleration	(m/s ²)	0.019	0.519	-2.325	1.940
Sway Acceleration	(m/s ²)	-0.127	1.759	-5.885	6.193
Heave Acceleration	(m/s ²)	0.143	1.052	-3.667	4.860

Notes:

- The draft is referenced to the datum baseline.
- The Surge and Sway channels had to be switched during the offline analysis because the tri-mounted accelerometers was installed incorrectly.
- The motions of the vessel were calculated using the body fixed coordinate system.
- The sign convention for Accelerometer is:

x : '+' forward	y : '+' starboard	z : '-' downwards
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- The sign convention for MotionPak is:

x : '+' forward	y : '+' starboard	z : '+' downwards
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- The distance to Lifting Position from the MotionPak:

Δx : -2.438 m	Δy : 0.914 m	Δz : -0.889 m
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- The distance to Accelerometers position from the MotionPak:

Δx : 3.302 m	Δy : -0.457 m	Δz : -2.286 m
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CCGA Nautical Twilight Seakeeping Trials

File Name: scott_quart_20031120095702

Date: November 20, 2003

NF Time: 9:57

Dockside

Location: Pier 31, St. John's Harbour

Nominal Draft FP: 2.29 m Nominal Draft AP: 3.26 m

Water Temperature: 5.4 °C Water Density: 1021.7 kg/m³

Static Stability Info - GM_T(Fluid): 2.49 m

Closest Stability Booklet Condition: At Grounds, 50% Consumables, Half Load Capelin

Trials Site:

Trials Location: 10 nautical miles East of St. John's

Duration of Run: 282 s Number of Samples: 14083

Peak Response Frequency: Roll Angle: 0.2525 Hz

Pitch Angle: 0.1262 Hz

Heave Accel: 0.2998 Hz

Channel		Average	St. Dev.	Minimum	Maximum
DGPS Antenna					
COG	(deg. True)	305.4	2.001	300.9	310.5
SOG	(m/s)	3.634	0.067	3.411	3.822
SOG	(knots)	7.064	0.130	6.631	7.430
Shaft Speed	(RPM)	322.9	1.007	320.1	326.6
Computed for the Lifting Position from the MotionPak					
Roll Angle	(deg.)	0.915	4.476	-13.061	15.644
Pitch Angle	(deg.)	-0.082	1.775	-6.953	5.411
Yaw Angle	(deg.)	0.054	2.669	-6.320	7.512
Surge Displacement	(m)	0.001	0.178	-0.512	0.567
Sway Displacement	(m)	0.008	0.619	-2.044	2.206
Heave Displacement	(m)	0.000	0.325	-0.857	0.833
Surge Acceleration	(m/s ²)	-0.009	0.200	-0.682	0.775
Sway Acceleration	(m/s ²)	-0.153	0.960	-3.204	2.717
Heave Acceleration	(m/s ²)	0.043	0.354	-1.008	1.238

CCGA Nautical Twilight Seakeeping Trials

File Name: scott_quart_20031120095702

Date: November 20, 2003

NF Time: 9:57

Channel		Average	St. Dev.	Minimum	Maximum
Output from Tri-Mounted Accelerometer positioned near DAS					
Surge Acceleration	(m/s ²)	0.416	0.249	-0.558	1.238
Sway Acceleration	(m/s ²)	0.030	1.161	-3.309	3.367
Heave Acceleration	(m/s ²)	-0.064	0.582	-1.776	1.619
Computed for the Accelerometers position from the MotionPak					
Surge Displacement	(m)	0.000	0.216	-0.592	0.751
Sway Displacement	(m)	0.007	0.678	-2.046	2.217
Heave Displacement	(m)	0.000	0.408	-1.321	1.168
Surge Acceleration	(m/s ²)	-0.016	0.264	-0.994	0.957
Sway Acceleration	(m/s ²)	-0.145	1.166	-3.572	3.351
Heave Acceleration	(m/s ²)	0.060	0.562	-1.629	1.995

Notes:

- The draft is referenced to the datum baseline.
- The Surge and Sway channels had to be switched during the offline analysis because the tri-mounted accelerometers was installed incorrectly.
- The motions of the vessel were calculated using the body fixed coordinate system.
- The sign convention for Accelerometer is:

x : '+' forward	y : '+' starboard	z : '-' downwards
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- The sign convention for MotionPak is:

x : '+' forward	y : '+' starboard	z : '+' downwards
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- The distance to Lifting Position from the MotionPak:

Δx :	-2.438 m	Δy :	0.914 m	Δz :	-0.889 m
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- The distance to Accelerometers position from the MotionPak:

Δx :	3.302 m	Δy :	-0.457 m	Δz :	-2.286 m
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CCGA Nautical Twilight Seakeeping Trials

File Name: scott_fol_20031120092544

Date: November 20, 2003

NF Time: 9:25

Dockside

Location: Pier 31, St. John's Harbour

Nominal Draft FP: 2.29 m Nominal Draft AP: 3.26 m

Water Temperature: 5.4 °C Water Density: 1021.7 kg/m³

Static Stability Info - GM_T(Fluid): 2.49 m

Closest Stability Booklet Condition: At Grounds, 50% Consumables, Half Load Capelin

Trials Site:

Trials Location: 10 nautical miles East of St. John's

Duration of Run: 510 s Number of Samples: 25525

Peak Response Frequency: Roll Angle: 0.1197 Hz

Pitch Angle: 0.1197 Hz

Heave Accel: 0.1197 Hz

Channel		Average	St. Dev.	Minimum	Maximum
DGPS Antenna					
COG	(deg. True)	25.7	3.774	12.3	34.3
SOG	(m/s)	3.745	0.106	3.467	4.047
SOG	(knots)	7.281	0.207	6.739	7.868
Shaft Speed	(RPM)	336.6	1.577	333.3	346.2
Computed for the Lifting Position from the MotionPak					
Roll Angle	(deg.)	0.598	1.682	-3.975	6.313
Pitch Angle	(deg.)	-0.208	1.748	-5.376	4.199
Yaw Angle	(deg.)	-0.023	4.683	-16.582	12.591
Surge Displacement	(m)	0.000	0.267	-0.772	0.714
Sway Displacement	(m)	0.008	0.584	-1.813	1.769
Heave Displacement	(m)	-0.001	0.321	-0.883	0.951
Surge Acceleration	(m/s ²)	-0.029	0.138	-0.508	0.399
Sway Acceleration	(m/s ²)	-0.102	0.350	-1.311	0.984
Heave Acceleration	(m/s ²)	0.006	0.221	-0.858	0.799

CCGA Nautical Twilight Seakeeping Trials

File Name: scott_fol_20031120092544

Date: November 20, 2003

NF Time: 9:25

Channel		Average	St. Dev.	Minimum	Maximum
Output from Tri-Mounted Accelerometer positioned near DAS					
Surge Acceleration	(m/s ²)	0.396	0.156	-0.139	0.884
Sway Acceleration	(m/s ²)	-0.014	0.380	-1.379	1.160
Heave Acceleration	(m/s ²)	-0.009	0.236	-0.768	0.686
Computed for the Accelerometers position from the MotionPak					
Surge Displacement	(m)	-0.001	0.285	-0.803	0.697
Sway Displacement	(m)	0.005	0.557	-1.742	1.661
Heave Displacement	(m)	-0.001	0.384	-1.056	0.957
Surge Acceleration	(m/s ²)	-0.037	0.183	-0.775	0.732
Sway Acceleration	(m/s ²)	-0.098	0.381	-1.355	1.227
Heave Acceleration	(m/s ²)	0.008	0.278	-1.071	1.147

Notes:

- The draft is referenced to the datum baseline.
- The Surge and Sway channels had to be switched during the offline analysis because the tri-mounted accelerometers was installed incorrectly.
- The motions of the vessel were calculated using the body fixed coordinate system.
- The sign convention for Accelerometer is:

x : '+' forward	y : '+' starboard	z : '-' downwards
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- The sign convention for MotionPak is:

x : '+' forward	y : '+' starboard	z : '+' downwards
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- The distance to Lifting Position from the MotionPak:

Δx :	-2.438 m	Δy :	0.914 m	Δz :	-0.889 m
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- The distance to Accelerometers position from the MotionPak:

Δx :	3.302 m	Δy :	-0.457 m	Δz :	-2.286 m
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