Description of seakeeping trial carried out on CCGA Nautical Twilight: November 1, 2004

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SUMMARY

This report describes seakeeping experiments carried out on the 45 ft. (13.72 m) long inshore fishing vessel CCGA Nautical Twilight off St. John's, NL November 1, 2004 carried out as part of the Fishing Vessel Safety Project (Proj. 2017). 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.

This document describes the CCGA Nautical Twilight, the trials instrumentation package, data acquisition system, test program, data analysis procedure and presents the results.

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DESCRIPTION OF SEAKEEPING TRIAL CARRIED OUT ON CCGA NAUTICAL TWILIGHT – NOVEMBER 1, 2004

TR-2004-13

T. Fleming, D. Cumming

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AP	aft perpendicular
BOK	bottom of keel
ºC	degrees Centigrade
CAD	Computer Aided Design
CCG	Canadian Coast Guard
CCGA	Canadian Coast Guard Auxiliary
CCGS	Canadian Coast Guard Ship
CG	Centre of Gravity
CIHR	Canadian Institutes of Health and Research
cm	centimetre(s)
COG	Course Over Ground
DAS	Data Acquisition System
DC	Direct Current
deg.	degree(s)
DGPS	Differential Global Positioning System
DOT	Department of Transport
EPIRB	Emergency Position Indicating Radiobeacon
FFT	Fast Fourier Transform
FP	forward perpendicular
ft	foot, feet
Fwd	forward
F/V	frequency/voltage
g	acceleration due to gravity
gal.	gallon(s)
GEDAP	General Data Analysis Program
GM_T	Transverse Metacentric Height
GPS	Global Positioning System
H_S, $H_{1/3}$, H_{m0}	Significant Wave Height

LIST OF ABBREVIATIONS (CONT'D)

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 datum
kt(s)	knot(s)
kW	kiloWatt(s)
l	litre(s)
lb(s)	pound(s)
LCG	Longitudinal Centre of Gravity
m	metre(s)
mag.	magnetic
mHz	megaHertz
MII(s)	Motion Induced Interrupt(s)
MUN	Memorial University of Newfoundland
MV	Motor Vessel
mW	megaWatt(s)
NIF	New Initiatives Fund
nm	nautical mile(s)
NMEA	National Marine Electronics Association
NRC	National Research Council
NSERC	Natural Sciences and Engineering Research Council of Canada
OCC	Oceanic Consulting Corporation
OEB	Offshore Engineering Basin
OSSC	Offshore Safety and Survival Centre

LIST OF ABBREVIATIONS (CONT'D)

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
SWH	significant wave height
t	tonne(s)
T_{av}	average period
T_Z	zero crossing period
UHF	Ultra High Frequency
UNESCO	United Nations Educational, Scientific and Cultural Organization
UPS	Uninterruptible Power Supply
V, VAC	volt(s)
VCG	Vertical Centre of Gravity
VHF	very high frequency

DESCRIPTION OF SEAKEEPING TRIAL CARRIED OUT ON CCGA NAUTICAL TWILIGHT – NOVEMBER 1, 2004

1.0 INTRODUCTION

This report describes seakeeping experiments carried out on the 45 ft. (13.72 m) long inshore fishing vessel CCGA Nautical Twilight off St. John's, NL November 1, 2004 as part of the Fishing Vessel Safety Project (Proj. 2017). 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 derive 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.

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.

This document describes the CCGA Nautical Twilight, the trials instrumentation package, data acquisition system, test program, data analysis procedure and presents the results. It should be noted that a trial was attempted on the CCGA Nautical Twilight in November 2003 (Reference 1) however no wave data was acquired during this trial due to a technical failure of the Neptune directional wave buoy – the only sensor available for measuring wave data at the time. Additional Fishing Vessel Research Project related seakeeping trials carried out in the Fall of 2003 are described in References 2,3.

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 4].

The effort described in this report is part of Component #3 of the overall Fishing Vessel Research project. The 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 motion, 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 and two 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 5 to 8.

3.0 DESCRIPTION OF THE CCGA NAUTICAL TWILIGHT

The CCGA Nautical Twilight [Figure 1] is a typical 45' fibreglass 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 set-up, 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 14 tons of flake ice to the fish hold. Once the vessel was ballasted and most of the outfit items installed, an inclining experiment was performed on October 27, 2004 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 2.387 m long in the fish hold, forward pendulum was 1.645 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. Note the fresh water tank was assumed to be approximately half full during the inclining however the results were not corrected for free surface due to the relatively small heel angles.

The following is a summary of the inclining experiment results:

Draft (from Bottom of Keel):	10.71 ft @ AP (3.264 m Aft)
	5.54 ft @ FP (1.689 m Fwd.)
Displacement:	83.197 Long Tons (81,274 kg)
Longitudinal Centre of Gravity (LCG):	19.917 feet (5.990 m) Fwd. of AP
Vertical Centre of Gravity (VCG):	11.442 feet (3.594 m) above datum
Transverse Metacentric Height (GM_T):	7.849 feet (2.392 m)
Longitudinal Metacentric Height (KM_L):	45.2 feet (13.777 m) above datum

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 centreline 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 linked to an internal magnetic compass. The vessel is fitted with a seven person Ovatek life boat capsule however the lifesaving equipment was augmented with floater suits on loan from the CCG for the trials period. A detailed list of the ‘Nautical Twilight’s’ principle particulars and list of outfit items can be found in Appendix B.

4.0 DESCRIPTION OF INSTRUMENTATION

IOT was tasked to provide the trials technical support to install and maintain 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 C while the analog channel calibration information is provided in Appendix D. 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 9.

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 was 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 centre 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 gear compartment.

Rudder angle was calibrated with respect to a protractor, drawn using CAD software, fixed to the top of the circular plate with zero degrees from the rudder indicator on the Bridge.

4.3 Ship's Motion Instrumentation

For the seakeeping trials carried out on November 1st, a MotionPak I was used to measure ship motions with six degrees of freedom. The MotionPak was mounted on an aluminium 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
- Pitch Rate
- Yaw Rate
- Surge Acceleration
- Sway Acceleration
- 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
- Pitch Angle/Rate/Acceleration
- Yaw Angle/Rate/Acceleration
- Surge Displacement/Velocity/Acceleration
- Sway Displacement/Velocity/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:

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

In addition, orthogonal linear accelerations (sway, surge and heave, Figure 5) were measured on the Bridge, behind the central circuit breaker panel 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 to measure 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 Defence. GPS consists of a constellation of 24 satellites providing worldwide, 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 10.

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 centreline, 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

Two directional wave buoys were used during the trials:

Neptune Sciences Sentry Wave Buoy
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 [Figure 7]. The buoy was moored in approximately 165 metres of water at 47° 32.80" N 52° 26.199" W. On the day of the trial, the buoy was manually deployed by lifting it over the side of the 'Nautical Twilight'. Retrieval was accomplished at the end of the trial using the vessel's pot hauler.

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 aluminium 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 co-ordinate 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 aluminium 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 aluminium 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.

- Shipboard 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 shipboard 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 system for the wave buoy was designed for a 165 m depth of water by personnel from the MUN Physical Oceanography Group after discussions with the buoy manufacturer. The mooring is described as follows:

  - Neptune Wave Buoy with floating tether
  - 4 meter half inch nylon cord in parallel with 3 meter shock cord
  - ½” stainless steel shackle and swivel
  - 55 meters of ¼” jacketed wire rope and shackles

- 183 meters 9/16” polypropylene rope
- 10’ ½” galvanized chain
- 40 lb. Danforth® anchor

Additional information on the Neptune directional wave buoy is provided in Reference 11 while further information and a typical output file is provided in Appendix E.

Datawell Waverider Mark II Wave Buoy

In previous trials, the Neptune buoy proved to be unreliable. To ensure acquisition of the required directional wave data, a 0.9 m diameter Datawell Waverider Mark II wave buoy manufactured by Datawell b.v. of the Netherlands was leased from Oceans Ltd. of St. John’s, NL. Oceans Ltd. was responsible for providing the buoy and mooring, supervising its launch/recovery from the Marine Institute training vessel MV Louis M. Lauzier, maintaining a base station on shore, acquiring the data during the trial and generating a final data product.

The buoy was deployed in 165 m of water in position 47 34.126 N, 52 26.154 W – about 10 nm east of St. John’s. Directional wave data was computed every half hour and transmitted to the base station at a frequency of 29.760 mHz with an output power of 150 – 200 mW. The high visibility yellow [Figure 8] buoy includes a flashing light that flashes 5 times every 20 seconds. The single point mooring provided by Oceans Ltd. was designed to ensure sufficient symmetrical horizontal buoy response with low stiffness permitting the buoy to follow waves up to a wave height of 40 m with a resolution of 1 cm, and wave periods between 1.6 and 30 s. The wave direction resolution was 1.5º while the wave frequency resolution was 0.005 Hz for frequencies less than 0.1 Hz and 0.01 Hz otherwise. The 212 kg buoy was anchored using two railway train wheels [Figure 8] weighing a total of 1400 lbs. (635 kg). The buoy was moored for the duration of the trials period (approximately 2 months).

The following sensors/equipment was included in the wave buoy:

- Hippy-40 pitch angle/roll angle/heave displacement
- Three axis flux gate compass
- Two fixed X and Y linear accelerometers
- Sea temperature sensor
- Micro-processor

The receiving system was installed ashore at the contractor’s office in St. John’s and consisted of a passive 3 m long (Kathrein) whip antenna with base. A dedicated laptop computer interfaced to the wave direction receiver for storing and displaying the acquired wave data. The receiver was set up to receive at 38.760 mHz (a higher frequency than being transmitted by the buoy). The base station was only monitored on the days when sea trials occurred.

The Datawell buoy and mooring description as well as typical raw output data files is provided in Appendix F. Additional information on the buoy can be obtained from the Datawell b.v. web site (Reference 12) and user's manual that includes a description of the data file format provided by Oceans Ltd. (Reference 13).

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 [Figure 9]. 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 at IOT using a laser tachometer that acted on the reflective target on the shaft of a variable speed motor and subsequently verified using the vessel's RPM gauge.

4.7 Directional Anemometer

A MUN "Weather Wizard III", manufactured by Davis Instruments, capable of monitoring and logging of essential weather conditions such as temperature, wind direction, wind speed and wind chill (Figure 10). This instrument was fixed to an aluminium 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 11). The required information, i.e. temperature and salinity, is collected by the probe and presented on the hand held display with an accuracy of ± 2% or ± 0.1 PPT (parts per thousand) for salinity and ± 0.1°C for the temperature. The instruments range for salinity and temperature is 0 to 80 PPT and -5° to +95°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 14, which provided density as a function of temperature, salinity, and pressure. Additional information on the YSI instrument is provided in Reference 15.

4.9 Electrical Power

Acquiring quality 120 V electrical power was not a problem on the 'Nautical Twilight'. IOT filtered 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 centreline. 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 aluminium 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 up to the main deck 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 and outside up to the top of the deckhouse.

5.0 TRIALS DESCRIPTION

The test plan for the trial is given in Appendix G. 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 1, 2004 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 Datawell wave buoy located at 47 34.126 N, 52 26.154 W.

Upon arrival at the wave buoy location, the sea conditions were found to be favourable for the experiment. The significant wave height was visually estimated at approximately 1.5 – 2 m however there was a low frequency wave coming from almost due north (~20 degrees TRUE) – a legacy of a storm system from that direction coupled with a higher frequency wind driven wave from due south. The nature of this wave field complicated the estimate of the valid direction to steer. A total of 12 runs were executed – two drift runs, a full set of five runs at trawl speed (~ 4 knots) and a full set of five runs at cruise speed (~ 8 knots). No appreciable water was noted on deck throughout the trial. The run log of the trials events can be found in Appendix H.

During the trial, two MUN Kinesiology students from the MUN School of Kinetics and Recreation were on board to carry out dedicated experiments however both were unfortunately incapacitated by seasickness.

Typical Procedure for a Set of Forward Speed Seakeeping Runs:

Each set reflected the recommended ITTC run pattern and was observed in the following manner for each nominal forward speed:

- The ship was first positioned in close proximity to the wave Neptune buoy and directional wave data acquired to derive the dominant wave direction.
- After reviewing the wave data from the buoy, the dominant head sea direction (degrees magnetic) was corrected using a value of approximately 21 degrees to determine the direction relative to true north.
- The forward speed over the ground for the first run sequence was adjusted to 4 knots. The heading angle was selected such that the vessel was heading directly into the sea (head sea run). The throttles were adjusted to achieve the desired course and speed. Data acquisition was initiated once steady state conditions were achieved. The course during all runs was maintained under autopilot control.
- After 25 minutes had elapsed on a steady course, data acquisition was terminated.
- The vessel then altered course by 180 degrees to complete the “following” sea run where the wave action is essentially pushing the vessel. The engine speed was adjusted to maintain a constant speed over ground in order to compare results between runs. Data acquisition was terminated after 40 minutes.
- Course adjustment of 135 degrees was selected to correspond with the next section of the run pattern (bow sea run). The engine speed was adjusted as necessary.
- After 25 minutes had elapsed on a steady course data acquisition was terminated.

- Course adjustment of 135 degrees was selected to correspond with the next section of the run pattern (beam sea run). The engine speed was adjusted as necessary.
- After 25 minutes had elapsed on a steady course data acquisition was terminated.
- Course adjustment of 135 degrees was selected to correspond with the next section of the run pattern (quartering sea run). The engine speed was adjusted as necessary.
- After 25 minutes had elapsed on a steady course data acquisition was terminated.
- After the five runs had been completed, the vessel returned to the wave buoy to verify that the dominant wave direction had not changed and confirm that the wave buoy was working correctly. A 25 minute zero speed drift run in nominally beam seas was carried out at this time.
- A second set of runs at a forward speed of 8 knots was carried out using the same procedure as was used for the 4 knot runs.

The dedicated trials team included:

- MUN co-op student – data acquisition and verification
- one IOT electronics staff – support in the event of problems with equipment at sea
- two MUN Kinesiology students

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. Two computers were used 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 Excel[1] format and standard Excel plotting utilities were used to view the data in the time domain. An example time series plot of surge acceleration from the MotionPak and x acceleration from the accelerometers is shown in Figure 12.

[1] © Microsoft Corp.

7.0 DESCRIPTION OF OFFLINE DATA ANALYSIS

Once the trial was complete, the following data analysis was carried out at IOT:

7.1 Wave Data Analysis

Wave data was acquired from two sources during the trial. This section describes the data analysis procedure used to generate the Datawell and Neptune wave buoy data products:

7.1.1 Datawell Wave Buoy Data Analysis

Oceans Ltd. carried out the wave analysis using standard software provided by the manufacturer of the buoy. The data was processed on the buoy and both raw and processed data then transmitted to the receiver on shore.

From the accelerations measured in the X and Y directions in the moving buoy reference frame, the accelerations along the fixed north and west axes are calculated. All three accelerations (vertical, north and west) are then digitally integrated to displacements and filtered to a high frequency cut off (0.6 Hz). Finally an FFT is performed on the data.

Raw data are compressed to motion vertical, motion north and motion west. Energy density, main sea direction, directional spreading angle and the normalized second harmonic of the directional distribution for each frequency band are computed on-board the wave buoy in addition to other standard sea state parameters such as significant wave height (SWH), H_{mo} and mean wave period T_Z.

Note that within the wave buoy, sea direction is measured using a flux gate compass and thus the data is generated in degrees magnetic. The magnetic deviation for St. John’s approaches during the trials period was ~21 degrees West and this correction was applied to derive wave direction in degrees TRUE.

A summary of wave statistics acquired using the Datawell wave buoy is provided in Appendix I. Nondirectional spectrum plots as well as Mean Wave Direction (corrected to degrees TRUE) versus Frequency plots are also provided in Appendix I for each half hour measurement cycle.

7.1.2 Neptune Wave Buoy Data Analysis

Directional wave data is calculated from the motion of the buoy whereby these motions, recorded by onboard sensors for angular and vertical accelerations, accurately mimic the attitude of the ocean due to its discus shaped floatation device. The recordings are then analyzed using spectral analysis to provide directional and nondirectional wave spectra. A directional wave spectrum describes the distribution of wave energy as a function of both frequency and direction, whereas the nondirectional wave spectrum is a function of frequency only.

More precisely, as a definition:

Nondirectional Wave Spectrum (C_{11}): is a one dimensional wave energy density that has its greatest value at the frequency where the nondirectional wave energy density is greatest.

This nondirectional wave spectrum is then used for computing wave energy where:

$S(f,\alpha) = C_{11}(f) * D(f, \alpha)$

By which, D is a directional spreading function with a dependency on both frequency f and direction α. S is a two dimensional wave energy density that has its greatest value at the frequency and direction where the directional wave energy is greatest. D(f, α) may be expanded in an infinite Fourier Series as a function of wave direction α. An approximation of the D(f, α) may be provided by computing the first two terms:

$D(f, \alpha) \approx [1/\pi] * [(1/2) + r_1 * \cos(\alpha - \alpha_1) + r_2 * \cos(2 * (\alpha - \alpha_2))]$

Where: alpha1 (α_1) – mean wave direction
alpha2 (α_2) – principal wave direction
r_1 , r_2 – frequency dependent parameters that theoretically lie between zero and one.

The following is a list of definitions needed to fully analyze wave data:

Significant Wave Height: Average height from wave crest to trough of the one-third highest waves measured. It is assumed that the nondirectional spectrum is relatively narrow and thus significant wave height is computed as:

Significant Wave Height = $H_{m0} = 4\, m_0^{1/2}$,
Where, m_0 is the area under the nondirectional wave spectrum C_{11}.

Dominant Wave Period/Frequency (Peak Wave Period/Frequency): is the period/frequency associated with center frequency of the frequency band that has the largest (peak) energy density in the nondirectional spectrum (C_{11}).

Average Wave Period/Frequency: The average wave period is computed from the spectral moments as follows:

$T_{av} = m_0/m_1$ and $f_{av} = 1/T_{av}$ where:
"m_1" – the first moment of area under the nondirectional wave spectrum C_{11}.

Dominant Wave Direction: the value of α_1 for the frequency band where the largest value of C_{11} occurs.

Average Wave Direction: is the weighted average over all frequency bands. This wave direction is the energy density weighted vector average of α_1 over all frequency bands and is computed from:

Average wave direction = $\tan^{-1}(Y, X)$
Where: $Y = \Sigma [C_{11}(f) * \sin(\alpha_1(f))]$
$X = \Sigma [C_{11}(f) * \cos(\alpha_1(f))]$

Note that within the wave buoy, sea direction is measured using a flux gate compass and thus the data is generated in degrees magnetic. The magnetic deviation for St. John's approaches during the trials period was ~21 degrees West and this correction was applied to derive wave direction in degrees TRUE.

A summary of wave statistics acquired using the Neptune wave buoy is also provided in Appendix I. Nondirectional spectrum plots as well as Mean Wave Direction (corrected to degrees TRUE) versus Frequency plots are also provided in Appendix I for each half hour measurement cycle.

7.2 Interpreting the Raw Ship 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 D. The data was converted to GEDAP format described in Reference 16 and standard IOT software used to analyze the data.

Example time series plots are provided as follows (cruise speed, bow seas):

Figure 13: Surge, Sway and Heave Displacement vs. Time
Figure 14: Surge, Sway and Heave Velocity vs. Time
Figure 15: Surge, Sway and Heave Acceleration vs. Time
Figure 16: Roll, Pitch and Yaw Angle vs. Time
Figure 17: Roll, Pitch and Yaw Rate vs. Time
Figure 18: Roll, Pitch and Yaw Acceleration vs. Time
Figure 19: Shaft Speed and Rudder Angle vs. Time
Figure 20: Speed Over Ground (SOG) and Course Over Ground (COG) vs. Time

7.3 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 (3.376 m Fwd, 0.64 m Port, and 2.48 m above) and then analyzed in the “Body” fixed coordinate system.

Table 1 shows the comparison between the data from MotionPak and the linear accelerometers for a bow seas run at cruise speed (Run bow_20041101143014). From the values of standard deviation computed, it is demonstrated that the accelerations recorded were very similar.

Instrument	Parameter	Unit	Mean	St. Dev.	Minimum	Maximum
Accelerometer	Surge Accel.	m/s^2	0.0	0.2639	-0.9952	0.9738
MotionPak	Surge Accel.	m/s^2	0.0	0.2812	-1.0420	1.0080
Accelerometer	Sway Accel.	m/s^2	0.0	0.8477	-2.8126	2.9293
MotionPak	Sway Accel.	m/s^2	0.0	0.8600	-2.7856	2.9213
Accelerometer	Heave Accel.	m/s^2	0.0	0.5851	-2.2307	1.9858
MotionPak	Heave Accel.	m/s^2	0.0	0.5878	-2.2337	1.9705

Table 1: MotionPak Validation

Example time series plots comparing the surge and sway acceleration provided in Figures 21 and 22 respectively indicate that there is a close correlation in the signals.

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.

7.4 Ship Motion Analysis

As stated above, there is the capability to translate the accelerations recorded to any position onboard the vessel using the MotionPak software. As part of this experiment, data from the MotionPak was used to compute the motions at two positions on the vessel: the vessel’s centre of gravity and the helmsman’s position.

Location of Centre of Gravity (CG) Relative to MotionPak:

X: CG was 0.406 m aft of MotionPak
Y: CG and MotionPak were assumed to be on transverse centreline.
Z: CG was 0.24 m below MotionPak.

Location of Helmsman Relative to MotionPak:

X: Helmsman was 5.056 m forward of MotionPak.
Y: Helmsman was 1.504 m to starboard of MotionPak.
Z: Helmsman was 2.48 m above MotionPak.

The following table is a summary of motion standard deviations at the ship's CG obtained from the experiment. Note that run Drift1 was acquired in the vicinity of the wave buoy prior to the 4 knot run set, while run Drift2 was acquired between the 4 knot and 8 knot run sets. Tables of basic information, peak response frequency for roll angle, pitch angle and heave acceleration as well as basic statistics (average, standard deviation, minimum and maximum) for each run computed both at the CG as well as at the helmsman's position are provided in Appendix J.

Speed (kts)	Run Heading	Roll Angle (deg)	Pitch Angle (deg)	Yaw Angle (deg)	Surge Accel. (m/s2)	Sway Accel. (m/s2)	Heave Accel. (m/s2)
0	Drift1	5.338	2.042	11.078	0.191	0.301	0.486
0	Drift2	5.619	2.347	9.460	0.242	0.304	0.509
4	Head	5.532	1.883	3.627	0.197	0.322	0.620
4	Bow	3.890	2.070	3.893	0.292	0.281	0.439
4	Beam	3.513	3.940	3.936	0.353	0.213	0.905
4	Quartering	3.359	2.347	2.808	0.345	0.199	0.374
4	Following	5.396	1.745	2.875	0.231	0.341	0.583
8	Head	4.714	1.809	2.469	0.216	0.331	0.817
8	Bow	3.715	1.561	2.854	0.220	0.290	0.481
8	Beam	2.887	2.961	1.637	0.293	0.232	1.165
8	Quartering	2.908	1.638	2.568	0.235	0.196	0.392
8	Following	4.196	1.646	2.132	0.232	0.311	0.618

Table 2: Standard Deviation of Motions

A plot of roll angle, pitch angle and heave acceleration standard deviation vs. heading is provided in Figure 23 and 24.

7.5 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 natural period. The following values of the spectral peak were output:

Roll Period: 3.8946 s
Pitch Period: 3.6164 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.

Trial Schedule:
Originally, IOT was scheduled to carry out a trial on the 45' CCGA Nautical Twilight in early October with outfit commencing October 4th in St. John's. During the weekend of October 2nd however, additional shrimp quota was allocated to the Newfoundland fishing fleet and all fishing vessels designated for trials departed for sea disrupting IOT planning. Thus trials equipment was fitted to the CCGA Miss Jacqueline IV, the first vessel available after acquiring their quota, on October 12th - much earlier than planned. The 'Nautical Twilight' trial was carried out later in the Fall when the environmental conditions are statistically worse increasing the overall risks for this smaller vessel. Disruptions to accommodate fishing schedules are one of the many risk factors associated with acquiring full scale data of these vessels.

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. After the trial, the vessel owner requested that the ice be left in place for use in an upcoming experimental fishery.

Overall Outfit:
Overall the outfit of the 'Nautical Twilight' went well with few complications. Since the vessel was less than a 3 years old, it afforded a clean, attractive work environment. Accessing the tiller flat for a rudder angle signal was accomplished by replacing the existing aluminium access hatch in the aft fish hold transverse bulkhead with an IOT fabricated Plexiglas hatch with integral cable gland. The decision was made not to install a gland in the aluminium hatch to be sealed up after the trial in order to minimize damage to the ship. The Plexiglas hatch had been fabricated for the trial conducted in 2003.

Fresh Water Tanks:
It was not possible to fill the fresh water tanks prior to the inclining experiment and 10 minute drift run due to water quality issues at the St. John's Coast Guard base. As a result, the tanks were only half full (approximately) during the trials period. The GM_T was not corrected to fluid metacentric height due to the small heel angles possible during the inclining experiment and there was likely a minor free surface effect influencing the vessel motions during the trial.

Draft Measurement:
The transom of the 'Nautical Twilight' was covered with aluminium 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 at the stern - and the draft estimated from a profile drawing of the vessel.

Trawl Speed:
The normal trawl speed for the 'Nautical Twilight' is roughly 2 knots however without the trawl deployed, to maintain adequate directional stability in waves under autopilot control, a minimum speed of some 4 knots was required.

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.

Wave Buoy Issues:
Because of problems found during trials in 2003, a work instruction (Reference 17) for the buoy was written to instruct users of the Neptune directional wave buoy. This was fortunate, as several previously unseen anomalies were found. Although the Neptune manual lists a 10 nm radio communication range, in practice, unless the buoy was in sight, there was no signal. This may be due to the small vessel size or the seas being outside of the buoy capabilities. It was also discovered during a previous trial that the Neptune buoy would loose data if communications were occurring during the time period when the buoy normally performed it's on board analysis. This data file was subsequently not recoverable. The work instruction was amended to reflect this problem and outline the correct communication time periods.

For some reason, it was not possible to put the Neptune buoy on half hour data sampling for the first half of the day although midway through the day, the change in sampling time was affected without problems. In addition, there was one loss of transmission between the Datawell buoy and its shore station during the day resulting in about 2 hours of omitted or corrupt data due to technical difficulties with the shore mounted antenna.

Comparison of Neptune & Datawell Wave Data:
A comparison of wave data acquired from both wave buoys for the same time period is provided in Table 3 below.

	Neptune Directional Wave Buoy Data			Datawell Directional Wave Buoy Data		
NF Time	H1/3 (m)	Tavg (s)	DirMax (deg. TRUE)	Hs (m)	Tz (s)	DirMax (deg. TRUE)
09:00	1.74	6.20	263.0	1.78	6.154	28.3
10:00	1.76	5.95	220.9	1.85	5.970	25.5
13:30	2.09	6.30	231.1	1.94	5.970	192.9
14:00	1.96	6.14	214.7	1.98	6.154	18.5
14:30	1.88	6.23	240.5	2.13	6.250	177.4
15:30	2.03	6.39	263.2	1.91	6.250	187.2
16:00	1.93	6.45	305.5	2.22	6.557	184.4

Table 3: Datawell/Neptune Wave Data Comparison

The results for both buoys were computed using spectral data. Minor differences can be expected for any two wave buoys moored 0.5 nm apart. The wave period and significant wave heights are comparable however it is apparent that there is a major discrepancy in the wave direction derived. The Datawell wave direction data closely reflects what was observed during the trial – the direction of the dominant wave changed during the day from the low frequency swell from ~ 20 deg. True to the high frequency wind driven wave from due south. The wave direction acquired by the Neptune buoy, however, appears to be an average value somewhere between the major wave components. Since the output from the Neptune buoy was being used to determine the dominant wave direction during the trial, it is likely that the selected courses with respect to the incident waves is about 90 degrees off reality. This assumption is supported by the vessel motion statistics where the roll angles are a maximum in head and following seas and a minimum in beam seas (Table 2).

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 Neptune wave buoy mooring, Reg Fitzgerald of Oceans Ltd. for provision of the Datawell wave buoy data, support from the crew of the Marine Institute training vessel MV Louis M. Lauzier to deploy the Datawell wave buoy, and IOT technical staff for their efforts throughout the planning and execution of the trial. Funding support from the Search & Rescue (SAR) New Initiatives Fund (NIF) and the Canadian Institutes of Health and Research (CIHR) is gratefully acknowledged.

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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

Figure 6: GPS Antenna

Figure 7: Neptune Directional Wave Buoy

Figure 8: Datawell Directional Wave Buoy and Anchor

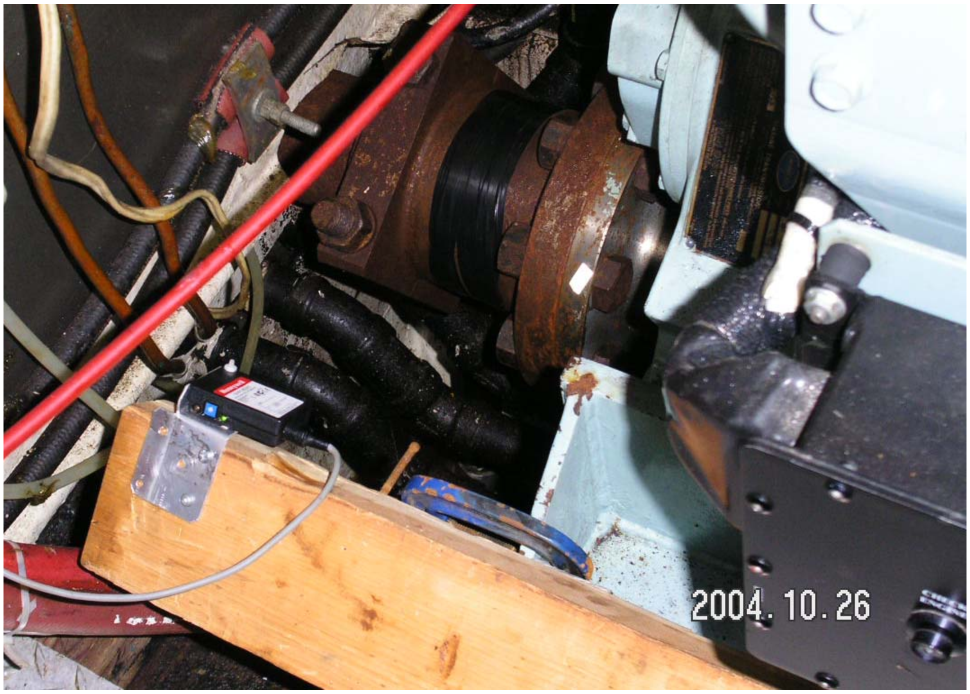


Figure 9: Shaft RPM Measurement

Figure 10: Directional Anemometer

Figure 11: Hand Held Salinometer

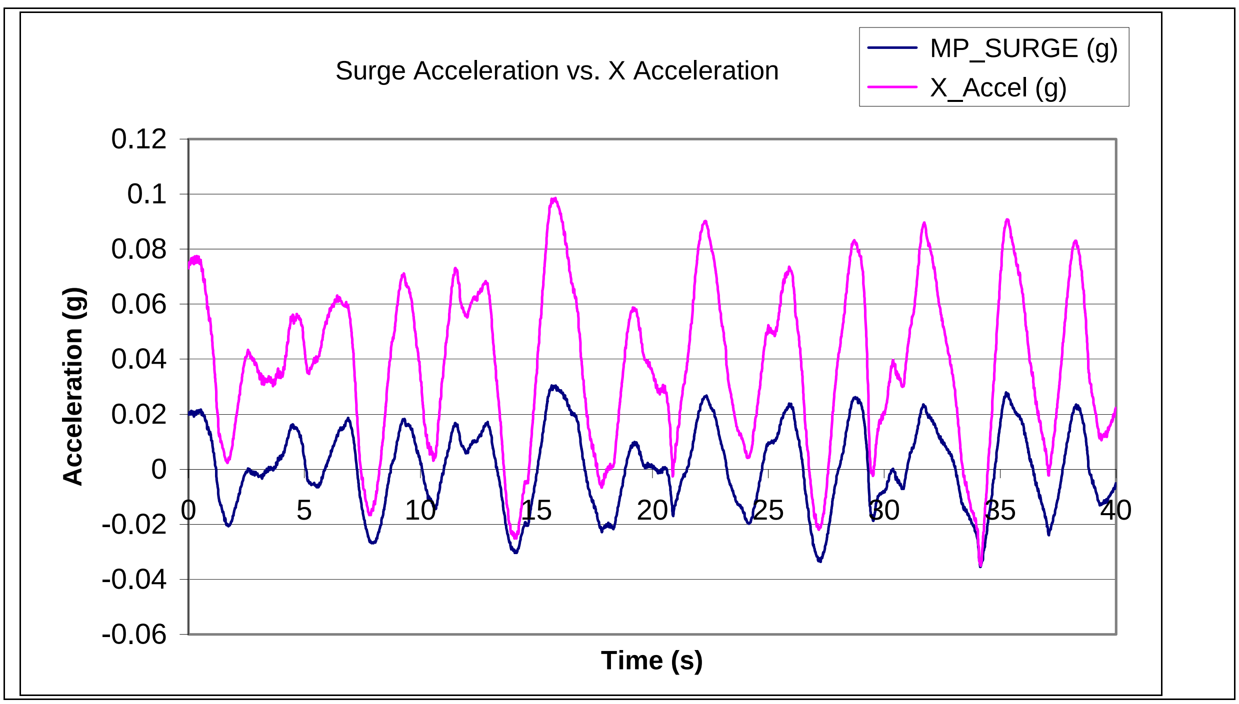


Figure 12: Example Online Data Analysis

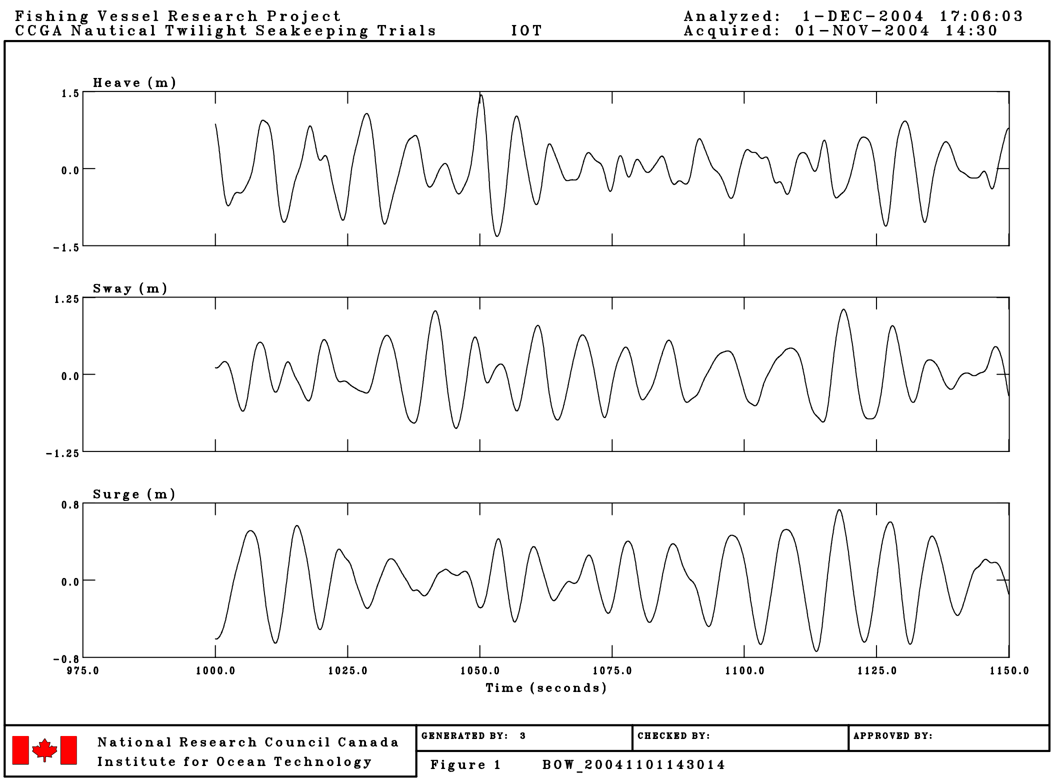


Figure 13: Offline Data Analysis – Surge, Sway and Heave Displacement

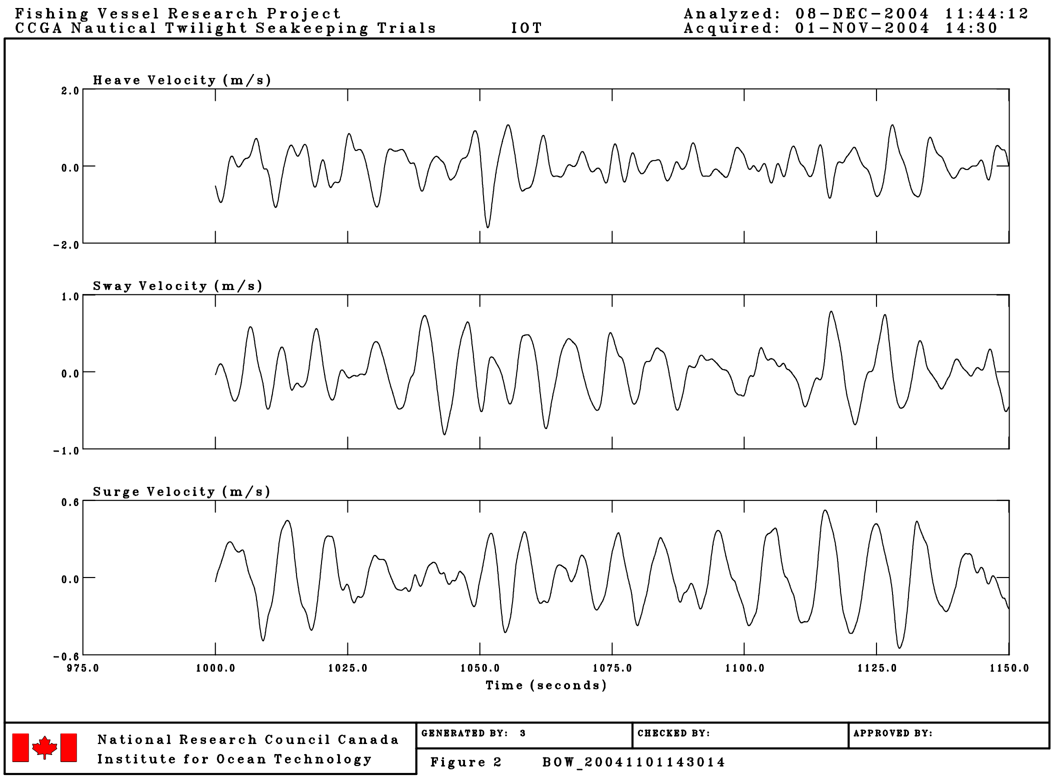


Figure 14: Offline Data Analysis – Surge, Sway and Heave Velocity

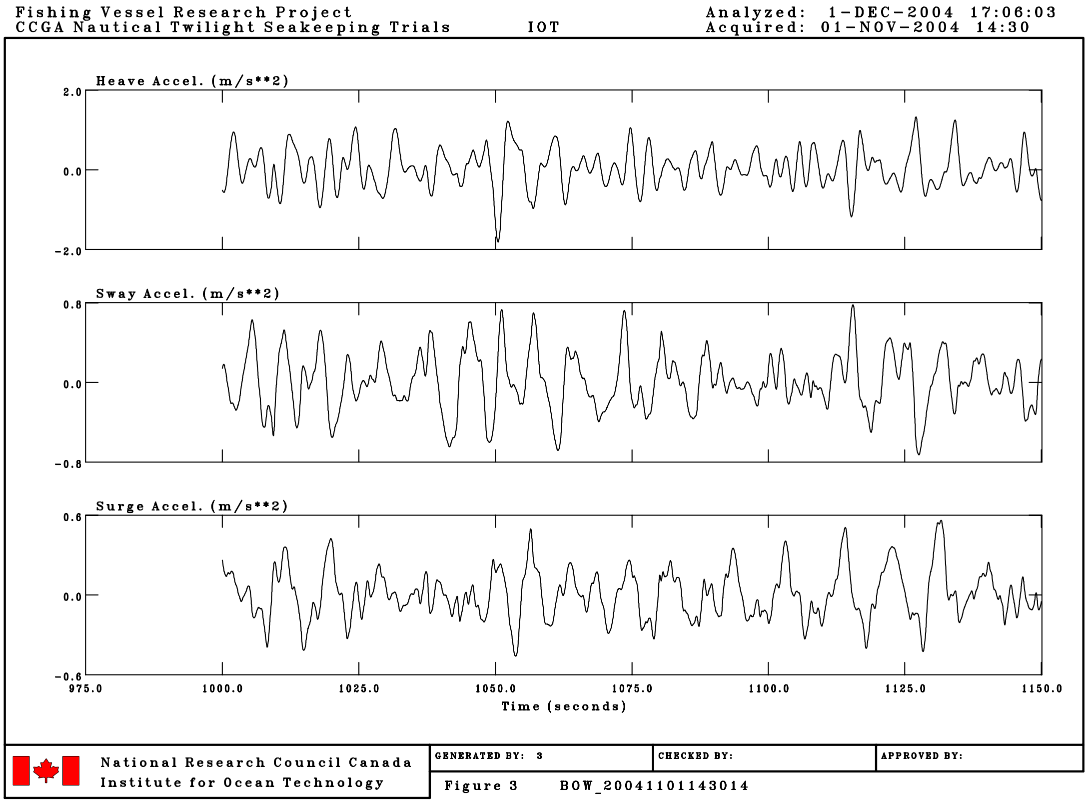


Figure 15: Offline Data Analysis – Surge, Sway and Heave Acceleration

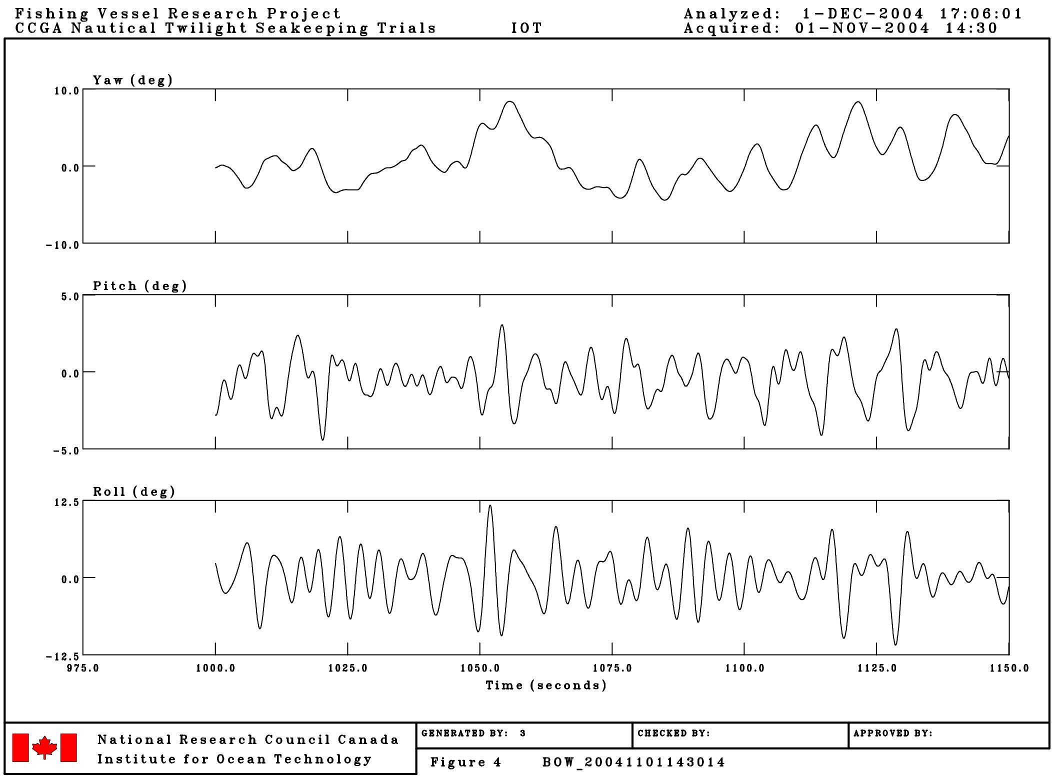


Figure 16: Offline Data Analysis – Roll, Pitch and Yaw Angle

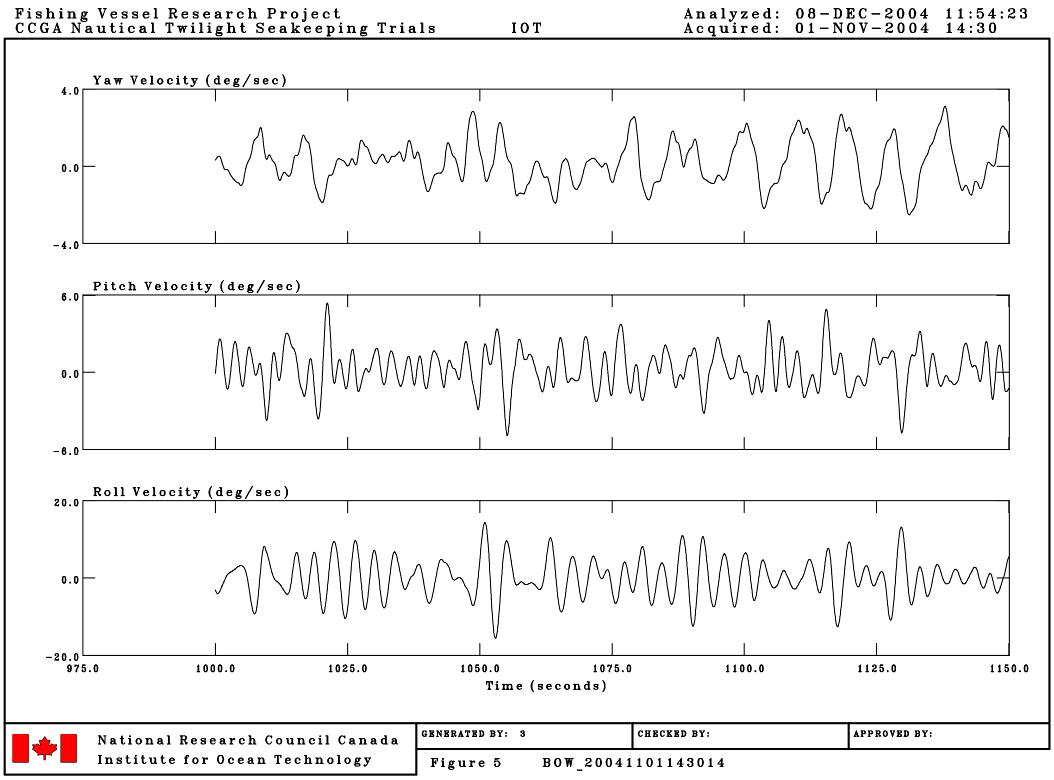


Figure 17: Offline Data Analysis – Roll, Pitch and Yaw Rate

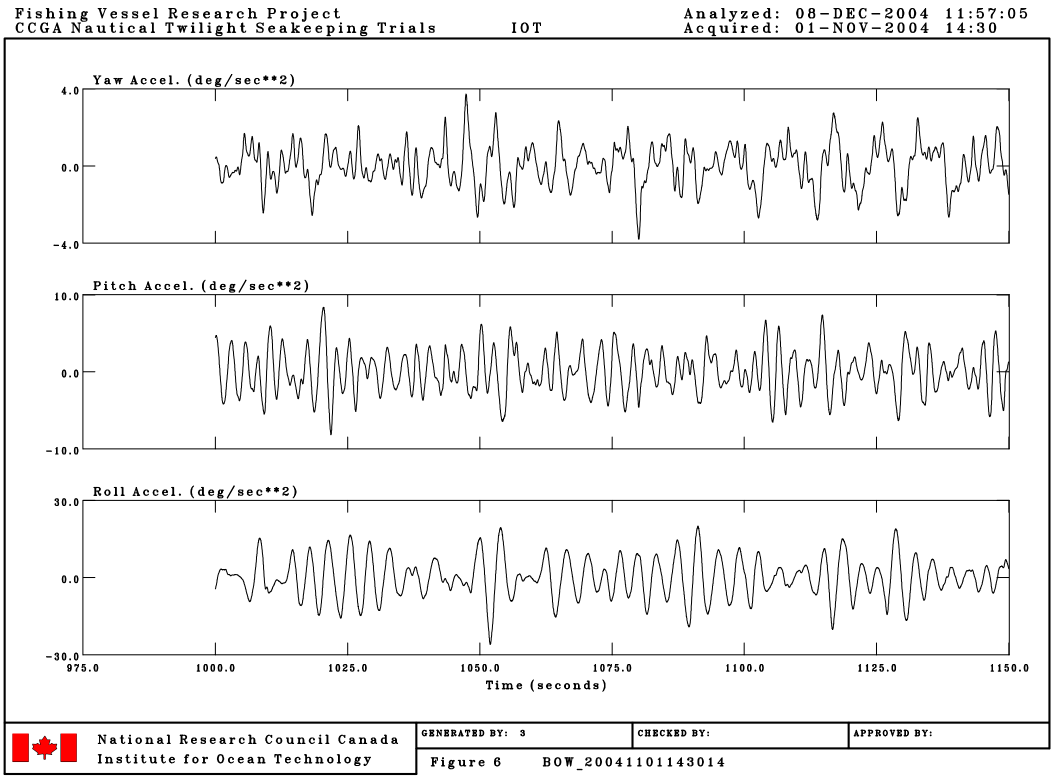


Figure 18: Offline Data Analysis – Roll, Pitch and Yaw Acceleration

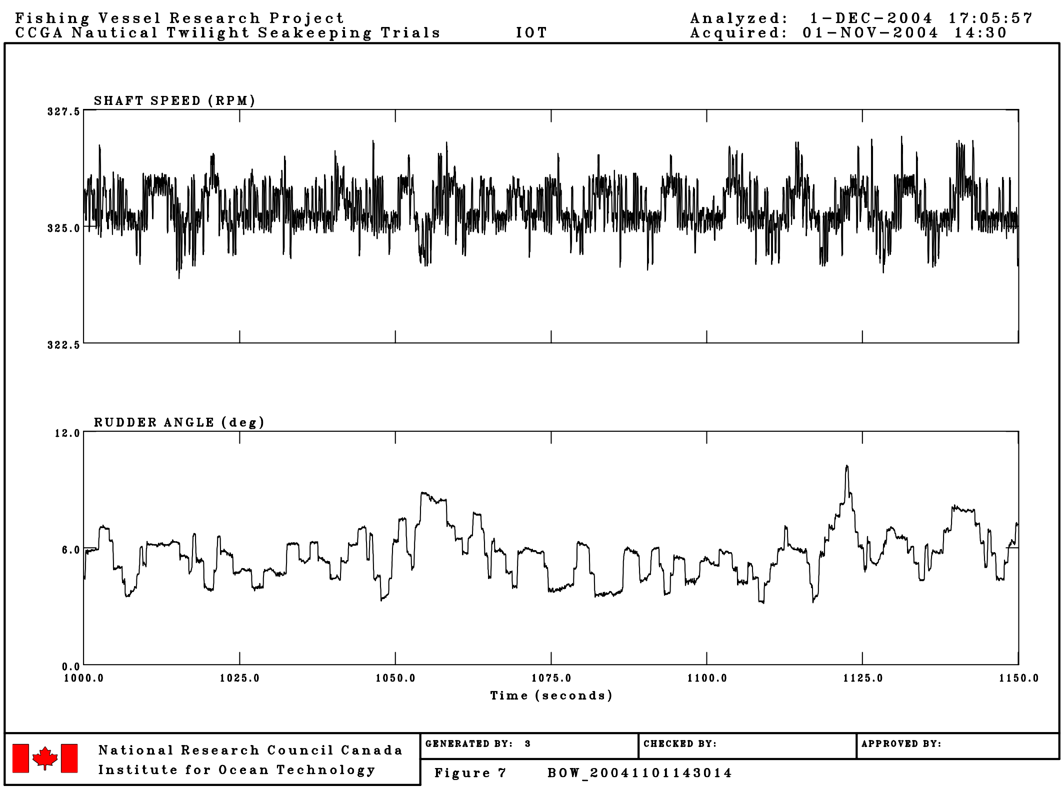


Figure 19: Offline Data Analysis – Shaft Speed and Rudder Angle

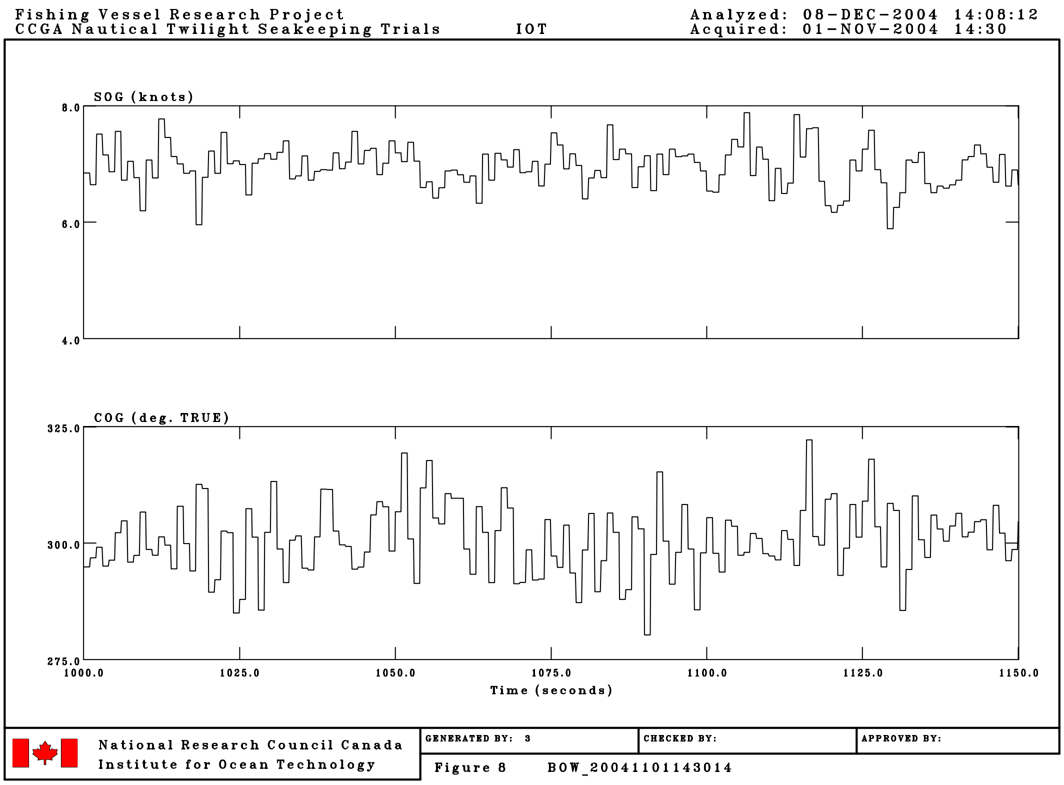


Figure 20: Offline Data Analysis – Speed Over Ground (SOG) and Course Over Ground (COG)

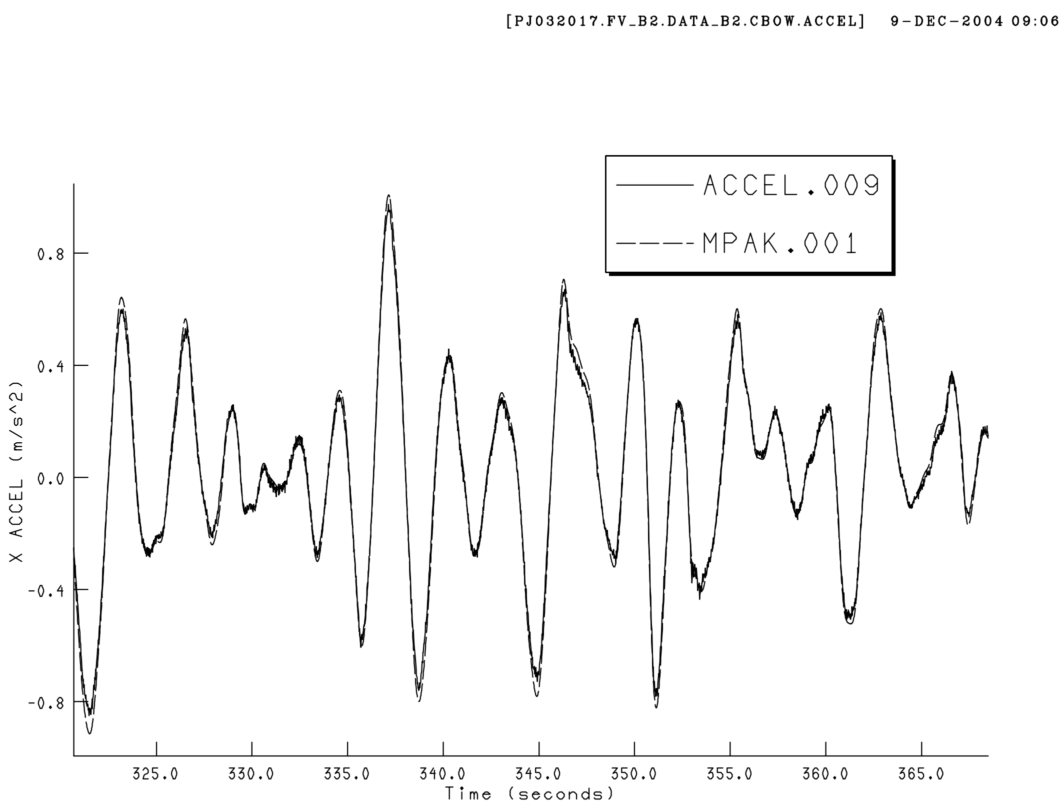


Figure 21: MotionPak/Linear Accelerometer Comparison – Surge Acceleration

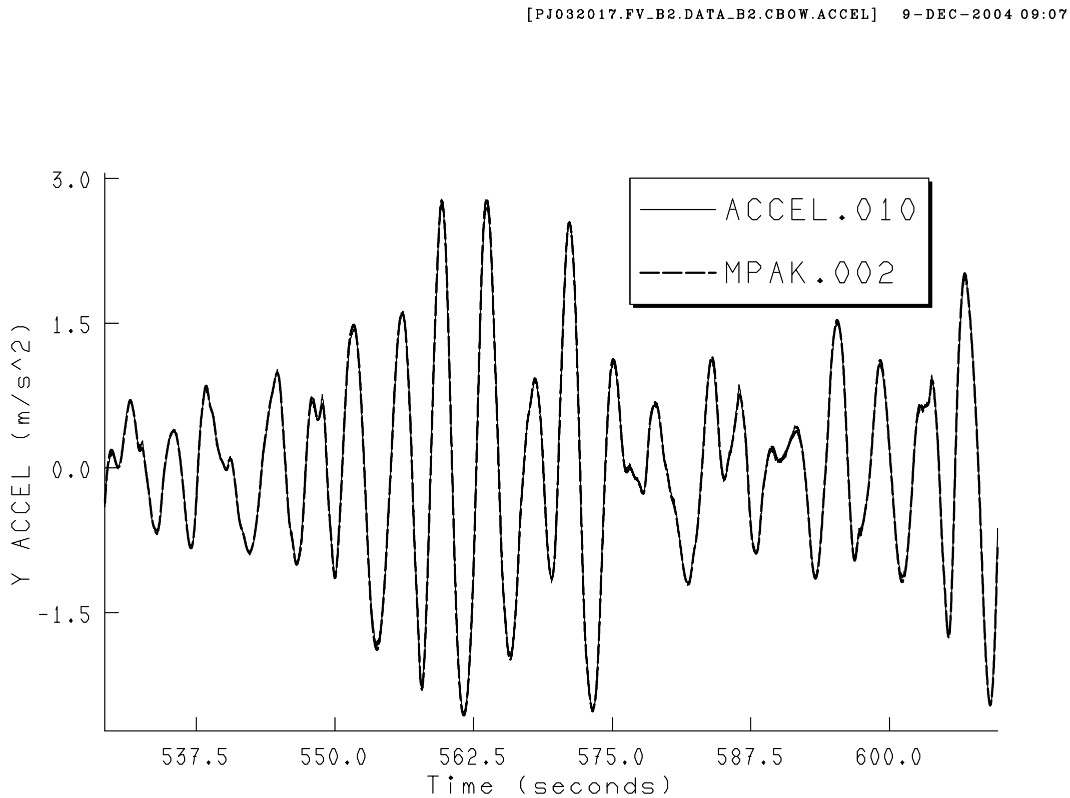


Figure 22: MotionPak/Linear Accelerometer Comparison – Sway Acceleration

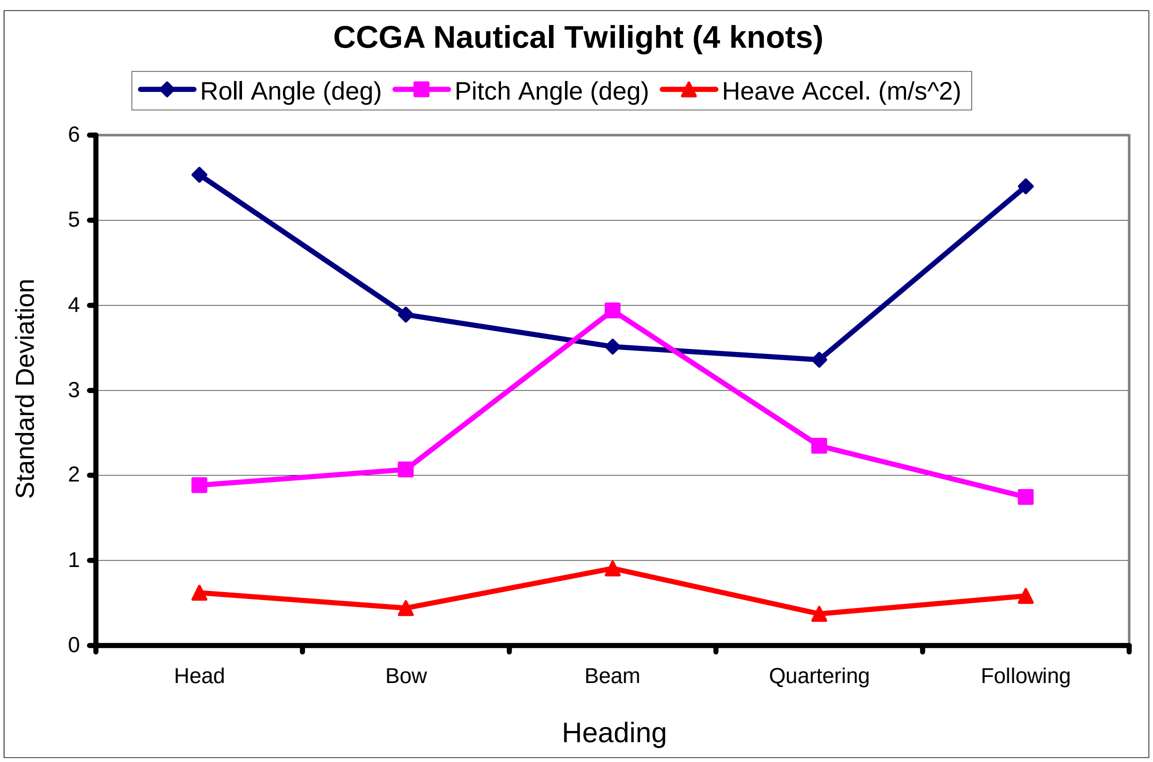


Figure 23: Standard Deviation vs. Heading (4 knots)

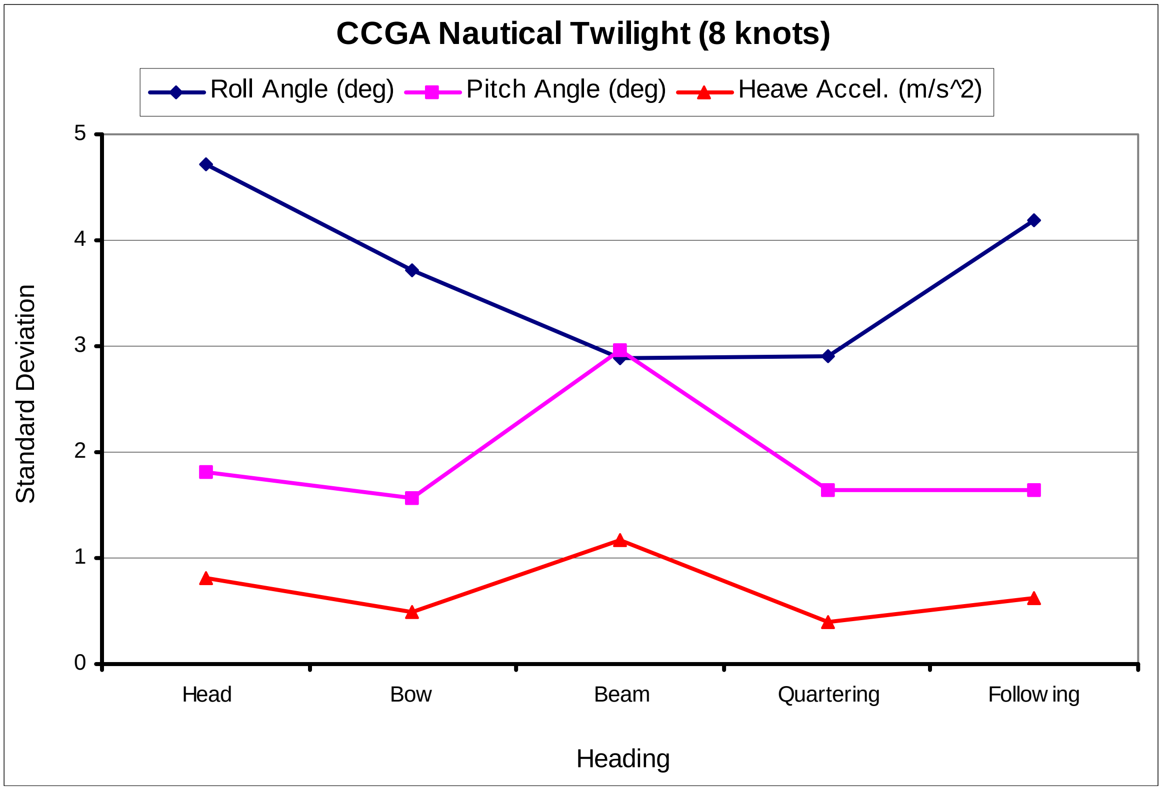


Figure 24: Standard Deviation vs. Heading (8 knots)

Appendix A
Inclining Experiment Report

TRI NAV

Naval Architecture *Fisheries Consulting* *Marine Brokerage*

INCLINING REPORTS

FOR THE SMALL FISHING VESSEL

"NAUTICAL TWILIGHT"

- PORT DEPARTURE CONDITION

COMPLETED BY: TRINAV CONSULTANTS INC.

NOVEMBER 10, 2004

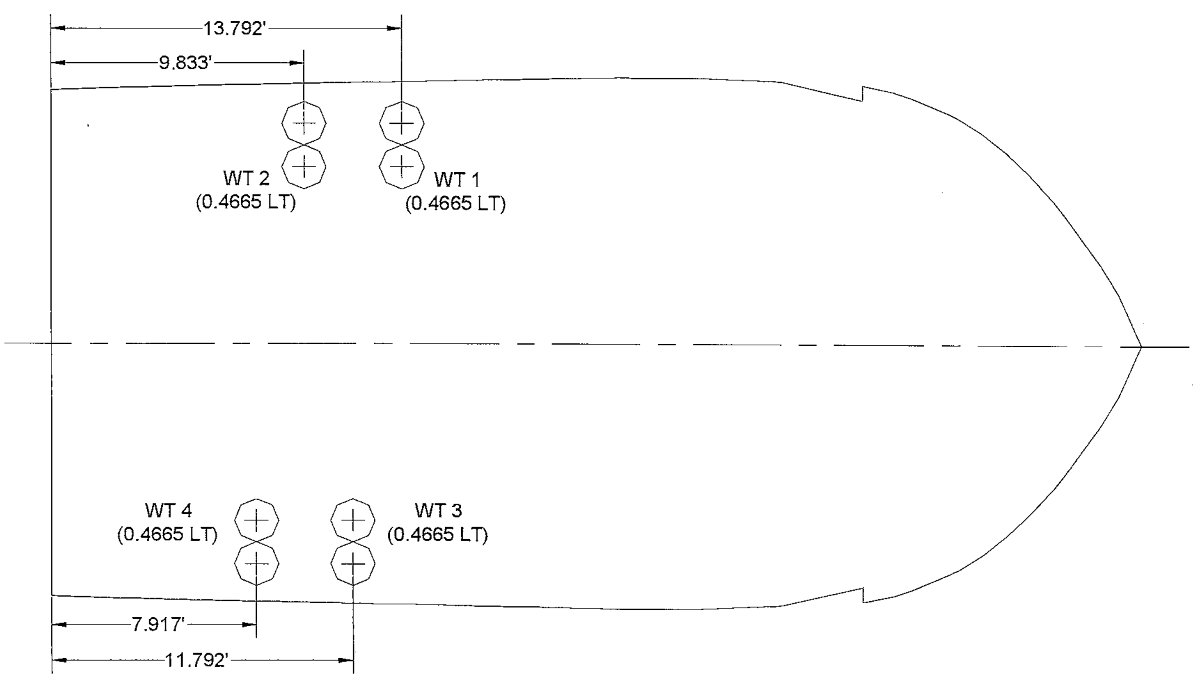
TriNav Consultants Inc.
Correspondence: P.O. Box 29126, St. John's, NL, A1A 5B5
Location Address: 197 Majors Path, St. John's, NL, A1A 5A1
Telephone: (709) 754-7060 Fax: (709) 754-6171 e-mail: admin@trinav.com

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

Inclining Report (Fresh Water Tank Half Full)

VESSEL:	Nautical Twilight
CONSTRUCTION MATERAIL:	GRP
DATE OF INCLINING EXPERIMENT:	October 27, 2004
EXPERIMENT CONDUCTED AT:	St. John's, NL
WEATHER CONDITIONS:	Overcast - Light Wind
DATUM LINE:	Baseline
SPECIFIC GRAVITY OF WATER:	1.022
NUMBER OF PERSONS ONBOARD	3
CONDITION OF VESSEL	Port Departure w/Flake Ice In Hold. Note: Fresh Water Tank Half Full

INCLINING WEIGHT DIAGRAM



NOTE: EACH WEIGHT CONSISTS OF TWO (2) 45 GAL STEEL DRUMS FILLED WITH FRESH WATER.

Inclining Experiment Drafts: (see Appendix A)

Draft aft - 10.71 ft. @ A.P. (based on freeboard measurements)

Draft fwd - 5.54 ft. @ F.P.

Length of Pendulums:

Aft pendulum - 7.833 ft., fish hold

Fwd pendulum - 5.396 ft., galley/mess

Weight per shift- 0.4665 Lt (2 x 45 Gal Steel Drums Filled with Fresh Water)

CALCULATION OF GM BASED ON PENDULUM RESULTS

FWD PENDULUM DEFLECTIONS

SHIFT NO.	DISTANCE (ft.)	WEIGHT (Lt.)	DEFLECTION (ft.)
1	16.958	0.4665	0.0656
2	16.563	0.4665	0.0607
3	16.563	0.4665	0.0607
4	16.958	0.4665	0.0640
5	16.833	0.4665	0.0640
6	16.167	0.4665	0.0591
7	16.167	0.4665	0.0591
8	16.833	0.4665	0.0623
AVERAGE	16.630	0.4665	0.0619

GM = wdl/Wx

$$= \frac{0.4665 \times 16.630 \times 5.396}{(84.84)(0.0619)}$$

= 7.971 ft

w = 0.4665 Lt

d = 16.630 ft

l = 5.396 ft

W= 84.84 Lt (See Appendix B)

x = 0.0619 ft

AFT PENDULUM DEFLECTIONS

SHIFT NO.	DISTANCE (ft.)	WEIGHT (Lt.)	DEFLECTION (ft.)
1	16.958	0.4665	0.0951
2	16.563	0.4665	0.0853
3	16.563	0.4665	0.0935
4	16.958	0.4665	0.0984
5	16.833	0.4665	0.0869
6	16.167	0.4665	0.0951
7	16.167	0.4665	0.0886
8	16.833	0.4665	0.0984
AVERAGE	16.630	0.4665	0.0927

GM = wdl/Wx

$$= \frac{0.4665 \times 16.630 \times 7.833}{(84.84) \times (0.0927)}$$

= 7.727 ft

w = 0.4665 Lt
d = 16.630 ft
l = 7.833 ft
W= 84.84 Lt
x = 0.0927 ft

CALCULATION OF VCG

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

= 7.971 ft + 7.727 ft / 2
= 7.849 ft

VCG = KM(from hydrostatics) - GM (solid)
= 19.34 ft - 7.849 ft
= 11.491 ft

WEIGHTS TO REMOVE

	Mass (Lt)	VCG (ft.)	VMOM (Lt ft)	LCG (ft)	LMOM (Lt ft)
WT 1	-0.4665	14.804	-6.906	-13.792	6.434
WT 2	-0.4665	14.929	-6.964	-9.833	4.587
WT 3	-0.4665	14.859	-6.932	-11.792	5.501
WT 4	-0.4665	15.013	-7.004	-7.917	3.693
Persons (3)	-0.2679	14.096	-3.776	-28.221	7.560
Incl. Equip	-0.0223	10.531	-0.235	-26.144	0.584
Trolley	-0.0223	13.793	-0.308	-11.250	0.251
TOTAL	**-2.179**		**-32.125**		**28.610**

WEIGHTS TO ADD

	Mass (Lt)	VCG (ft.)	VMOM (Lt ft)	LCG (ft)	LMOM (Lt ft)
6 Persons	0.536	17.051	9.139	-29.922	-16.038
TOTAL	**0.536**		**9.139**		**-16.038**

NOTE: - VCG is measured above baseline in feet
- LCG is measured forward of AP in feet
- The Inclined GM wasn't corrected for free surface of the fresh water tank because of the relatively small amount of heel

LIGHTSHIP CALCULATION

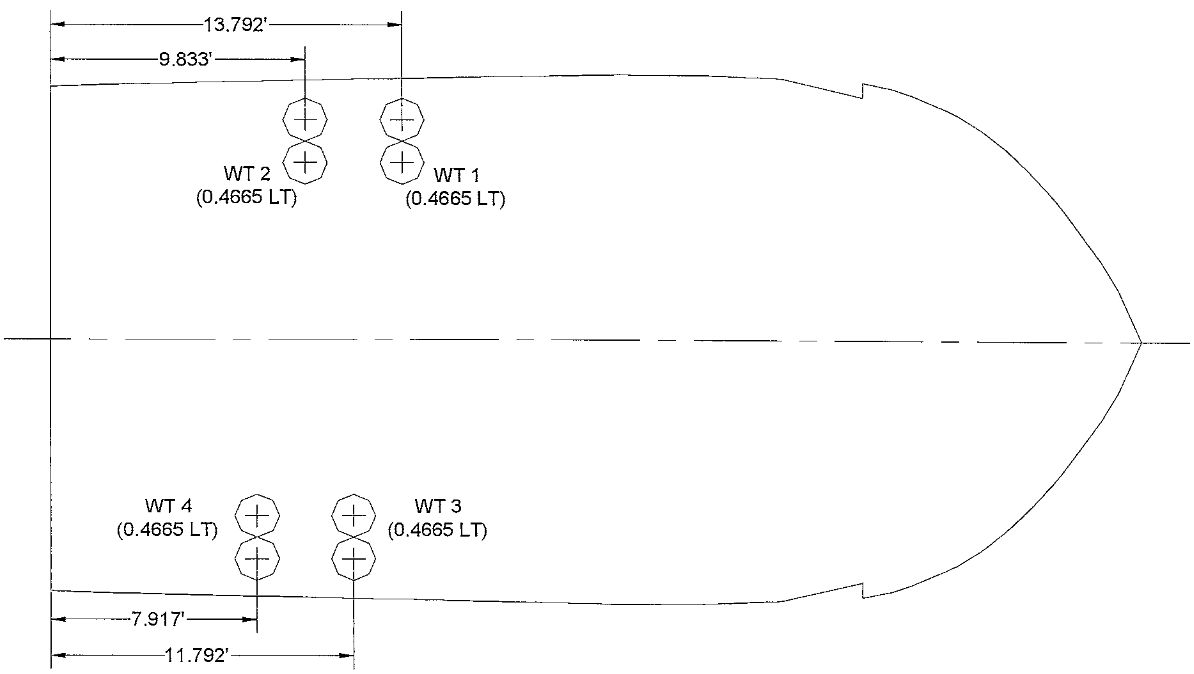
	Mass (Lt)	VCG (ft.)	VMOM (Lt ft)	LCG (ft)	LMOM (Lt ft)
Loaded vessel	84.840	11.491	974.896	-19.680	-1669.651
Weights to Remove	-2.179	14.746	-32.125	13.133	28.610
Weights to Add	0.536	17.051	9.139	-29.922	-16.038
Total	83.197		951.911		-1657.079

LIGHTSHIP MASS = **83.197 Lt**
LIGHTSHIP VCG = **11.442 ft. above Baseline.**
LCG = **19.917 forward of A.P.**

Inclining Report (Fresh Water Tank Full)

VESSEL:	Nautical Twilight
CONSTRUCTION MATERAIL:	GRP
DATE OF INCLINING EXPERIMENT:	October 27, 2004
EXPERIMENT CONDUCTED AT:	St. John's, NL
WEATHER CONDITIONS:	Overcast - Light Wind
DATUM LINE:	Baseline
SPECIFIC GRAVITY OF WATER:	1.022
NUMBER OF PERSONS ONBOARD	3
CONDITION OF VESSEL	Port Departure w/Flake Ice In Hold. Note: Fresh Water Tank Full

INCLINING WEIGHT DIAGRAM



NOTE: EACH WEIGHT CONSISTS OF TWO (2) 45 GAL STEEL DRUMS FILLED WITH FRESH WATER.

Inclining Experiment Drafts: (see Appendix A)

Draft aft -	10.71 ft. @ A.P. (based on freeboard measurements)
Draft fwd -	5.54 ft. @ F.P.

Length of Pendulums:

Aft pendulum -	7.833 ft., fish hold
Fwd pendulum -	5.396 ft., galley/mess

Weight per shift- 0.4665 Lt (2 x 45 Gal Steel Drums Filled with Fresh Water)

CALCULATION OF GM BASED ON PENDULUM RESULTS

FWD PENDULUM DEFLECTIONS

SHIFT NO.	DISTANCE (ft.)	WEIGHT (Lt.)	DEFLECTION (ft.)
1	16.958	0.4665	0.0656
2	16.563	0.4665	0.0607
3	16.563	0.4665	0.0607
4	16.958	0.4665	0.0640
5	16.833	0.4665	0.0640
6	16.167	0.4665	0.0591
7	16.167	0.4665	0.0591
8	16.833	0.4665	0.0623
AVERAGE	16.630	0.4665	0.0619

GM = wdl/Wx

$$= \frac{0.4665 \times 16.630 \times 5.396}{(84.84)\,(0.0619)}$$

= 7.971 ft

w = 0.4665 Lt

d = 16.630 ft

l = 5.396 ft

W= 84.84 Lt (See Appendix B)

x = 0.0619 ft

AFT PENDULUM DEFLECTIONS

SHIFT NO.	DISTANCE (ft.)	WEIGHT (Lt.)	DEFLECTION (ft.)
1	16.958	0.4665	0.0951
2	16.563	0.4665	0.0853
3	16.563	0.4665	0.0935
4	16.958	0.4665	0.0984
5	16.833	0.4665	0.0869
6	16.167	0.4665	0.0951
7	16.167	0.4665	0.0886
8	16.833	0.4665	0.0984
AVERAGE	16.630	0.4665	0.0927

GM = wdl/Wx

$$= \frac{0.4665 \times 16.630 \times 7.833}{(84.84) \times (0.0927)}$$

= 7.727 ft

w = 0.4665 Lt
d = 16.630 ft
l = 7.833 ft
W= 84.84 Lt
x = 0.0927 ft

CALCULATION OF VCG

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

= 7.971 ft + 7.727 ft / 2
= 7.849 ft

VCG = KM(from hydrostatics) - GM (solid)
= 19.34 ft - 7.849 ft
= 11.491 ft

WEIGHTS TO REMOVE

	Mass (Lt)	VCG (ft.)	VMOM (Lt ft)	LCG (ft)	LMOM (Lt ft)
WT 1	-0.4665	14.804	-6.906	-13.792	6.434
WT 2	-0.4665	14.929	-6.964	-9.833	4.587
WT 3	-0.4665	14.859	-6.932	-11.792	5.501
WT 4	-0.4665	15.013	-7.004	-7.917	3.693
Persons (3)	-0.2679	14.096	-3.776	-28.221	7.560
Fresh Water (Half Tank)	-0.7800	7.090	-5.530	-36.630	28.571
Incl. Equip	-0.0223	10.531	-0.235	-26.144	0.584
Trolley	-0.0223	13.793	-0.308	-11.250	0.251
TOTAL	**-2.959**		**-37.655**		**57.182**

WEIGHTS TO ADD

	Mass (Lt)	VCG (ft.)	VMOM (Lt ft)	LCG (ft)	LMOM (Lt ft)
6 Persons	0.536	17.051	9.139	-29.922	-16.038
Fresh Water (Full Tank)	1.530	7.550	11.552	-36.650	-56.075
TOTAL	**2.066**		**20.691**		**-72.113**

NOTE:
- VCG is measured above baseline in feet
- LCG is measured forward of AP in feet
- The Inclined GM wasn't corrected for free surface of the fresh water tank because of the relatively small amount of heel

LIGHTSHIP CALCULATION

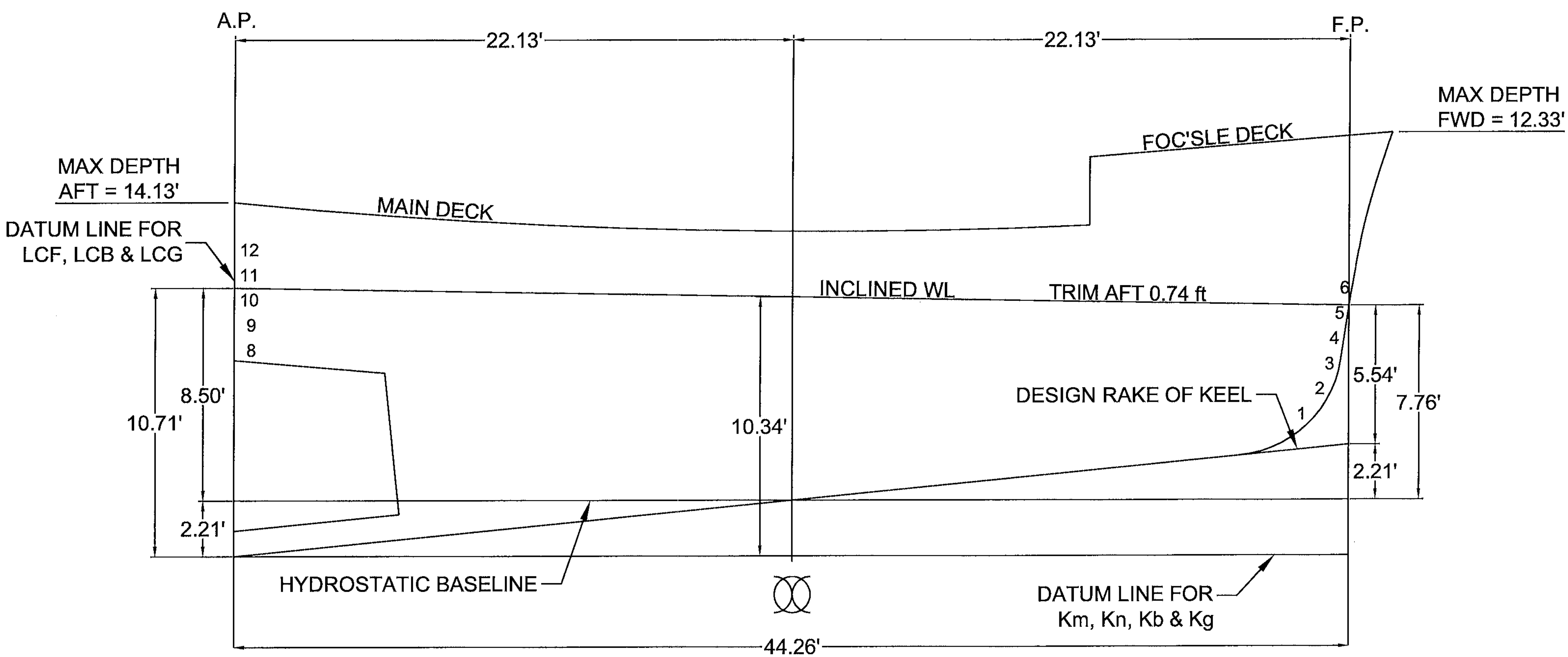
	Mass (Lt)	VCG (ft.)	VMOM (Lt ft)	LCG (ft)	LMOM (Lt ft)
Loaded vessel	84.840	11.491	974.896	-19.680	-1669.651
Weights to Remove	-2.959	12.728	-37.655	19.328	57.182
Weights to Add	2.066	7.550	20.691	-36.650	-72.113
Total	83.947		957.932		-1684.582

LIGHTSHIP MASS = **83.947 Lt**
LIGHTSHIP VCG = **11.411 ft. above Baseline.**
LCG = **20.067 forward of A.P.**

Appendix A

Datum Line Drawing

DATUM LINE
FOR THE FISHING VESSEL
"NAUTICAL TWILIGHT"



NOTE:

1. VESSEL INCLINED WITH 0.11 DEGREES STARBOARD HEEL.
2. DRAFT READINGS:
   - FWD; 5'-6$\frac{1}{2}$"
   - AFT; DRAFT MARKS NOT VISABLE, FREEBOARDS TAKEN.
     - FREEBOARD STBD - 41.25"
     - FREEBOARD PORT - 40.75"

Appendix B

Inclined Hydrostatics & Cross Curves

INCLINED HYDROSTATICS

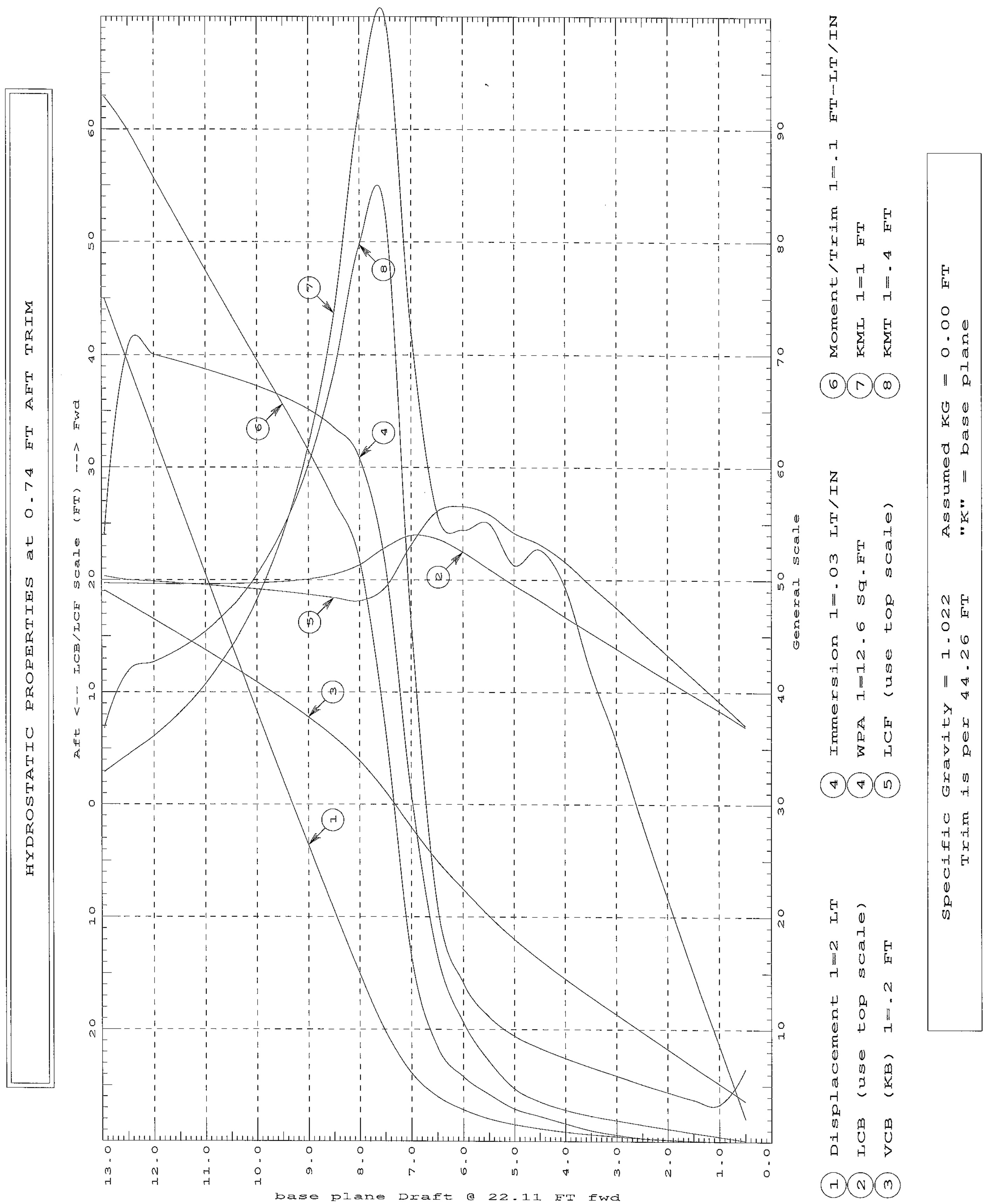
HYDROSTATIC PROPERTIES
Trim: Aft 0.74/44.26, No Heel, VCG = 0.00

Draft@ 22.11f	Displacement Weight(LT)	Buoyancy-Ctr. LCB	VCB	Weight/ Inch	LCF	Moment/ IN trim	KML	KMT
0.500	0.00	6.91f	0.72	0.00	7.05f	0.00	2.0	2.59
1.000	0.05	8.35f	1.03	0.01	9.18f	0.00	8.6	1.33
1.500	0.16	9.72f	1.34	0.02	11.23f	0.00	15.0	1.50
2.000	0.33	11.08f	1.65	0.03	13.29f	0.01	21.7	1.76
2.500	0.57	12.46f	1.96	0.04	15.38f	0.03	28.4	2.04
3.000	0.87	13.88f	2.27	0.06	17.53f	0.06	35.6	2.34
3.500	1.24	15.28f	2.58	0.07	19.52f	0.10	41.8	2.65
4.000	1.69	16.70f	2.90	0.08	21.60f	0.16	49.4	2.97
4.500	2.27	18.19f	3.24	0.11	23.15f	0.22	52.7	3.33
5.000	2.99	19.52f	3.60	0.14	24.16f	0.29	51.3	3.76
5.500	4.05	20.98f	4.02	0.21	25.84f	0.42	55.0	4.45
6.000	5.62	22.47f	4.49	0.32	26.51f	0.58	54.4	5.65
6.500	8.00	23.65f	5.00	0.50	26.05f	0.84	56.0	8.46
7.000	12.17	23.94f	5.59	0.93	23.09f	1.65	72.2	18.49
7.500	19.58	22.86f	6.23	1.54	19.30f	3.68	99.9	33.09
8.000	29.92	21.31f	6.78	1.83	18.15f	5.18	91.9	31.90
8.500	41.13	20.49f	7.20	1.91	18.42f	5.71	73.7	27.37
9.000	52.72	20.07f	7.55	1.95	18.71f	6.15	61.9	24.08
9.500	64.56	19.84f	7.87	1.99	18.96f	6.56	54.0	21.79
10.000	76.57	19.72f	8.18	2.02	19.18f	6.96	48.2	20.18
10.340	84.84	19.68f	8.38	2.03	19.32f	7.22	45.2	19.34
10.500	88.75	19.66f	8.47	2.04	19.38f	7.35	44.0	19.01
11.000	101.06	19.64f	8.75	2.06	19.55f	7.75	40.7	18.17
11.500	113.49	19.64f	9.03	2.08	19.72f	8.16	38.2	17.54
12.000	126.04	19.65f	9.30	2.10	19.87f	8.57	36.1	17.08
12.500	138.70	19.68f	9.58	2.12	20.02f	8.99	34.4	16.73
12.950	149.99	19.71f	9.82	1.62	20.34f	9.29	32.9	14.73

Distances in FEET.--------Specific Gravity = 1.022.-----------Moment in Ft-LT.
Trim is per 44.26Ft

Draft is from base plane.

INCLINED HYDROSTATICS



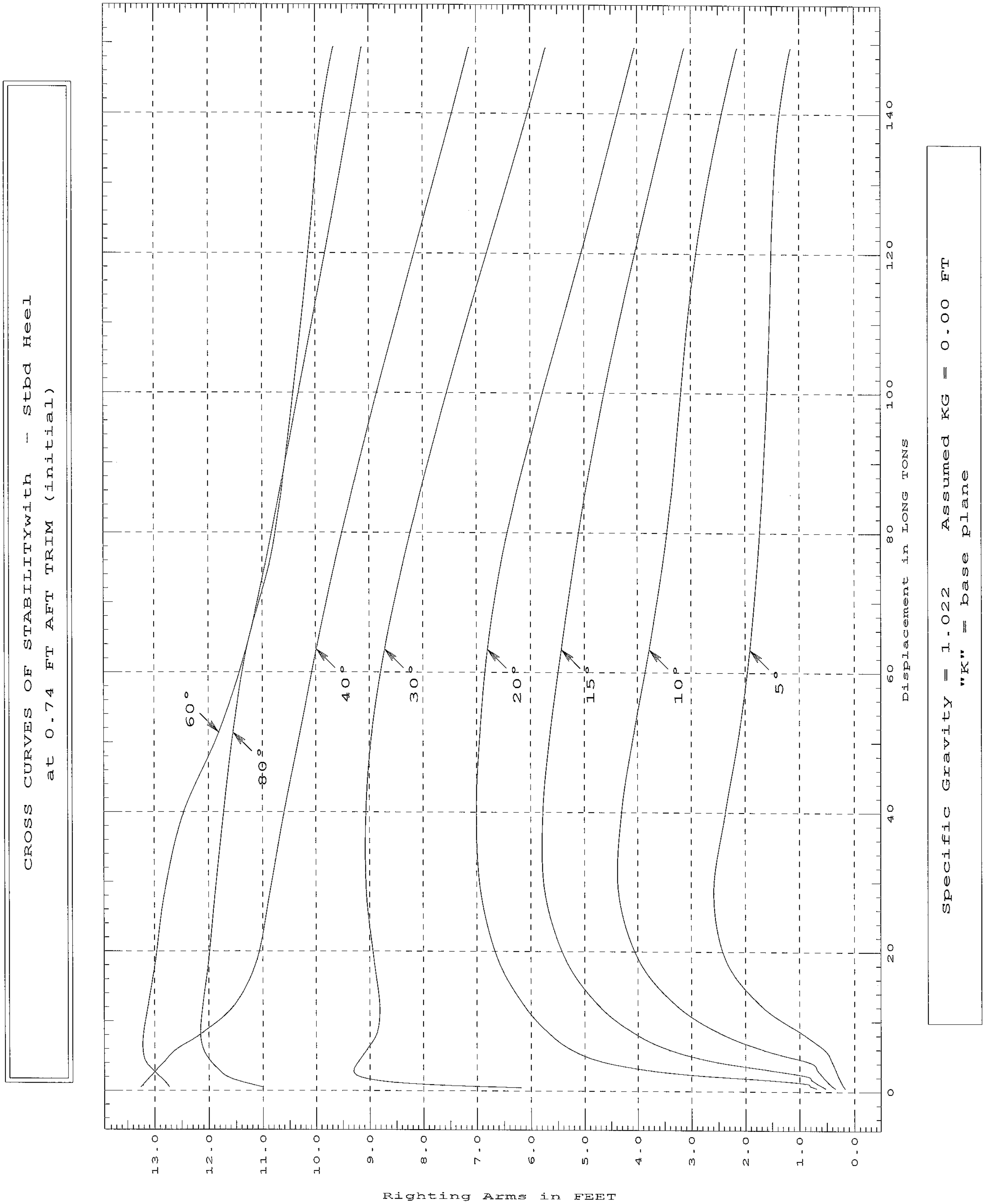
AS INCLINED CROSS CURVES OF STABILITY

Showing righting arms in heel at VCG = 0.00
Trim: Aft 0.74/44.26 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	6.19s	13.26s	12.73s	11.00s
0.81	0.21s	0.41s	0.61s	0.80s	7.65s	13.22s	12.76s	11.17s
1.20	0.24s	0.46s	0.69s	0.92s	8.54s	13.17s	12.80s	11.36s
1.69	0.27s	0.53s	0.78s	1.64s	9.02s	13.12s	12.86s	11.57s
2.29	0.30s	0.59s	0.88s	2.84s	9.25s	13.05s	12.94s	11.72s
3.06	0.34s	0.67s	1.52s	3.84s	9.30s	12.96s	13.04s	11.82s
4.22	0.41s	0.82s	2.53s	4.68s	9.21s	12.82s	13.17s	11.97s
5.92	0.54s	1.65s	3.41s	5.26s	9.05s	12.60s	13.22s	12.10s
8.39	0.96s	2.48s	4.08s	5.68s	8.86s	12.11s	13.20s	12.16s
12.34	1.72s	3.29s	4.75s	6.14s	8.82s	11.52s	13.12s	12.11s
18.82	2.36s	3.99s	5.35s	6.61s	8.92s	11.11s	12.98s	12.00s
28.47	2.58s	4.36s	5.74s	6.92s	9.06s	10.87s	12.81s	11.88s
39.71	2.38s	4.31s	5.78s	7.01s	9.07s	10.60s	12.47s	11.73s
51.38	2.11s	4.07s	5.64s	6.94s	8.95s	10.30s	11.81s	11.55s
63.29	1.92s	3.78s	5.43s	6.80s	8.71s	9.99s	11.30s	11.30s
75.38	1.77s	3.53s	5.20s	6.55s	8.38s	9.64s	10.95s	10.87s
83.69	1.70s	3.39s	5.03s	6.32s	8.11s	9.39s	10.73s	10.68s
87.62	1.67s	3.33s	4.94s	6.20s	7.98s	9.26s	10.63s	10.61s
99.99	1.59s	3.18s	4.62s	5.77s	7.55s	8.85s	10.32s	10.42s
112.49	1.53s	3.03s	4.27s	5.32s	7.09s	8.42s	10.00s	10.24s
125.09	1.49s	2.81s	3.89s	4.88s	6.61s	7.98s	9.70s	10.07s
137.81	1.39s	2.50s	3.49s	4.44s	6.13s	7.53s	9.40s	9.92s
149.35	1.16s	2.15s	3.13s	4.05s	5.72s	7.14s	9.13s	9.66s

Distances in FEET.-------Specific Gravity = 1.022.---------------------------

AS INCLINED CROSS CURVES OF STABILITY



Appendix B
Principle Particulars & List of Outfit Items

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

Machinery Description:

Engine:	John Deere
Propulsion Power:	450 H.P.
Trawl Speed:	4 knots
Cruising Speed:	8 knots
Maximum Rudder Angle:	$\pm 46°$ (nominal)
Electrical Power:	120 VAC

Life Saving Equipment:

Life boat: 7 person
EPIRB
Full suite DOT approved firefighting and emergency equipment

Appendix C
Instrumentation Plan

Instrumentation Plan for Fishing Vessel Trials

See Proj PIP for additional info on instrumentation requirements incl. critical levels.

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, otherwise measure if convenient
Shaft RPM	freq./volt. converter	0 - 1000	RPM	low critical parameter

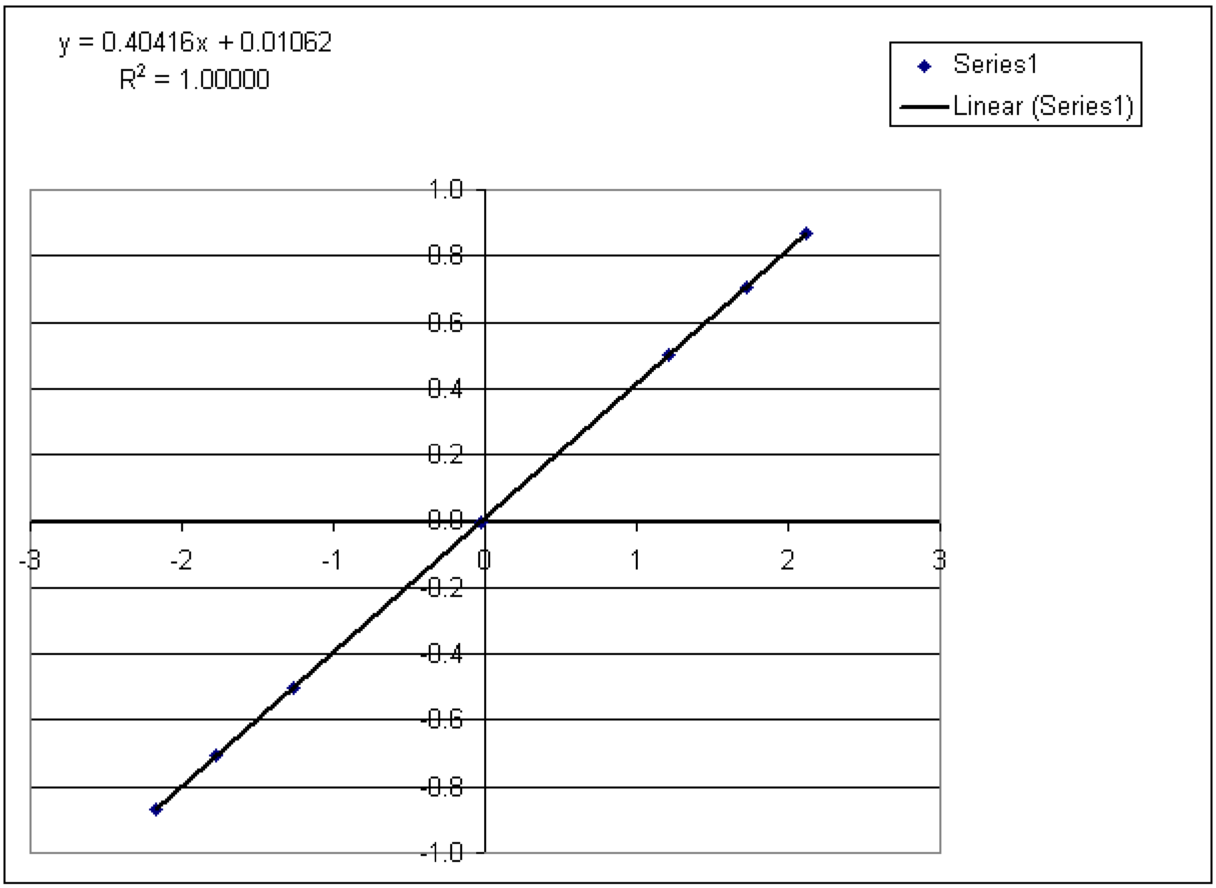
Appendix D
Calibration Information

Ch. 01
X Accel, Motion Pak

S/N 0689

Gravity 1

Angle	Sin(angle)	Acceleration	Voltage	slope	offset
0	0	0.0000	-0.026	0.4042	0.0106
29.994	0.499909307	0.4999	1.211		
45.016	0.707304215	0.7073	1.723		
59.9	0.865151421	0.8652	2.114		
-59.9	-0.865151421	-0.8652	-2.17		
-45.016	-0.707304215	-0.7073	-1.775		
-29.994	-0.499909307	-0.4999	-1.261		



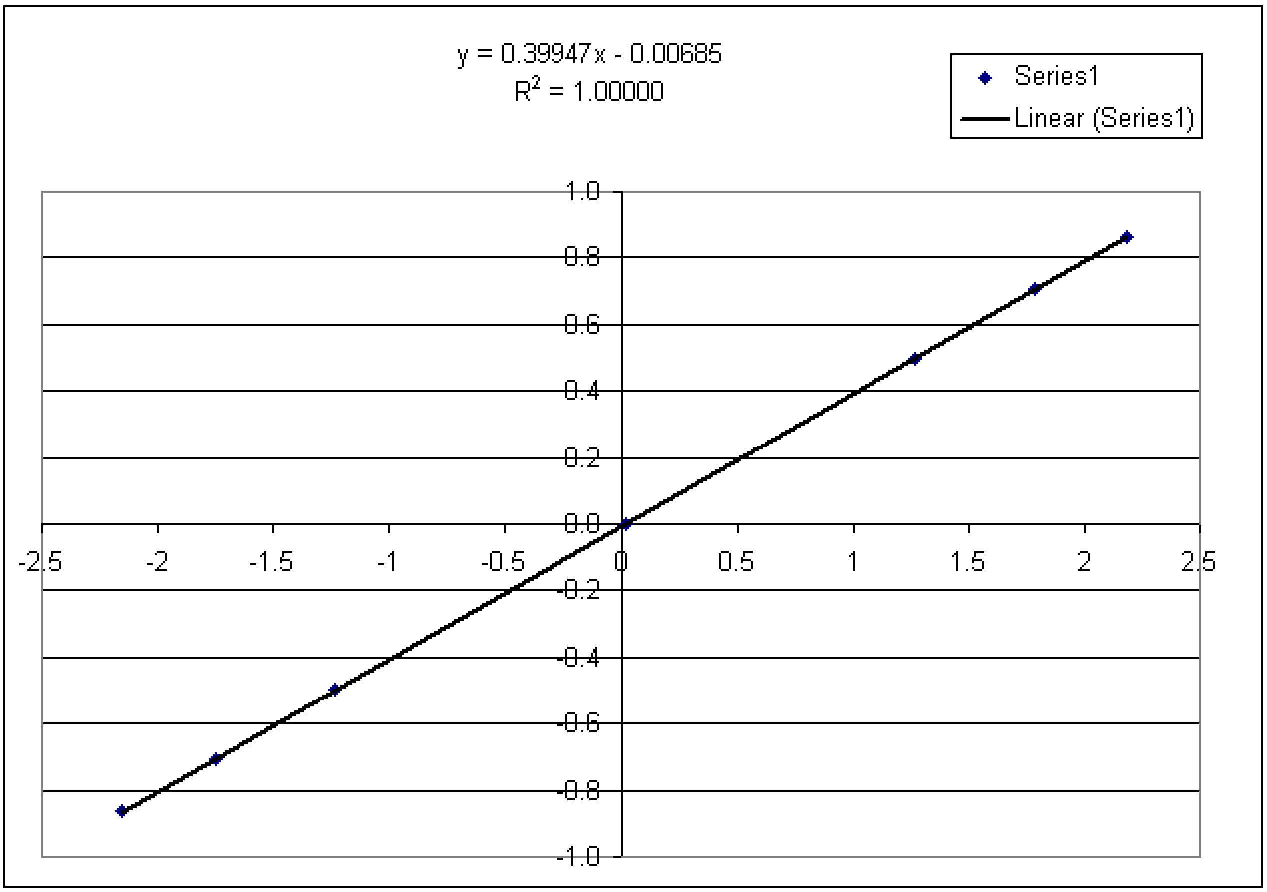
Ch 02
Y Accel, Motion Pak

S/N 0689

Gravity 1

Angle	Sin(angle)	Acceleration	Voltage
0	0	0.0000	0.02
29.994	0.499909307	0.4999	1.269
45.016	0.707304215	0.7073	1.786
59.9	0.865151421	0.8652	2.182
-59.9	-0.865151421	-0.8652	-2.153
-45.016	-0.707304215	-0.7073	-1.753
-29.994	-0.499909307	-0.4999	-1.231

slope	offset
0.3995	-0.0068



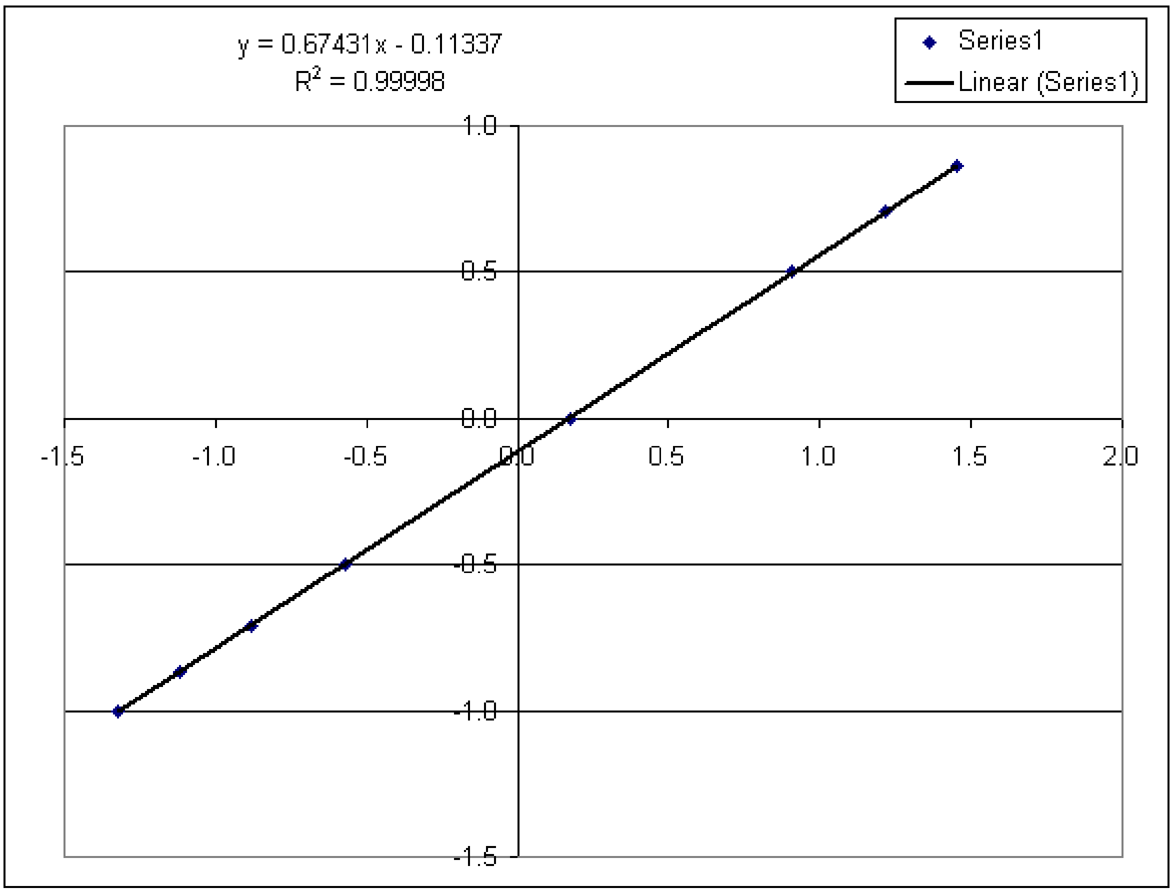
Ch 03
Z Accel, Motion Pak

S/N 0689

Gravity 1

wedge	Angle	-Sin(angle)	Acceleration	Voltage
0	90	-1	-1.0000	-1.321
29.994	60.006	-0.866077759	-0.8661	-1.118
45.016	44.984	-0.706909292	-0.7069	-0.879
59.9	30.1	-0.501510737	-0.5015	-0.570
90	0	0	0.0000	0.177
-59.9	-30.1	0.501510737	0.5015	0.905
-45.016	-44.984	0.706909292	0.7069	1.215
-29.994	-60.006	0.866077759	0.8661	1.453

slope	offset
0.6743	-0.1134



Ch. 04
X Rate, Motion Pak

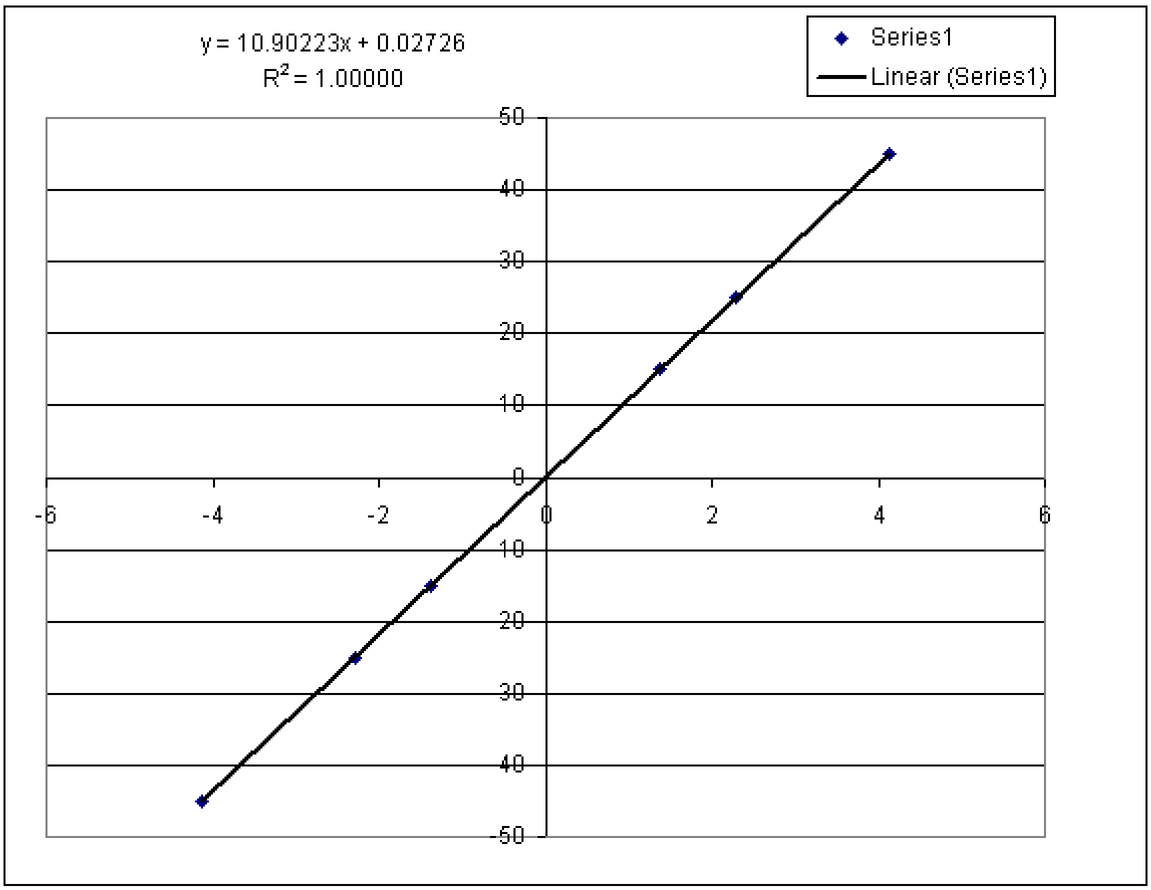
S/N 0689

Scale Factor 24.941 mV/deg/s

Universal Source 169644

Deg/second	injected voltage Volts	Output, Volts
45	1.1223	4.125
25	0.6235	2.291
15	0.3741	1.373
-15	-0.3741	-1.378
-25	-0.6235	-2.296
-45	-1.1223	-4.130

slope	offset
10.9022	0.0273



Ch. 05
Y Rate, Motion Pak

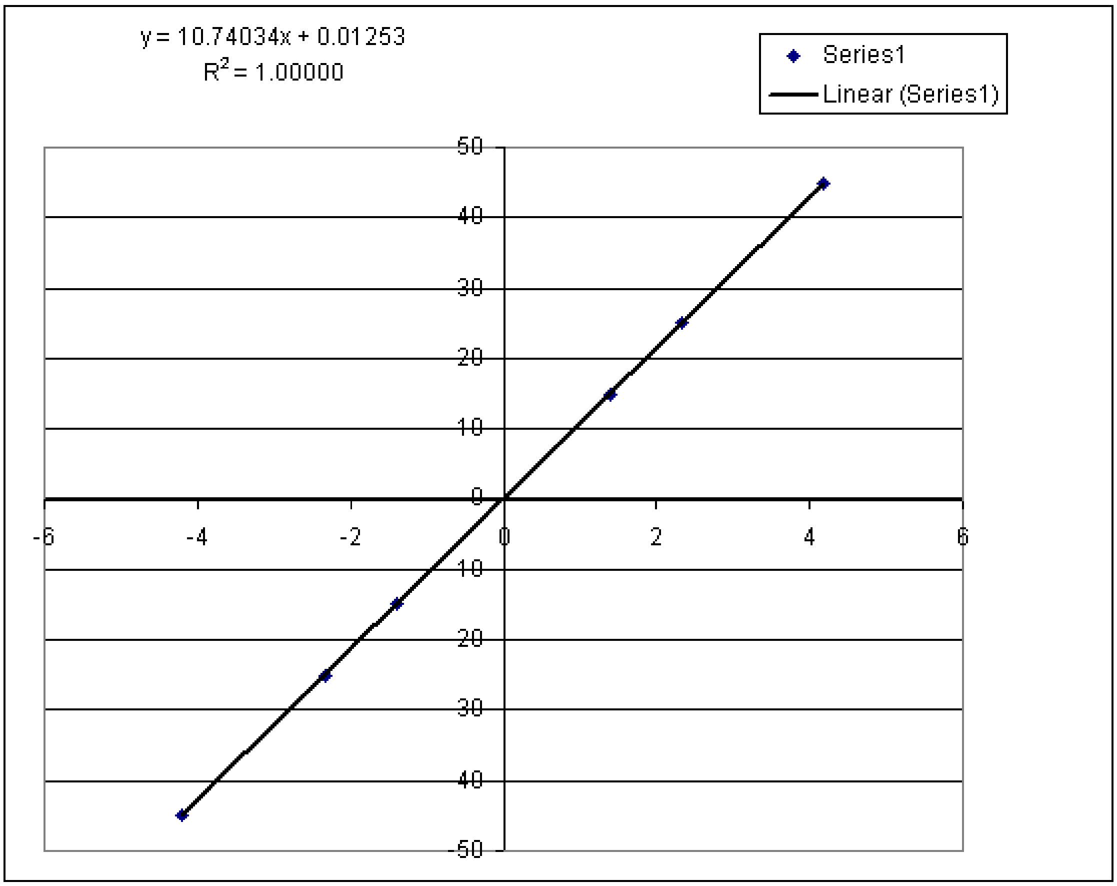
S/N 0689

Scale Factor 25.051 mV/deg/s

Universal Source 169644

Deg/second	injected voltage, V	Output, Volts
45	1.1273	4.188
25	0.6263	2.327
15	0.3758	1.396
-15	-0.3758	-1.398
-25	-0.6263	-2.329
-45	-1.1273	-4.191

slope	offset
10.7403	0.0125



Ch. 06
Z Rate, Motion Pak

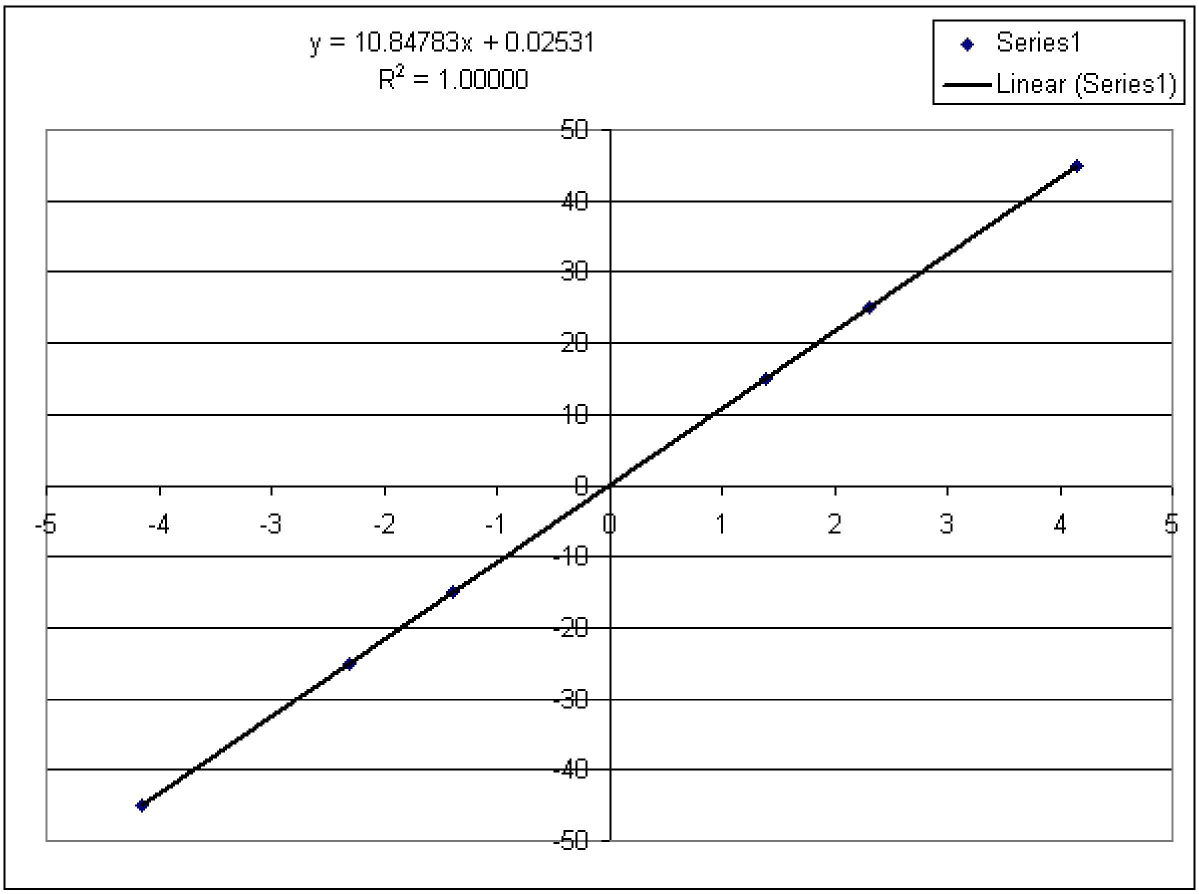
S/N 0689

Scale Factor 24.89 mV/deg/s

Universal Source 169644

Deg/second	injected voltage	Output, Volts
45	1.1201	4.145
25	0.6223	2.303
15	0.3734	1.381
-15	-0.3734	-1.385
-25	-0.6223	-2.307
-45	-1.1201	-4.151

slope	offset
10.8478	0.0253



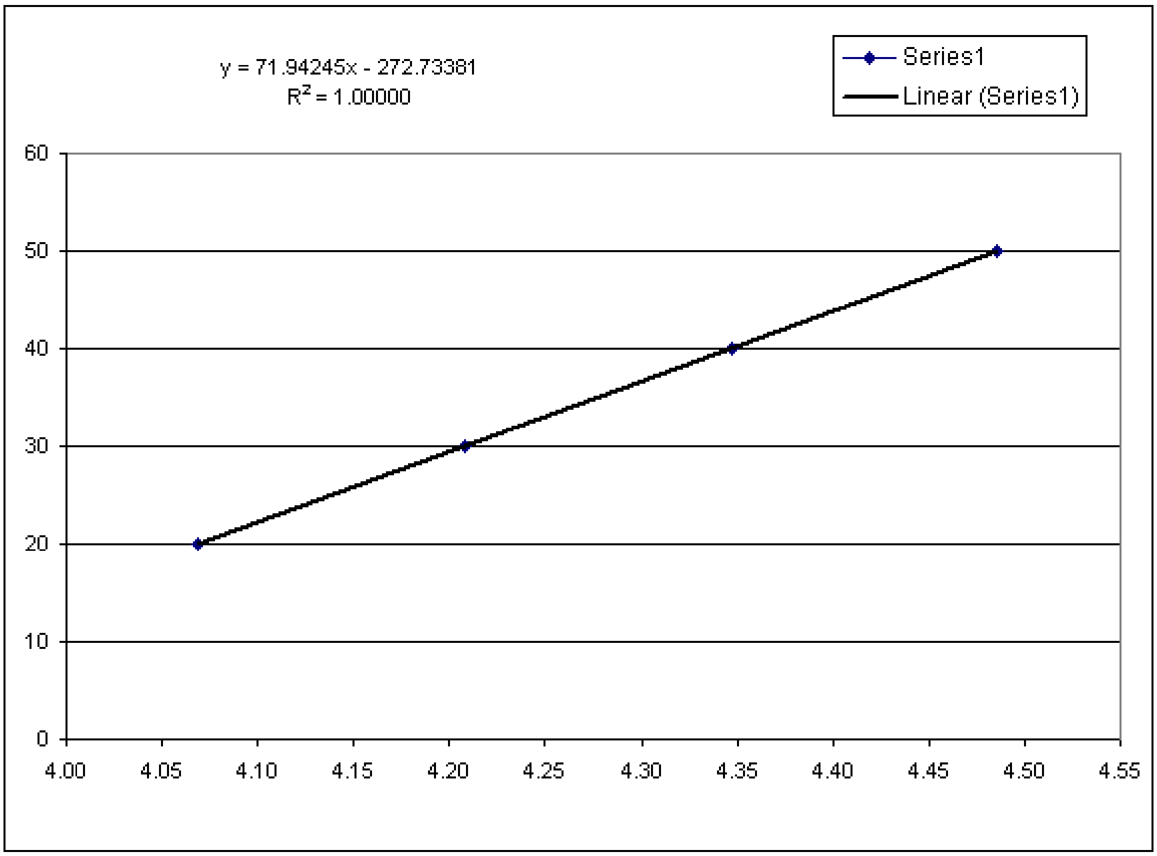
Ch. 07
Temperature, Motion Pak

S/N 0326

1.00E-06	A/°K
13.91	Kohms

Temperature	injected voltage	Output, Volts
Celsius	**V**	**Volts**
-10	3.660	3.652
0	3.800	3.791
20	4.078	4.069
30	4.217	4.208
40	4.356	4.347
50	4.495	4.486

slope	offset
71.9424	-272.7338



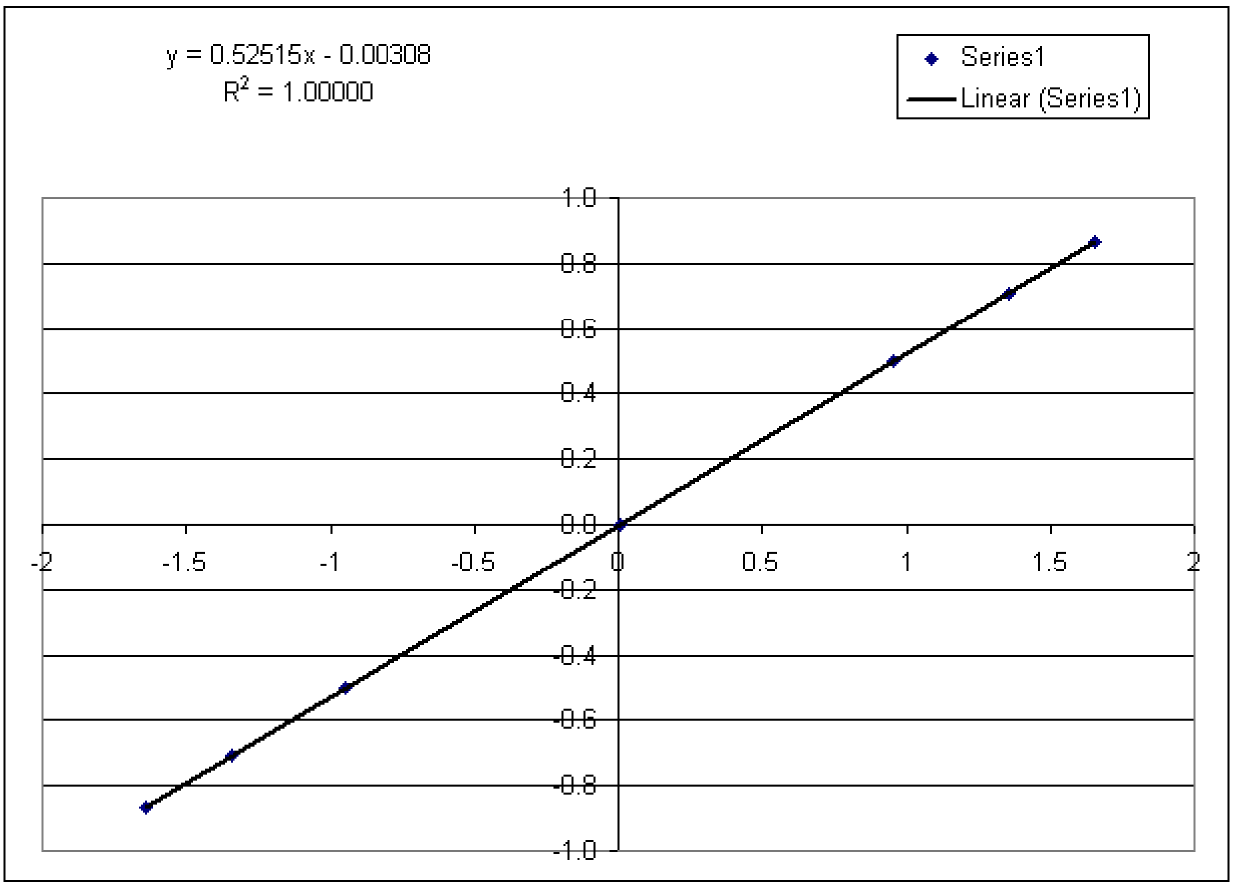
Ch 08
X Accel (Surge)

Model	**QA1400**
serial #	**1102**

Gravity 1

Angle	Sin(angle)	Acceleration	Voltage
0	0	0.0000	0.005
29.994	0.499909307	0.4999	0.956
45.016	0.707304215	0.7073	1.356
59.9	0.865151421	0.8652	1.652
-59.9	-0.865151421	-0.8652	-1.641
-45.016	-0.707304215	-0.7073	-1.342
-29.994	-0.499909307	-0.4999	-0.945

slope	offset
0.5252	-0.0031



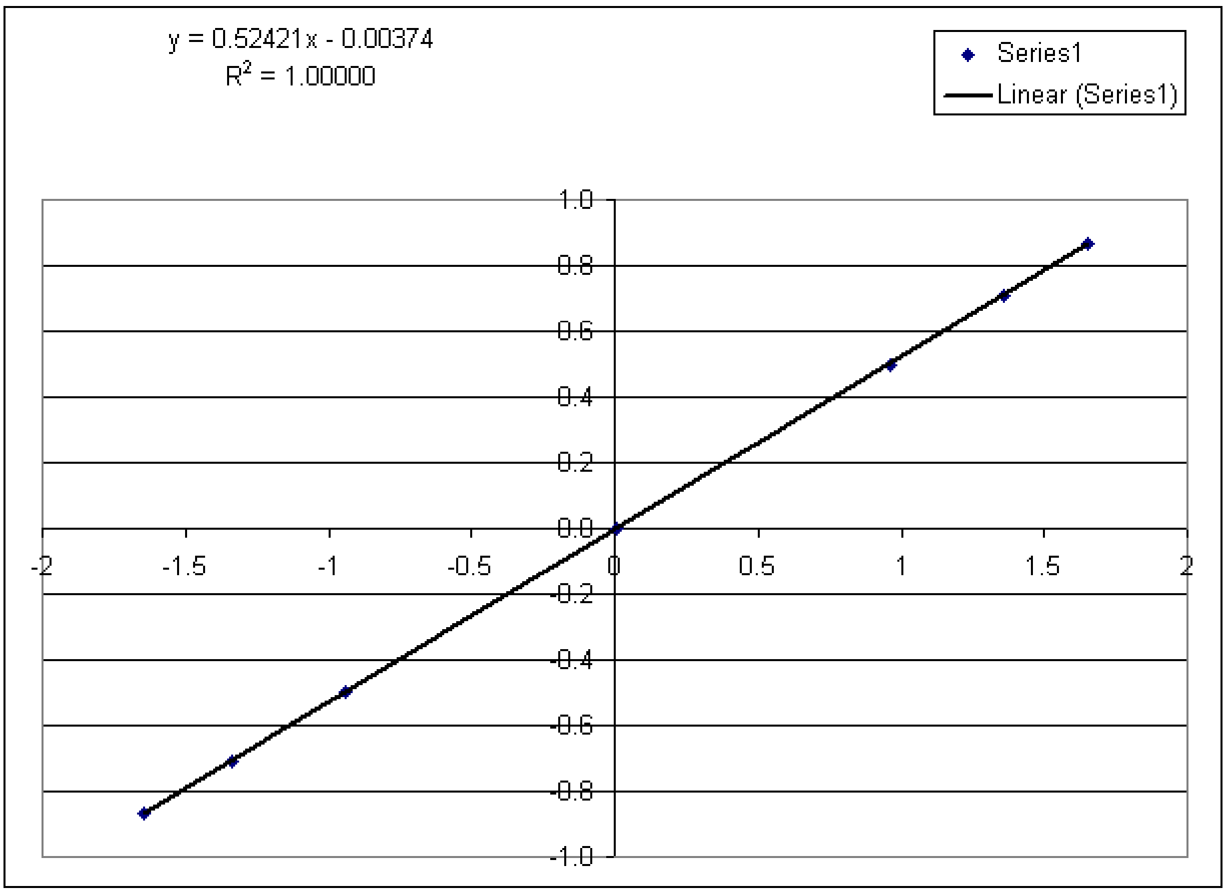
Ch 09
Y Accel (Sway)

Model **QA1400**
serial # **1101**

Gravity 1

Angle	Sin(angle)	Acceleration	Voltage
0	0	0.0000	0.009
29.994	0.499909307	0.4999	0.959
45.016	0.707304215	0.7073	1.359
59.9	0.865151421	0.8652	1.655
-59.9	-0.865151421	-0.8652	-1.647
-45.016	-0.707304215	-0.7073	-1.341
-29.994	-0.499909307	-0.4999	-0.944

slope	offset
0.5242	-0.0037



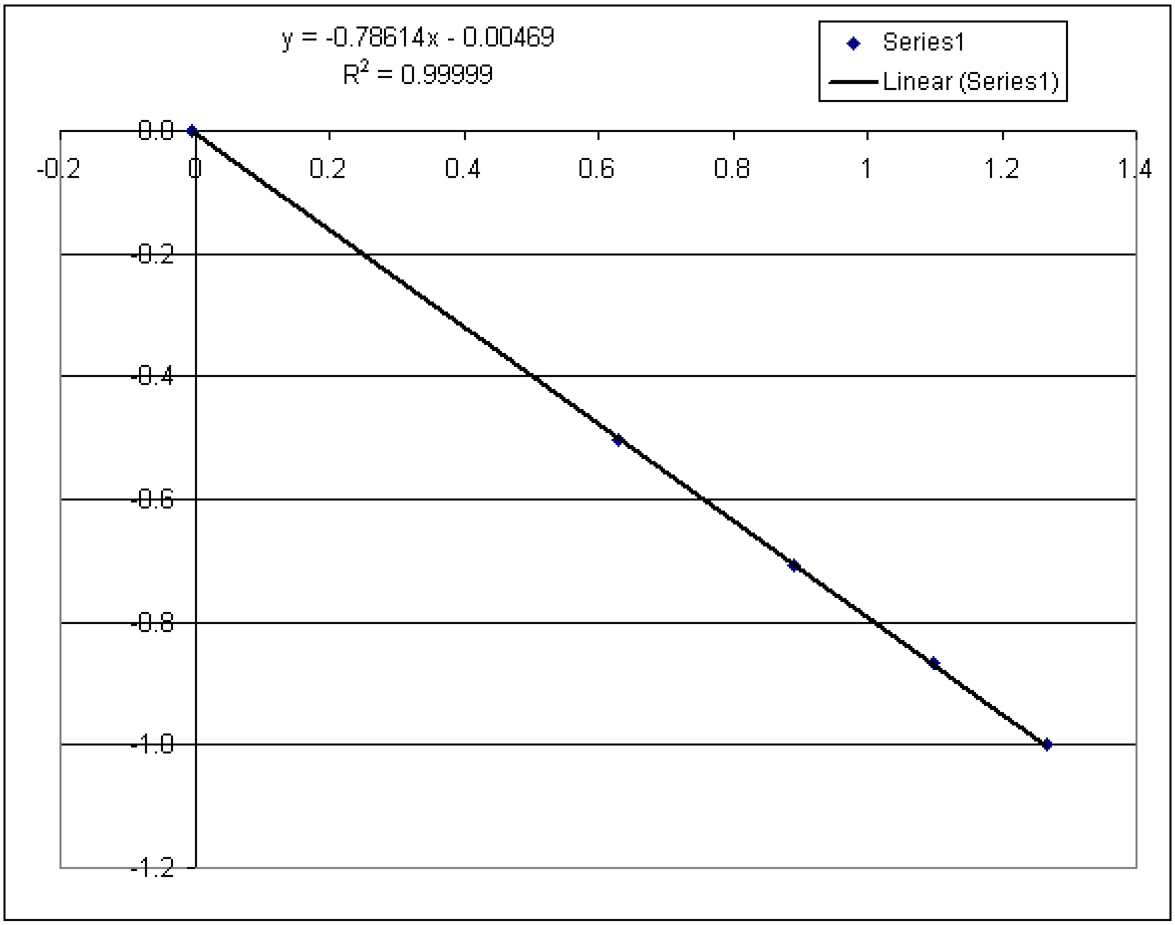
Ch 10
Z Accel (Heave)

Model **QA1400**
serial # **149**

Gravity 1

wedge	Angle	SIN(angle)	Acceleration	Voltage
0	90	-1	-1.0000	1.267
29.994	60.006	-0.866077759	-0.8661	1.097
45.016	44.984	-0.706909292	-0.7069	0.891
59.9	30.1	-0.501510737	-0.5015	0.631
90	0	0	0.0000	-0.005

slope	offset
-0.7861	-0.0047



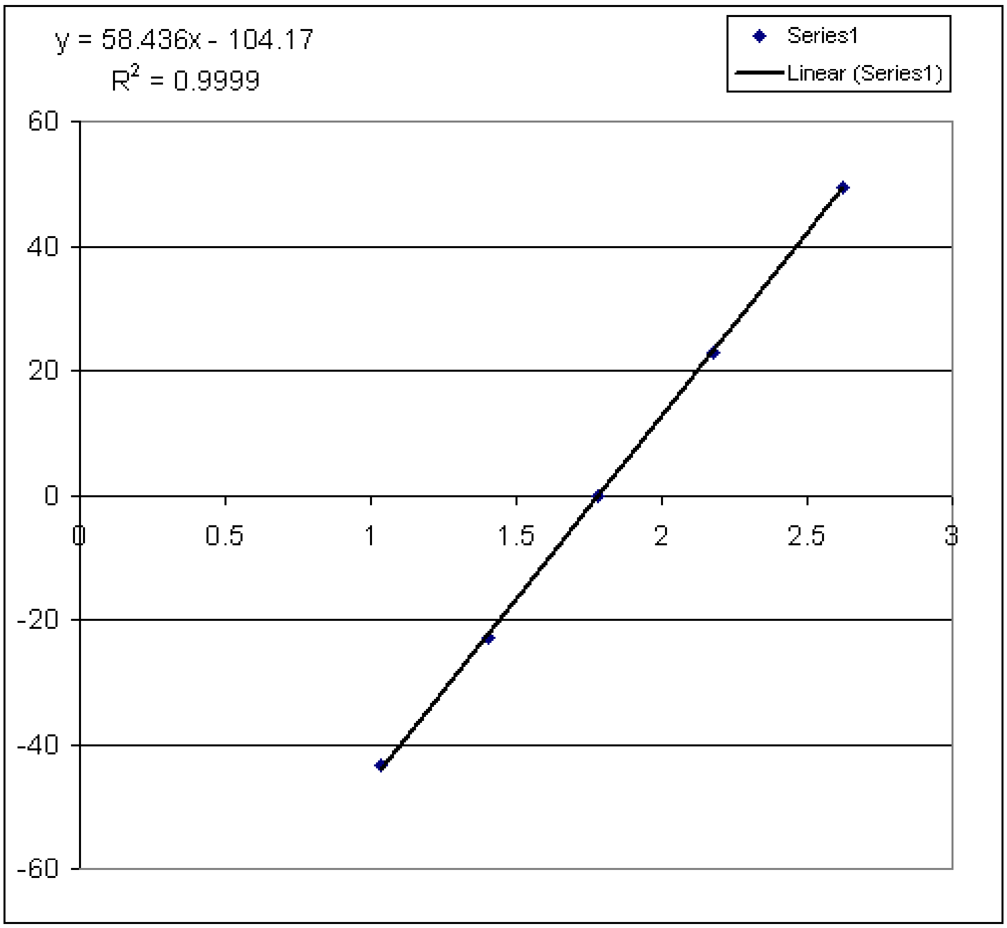
Ch 11
Rudder Angle

Model **PV-25A**
serial # **A1080703-2058206**

Gravity 1

Angle	Voltage
49.5	2.6267
23	2.178
0	1.7813
-22.75	1.403
-43.5	1.0309

slope	Intercept
58.4361	-104.1675



Ch 12
Roll Angle (inclinometer)

Model	**LSOC-30**
serial #	**52732**

Angle	Voltage
22.3	3.849
14.1	2.482
6.85	1.224
-0.04	0.019
-8.47	-1.452
-15.6	-2.675
-23.2	-3.938

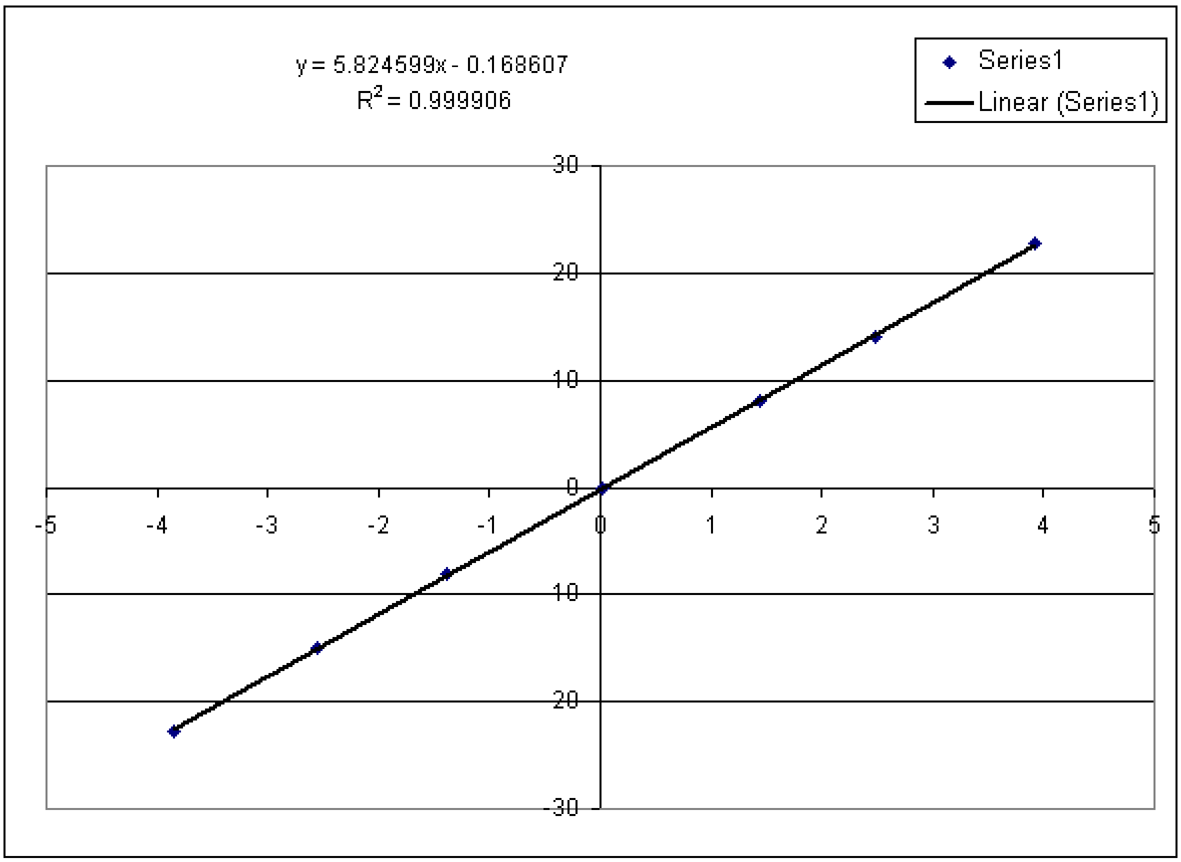
slope	offset
5.8105	-0.1724

Ch 13
Pitch Angle (Inclinometer)

Model	**LSOC-30**
serial #	**52734**
Gravity	1

Angle	Voltage
22.80	3.918
14.10	2.485
8.16	1.446
-0.03	0.021
-8.12	-1.393
-14.90	-2.554
-22.80	-3.856

slope	Offset
5.8246	-0.1686

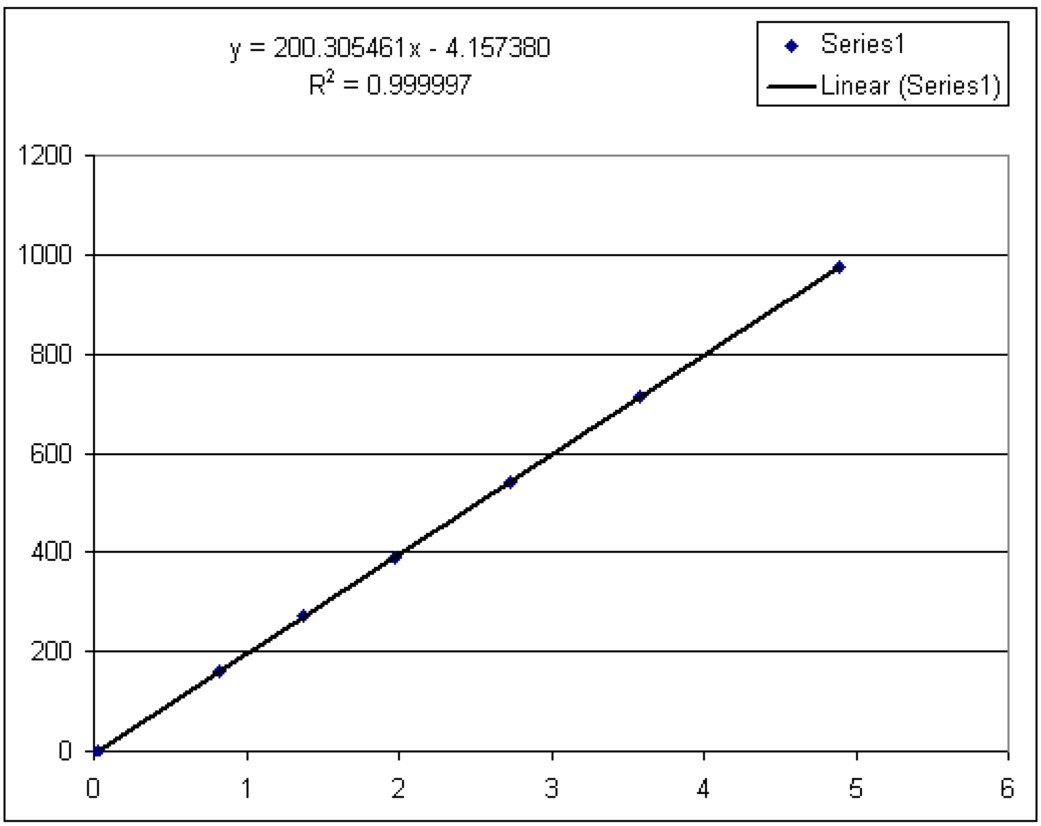


Ch 14
Shaft RPM
Model **IMD RPM to voltage converter**
serial #

rpm	Voltage Out
0	0.025
162	0.827
271	1.37
390	1.97
543	2.73
713	3.58
975	4.89

slope	Offset
200.3055	-4.1574

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



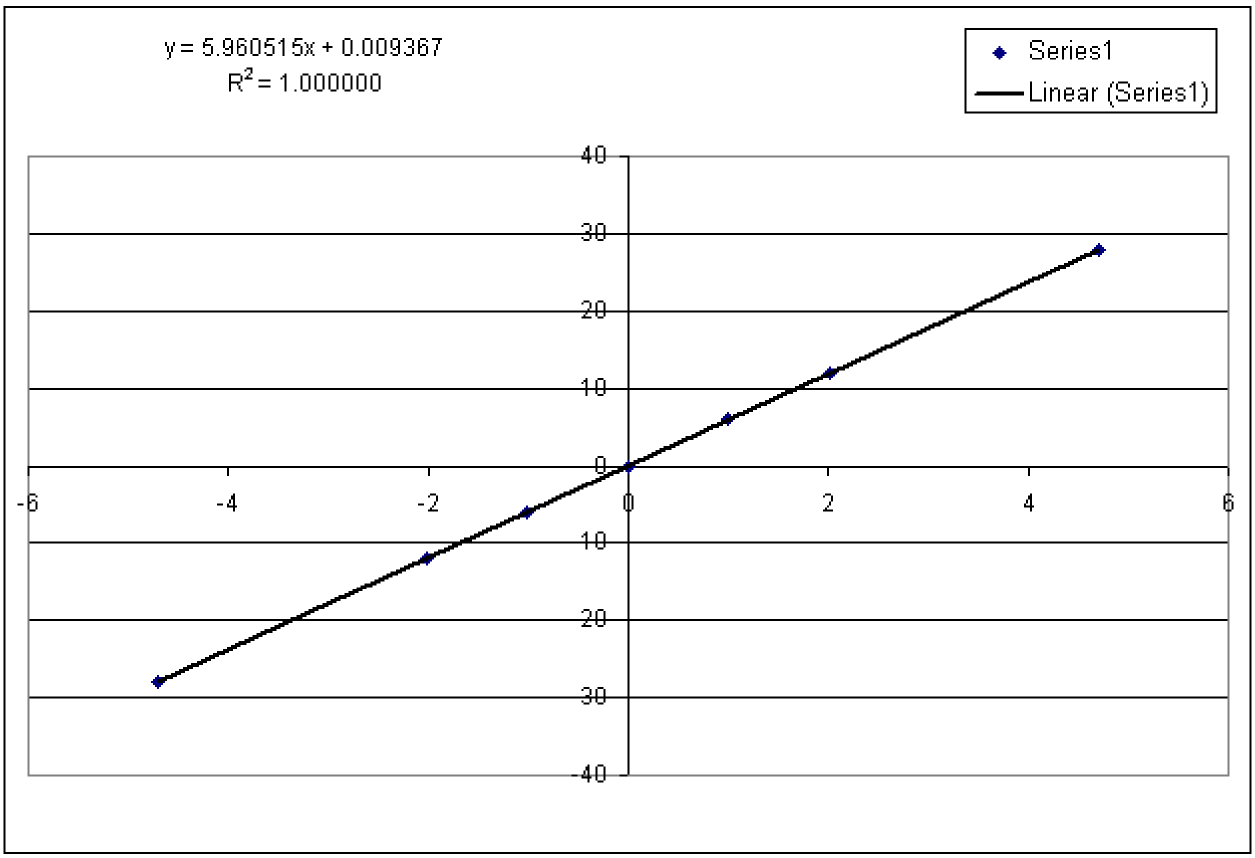
Ch 15
Rudder Slew Rate

Model **PV-25A**
serial # **0703-20582**

Gravity 1

in/s	injected voltage	Voltage
28	4.704	4.696
12	2.016	2.012
6	1.008	1.005
0	0	-0.002
-6	-1.008	-1.008
-12	-2.016	-2.015
-28	-4.704	-4.699

slope	Intercept
5.9605	0.0094



Appendix E
Neptune Wave Buoy Specifications and Typical Output Files

Typical Neptune Wave Buoy Output File:

```
NSI-Neptune Sciences, Inc - Wave Sentry Data Processing Software Version 1.33
Sun Oct 17 11:00:00 2004
VBat = 13.29, Leak = DRY, Temp = 9.1
Significant wave height            =   2.40 m
Dominant and average frequency     =   0.09 Hz   0.12 Hz
Dominant and average period        =  10.89 s    8.04 s

Wave directions are compass headings from which waves approach.
Dominant wave direction =   84.8 deg magnetic
Average wave direction  =   48.8 deg magnetic
--


--

 bnd   cfrq         c11          r1          r2         0     alpha1  alpha2
  1   0.038      0.0000    999.9000    999.9000         0   999.9   999.9
  2   0.049      0.0000    999.9000    999.9000         0   999.9   999.9
  3   0.060      0.0000    999.9000    999.9000         0   999.9   999.9
  4   0.070      4.7444      0.3753      0.2412         0    14.5    91.7
  5   0.081      6.0094      0.2542      0.5294         0    92.3   108.6
  6   0.092      7.2636      0.3818      0.7142         0    84.8    99.0
  7   0.103      5.8444      0.3488      0.5637         0   302.8   278.3
  8   0.113      3.0552      0.4300      0.6603         0    77.8    92.4
  9   0.124      1.8820      0.3787      0.6811         0   292.8   273.5
 10   0.135      0.6413      0.1445      0.2893         0   348.1   292.0
 11   0.146      0.5313      0.3082      0.1294         0   116.7    88.4
 12   0.156      0.5597      0.5231      0.4023         0    46.4    53.1
 13   0.167      0.4211      0.1975      0.3689         0   229.7   269.1
 14   0.178      0.3438      0.2008      0.3688         0   301.0   277.8
 15   0.188      0.2643      0.4430      0.1492         0   343.2   281.5
 16   0.199      0.0693      0.5855      0.2870         0   282.2   274.0
 17   0.210      0.1496      0.2919      0.1041         0   335.1   330.1
 18   0.221      0.0604      0.1283      0.5735         0   309.0   269.5
 19   0.231      0.0652      0.2153      0.3479         0   186.6   171.4
 20   0.242      0.0772      0.2703      0.3877         0   227.1   258.7
 21   0.253      0.1055      0.4117      0.3117         0   204.8   163.0
 22   0.264      0.0760      0.3987      0.0691         0   215.4   146.3
 23   0.274      0.1702      0.6832      0.3541         0   193.7   194.6
 24   0.285      0.0937      0.7562      0.4358         0   176.4   179.3
 25   0.296      0.1658      0.7765      0.5154         0   185.8   181.0
 26   0.307      0.1659      0.7884      0.5085         0   177.7   174.3
 27   0.317      0.0671      0.5157      0.2361         0   196.9   227.9
 28   0.328      0.1472      0.8236      0.6080         0   197.1   194.6
 29   0.339      0.0456      0.7009      0.5243         0   189.4   191.6
 30   0.350      0.0844      0.7218      0.3789         0   196.3   183.9
 31   0.360      0.0555      0.7693      0.5303         0   197.7   198.8
 32   0.371      0.0463      0.7093      0.3606         0   156.8   160.2
 33   0.382      0.0457      0.7396      0.3248         0   197.2   204.1
 34   0.393      0.0245      0.6522      0.6597         0   171.7   165.4
 35   0.403      0.0264      0.5883      0.1037         0   180.2   177.8
 36   0.414      0.0412      0.8284      0.6495         0   184.6   189.0
 37   0.425      0.0363      0.7614      0.5169         0   173.3   168.9
 38   0.436      0.0197      0.6973      0.3496         0   172.0   168.2
 39   0.446      0.0173      0.7455      0.4232         0   183.7   183.3
 40   0.457      0.0217      0.7924      0.5352         0   181.4   179.9
 41   0.468      0.0178      0.6057      0.3783         0   168.1   143.9
 42   0.479      0.0135      0.5434      0.1797         0   195.6   231.4
 43   0.489      0.0151      0.8104      0.4948         0   180.0   183.4
 44   0.500      0.0095      0.6900      0.3071         0   182.7   182.2

Mean, min, max acc (g)    = -0.01  -0.51   0.35
Mean, min, max pitch (deg)=  -0.0  -12.0    9.9
Mean, min, max roll (deg) =  -0.0  -12.3   12.8
Maximum tilt (deg)        =  15.0
```

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.

- 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: ±2°, 0° - 360°
- Nondirectional and directional spectra are limited by statistical confidence related to record length rather than the instrumentation.

Appendix F
Datawell Wave Buoy Specifications and Typical Output Files

1. General Description of the Datawell Directional Waverider Mark II

The directional waverider buoy is a spherical, 0.9 m diameter buoy which measures wave height and wave direction. The buoy is manufactured by Datawell bv of the Netherlands. The buoy used in the NRC trials transmitted on 29.760 Mhz. Output power is 150-200 mW. The buoy is powered by 85 Leclanche zinc-carbon batteries, 80 Wh per cell. The buoy contains a flashing light that flashes 5 times every 20 seconds.

The direction measurement is based on the translational principle which means that horizontal motions instead of wave slopes are measured. As a consequence the measurement is independent of buoy roll motions and therefore a relative small buoy can be used.

A single point vertical mooring ensures sufficient symmetrical horizontal buoy response also for small motions at low frequencies.

The buoy comes standard with sea surface temperature measurement.

Installed Sensors

The buoy contains:

- heave-pitch-roll sensor Hippy-40
- three axis fluxgate compass
- two fixed “x” and “y” accelerometers
- temperature sensor
- micro-processor

Directional Measurement

From the accelerations measured in the x and y directions of the moving “buoy reference frame” the accelerations along the fixed, horizontal, north and west axis are calculated. All three accelerations (vertical, north and west) are digitally integrated to get filtered displacements with a high frequency cut-off at 0.6 Hz.

Finally, every half hour, FFT transforms of 8 series of 256 data points (200 sec) are summed to give 16 degrees of freedom on 1600 seconds of data.

Data Compression

To save transmitting power the real time data are compressed to motion vertical, motion north and motion west.

Data Reduction

Onboard data reduction computes energy density, main direction, directional spread and the normalized second harmonic of the directional distribution.

Frequency resolution:
0.005 Hz from 0.025 to 0.1 Hz and
0.01 Hz from 0.1 to 0.59 Hz.

Standard Transmission

The Directional Waverider transmits HF in the 27-40 Mhz band continuously. The Directional Waverider transmits:

- Real time data:
  - motion vertical
  - motion north
  - motion west
- Quasi static data:
  - computed spectral density
  - directional parameters
  - Hmo (significant wave height)
  - Tz (mean zero crossing period)
  - Monitoring data such as sea temperature, battery voltage, system status, GPS position (optional) and parity bits for error checking purposes.

Mooring

The Directional Waverider is fitted with a 5 kg chain ballast attached to the mooring eye. This provides stability when only a small vertical mooring force is present (free floating or shallow water).

A single point vertical mooring with 30 m rubbercord ensures sufficient symmetrical horizontal buoy response also for small motions at low frequencies.

The low stiffness of the 30 m rubbercord allows the Directional Waverider to follow waves up to 40 m.

Current velocities of up to 3 m/sec (6 knots) can be accommodated. The static buoyancy of the buoy is 1630 N.

The mooring design used for the NRC trials is shown in Figure 1 at the end of this document.

2. Directional Waverider Mark II Specifications

Hull diameter	0.9 m
Buoy weight	212 kg
Static buoyancy	1630 N
Maximum current speed	3 m/sec
Sampling frequency	3.84 Hz

Heave:

Range	-20 to +20 m
Resolution	1 cm
Scale of accuracy	3 % of measured value
Zero offset	< 0.1 m
Period time	1.6 sec – 30 sec
Cross sensitivity	< 3 %

Direction:

Range	0 – 360 degrees
Resolution	1.5 degrees
Buoy heading error	typical .5 degrees
Period time in free floating condition	1.6 sec – 30 sec
Period time in moored condition	1.6 sec – 20 sec

3. General Description of the Directional Waverider Receiver System

The receiving system installed on the roof of OCEANS Ltd. offices at 85 LeMarchant Rd. St. John's consisted of an omnidirectional antenna (a 3 metre Kathrein radiator whip antenna and 3 radial antennae) and antenna mount connected via a coax cable (RG 213 U) routed from the antenna mount to the wave direction receiver installed in an office below. A laptop interfaced to the wave direction receiver for storing and displaying wave data. The receiver was receiving on 38.760 Mhz. Standard 120 volt AC was used to power the wave direction receiver.

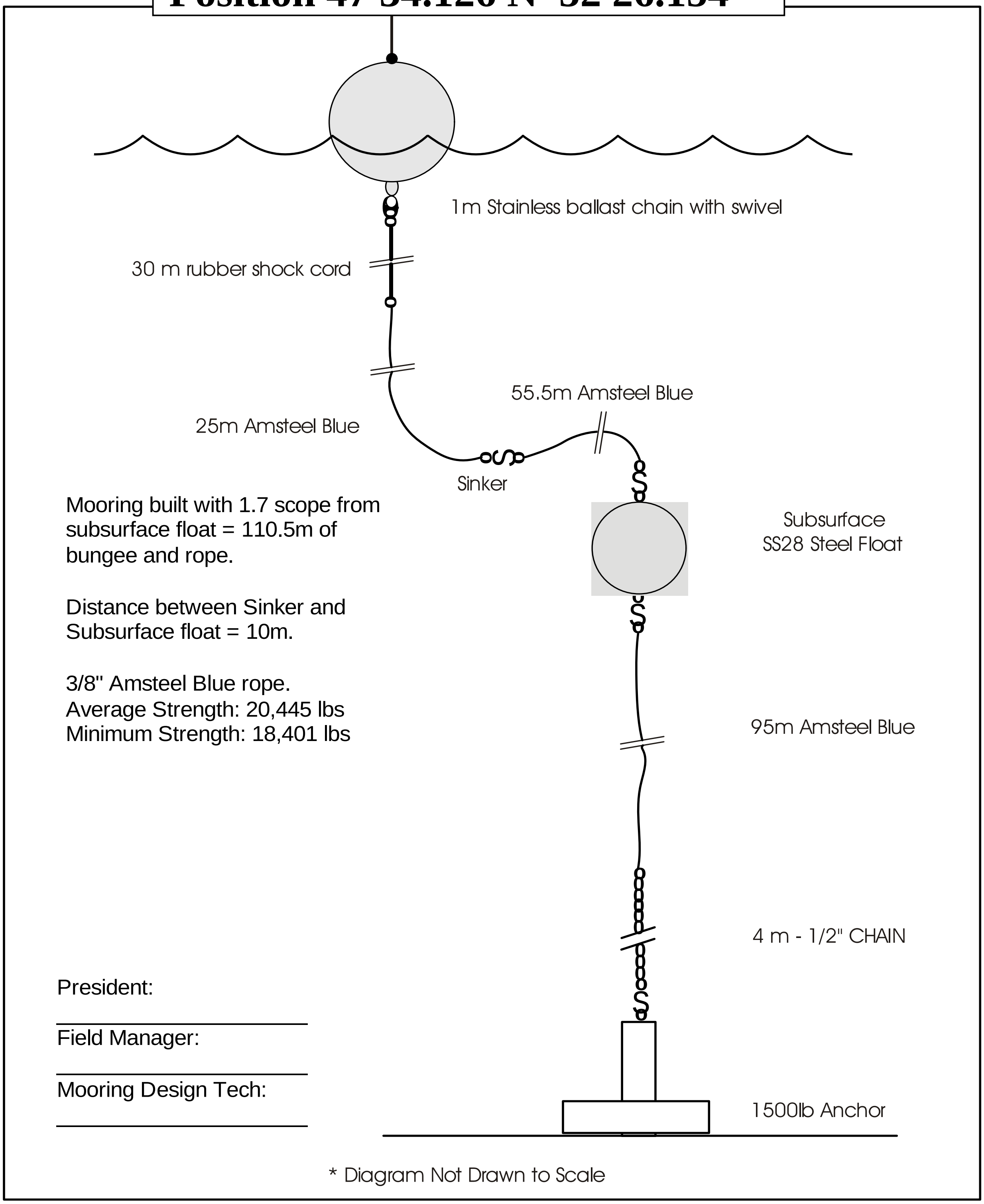
During the trials data was recorded every half hour. The recorded data included spectral, raw and statistics data. These data were passed to NRC within 48 hours after the end of a sea trial. In addition to other wave parameters the following basic wave parameters were included in the wave data provided to NRC:

start time of the data collection in UTC time
significant wave height in centimetres
mean zero crossing period in seconds
direction of the spectral peak in degrees magnetic
directional spread of the spectral peak in degrees

The directional waverider buoy was deployed October 8, 2004 at 17:00 UTC time by the 40 m long Marine Institute training vessel M/V Louis M. Lauzier in position 47 34.126 N 52 26.154 W in a water depth of 163 metres.

NRC September 2004 - Directional Waverider Mooring
Water Depth - 165 Metres

Position 47 34.126 N 52 26.154



Typical Raw Datawell Wave Buoy Output Files:

10171100.dat

```
10-17-2004 1100 to 1120 ,100% , 442 ,10.0 , 340 ,11.1 , 272 ,11.1 , 169 , 8.8 ,0.82
  86 , +155 , -173 ,10.91
 126 , +147 , -202 ,11.86
  45 , +105 , -101 ,15.56
  85 ,  +97 , -146 ,14.55
   1 , +128 , -120 ,13.83
   0 , +181 , -141 ,11.92
 118 ,  +27 ,   -5 , 2.30
   5 ,  +71 ,  -61 , 9.96
  44 ,  +62 ,  -90 , 6.57
  87 , +111 ,  -81 ,11.44
 124 ,  +52 ,   -6 , 7.21
 130 ,   +6 ,  -38 , 4.31
 119 ,  +19 ,  -75 , 5.46
  82 ,  +82 , -116 ,13.05
  46 ,  +68 ,  -64 ,15.58
  79 , +110 ,  -39 , 8.55
  29 ,  +66 ,  -74 , 8.07
  90 ,  +38 ,   +0 , 1.08
 131 ,  +77 , -113 ,10.59
  81 ,  +77 ,  -48 , 8.10
  30 ,  +45 ,  -47 , 7.01
  76 ,  +17 ,  -64 , 6.06
  33 ,  +93 , -122 ,10.20
 127 ,  +44 ,   -5 , 1.86
 125 ,  +79 ,  -12 , 7.19
   4 ,  +25 ,  -78 , 5.73
  66 ,  +56 ,  -14 , 4.63
  28 ,  +22 ,  -56 , 5.03
   3 , +100 , -147 ,10.42
 122 , +144 , -131 ,13.73
  89 , +123 , -141 ,11.58
  94 ,  +66 ,   -7 , 6.64
 107 ,  +57 ,  -81 , 7.76
 134 , +148 , -110 , 8.34
  84 , +115 ,  -82 , 8.84
 129 ,  +65 ,  -39 , 6.76
  77 ,   +1 ,  -32 , 3.26
  80 ,  +55 ,  -34 , 2.43
  83 ,  +71 ,  -32 , 7.32
  65 ,  +19 ,  -32 , 2.36
  22 ,  +35 ,  -39 , 3.82
  75 ,  +58 ,  -52 ,10.33
   2 ,   +1 ,  -36 , 2.66
  62 ,  +67 , -138 ,11.01
  43 , +137 , -182 ,11.82
 116 , +184 , -204 ,11.34
 108 , +190 ,  -93 ,10.61
  13 ,  +84 ,  -61 , 9.87
  34 ,  +82 ,  -62 ,10.04
  78 ,  +22 ,  -36 , 3.00
 128 ,  +84 ,  -66 ,10.40
   9 ,  +23 ,  -17 , 1.17
  18 ,  +10 ,  -17 , 3.28
 117 ,  +61 ,  -90 , 9.50
 123 ,  +69 ,  -81 ,12.25
  67 ,  +81 ,  -74 ,10.20
  61 ,  +34 ,   -8 , 3.19
  70 ,  +39 ,  -80 , 7.45
  74 ,  +46 ,  -49 , 5.95
 121 ,  +73 ,  -92 , 8.90
 109 ,  +53 ,  -31 , 9.55
  69 ,  +64 , -114 , 6.83
  59 ,  +90 , -116 ,11.23
  88 ,  +81 ,  -27 , 7.90
 102 ,  +42 ,  -99 , 6.87
  92 , +127 ,  -92 ,11.02
```

```
104 , +123 , -125 ,10.30
132 ,  +89 ,  -93 ,11.25
 55 ,  +78 ,  -61 ,10.59
115 ,  +69 ,  -98 ,11.45
  8 ,  +95 ,  -80 , 9.08
 53 ,  +24 ,  -29 , 2.83
 50 ,  +32 ,  -34 , 8.37
 54 ,  +76 ,  -73 , 9.41
 95 ,  +76 ,  -95 ,10.05
 15 ,  +76 , -133 ,10.56
 73 , +138 , -124 ,11.54
 47 , +119 , -102 , 8.12
105 ,  +99 ,  -96 ,11.21
120 , +117 , -165 ,11.72
133 , +118 , -102 , 9.90
 48 , +139 , -130 , 9.95
 64 , +155 , -132 ,12.15
 16 , +116 , -104 ,13.92
 68 ,  +97 , -129 ,13.99
 32 , +206 , -182 ,10.51
101 , +213 , -229 ,10.01
  7 , +205 , -108 ,12.39
 14 , +112 ,  -53 , 7.45
100 , +100 , -139 , 8.73
 19 , +158 , -115 ,10.75
 57 ,  +38 ,  -13 , 2.34
 93 ,  +60 , -102 ,13.11
 97 ,  +56 ,  -63 ,10.70
 41 ,  +93 , -136 , 9.43
 63 ,  +89 ,  -61 ,14.51
 35 ,  +59 ,   -2 , 6.03
 25 ,  +28 ,  -83 , 6.34
 38 ,  +40 ,   +0 , 2.77
 58 ,  +42 ,   -1 , 2.34
114 ,  +56 ,  -70 , 8.42
 12 ,  +59 ,  -75 , 9.03
 20 ,  +86 ,  -77 , 6.75
 24 ,  +34 ,  -48 , 6.38
 37 ,  +48 , -113 , 8.98
 60 ,  +92 ,  -53 ,10.06
103 ,  +20 ,  -27 , 4.70
 21 ,  +98 , -130 , 9.50
 27 ,  +90 , -109 ,11.89
110 ,  +89 ,  -81 ,11.98
 40 ,  +65 ,  -10 , 6.49
 31 ,  +26 ,  -22 , 2.26
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```

Appendix F
Datawell Wave Buoy Specifications and Typical Output Files

1. General Description of the Datawell Directional Waverider Mark II

The directional waverider buoy is a spherical, 0.9 m diameter buoy which measures wave height and wave direction. The buoy is manufactured by Datawell bv of the Netherlands. The buoy used in the NRC trials transmitted on 29.760 Mhz. Output power is 150-200 mW. The buoy is powered by 85 Leclanche zinc-carbon batteries, 80 Wh per cell. The buoy contains a flashing light that flashes 5 times every 20 seconds.

The direction measurement is based on the translational principle which means that horizontal motions instead of wave slopes are measured. As a consequence the measurement is independent of buoy roll motions and therefore a relative small buoy can be used.

A single point vertical mooring ensures sufficient symmetrical horizontal buoy response also for small motions at low frequencies.

The buoy comes standard with sea surface temperature measurement.

Installed Sensors

The buoy contains:
- heave-pitch-roll sensor Hippy-40
- three axis fluxgate compass
- two fixed “x” and “y” accelerometers
- temperature sensor
- micro-processor

Directional Measurement

From the accelerations measured in the x and y directions of the moving “buoy reference frame” the accelerations along the fixed, horizontal, north and west axis are calculated. All three accelerations (vertical, north and west) are digitally integrated to get filtered displacements with a high frequency cut-off at 0.6 Hz.

Finally, every half hour, FFT transforms of 8 series of 256 data points (200 sec) are summed to give 16 degrees of freedom on 1600 seconds of data.

Data Compression

To save transmitting power the real time data are compressed to motion vertical, motion north and motion west.

Data Reduction

Onboard data reduction computes energy density, main direction, directional spread and the normalized second harmonic of the directional distribution.

Frequency resolution:
0.005 Hz from 0.025 to 0.1 Hz and
0.01 Hz from 0.1 to 0.59 Hz.

Standard Transmission

The Directional Waverider transmits HF in the 27-40 Mhz band continuously. The Directional Waverider transmits:

- Real time data:
  - motion vertical
  - motion north
  - motion west
- Quasi static data:
  - computed spectral density
  - directional parameters
  - Hmo (significant wave height)
  - Tz (mean zero crossing period)
  - Monitoring data such as sea temperature, battery voltage, system status, GPS position (optional) and parity bits for error checking purposes.

Mooring

The Directional Waverider is fitted with a 5 kg chain ballast attached to the mooring eye. This provides stability when only a small vertical mooring force is present (free floating or shallow water).

A single point vertical mooring with 30 m rubbercord ensures sufficient symmetrical horizontal buoy response also for small motions at low frequencies.

The low stiffness of the 30 m rubbercord allows the Directional Waverider to follow waves up to 40 m.

Current velocities of up to 3 m/sec (6 knots) can be accommodated. The static buoyancy of the buoy is 1630 N.

The mooring design used for the NRC trials is shown in Figure 1 at the end of this document.

2. Directional Waverider Mark II Specifications

Hull diameter	0.9 m
Buoy weight	212 kg
Static buoyancy	1630 N
Maximum current speed	3 m/sec
Sampling frequency	3.84 Hz

Heave:

Range	-20 to +20 m
Resolution	1 cm
Scale of accuracy	3 % of measured value
Zero offset	< 0.1 m
Period time	1.6 sec – 30 sec
Cross sensitivity	< 3 %

Direction:

Range	0 – 360 degrees
Resolution	1.5 degrees
Buoy heading error	typical .5 degrees
Period time in free floating condition	1.6 sec – 30 sec
Period time in moored condition	1.6 sec – 20 sec

3. General Description of the Directional Waverider Receiver System

The receiving system installed on the roof of OCEANS Ltd. offices at 85 LeMarchant Rd. St. John's consisted of an omnidirectional antenna (a 3 metre Kathrein radiator whip antenna and 3 radial antennae) and antenna mount connected via a coax cable (RG 213 U) routed from the antenna mount to the wave direction receiver installed in an office below. A laptop interfaced to the wave direction receiver for storing and displaying wave data. The receiver was receiving on 38.760 Mhz. Standard 120 volt AC was used to power the wave direction receiver.

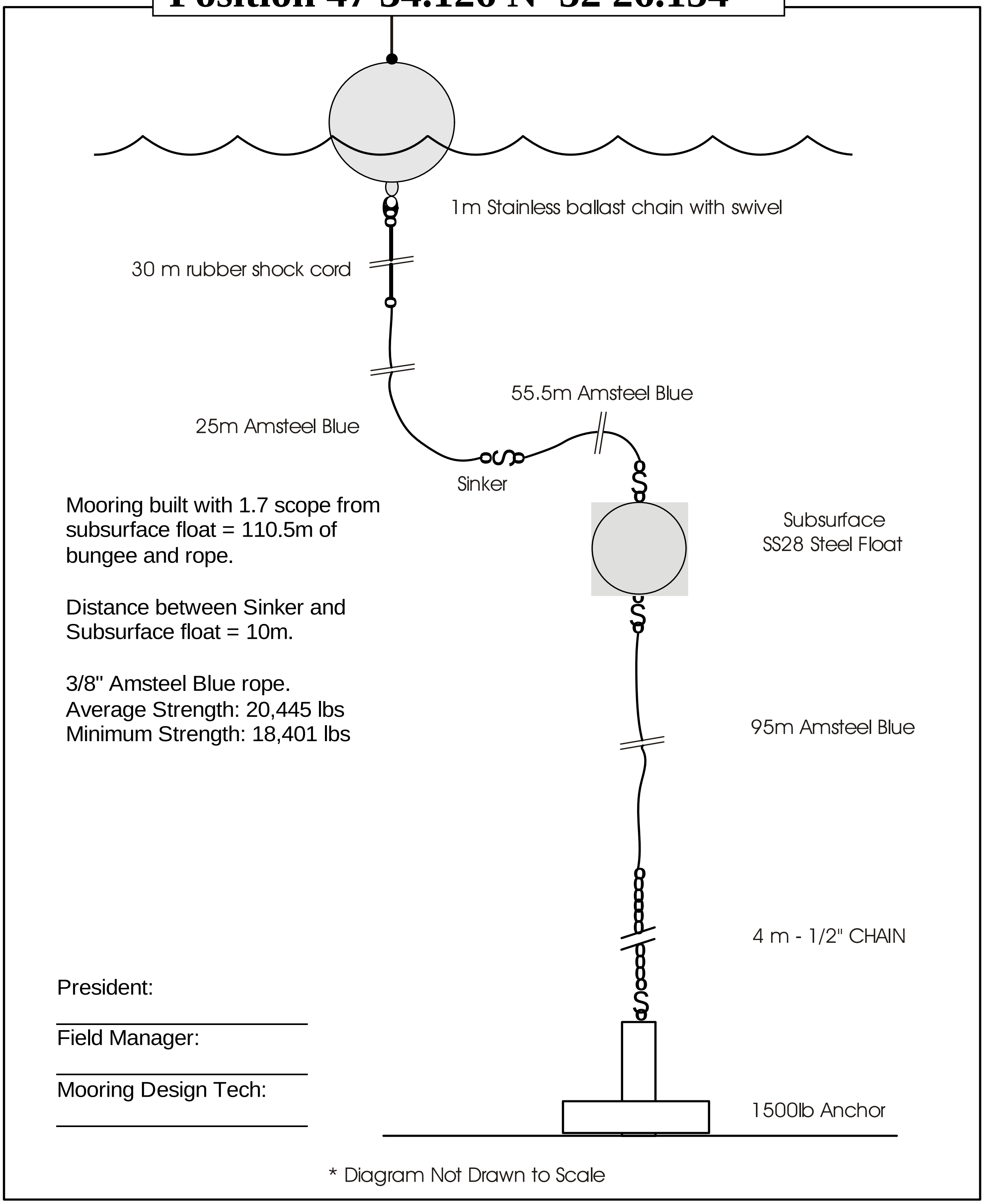
During the trials data was recorded every half hour. The recorded data included spectral, raw and statistics data. These data were passed to NRC within 48 hours after the end of a sea trial. In addition to other wave parameters the following basic wave parameters were included in the wave data provided to NRC:

start time of the data collection in UTC time
significant wave height in centimetres
mean zero crossing period in seconds
direction of the spectral peak in degrees magnetic
directional spread of the spectral peak in degrees

The directional waverider buoy was deployed October 8, 2004 at 17:00 UTC time by the 40 m long Marine Institute training vessel M/V Louis M. Lauzier in position 47 34.126 N 52 26.154 W in a water depth of 163 metres.

NRC September 2004 - Directional Waverider Mooring Water Depth - 165 Metres

Position 47 34.126 N 52 26.154



Typical Raw Datawell Wave Buoy Output Files:

10171100.dat

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 126 , +147 , -202 ,11.86
  45 , +105 , -101 ,15.56
  85 ,  +97 , -146 ,14.55
   1 , +128 , -120 ,13.83
   0 , +181 , -141 ,11.92
 118 ,  +27 ,   -5 , 2.30
   5 ,  +71 ,  -61 , 9.96
  44 ,  +62 ,  -90 , 6.57
  87 , +111 ,  -81 ,11.44
 124 ,  +52 ,   -6 , 7.21
 130 ,   +6 ,  -38 , 4.31
 119 ,  +19 ,  -75 , 5.46
  82 ,  +82 , -116 ,13.05
  46 ,  +68 ,  -64 ,15.58
  79 , +110 ,  -39 , 8.55
  29 ,  +66 ,  -74 , 8.07
  90 ,  +38 ,   +0 , 1.08
 131 ,  +77 , -113 ,10.59
  81 ,  +77 ,  -48 , 8.10
  30 ,  +45 ,  -47 , 7.01
  76 ,  +17 ,  -64 , 6.06
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 127 ,  +44 ,   -5 , 1.86
 125 ,  +79 ,  -12 , 7.19
   4 ,  +25 ,  -78 , 5.73
  66 ,  +56 ,  -14 , 4.63
  28 ,  +22 ,  -56 , 5.03
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  94 ,  +66 ,   -7 , 6.64
 107 ,  +57 ,  -81 , 7.76
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50	+32	-34	8.37
54	+76	-73	9.41
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73	+138	-124	11.54
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105	+99	-96	11.21
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64	+155	-132	12.15
16	+116	-104	13.92
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25	+28	-83	6.34
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40	+65	-10	6.49
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26	+20	-45	3.19
72	+10	-4	2.14
112	+40	-55	5.43
96	+74	-81	10.31
10	+92	-113	9.77
49	+96	-92	13.06
71	+165	-162	10.78
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91	+68	-77	9.01
23	+90	-81	12.30
111	+137	-106	10.08
106	+82	-102	15.85
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Appendix G
Seakeeping Trials Test Plan

Test Program for Seakeeping Trials on 45 ft. long Fishing Vessel Nautical Twilight - Vessel B2

Proj. 2017 Oct. 6, 2004 V2.0

Assumptions:
1) Vessel is docked in St. John's during trials preparation period & will sail from St. John's during trial.
2) Vessel has lifesaving gear for up to 4 IOT staff.
3) Vessel operator will be responsible for fueling vessel & acquiring required supplies to operate vessel.

Preliminary Preparations:

1) Fit out vessel with instrumentation as per instrumentation plan.
2) Set displacement condition roughly half load condition - this will require loading ice ballast.
Press up water & fuel tanks to minimize free surface.
3) Select location for trials ~ 10 nm off St. John's. Permission from St. John's Traffic Control may be required.
Design/compile mooring for wave buoy once water depth is known (J. Foley/MUN Oceanography).
4) Decision/arrangements required with respect deploying wave buoy prior to trial
5) Issue Notice to Mariners regarding deployment location (Lat., Long) of wave buoy & buoy identification info
(color, dimensions, radar beacon, flashing light etc.)
6) Borrow a cell phone for trials preparation period & sea trial. (687-3541)
7) Determine/record location (X, Y, Z co-ordinates) of GPS antenna relative to some known ship location
8) Determine/record location (X, Y, Z co-ordinates) of MotionPak & any accelerometers relative to some known ship location.
9) Take digital photos of instrumentation/equipment set up.
10) A more complex process will be required for GPS antenna alignment & set up with new GPS system than previously experienced.
11) Carry out inclining experiment with all instrumentation, consumables & ballast in place. Due to the relatively low overall displacement,
trials personnel or equivalent weight of personnel should be aboard vessel during inclining.

Prior to departing port on day of trial:

1) Check all instrumentation and data acquisition system. No IOT generator will be required for AC power.
2) Note draft bow & stern as well as any static list.
3) Record harbour water temperature & salinity at dock.
4) Ensure all freeing ports are open and unobstructed. Ensure all hatches are closed so that any water on deck can not accumulate.
5) Inform CCG traffic control that vessel is going to be on trials, name of vessel, location etc. so that vessels in vicinity can be warned.
6) 10 minute collection of data with mooring lines slack, engine off

At Trials Location - whenever vessel is stopped adjacent to wave buoy (ie: before each forward speed set):

1) Verify Communications with wave buoy & transfer any data files. Use initial wave buoy data to determine Average Wave Direction.
If there is a significant difference between dominant & average wave direction from the buoy, there are probably 2 major sea directions.

Some judgment including visual observation will be required to determine the actual sea direction.
Note the wave buoy outputs sea direction information in deg. Magnetic - roughly 21 deg. (exact number to be determined) deviation from deg. True North)
2) Record sea temperature and salinity information adjacent to wave buoy.
3) Record wind speed and absolute direction.
4) Record estimated sea conditions from visual observation - sea state, direction.
5) Record general weather conditions, - fog, visibility, precipitation.

<u>Execute Runs as per ITTC Recommended Pattern:</u>

For each run, manually record the following information after vessel attained steady state speed/direction:
wind speed/relative direction
engine speed/ shaft speed from any onboard instrumentation
general motion behavior of vessel (heavy roll, pitch etc.)
incidents of slamming, water on deck, spray - is water accumulating on deck?
difficulty for personnel to maintain balance, seasickness
take digital photos during trial of deployed wave buoy, taking salinity readings etc.

Run 1: 2-3 knots, head seas, 25 minutes
Run 2: 2-3 knots, following seas, 40 minutes
Run 3: 2-3 knots, bow sea, 25 minutes
Run 4: 2-3 knots, beam sea, 25 minutes
Run 5: 2-3 knots, quartering sea, 25 minutes
NOTE: that directional stability of vessel may be an issue without trawl deployed
- may have to increase speed.

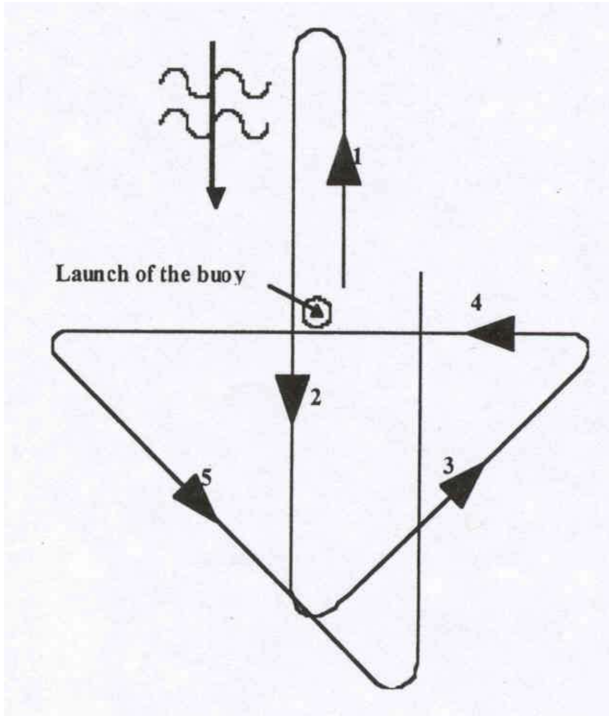
Return to wave buoy location.

Run 6: 8.5 knots, head seas, 25 minutes
Run 7: 8.5 knots, following seas, 40 minutes
Run 8: 8.5 knots, bow sea, 25 minutes
Run 9: 8.5 knots, beam sea, 25 minutes
Run 10: 8.5 knots, quartering sea, 25 minutes

Return to wave buoy location.

Run 11: 0 knots, beam seas, 25 minutes

Return to wave buoy location.



ITTC Recommended Run Pattern
ITTC Procedures Book, 22nd ITTC, Sept. 1999.
Run 1: Head Sea
Run 2: Following Sea
Run 3: Bow Sea
Run 4: Beam Sea
Run 5: Quartering Sea

After vessel has returned to dock upon completion of trial:

1) Note draft bow & stern as well as any static list.
2) Record harbour water temperature & salinity at dock.
3) Record fuel, water tank levels.
4) Remove all instrumentation, ballast from vessel.
5) Return borrowed cell phone.
6) Arrange to retrieve wave buoy, return mooring equipment to MUN.

NOTE: 180 deg. is defined as a head sea.
The CCGA Nautical Twilight has an autopilot & thus all non-zero forward speed runs to be carried out on autopilot.

Appendix H
Seakeeping Trials Run Log

Run Log for Seakeeping Trial on CCGA Nautical Twilight- Vessel 'B2'

Fishing Vessel Research Project (Proj. 2017) **Date: Nov 01 2004**

06:30	Drafts; 5' 7" (1.702m) fwd , 78.25" (1.988m) stbd aft, 79" (2.007) port aft down from bulwark	Aft Draft 10' 2" from baseline
	Salinity 28.9 ppt (heavy rain), Sea temp 7.9 C @ dock	Density: 1022.51 kg/m^3
06:45	Departed St. John's	
08:40	Wave buoy deployed 47 32.80N 52 26.199W	
	Salinity 30.4 ppt (heavy rain), Sea temp 8.0 C @ buoy	Density: 1023.67 kg/m^3
13:00	Salinity 30.3 ppt, sea temp 8.1 C @ buoy	Density: 1023.58 kg/m^3
16:30	Wave buoy retrieved	
18:22	Salinity 29.4ppt, 8.0 C at dock	Density: 1022.89 kg/m^3
	Drafts; 5' 6" (1.676m) fwd78.25 (1.988m) stbd aft, 78" (1.981m) port aft down from bulwark	Aft Draft 10' 2" from baseline

Run #	File Name	Start Finish Time	Course Relative to Incident Waves	Location Start/Finish Latitude deg N	Long. deg W	Nominal SWH (m)	Nominal Period (s)	SOG (kts.)	COG (Deg. TRUE)	Wind Speed (kts.)	Wind Direction (Deg. Mag.)	Engine Rpm	Shaft Rpm	Comments:
														apparent wave height 2 m, light wind chop
1	Beam_drift_20041101084833.csv	08:48	beam drift	47.5458	52.4369	1.74	10.89	N/A	N/A	6	10	N/A	0	Rain, good vis
		09:13		47.5424	52.4383									MUN Kinesiology crew sea sick
2	Head_20041101093602.csv	09:36	head	47.5450	52.4459	1.74	10.89	4.0	263	14	230	670	167	apparent wave direction ~180!
		10:01		47.5395	52.4854									
3	fol_20041101100633.csv	10:06	following	47.5404	52.4804	1.76	5.63	4.3	083	2	340	650	184	apparent wave direction ~180
		10:46		47.5471	52.4169									buoy: 241.9 dominant, -110.2 average (magnetic)
4	bow_20041101105259.csv	10:53	bow	47.5504	52.4214	1.97	10.89	4.0	308	6	190	810	177	rain stopped
		11:18		47.6161	52.4521									apparent beam sea
5	beam_20041101112356.csv	11:23	beam	47.5627	52.4520	1.97	10.89	4.0	173	6	300	811	177	appears to be a head sea. Splashing over bow
		11:48		47.5359	52.4491									some sea sickness
6	quart_20041101115425.csv	11:54	quartering	47.5351	52.4453	1.83	6.87	4.0	038	3	30	875	191	seas on stbd stern quarter
		12:19		47.5600	52.4211									

CCGA Nautical Twilight Seakeeping Trials

Run #	File Name	Start Finish Time	Course Relative to Incident Waves	Location Start/Finish Latitude deg N	Long. deg W	Nominal SWH (m)	Nominal Period (s)	SOG (kts.)	COG (Deg. TRUE)	Wind Speed (kts.)	Wind Direction (Deg. Mag.)	Engine Rpm	Shaft Rpm	Comments:
7	beam_drift_20041101124520.csv	12:45	beam drift	47.5466	52.4360	2.04	6.87	N/A	N/A	9	190	N/A	0	brief rain squalls, fog
		13:10		47.5458	52.4359									
8	Head_20041101131645.csv	13:16	head	47.5443	52.4434	2.09	6.87	7.8	259	12	230	1450	325	fog, apparent port beam sea
		13:41		47.5315	52.5201									
9	fol_20041101134527.csv	13:45	following	47.5323	52.5166	1.96	6.87	7.8	079	9	0	1460	320	fog, apparent stbd beam sea
		14:25		47.5482	52.3932									some slamming, kinesiology crew up and about
														kinesiology crew down again
10	bow_20041101143014.csv	14:30	bow	47.5503	52.3926	1.88	7.42	7.5	304	5	250	1490	325	heavy fog
		14:55		47.5748	52.4548									apparent sea on port aft quarter
														fog
11	beam_20041101145953.csv	14:59	beam	47.5733	52.4569	1.88	7.42	7.9	169	7	290	1490	325	apparent head sea
		15:24		47.5171	52.4386									spray over the bow
12	quart_20041101153615.csv	15:36	quartering	47.5225	52.4298	2.03	7.42	7.5	034	5	330	1505	328	apparent stbd aft quarter sea
		16:01		47.5653	52.3898									fog lifted

Wind speed is provided relative in knots, wind direction is magnetic deg.

SOG - Speed Over Ground COG - Course Over Ground SWH - Significant Wave Height (m) - from Neptune directional wave buoy N/A - not applicable

Nominal wave period is taken as dominant wave period from Neptune directional wave buoy.

Trial carried out around moored Neptune directional wave buoy nominally 10 nm east of St. John's, NL in 165 m of water approx. @ 47 32.80 North (Lat.) and 52 26.199 West (Long.).

CCGA Nautical Twilight used a single flat plate section rudder and a single, 4 bladed propeller. No anti-roll device fitted

The difference between deg. magnetic and deg. TRUE was approximately 20.94 deg Thus True Direction = Mag - 21 deg.

Auto pilot controlled by magnetic compass

Deck stayed very dry for entire trial.

Neptune buoy only recorded once per hour form 0900 to 1200, every half hour afterwards.

Two MUN Kinesiology students unable to collect MII data due to seasickness.

Apparent direction of waves 90 degrees < direction given by Neptune wave buoy

Potable water tanks only approximately 1/2 full, no way to sound.

Aft drafts measured down from aft bulwark as draft marks covered by stainless sheeting, converted to drafts from baseline by measuring G.A. drawing

OCEANS Ltd. Datawell wave buoy moored at position: 47 34.126 N 52 26.154 W, in 165 metres of water

CCGA Nautical Twilight moored Canadian Coast Guard base St. John's.

Appendix I
Summary Wave Statistics, Non-dimensional Spectrum Plots, and Mean Wave Direction vs. Frequency Plots From The Directional Wave Buoys

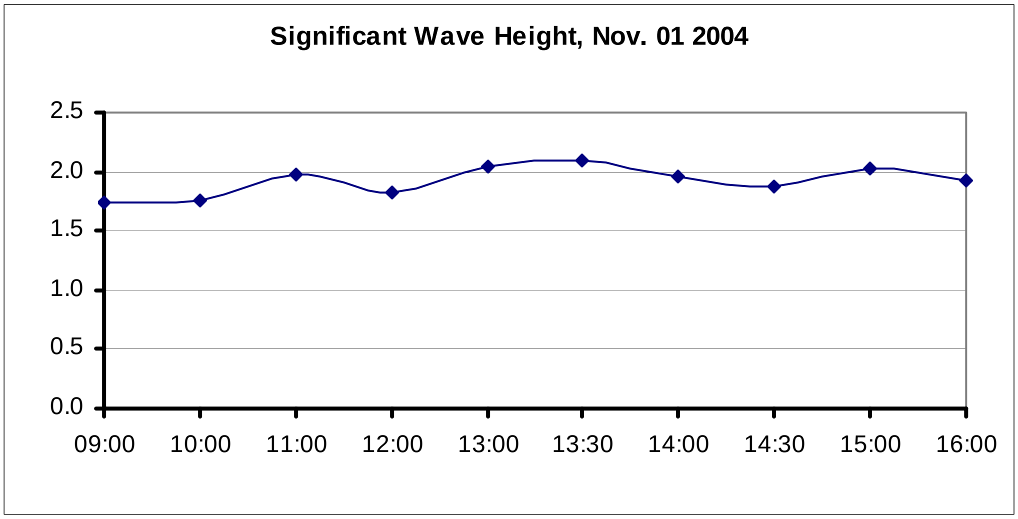
Summary of Wave Statistics Collected Using Neptune Directional Wave Buoy

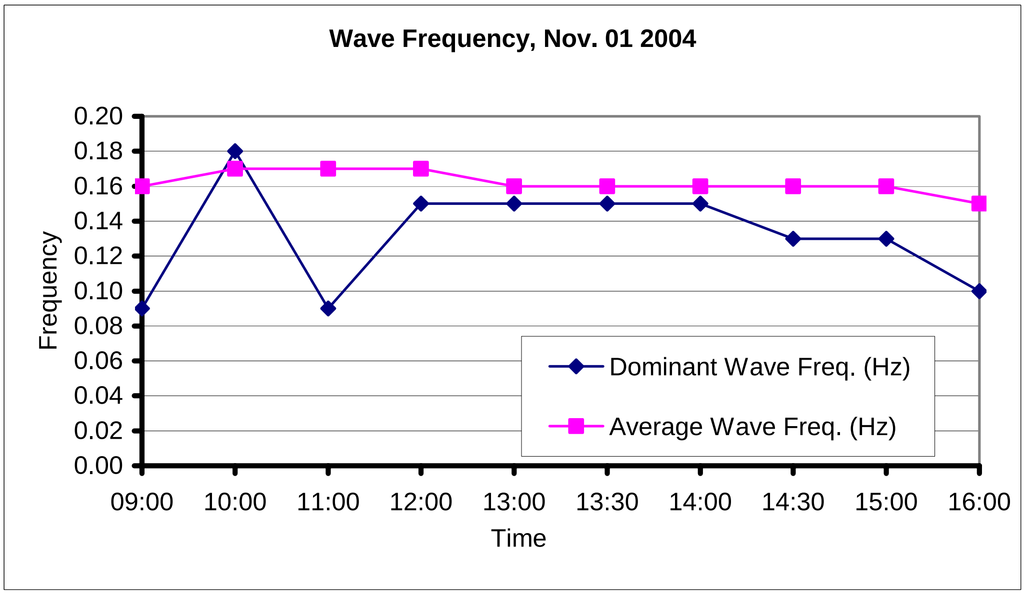
CCGA Nautical Twilight **Fishing Vessel Research Proj. 2017**
November 01, 2004

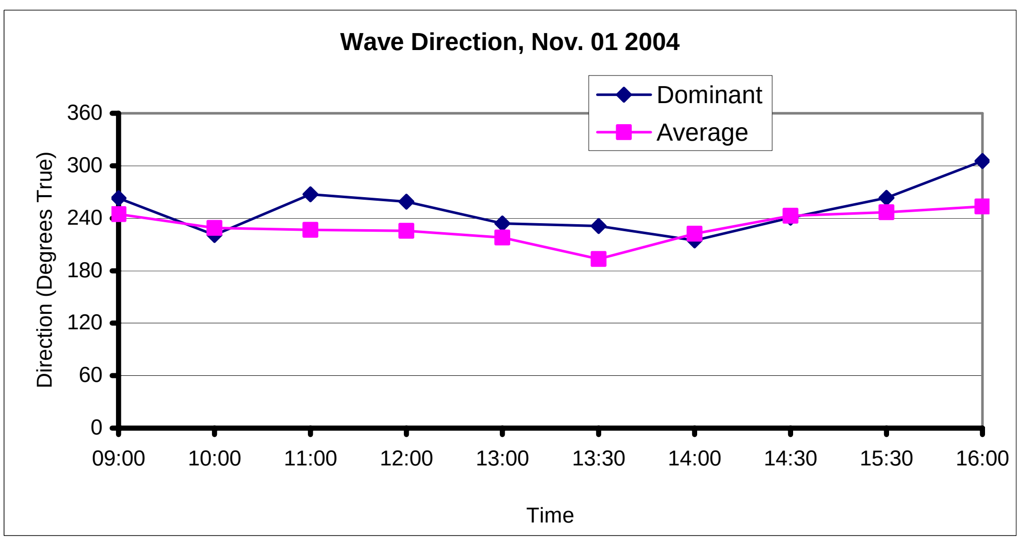
NF Time	Sig. Wave Height (m)	Dominant Wave Freq. (Hz)	Average Wave Freq. (Hz)	Dominant Wave Period (s)	Average Wave Period (s)	Dominant Wave Dir. (deg. mag.)	Average Wave Dir. (deg. mag.)	Dominant Wave Dir. (deg. TRUE)	Average Wave Dir. (deg. TRUE)
09:00	1.74	0.09	0.16	10.89	6.20	284.00	-94.50	263.00	-115.50
10:00	1.76	0.18	0.17	5.63	5.95	241.90	-110.20	220.90	-131.20
11:00	1.97	0.09	0.17	10.89	6.04	288.40	-112.20	267.40	-133.20
12:00	1.83	0.15	0.17	6.87	5.89	279.90	-113.40	258.90	-134.40
13:00	2.04	0.15	0.16	6.87	6.11	254.90	-121.20	233.90	-142.20
13:30	2.09	0.15	0.16	6.87	6.30	252.10	-145.60	231.10	-166.60
14:00	1.96	0.15	0.16	6.87	6.14	235.70	-116.80	214.70	-137.80
14:30	1.88	0.13	0.16	7.42	6.23	261.50	-96.20	240.50	-117.20
15:00	2.03	0.13	0.16	7.42	6.39	284.20	-92.00	263.20	-113.00
16:00	1.93	0.10	0.15	9.75	6.45	326.50	-85.40	305.50	-106.40

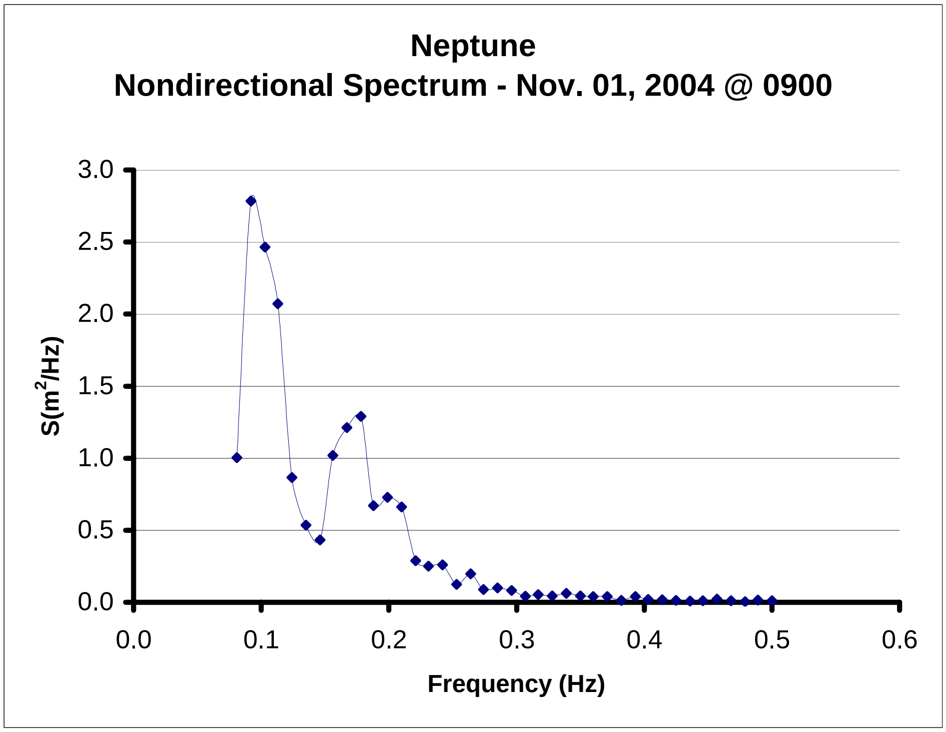
Note: File for 1200 has a file name time stamp of 1200, but an internal data time of 1230.

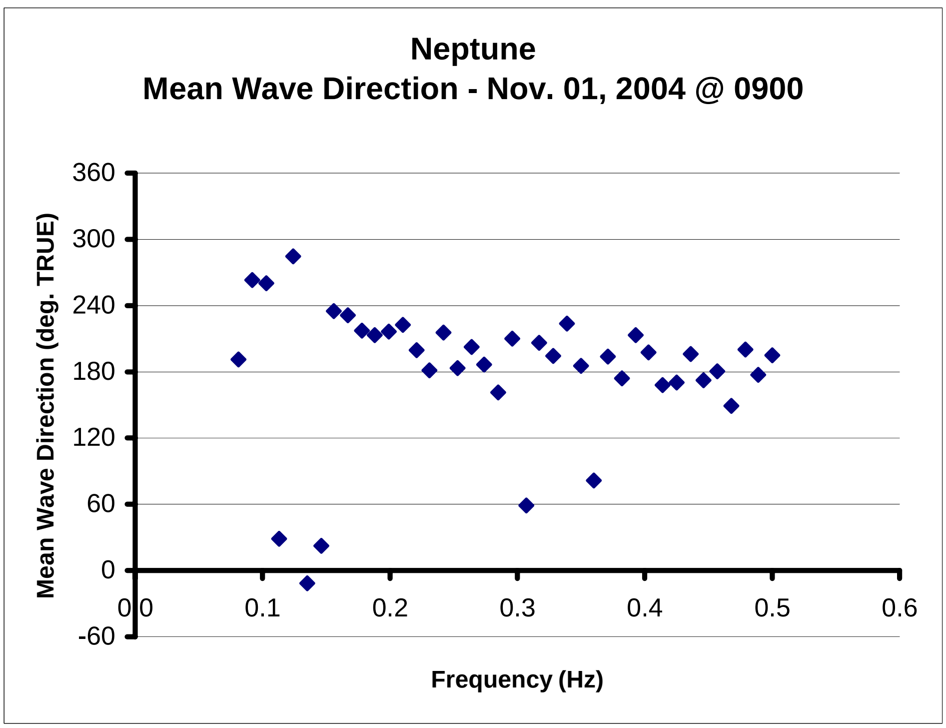
Note: File for 1500 has a file name time stamp of 1500, but an internal data time of 1530.

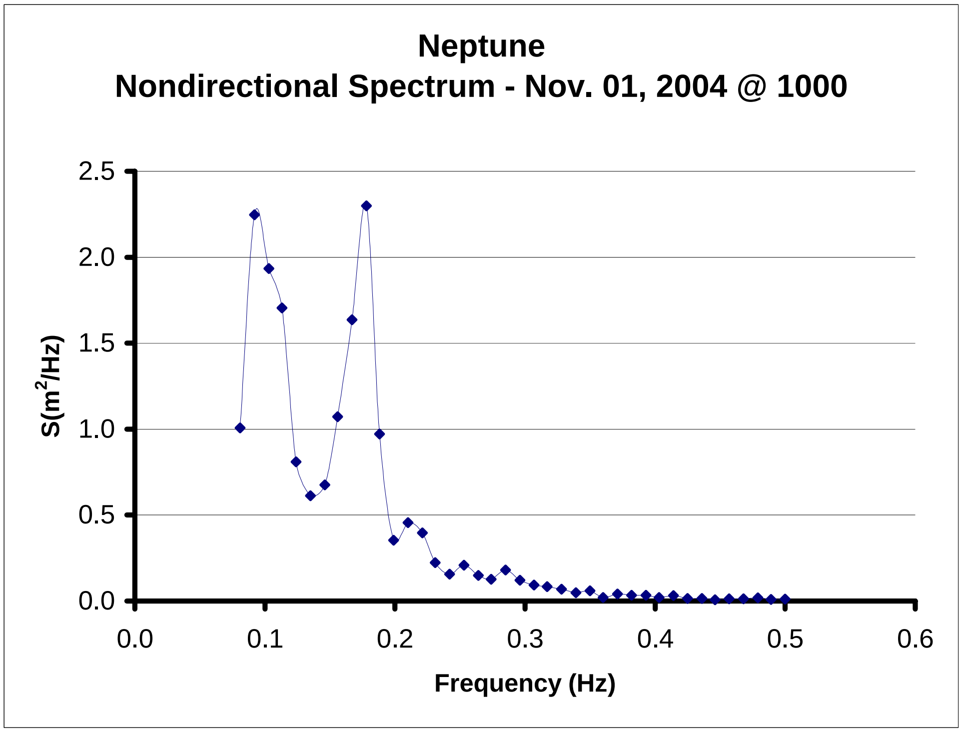

Significant Wave Height, Nov. 01 2004
2.5
2.0
1.5
1.0
0.5
0.0
09:00
10:00
11:00
12:00
13:00
13:30
14:00
14:30
15:00
16:00

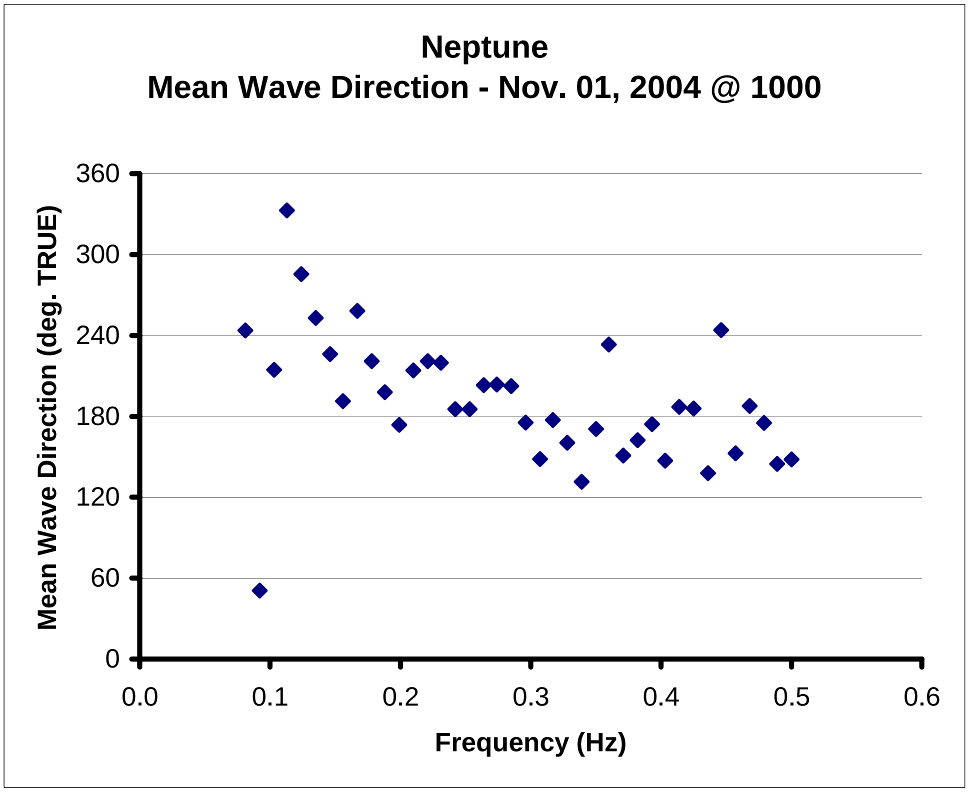

Wave Frequency, Nov. 01 2004
Frequency
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Dominant Wave Freq. (Hz)
Average Wave Freq. (Hz)
09:00
10:00
11:00
12:00
13:00
13:30
14:00
14:30
15:00
16:00
Time

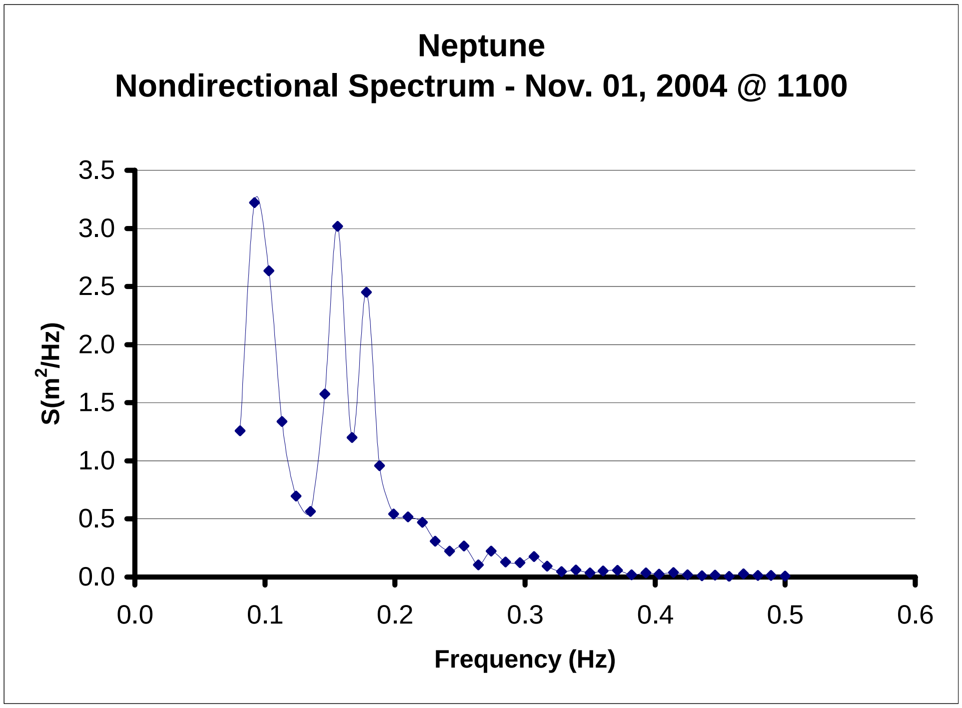

Wave Direction, Nov. 01 2004
Dominant
Average
Direction (Degrees True)
360
300
240
180
120
60
0
09:00
10:00
11:00
12:00
13:00
13:30
14:00
14:30
15:30
16:00
Time

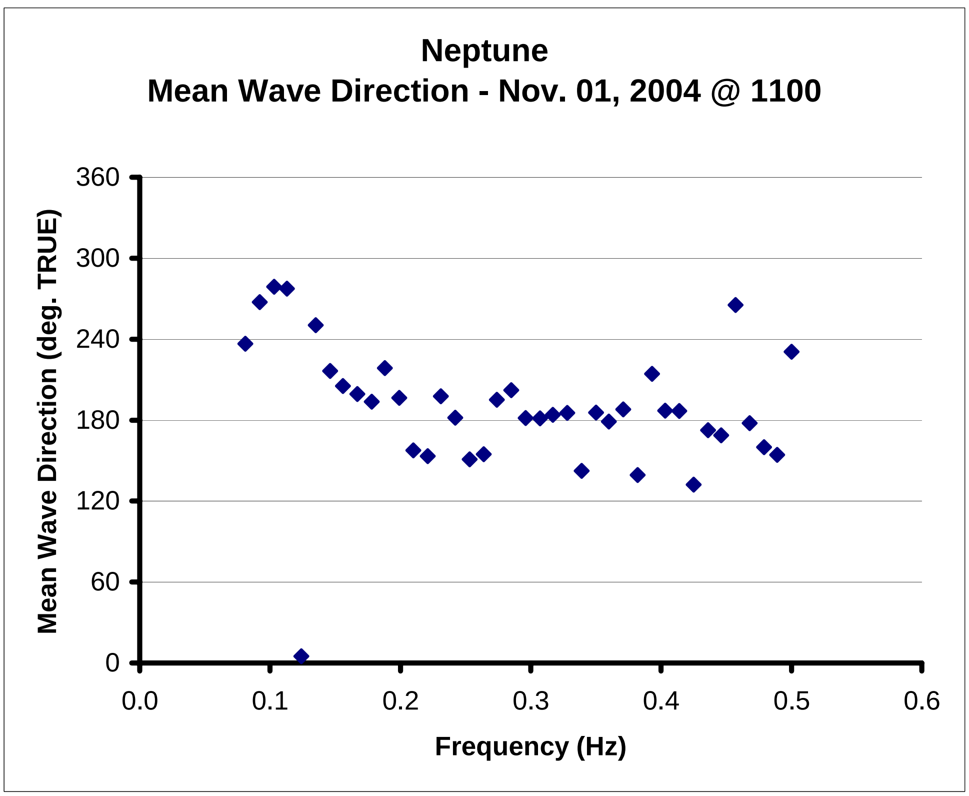

Neptune
Nondirectional Spectrum - Nov. 01, 2004 @ 0900
S(m2/Hz)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Frequency (Hz)

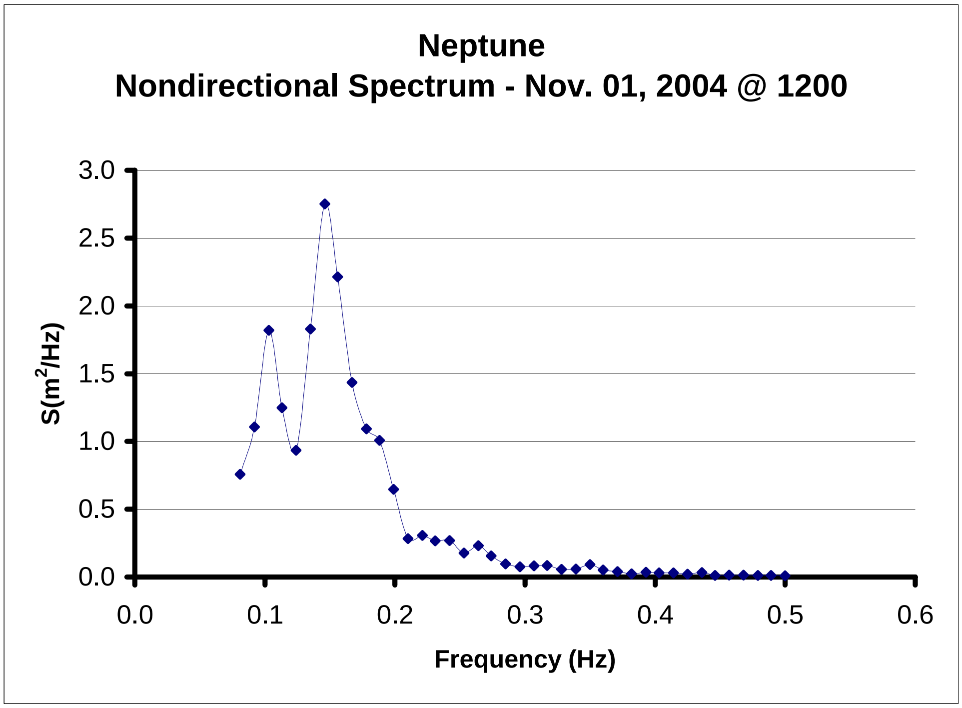

Neptune
Mean Wave Direction - Nov. 01, 2004 @ 0900
Mean Wave Direction (deg. TRUE)
360
300
240
180
120
60
0
-60
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Frequency (Hz)

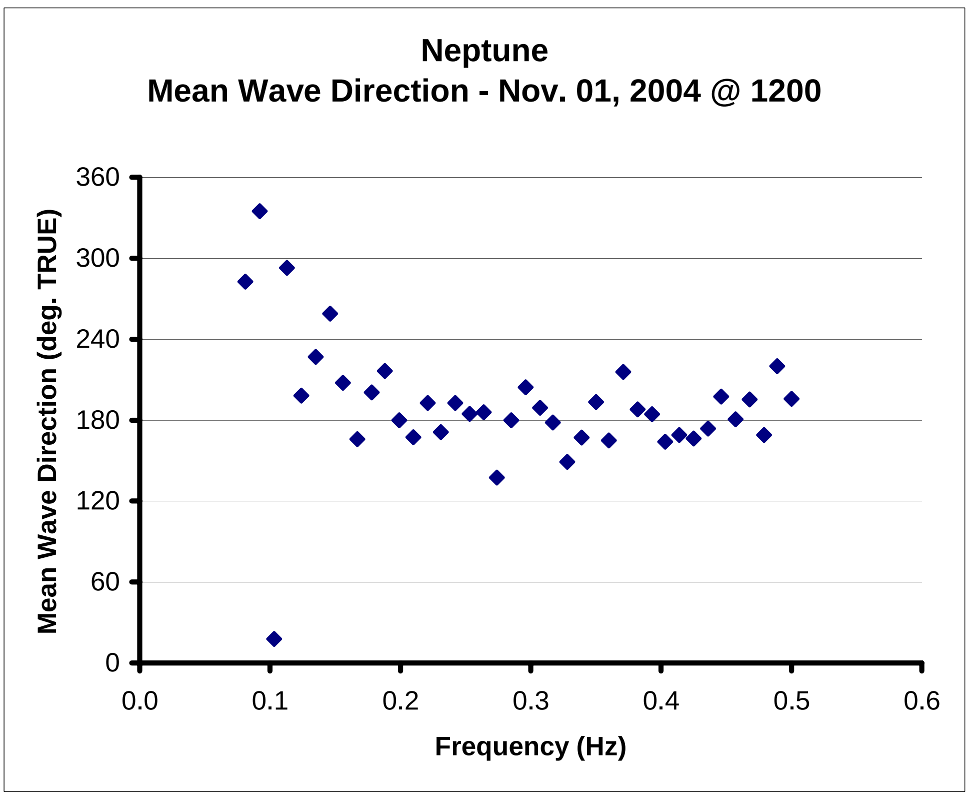

Neptune
Nondirectional Spectrum - Nov. 01, 2004 @ 1000
S(m²/Hz)
2.5
2.0
1.5
1.0
0.5
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Frequency (Hz)

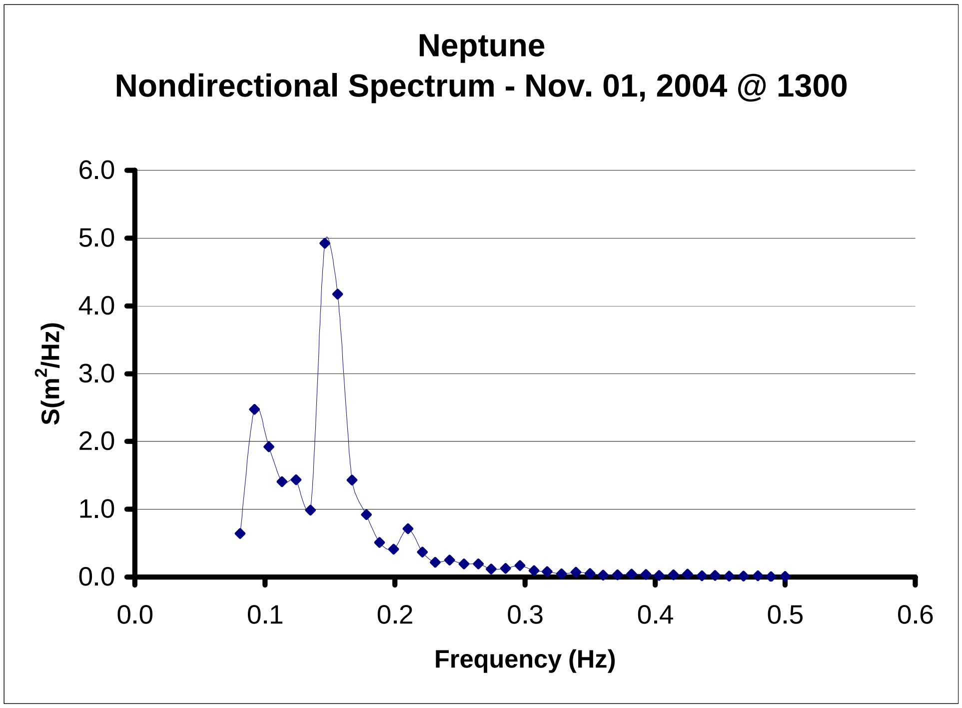

Neptune
Mean Wave Direction - Nov. 01, 2004 @ 1000
Mean Wave Direction (deg. TRUE)
360
300
240
180
120
60
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Frequency (Hz)

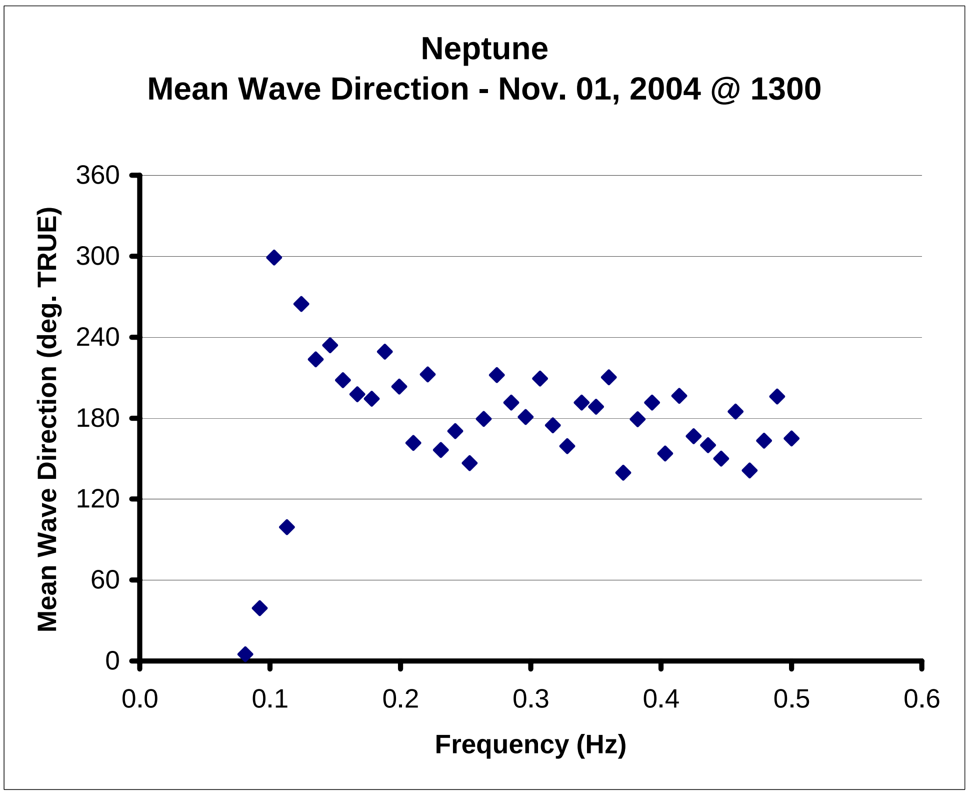

Neptune
Nondirectional Spectrum - Nov. 01, 2004 @ 1100
S(m²/Hz)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Frequency (Hz)

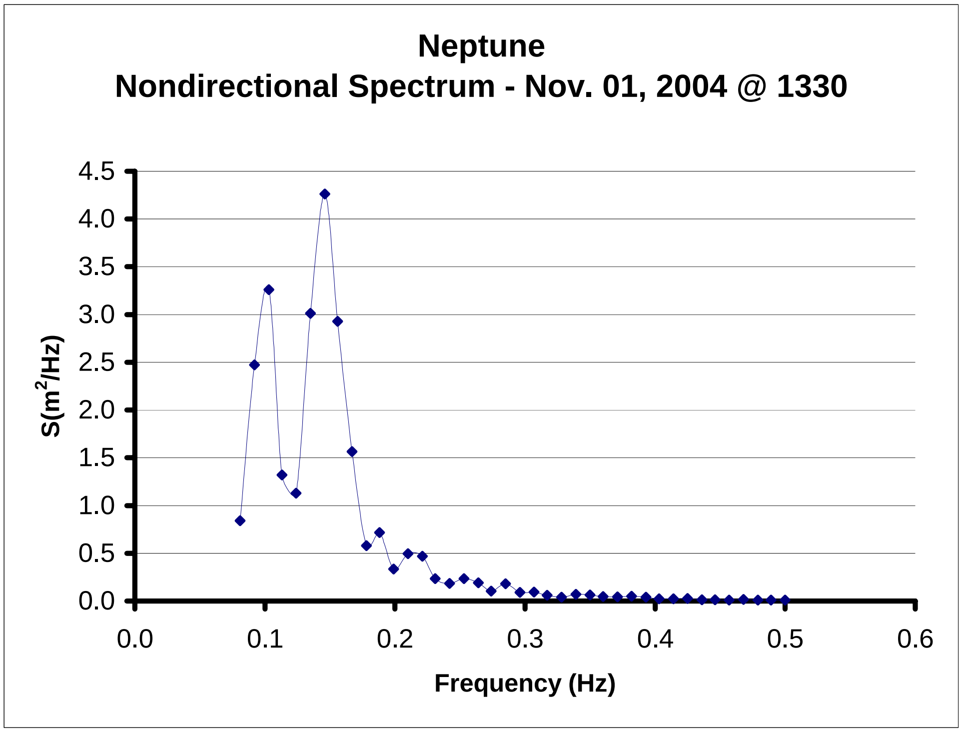

Neptune
Mean Wave Direction - Nov. 01, 2004 @ 1100
Mean Wave Direction (deg. TRUE)
360
300
240
180
120
60
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Frequency (Hz)

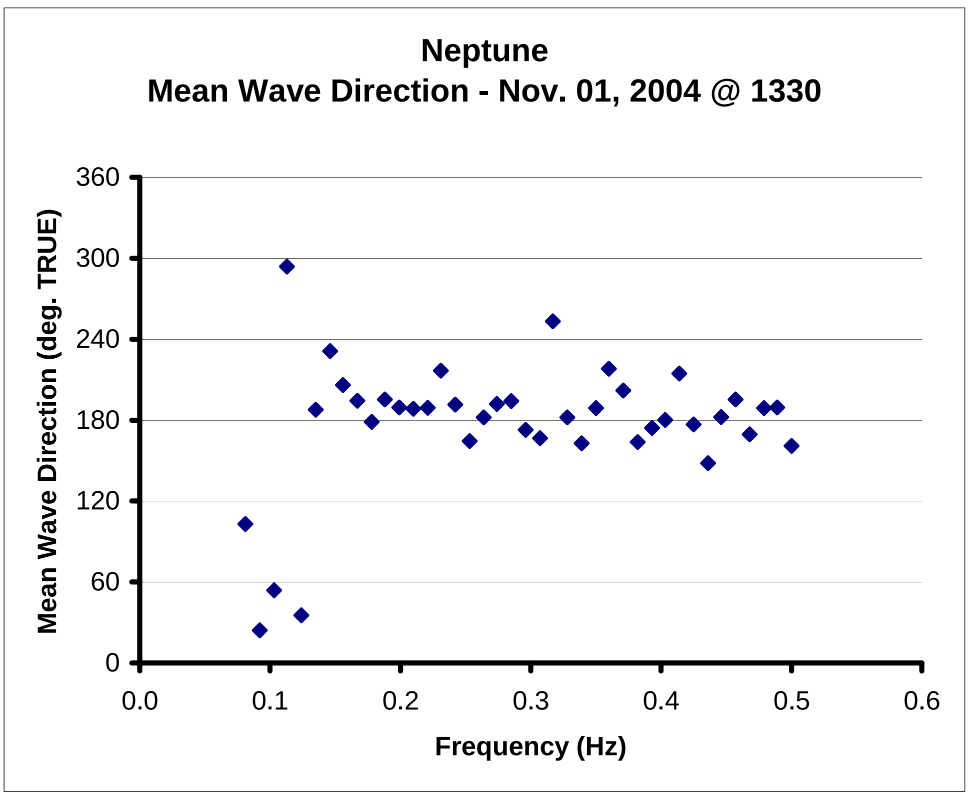

Neptune
Nondirectional Spectrum - Nov. 01, 2004 @ 1200
S(m2/Hz)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Frequency (Hz)

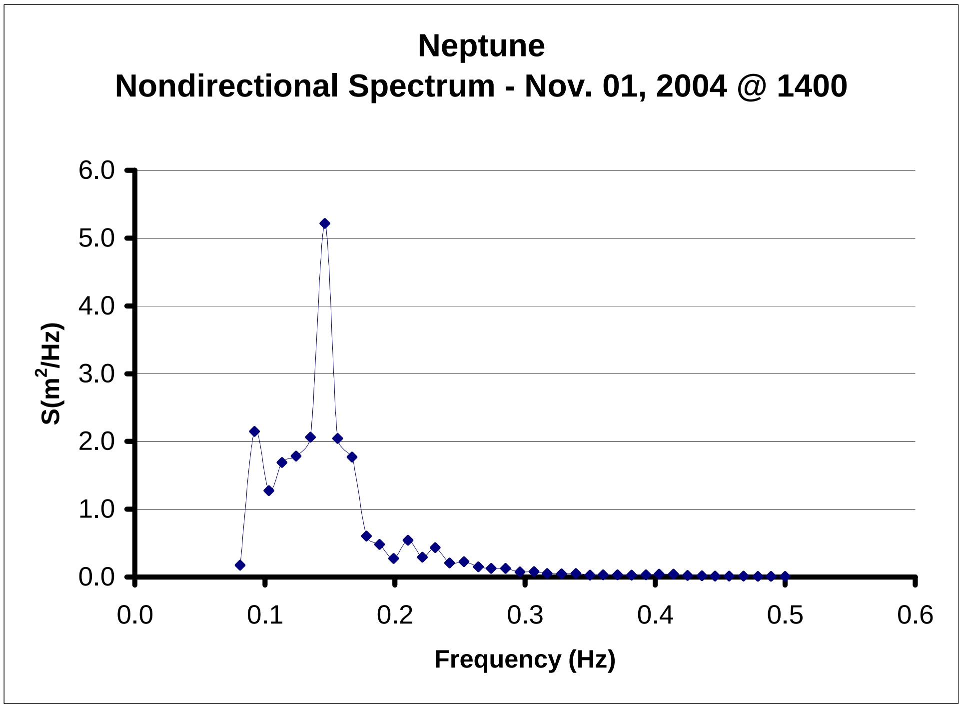

Neptune
Mean Wave Direction - Nov. 01, 2004 @ 1200
Mean Wave Direction (deg. TRUE)
360
300
240
180
120
60
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Frequency (Hz)

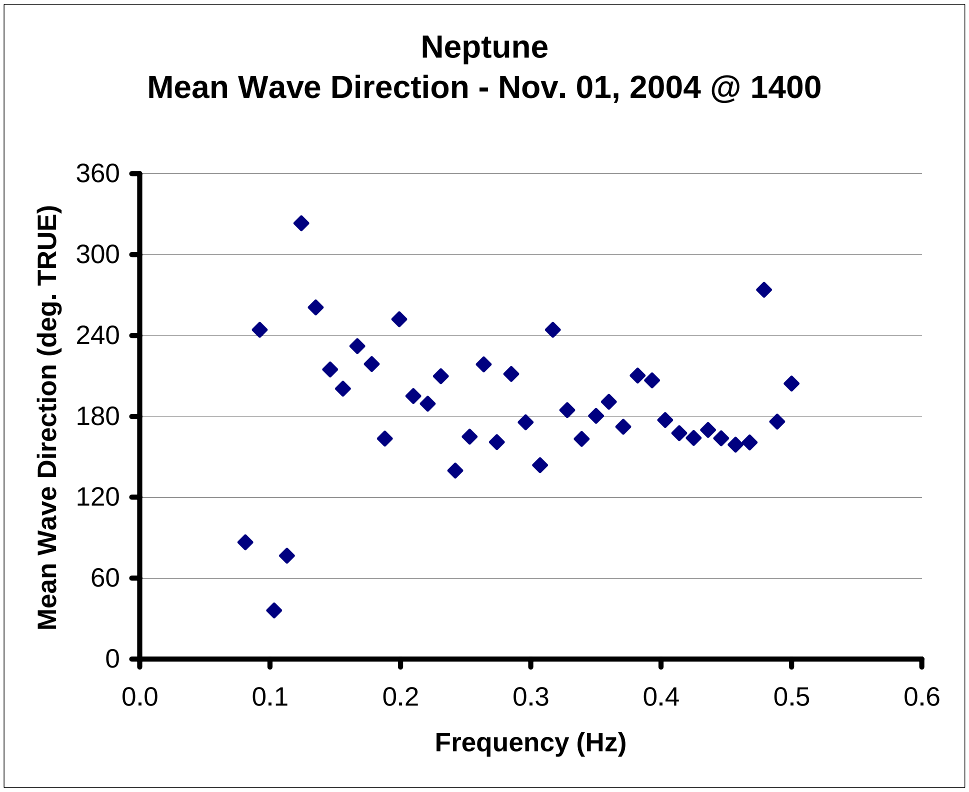

Neptune
Nondirectional Spectrum - Nov. 01, 2004 @ 1300
S(m2/Hz)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Frequency (Hz)

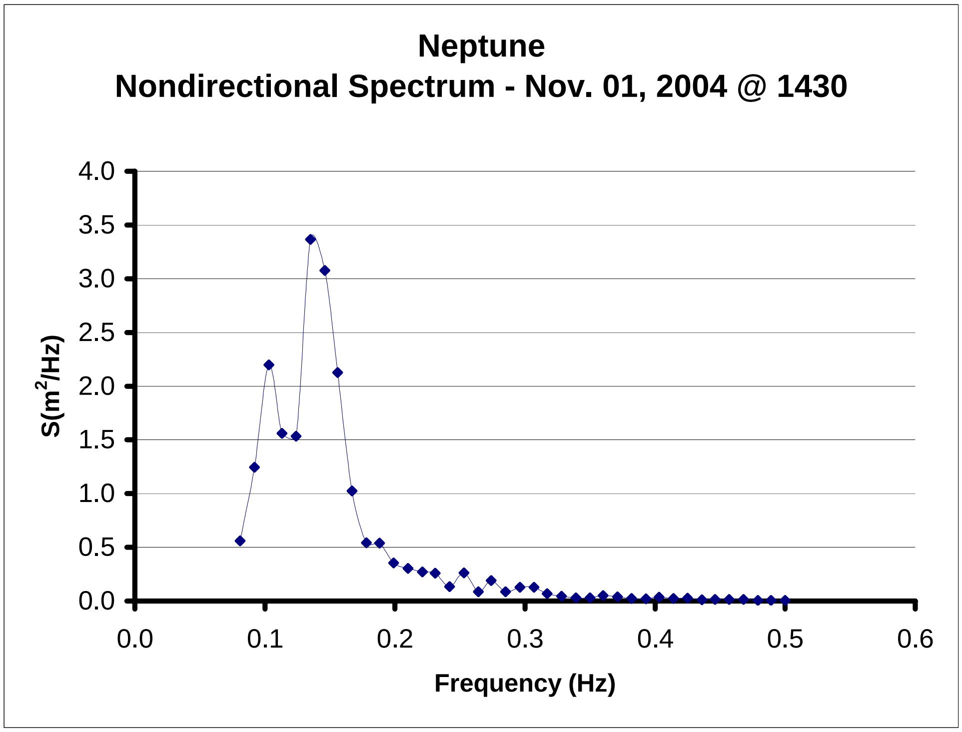

Neptune
Mean Wave Direction - Nov. 01, 2004 @ 1300
Mean Wave Direction (deg. TRUE)
360
300
240
180
120
60
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Frequency (Hz)

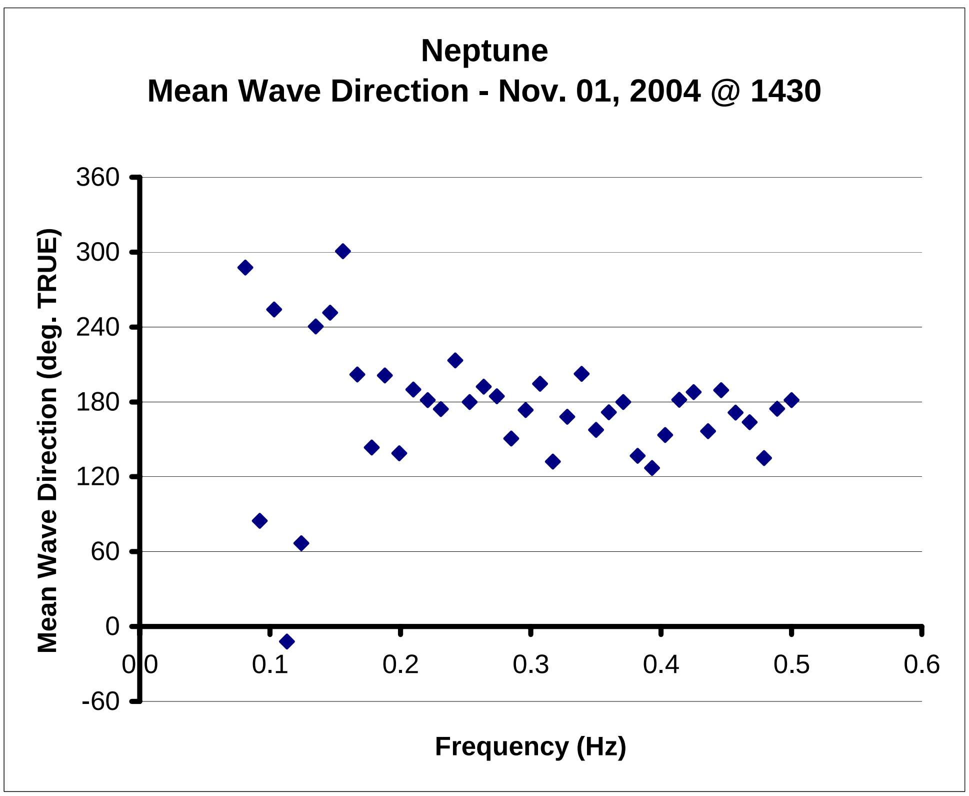

Neptune
Nondirectional Spectrum - Nov. 01, 2004 @ 1330
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
S(m2/Hz)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Frequency (Hz)

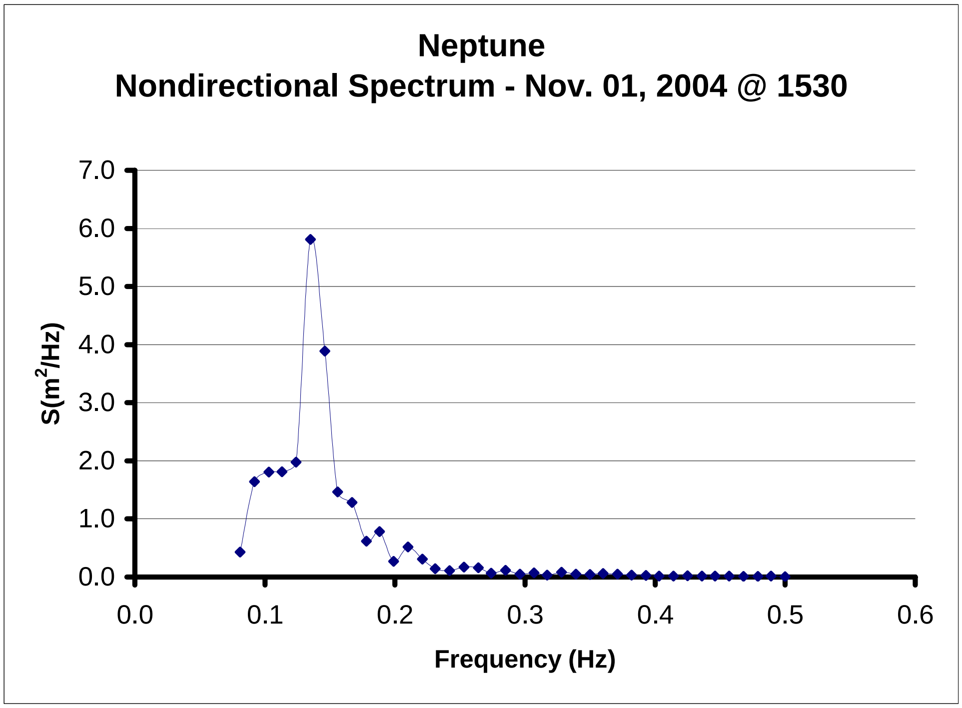

Neptune
Mean Wave Direction - Nov. 01, 2004 @ 1330
360
300
240
180
120
60
0
Mean Wave Direction (deg. TRUE)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Frequency (Hz)

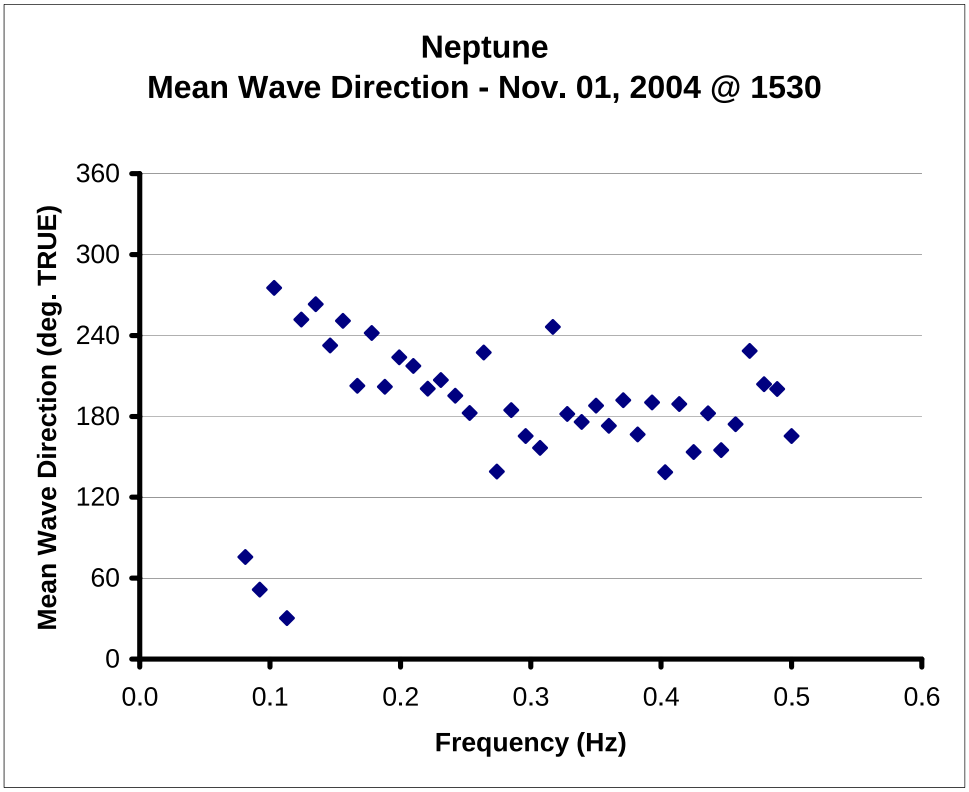

Neptune
Nondirectional Spectrum - Nov. 01, 2004 @ 1400
S(m²/Hz)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Frequency (Hz)

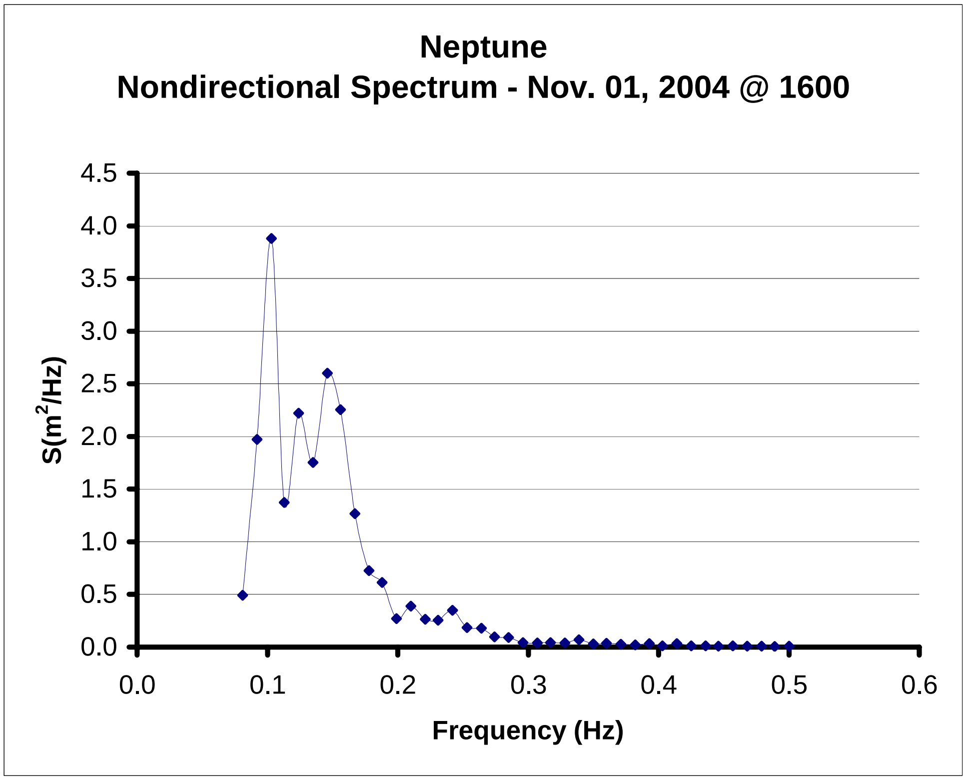

Neptune
Mean Wave Direction - Nov. 01, 2004 @ 1400
Mean Wave Direction (deg. TRUE)
360
300
240
180
120
60
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Frequency (Hz)

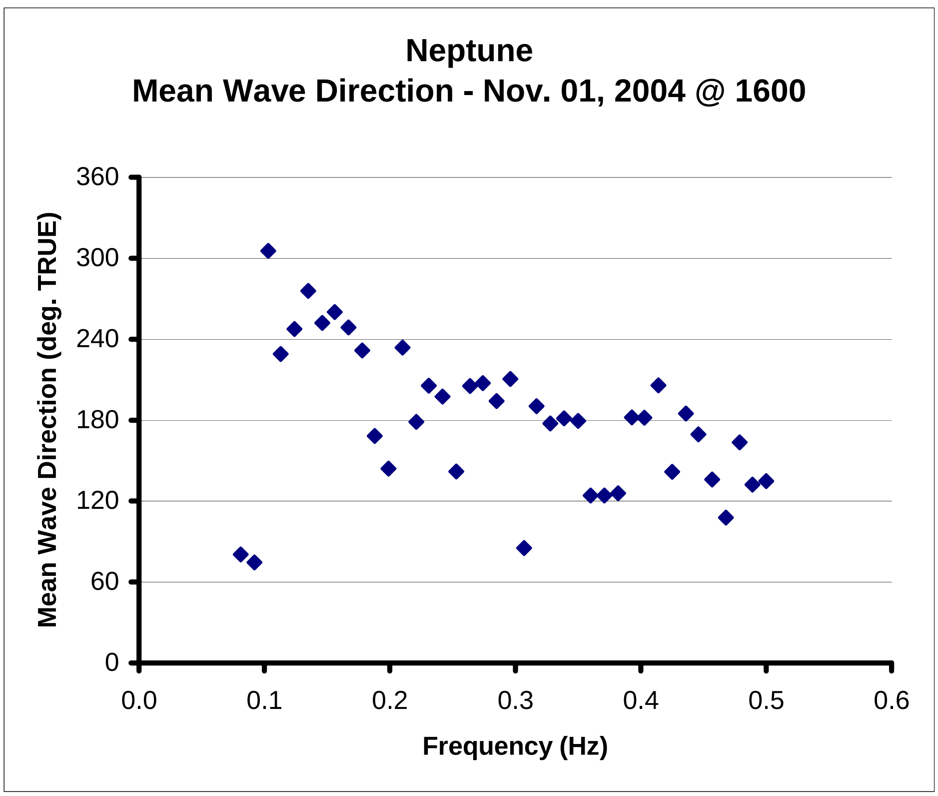

Neptune
Nondirectional Spectrum - Nov. 01, 2004 @ 1430
S(m2/Hz)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Frequency (Hz)


Neptune
Mean Wave Direction - Nov. 01, 2004 @ 1430
Mean Wave Direction (deg. TRUE)
360
300
240
180
120
60
0
-60
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Frequency (Hz)


Neptune
Nondirectional Spectrum - Nov. 01, 2004 @ 1530
S(m2/Hz)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Frequency (Hz)


Neptune
Mean Wave Direction - Nov. 01, 2004 @ 1530
Mean Wave Direction (deg. TRUE)
360
300
240
180
120
60
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Frequency (Hz)

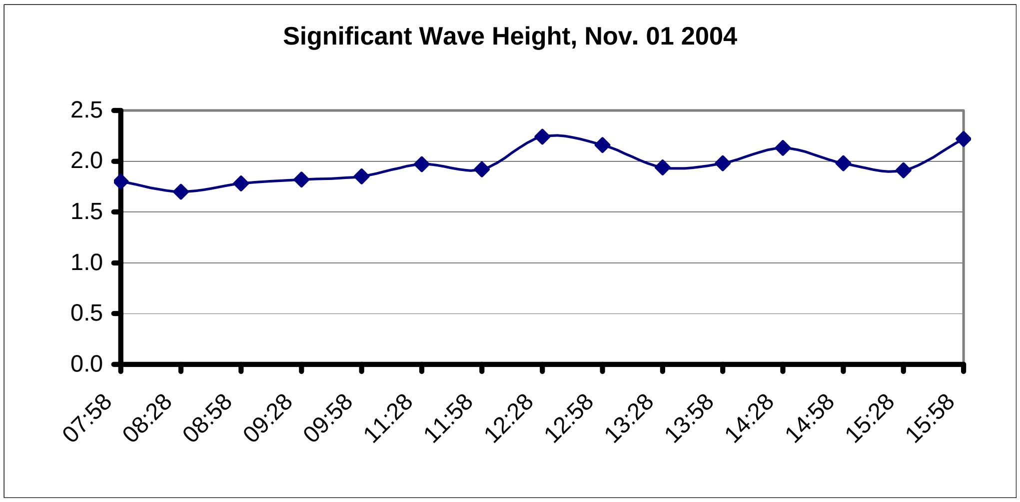

Neptune
Nondirectional Spectrum - Nov. 01, 2004 @ 1600
S(m2/Hz)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Frequency (Hz)

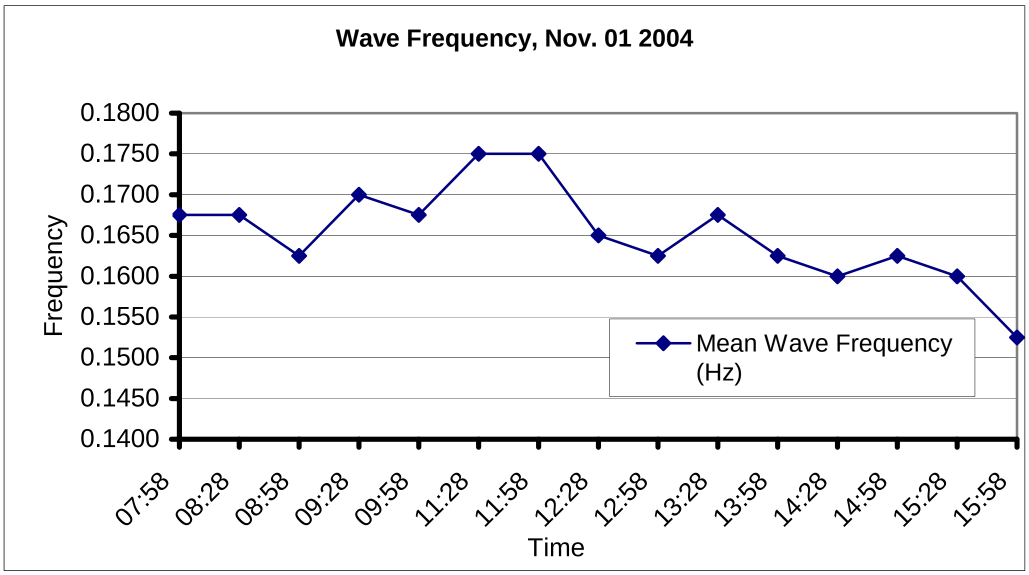

Neptune
Mean Wave Direction - Nov. 01, 2004 @ 1600
Mean Wave Direction (deg. TRUE)
360
300
240
180
120
60
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Frequency (Hz)

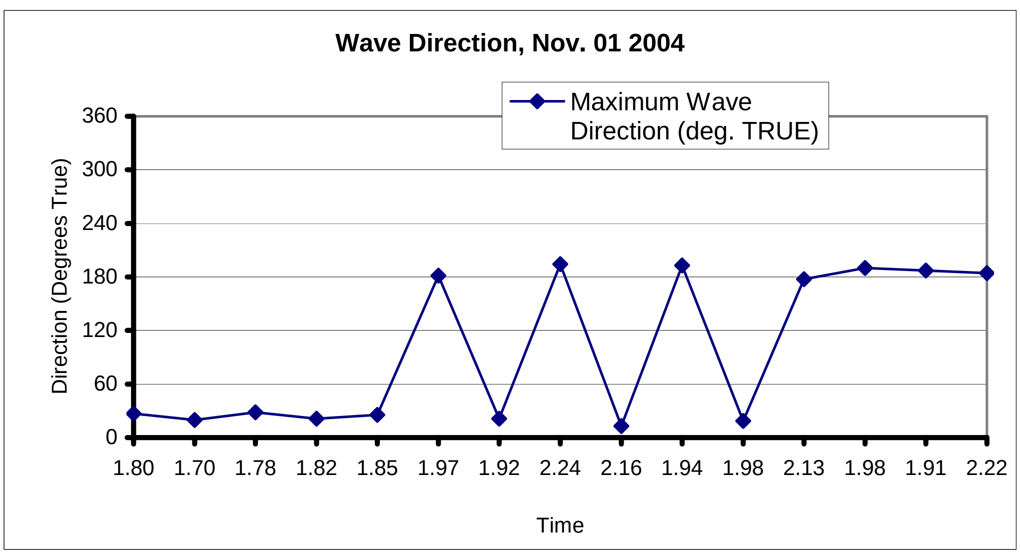
Summary of Wave Statistics Collected Using Datawell Directional Wave Buoy

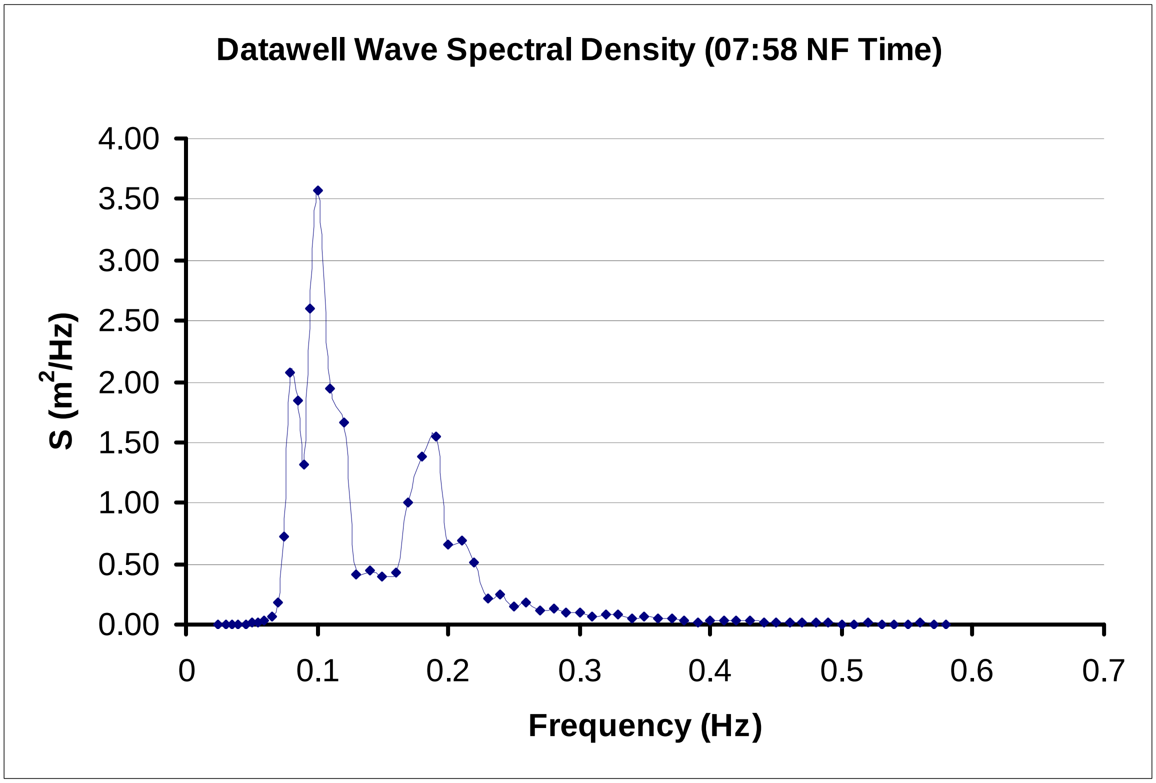
CCGA Nautical Twilight **Fishing Vessel Research Proj. 2017**
November 1, 2004

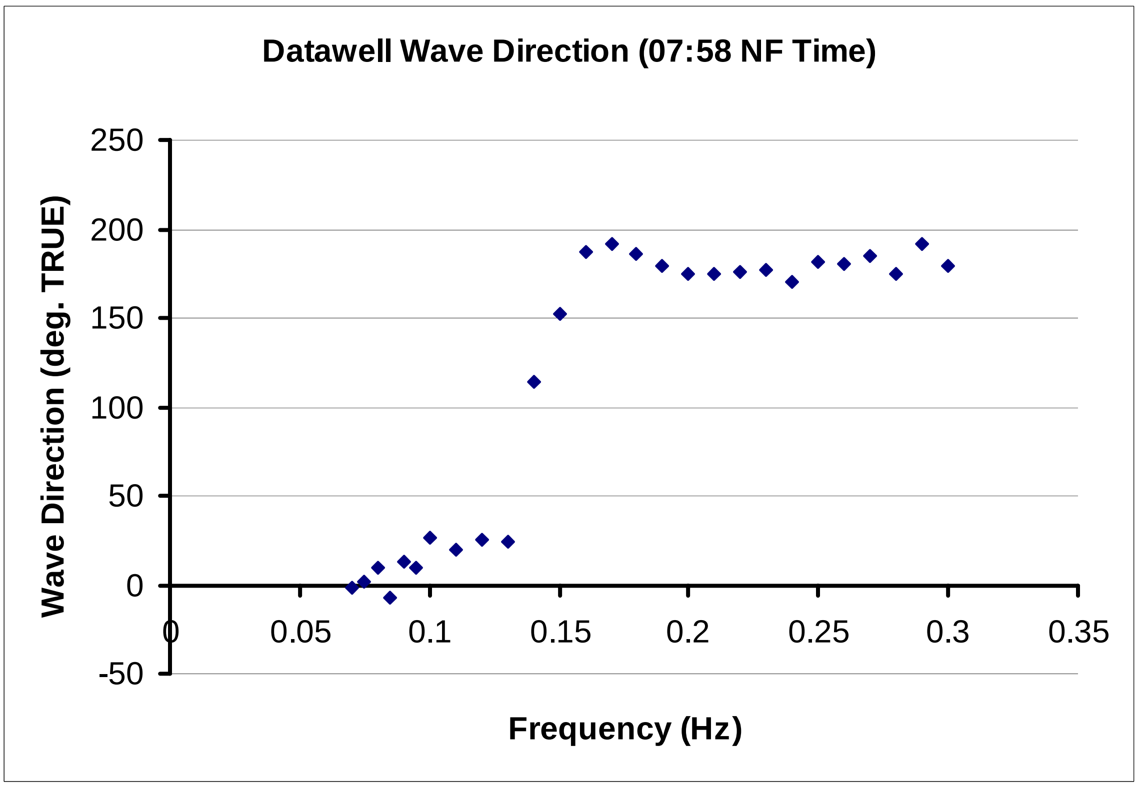
NF Time	Sig. Wave Height (m)	Mean Wave Period (s)	Mean Wave Frequency (Hz)	Maximum Spectral Density (m^2/Hz)	Maximum Wave Direction (deg. TRUE)
07:58	1.80	5.97	0.1675	3.57	26.91
08:28	1.70	5.97	0.1675	3.71	19.88
08:58	1.78	6.15	0.1625	4.42	28.32
09:28	1.82	5.88	0.1700	5.43	21.29
09:58	1.85	5.97	0.1675	3.60	25.51
11:28	1.97	5.71	0.1750	3.31	181.60
11:58	1.92	5.71	0.1750	2.54	21.29
12:28	2.24	6.06	0.1650	5.04	194.26
12:58	2.16	6.15	0.1625	4.45	12.85
13:28	1.94	5.97	0.1675	2.92	192.85
13:58	1.98	6.15	0.1625	3.23	18.48
14:28	2.13	6.25	0.1600	4.32	177.38
14:58	1.98	6.15	0.1625	3.06	190.04
15:28	1.91	6.25	0.1600	3.20	187.23
15:58	2.22	6.56	0.1525	4.77	184.41

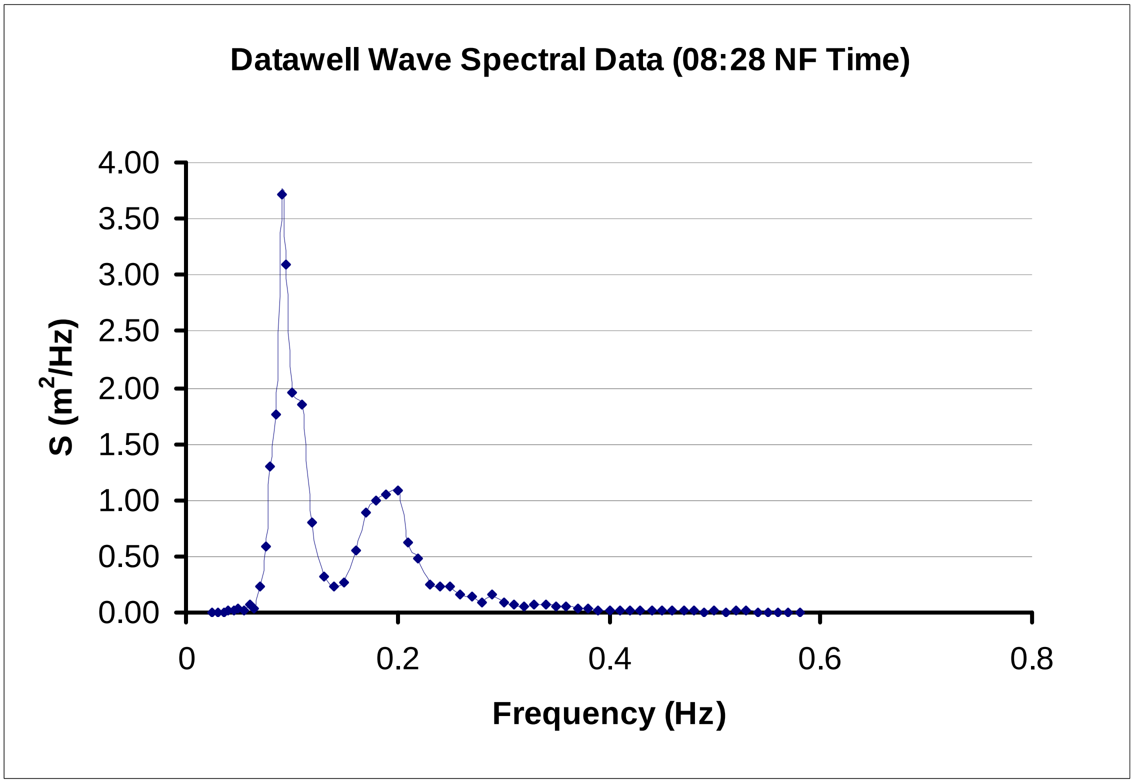

Significant Wave Height, Nov. 01 2004
2.5
2.0
1.5
1.0
0.5
0.0
07:58
08:28
08:58
09:28
09:58
11:28
11:58
12:28
12:58
13:28
13:58
14:28
14:58
15:28
15:58

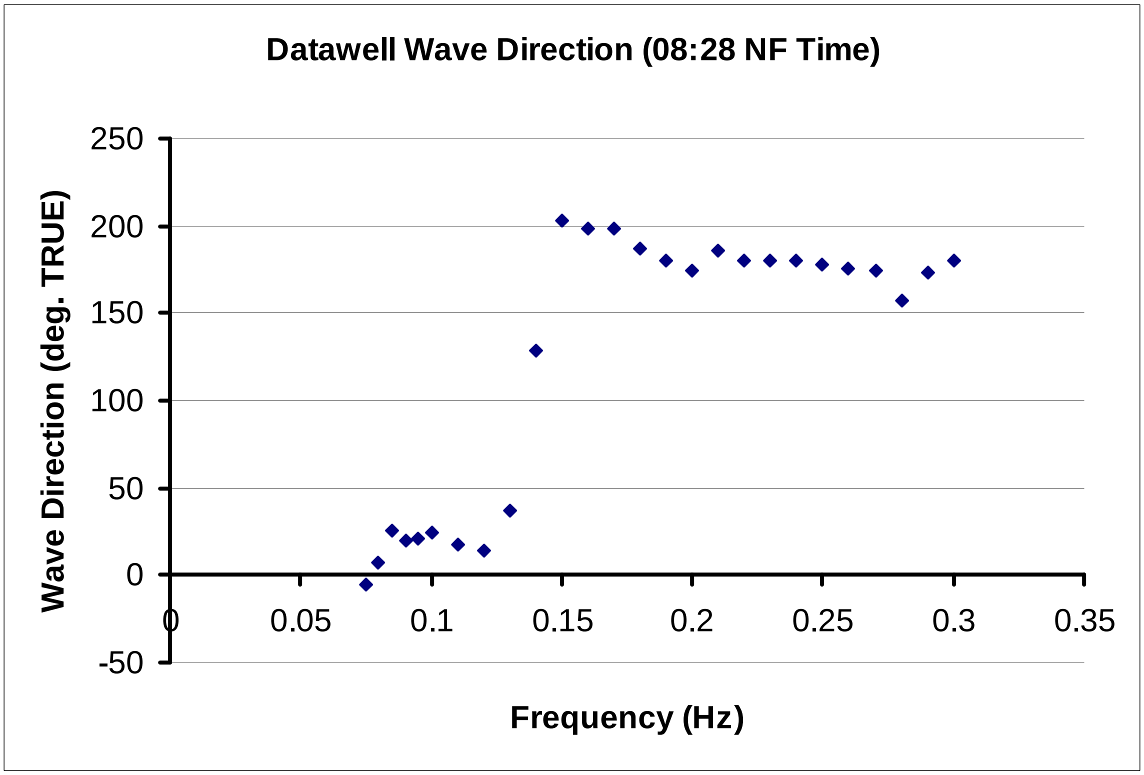

Wave Frequency, Nov. 01 2004
Frequency
0.1800
0.1750
0.1700
0.1650
0.1600
0.1550
0.1500
0.1450
0.1400
Mean Wave Frequency (Hz)
07:58
08:28
08:58
09:28
09:58
11:28
11:58
12:28
12:58
13:28
13:58
14:28
14:58
15:28
15:58
Time

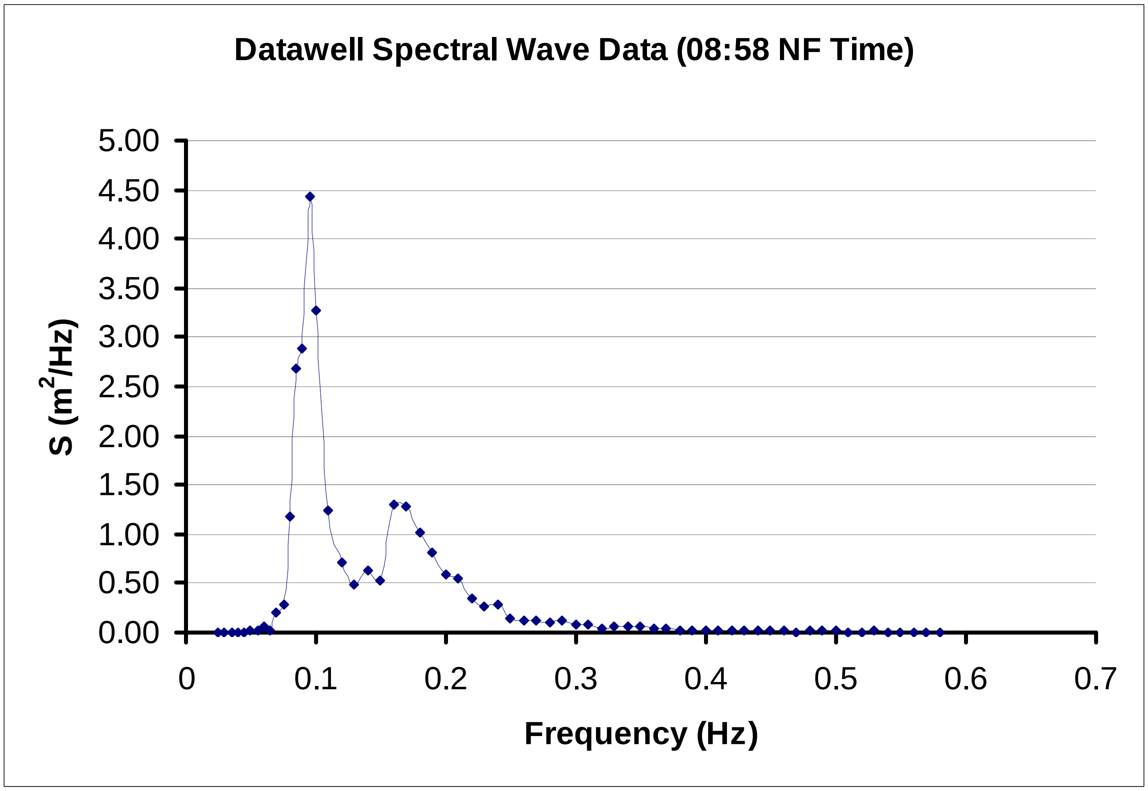

Wave Direction, Nov. 01 2004
Maximum Wave Direction (deg. TRUE)
Direction (Degrees True)
360
300
240
180
120
60
0
1.80
1.70
1.78
1.82
1.85
1.97
1.92
2.24
2.16
1.94
1.98
2.13
1.98
1.91
2.22
Time

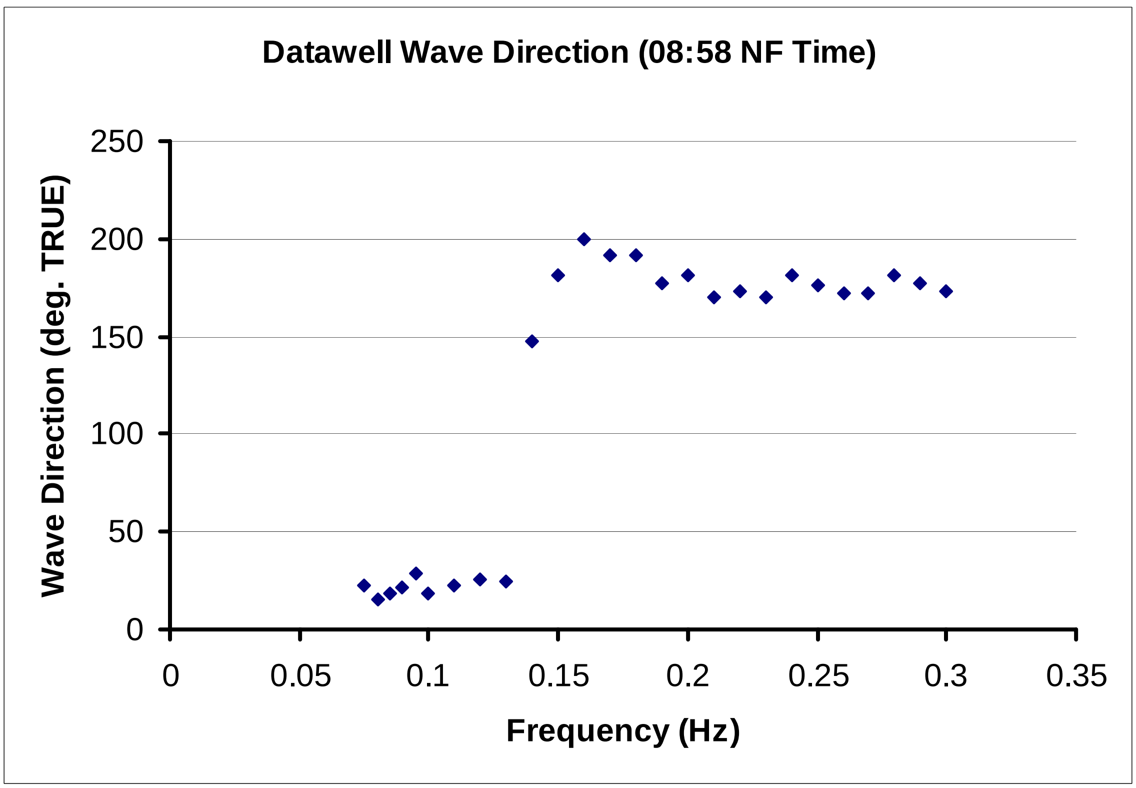

Datawell Wave Spectral Density (07:58 NF Time)
S (m2/Hz)
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Frequency (Hz)

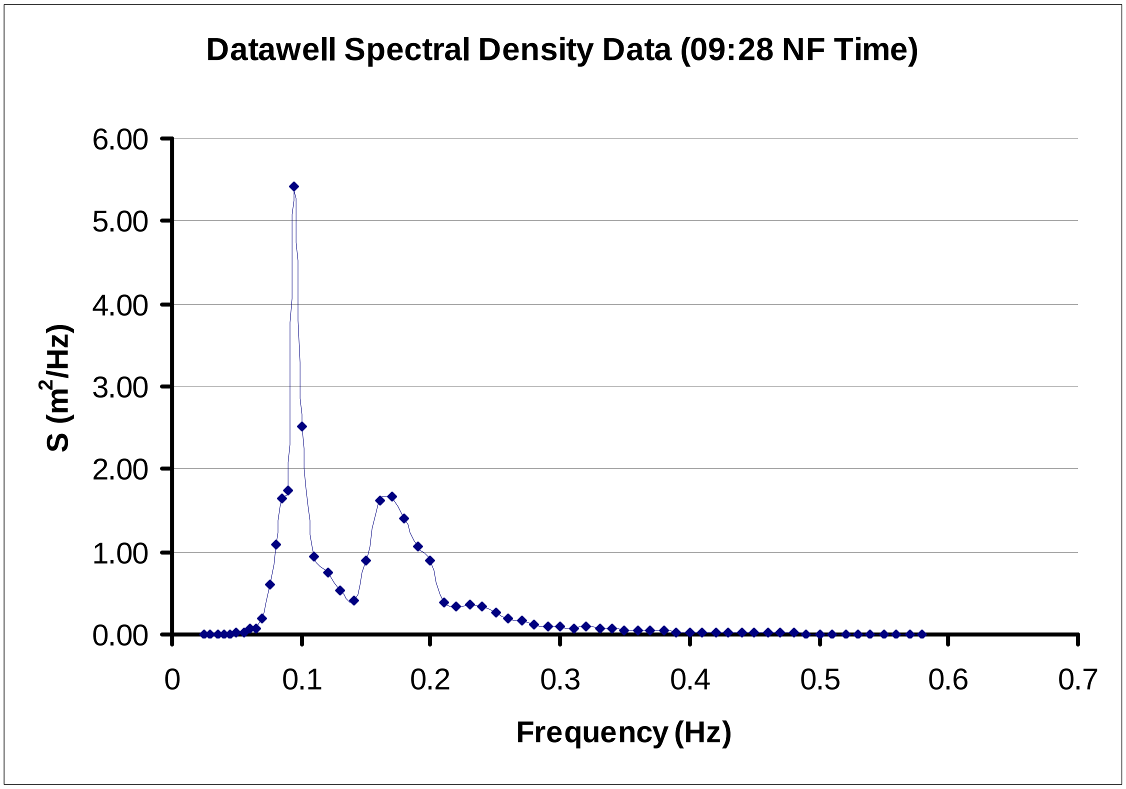

Datawell Wave Direction (07:58 NF Time)
Wave Direction (deg. TRUE)
250
200
150
100
50
0
-50
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
Frequency (Hz)

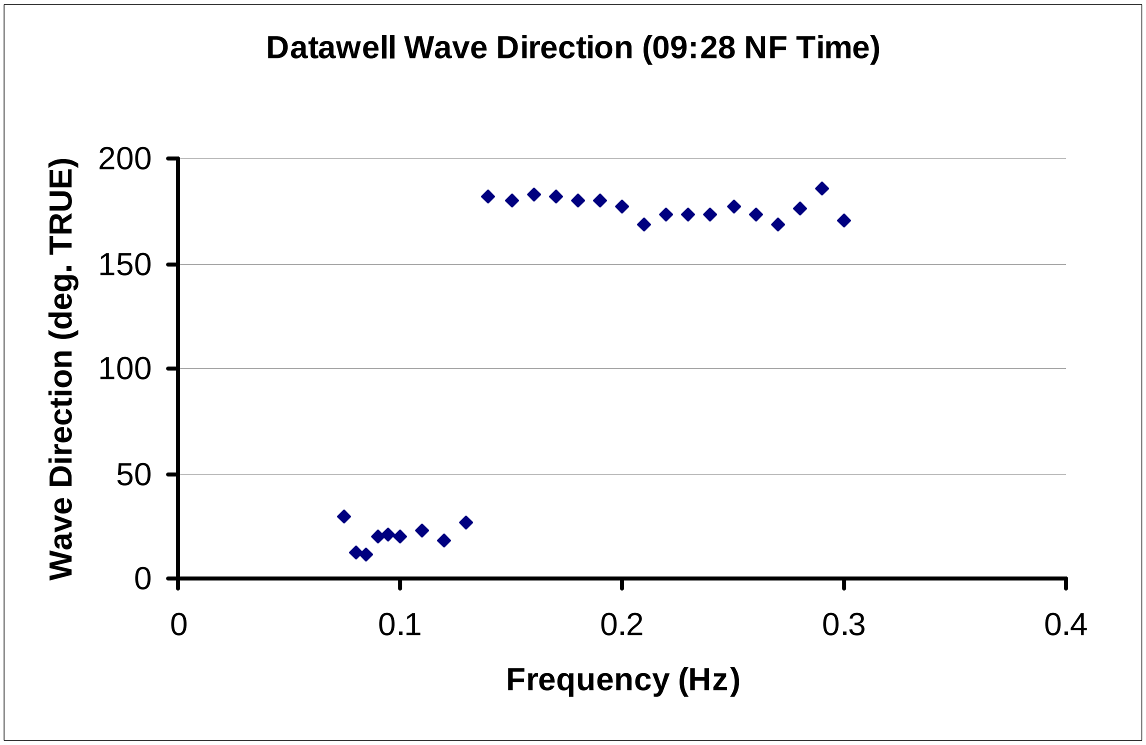

Datawell Wave Spectral Data (08:28 NF Time)
S (m²/Hz)
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
0.2
0.4
0.6
0.8
Frequency (Hz)

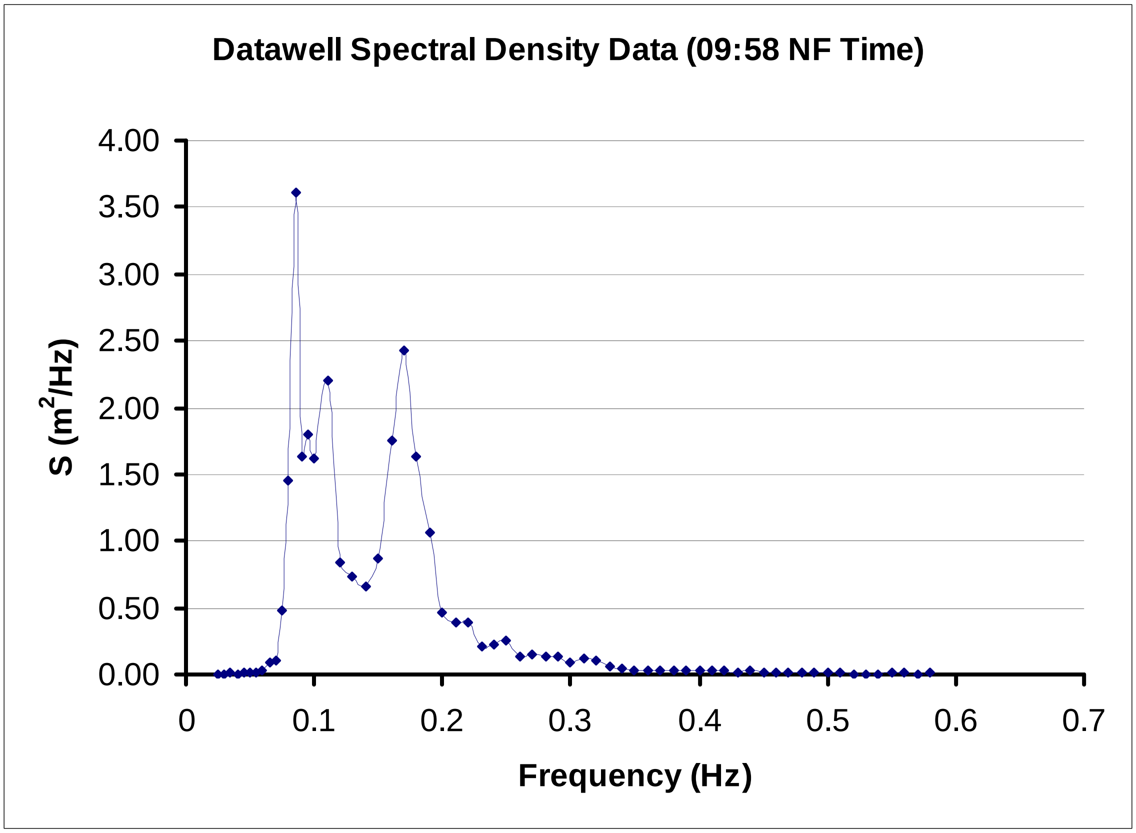

Datawell Wave Direction (08:28 NF Time)
Wave Direction (deg. TRUE)
250
200
150
100
50
0
-50
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
Frequency (Hz)

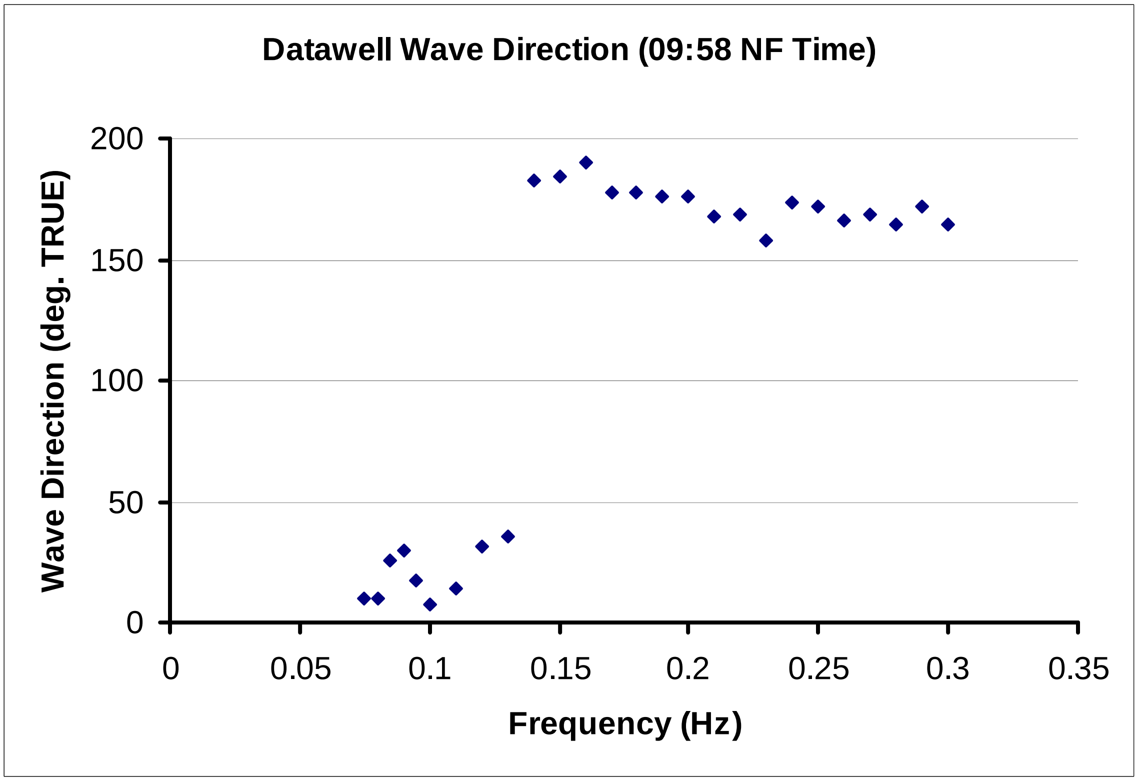

Datawell Spectral Wave Data (08:58 NF Time)
S (m²/Hz)
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Frequency (Hz)

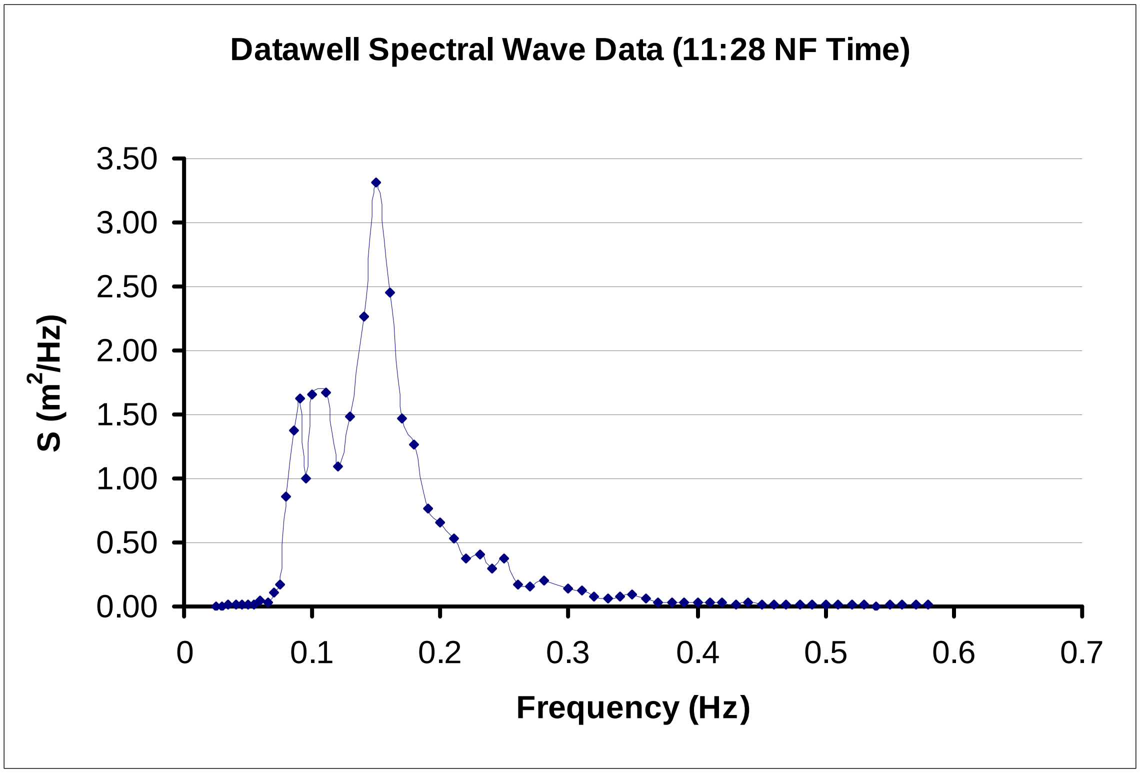

Datawell Wave Direction (08:58 NF Time)
Wave Direction (deg. TRUE)
250
200
150
100
50
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
Frequency (Hz)

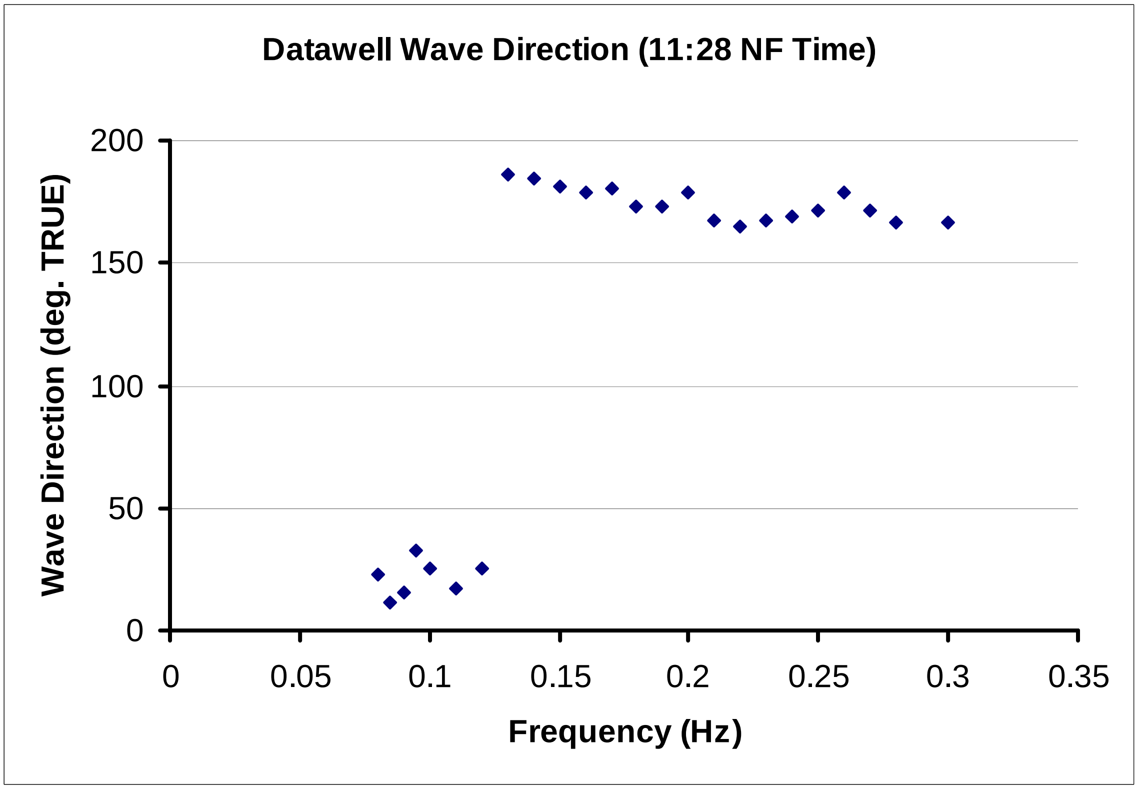

Datawell Spectral Density Data (09:28 NF Time)
S (m^2/Hz)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Frequency (Hz)

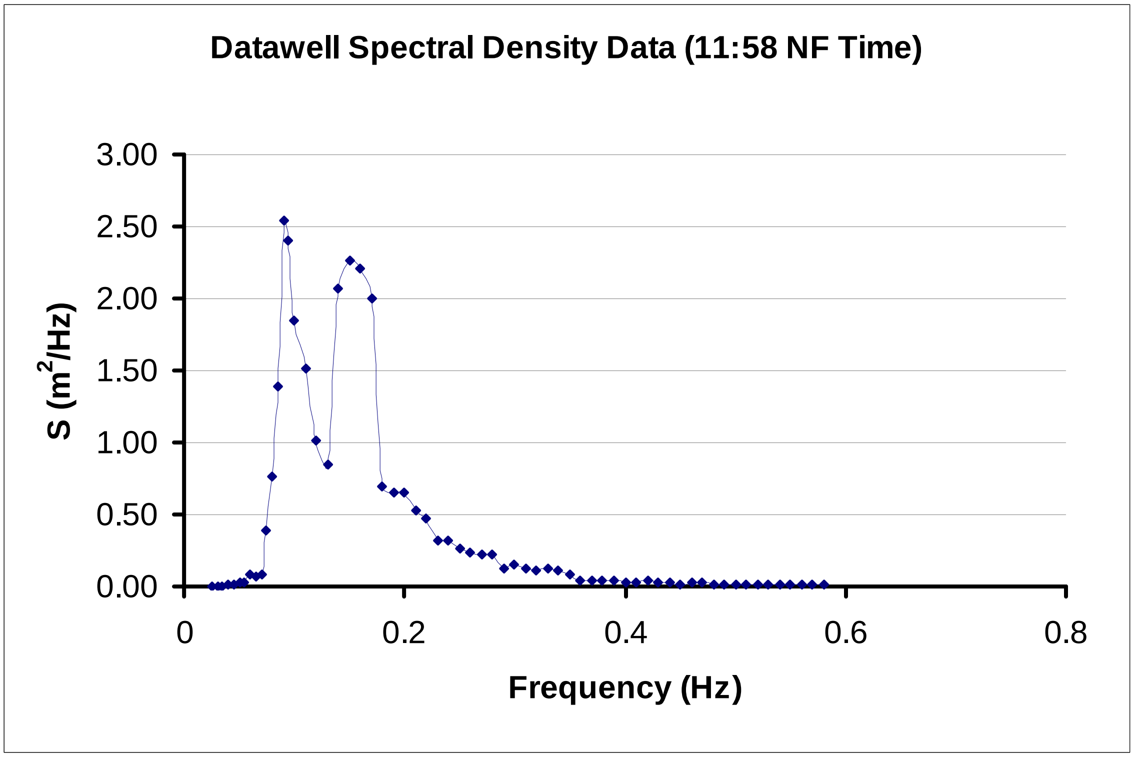

Datawell Wave Direction (09:28 NF Time)
Wave Direction (deg. TRUE)
200
150
100
50
0
0
0.1
0.2
0.3
0.4
Frequency (Hz)

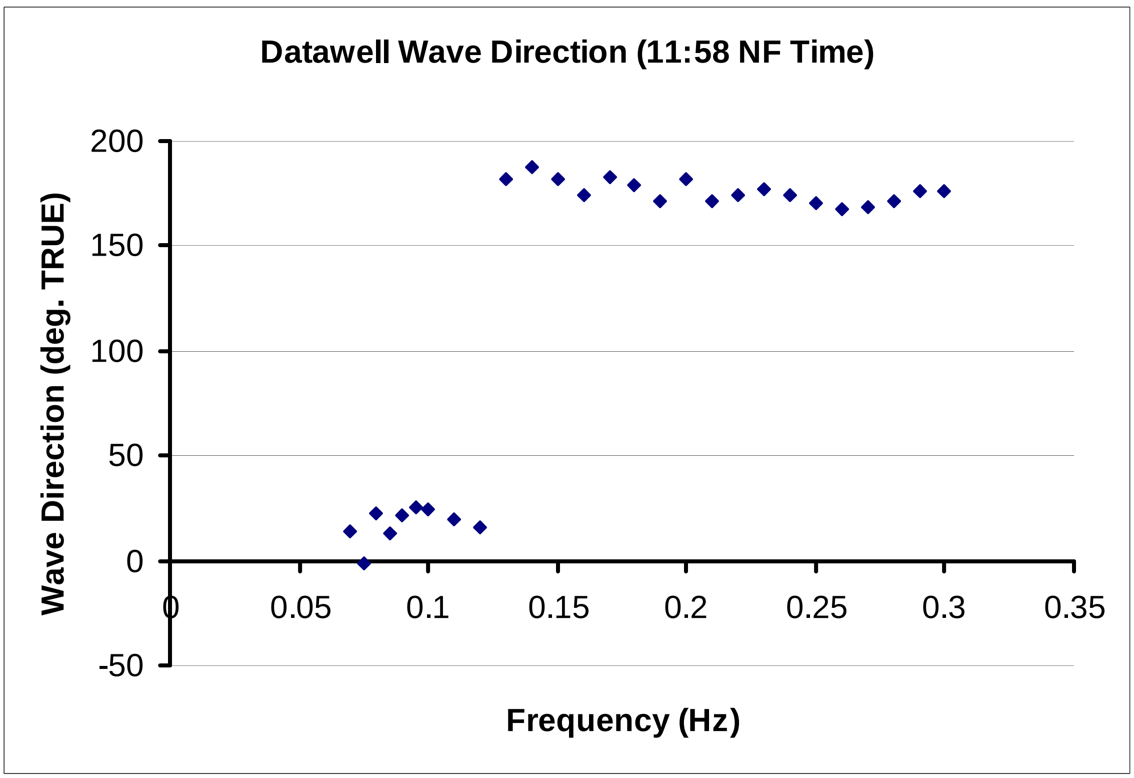

Datawell Spectral Density Data (09:58 NF Time)
S (m2/Hz)
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Frequency (Hz)

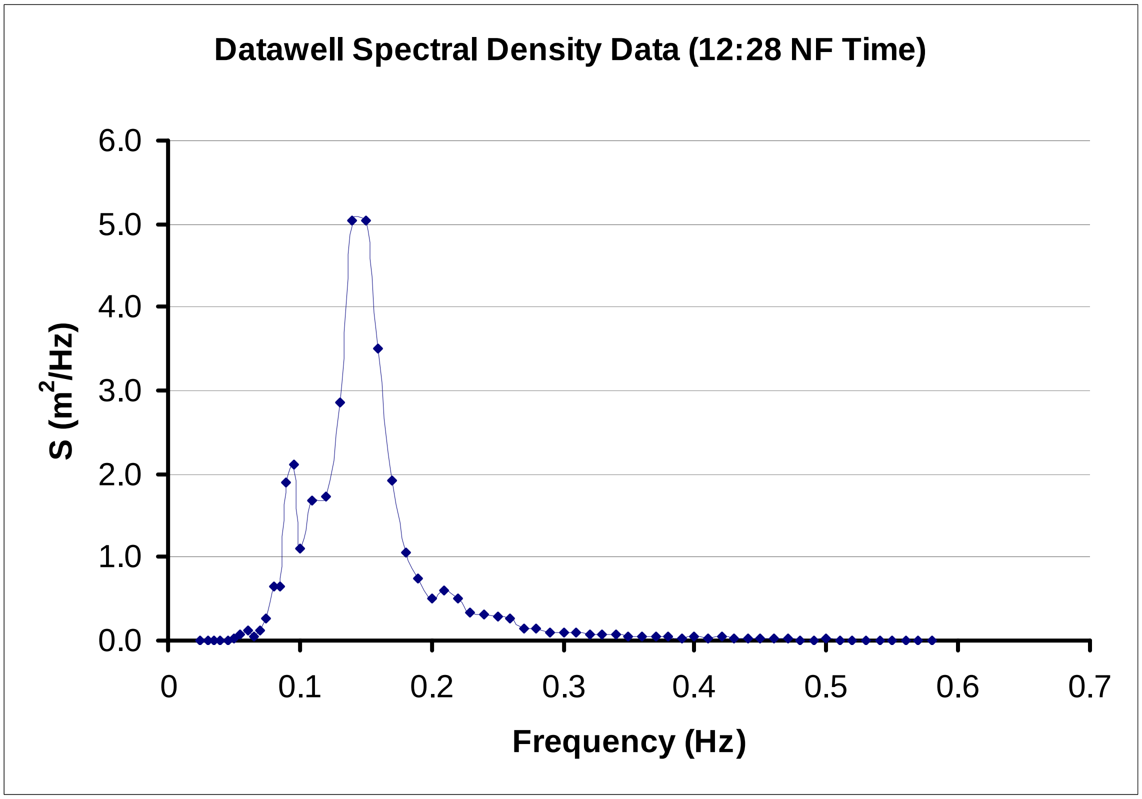

Datawell Wave Direction (09:58 NF Time)
Wave Direction (deg. TRUE)
200
150
100
50
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
Frequency (Hz)

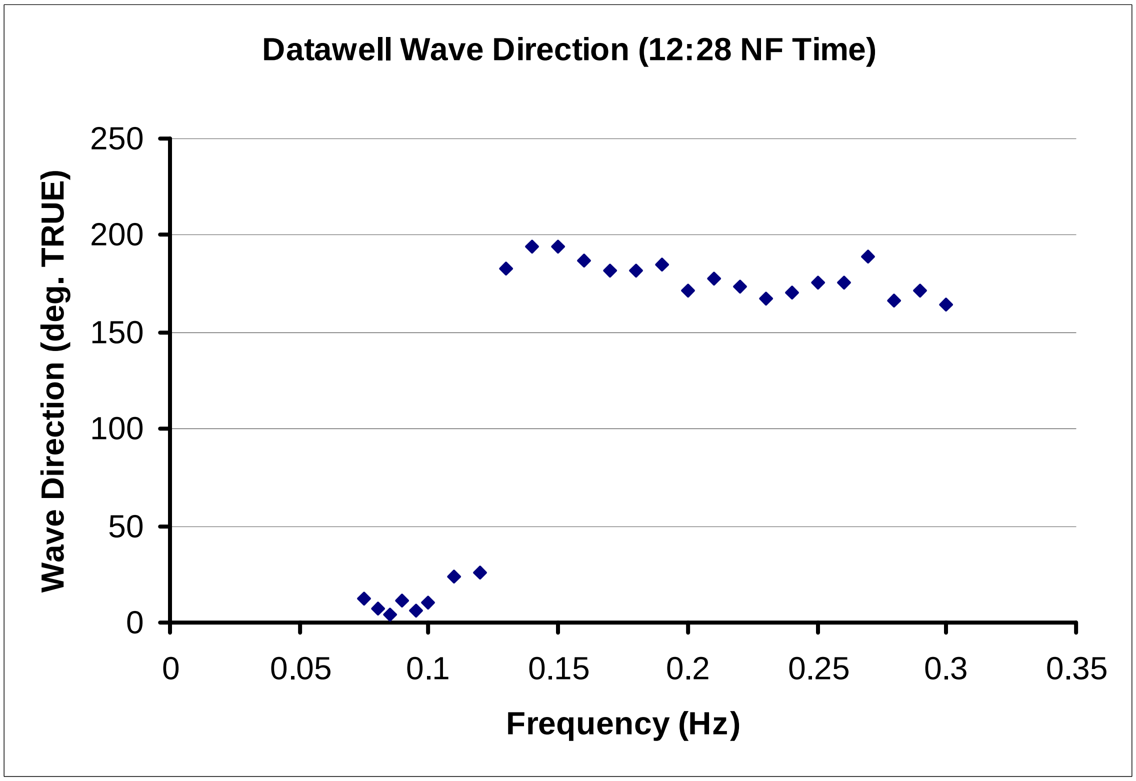

Datawell Spectral Wave Data (11:28 NF Time)
S (m²/Hz)
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Frequency (Hz)

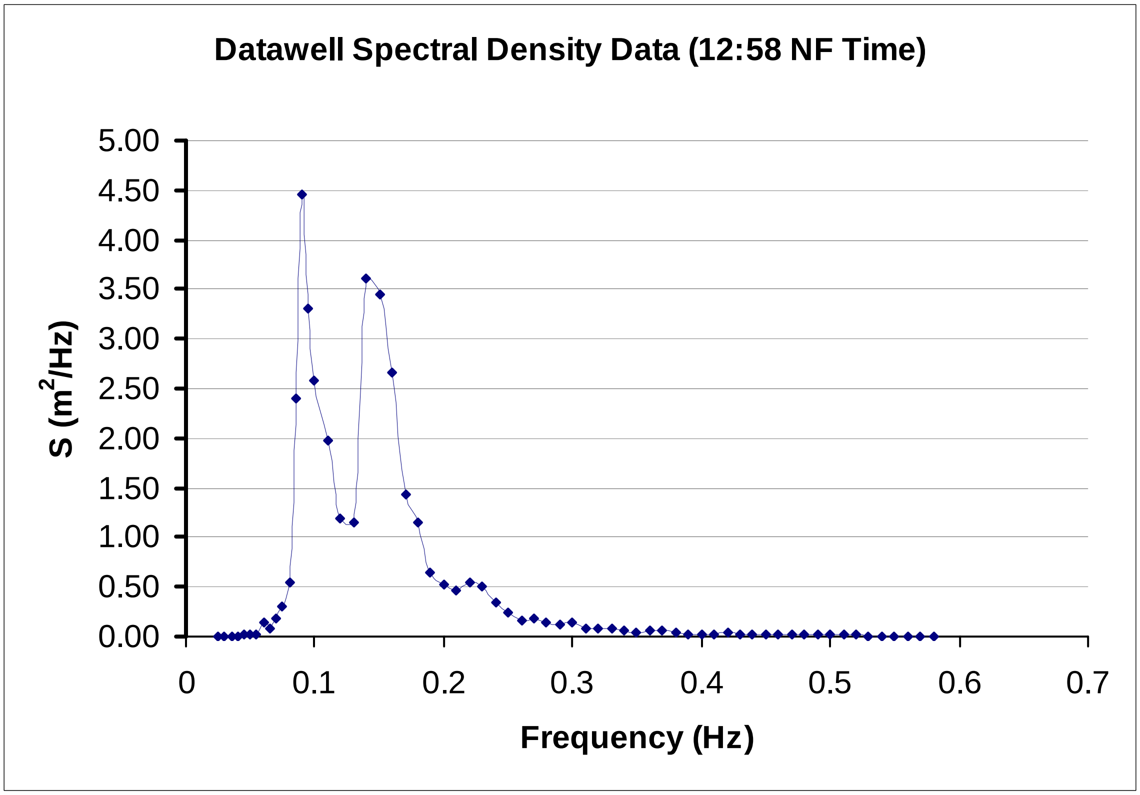

Datawell Wave Direction (11:28 NF Time)
Wave Direction (deg. TRUE)
200
150
100
50
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
Frequency (Hz)

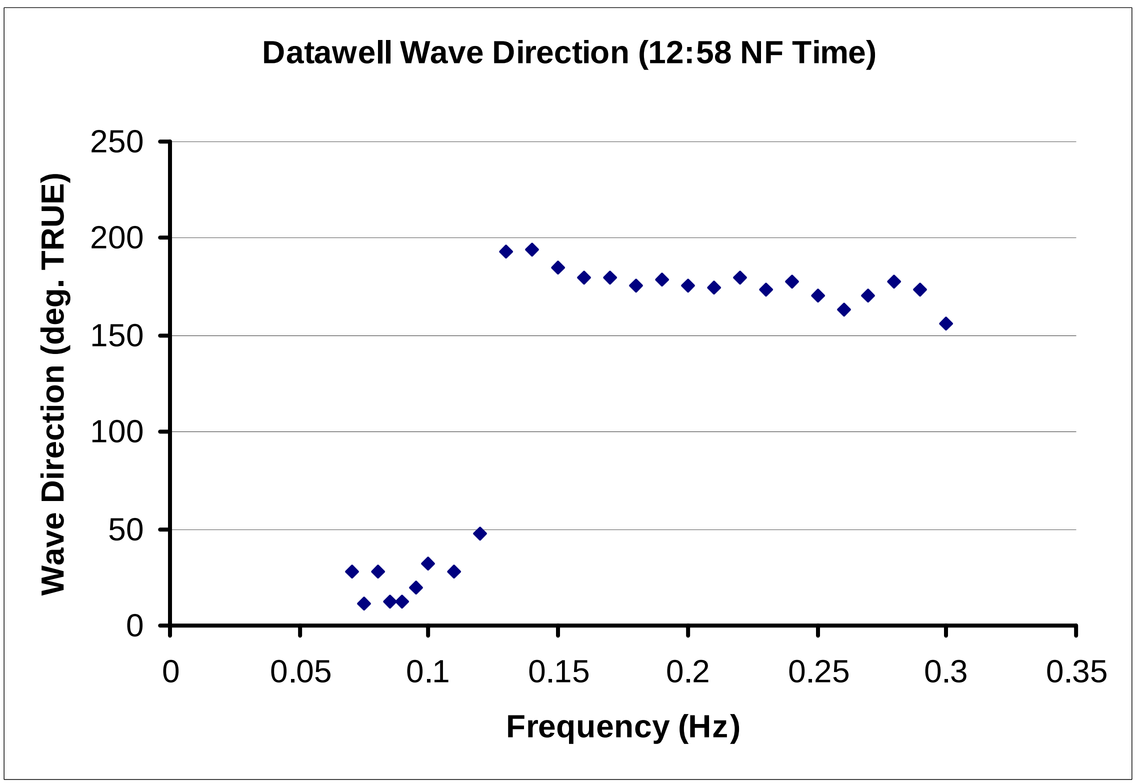

Datawell Spectral Density Data (11:58 NF Time)
S (m²/Hz)
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
0.2
0.4
0.6
0.8
Frequency (Hz)

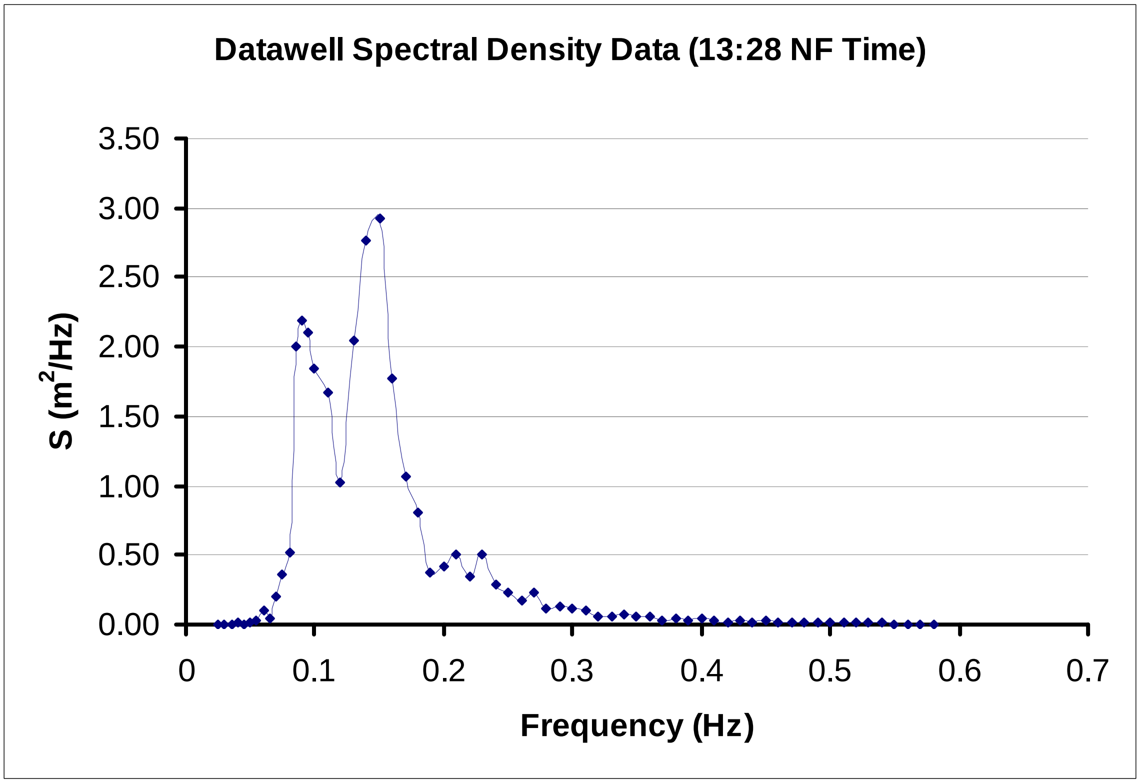

Datawell Wave Direction (11:58 NF Time)
Wave Direction (deg. TRUE)
200
150
100
50
0
-50
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
Frequency (Hz)


Datawell Spectral Density Data (12:28 NF Time)
S (m2/Hz)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Frequency (Hz)

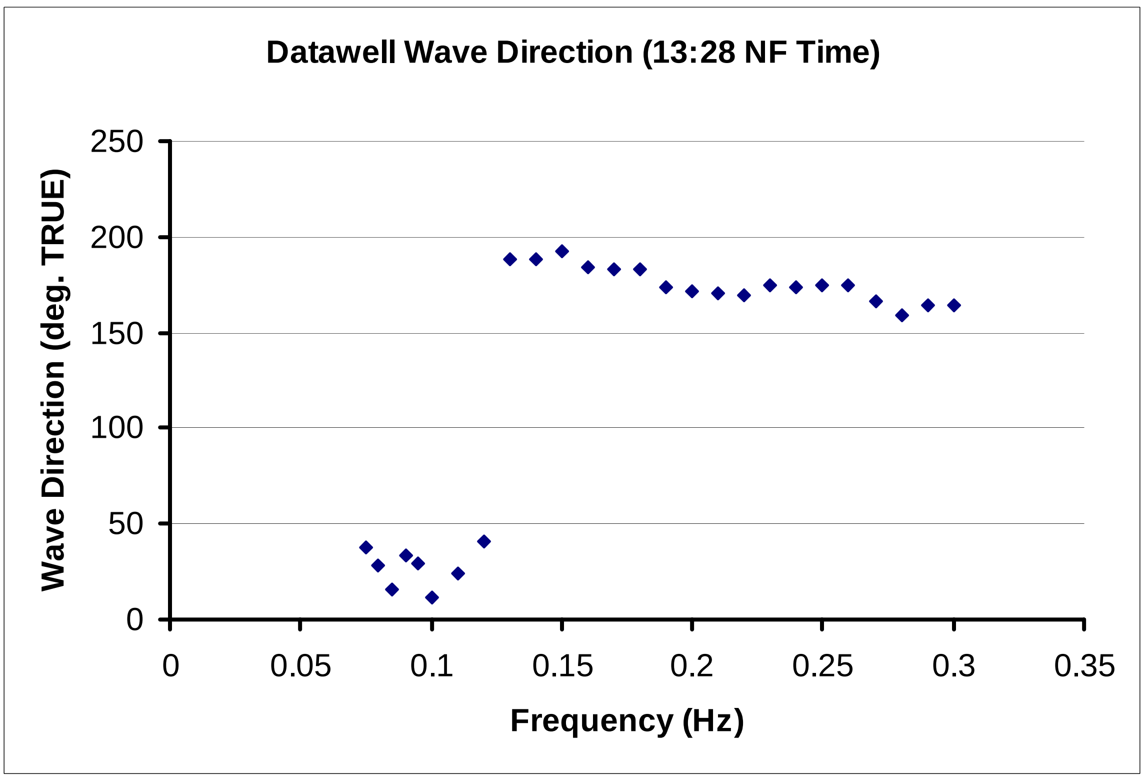

Datawell Wave Direction (12:28 NF Time)
Wave Direction (deg. TRUE)
250
200
150
100
50
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
Frequency (Hz)


Datawell Spectral Density Data (12:58 NF Time)
S (m²/Hz)
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Frequency (Hz)

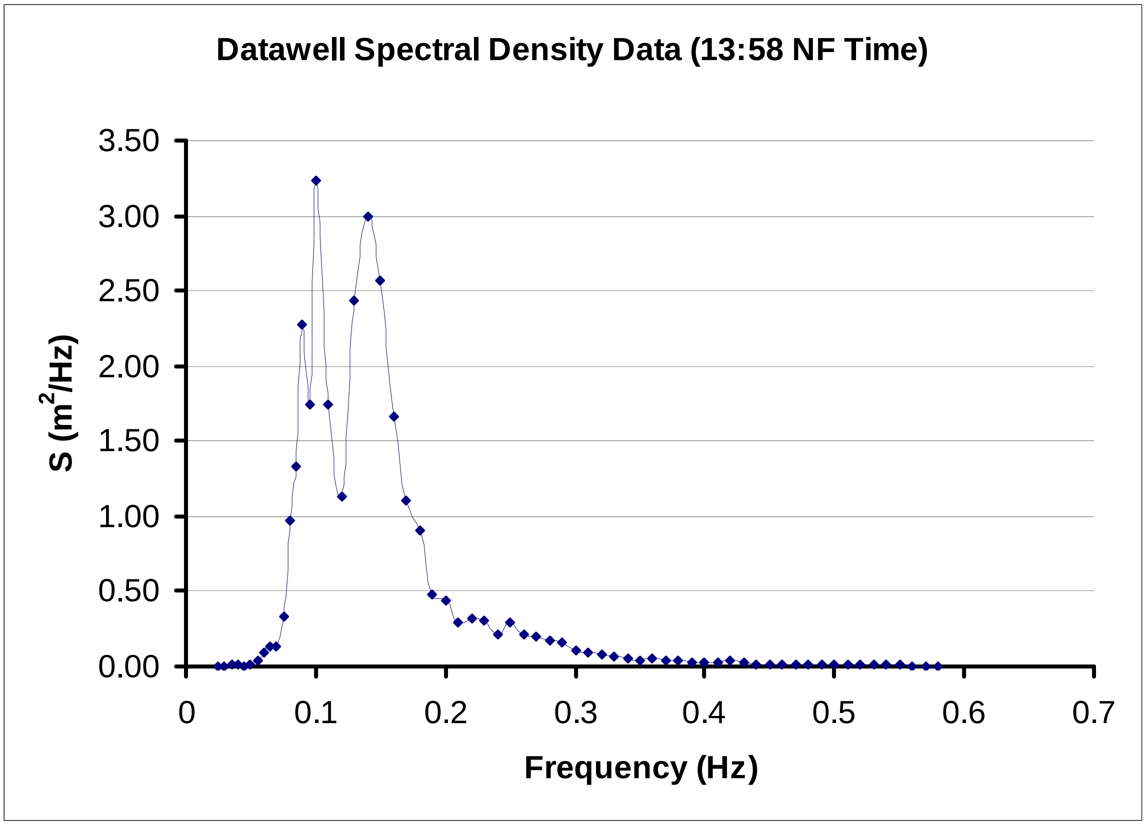

Datawell Wave Direction (12:58 NF Time)
Wave Direction (deg. TRUE)
250
200
150
100
50
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
Frequency (Hz)

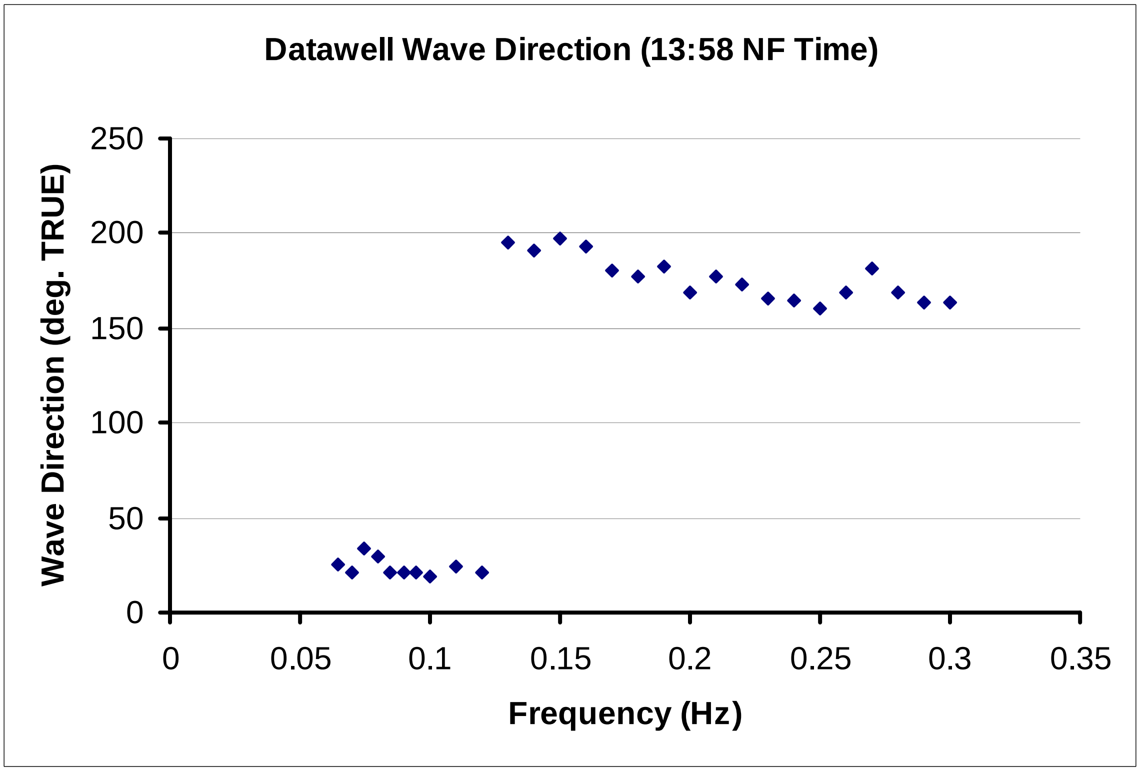


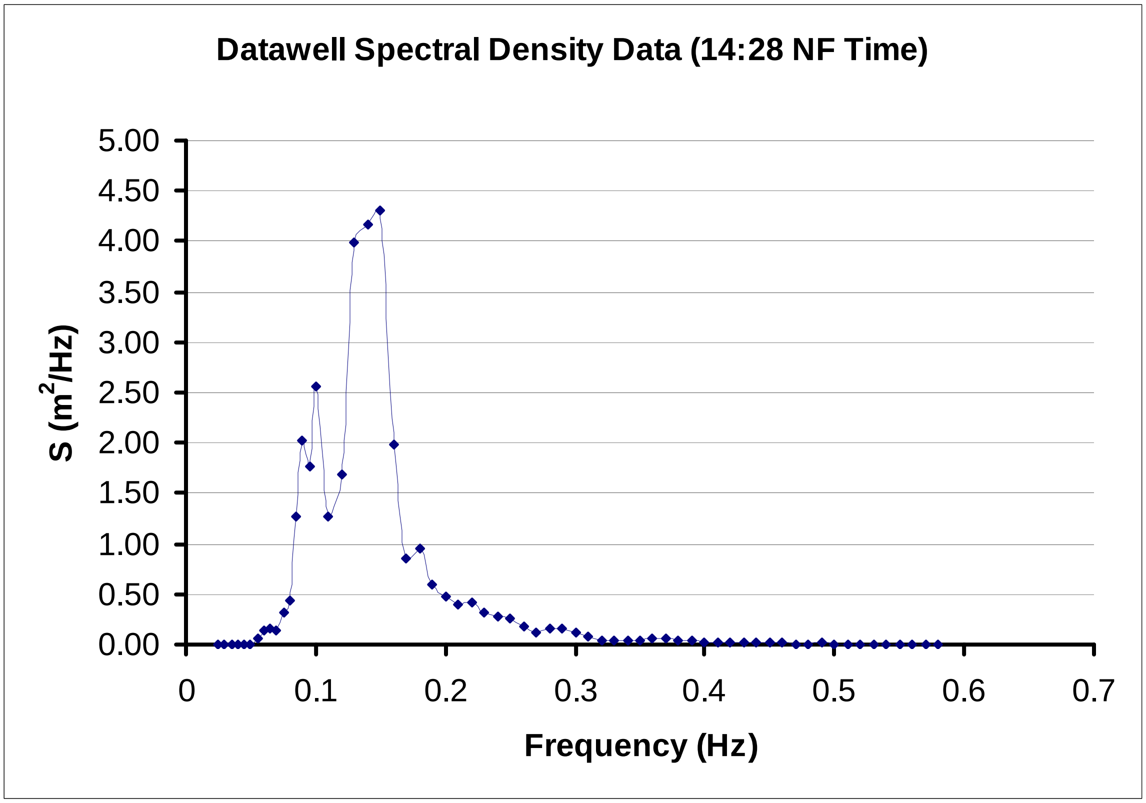
Datawell Spectral Density Data (13:28 NF Time)
S (m2/Hz)
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Frequency (Hz)

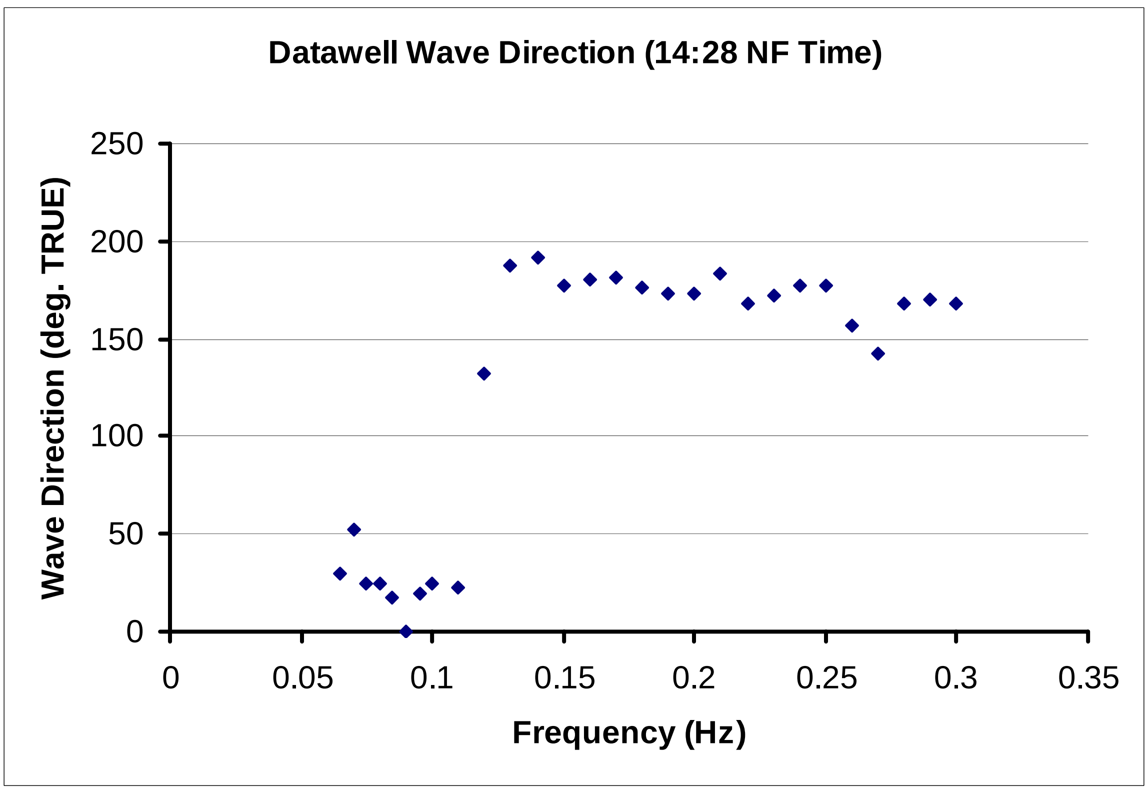


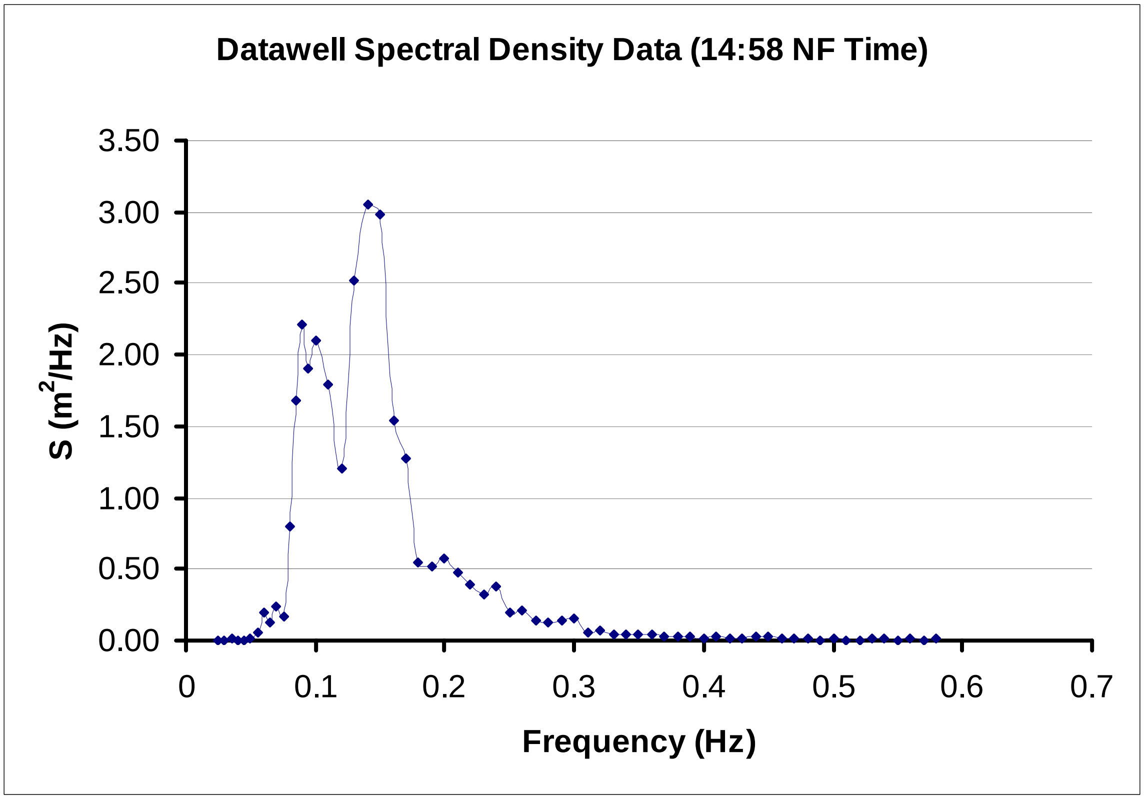
Datawell Wave Direction (13:28 NF Time)
Wave Direction (deg. TRUE)
250
200
150
100
50
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
Frequency (Hz)

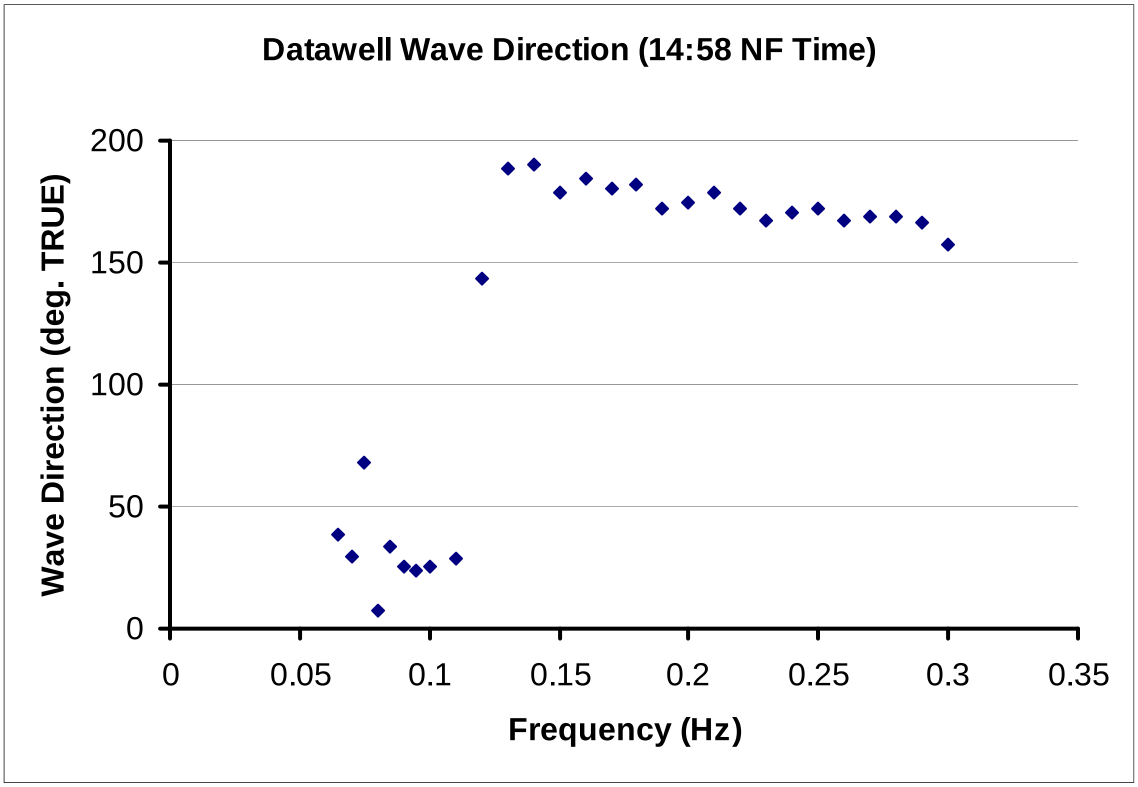

Datawell Spectral Density Data (13:58 NF Time)
S (m²/Hz)
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Frequency (Hz)

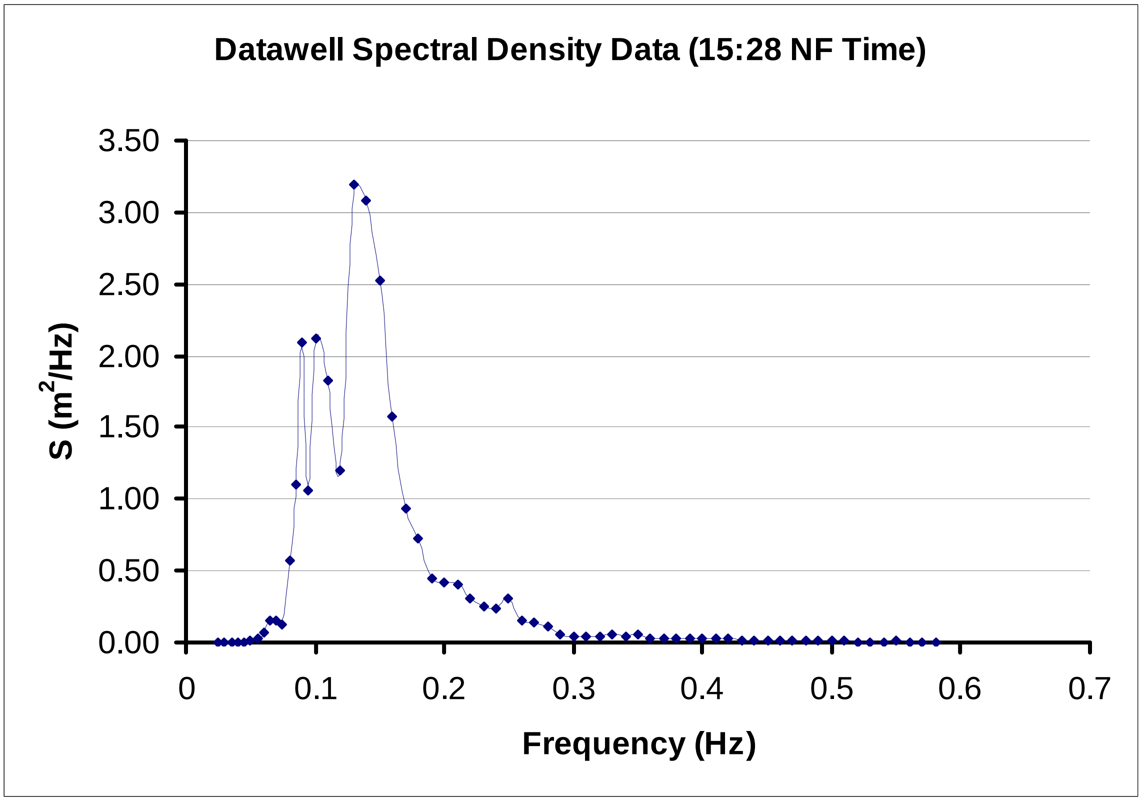

Datawell Wave Direction (13:58 NF Time)
Wave Direction (deg. TRUE)
250
200
150
100
50
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
Frequency (Hz)

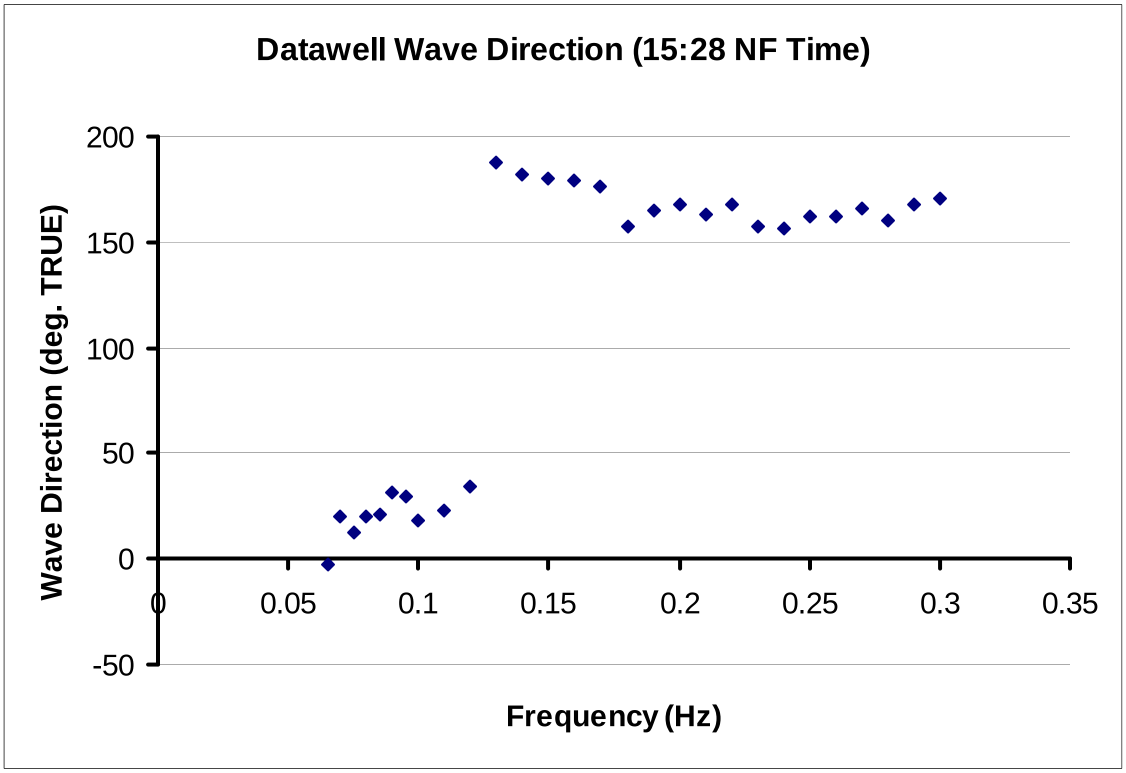

Datawell Spectral Density Data (14:28 NF Time)
S (m^2/Hz)
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Frequency (Hz)

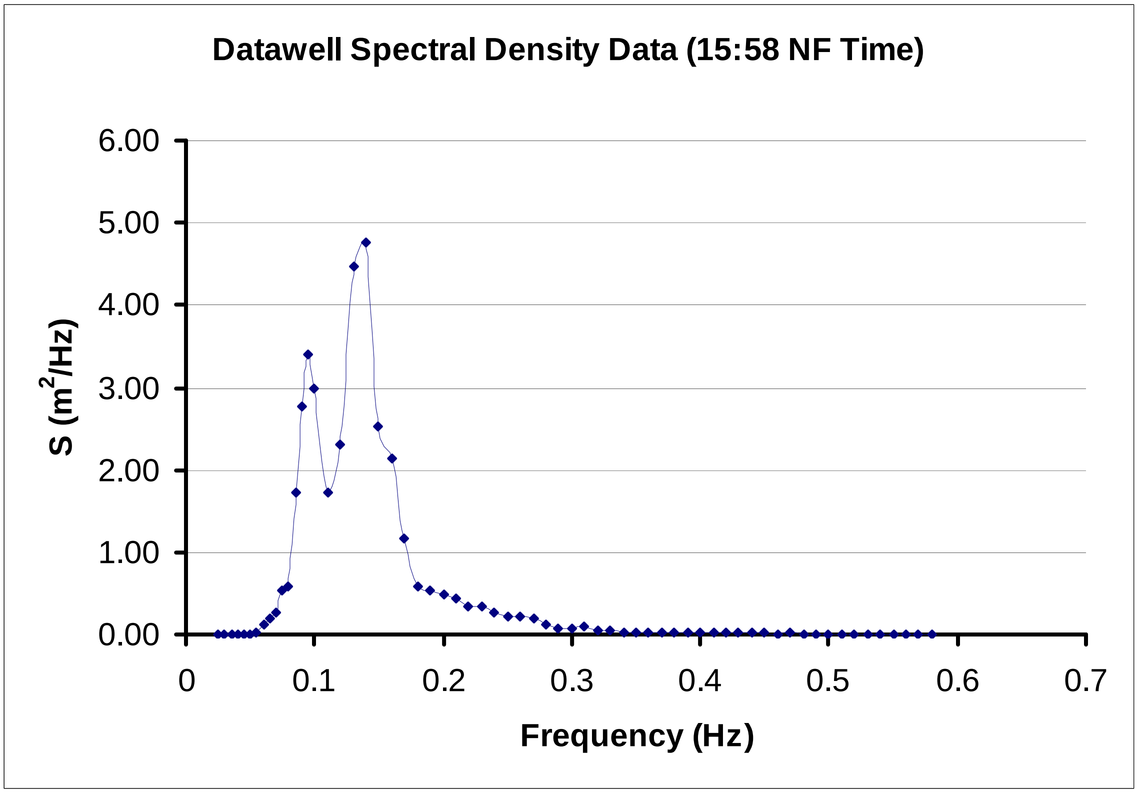

Datawell Wave Direction (14:28 NF Time)
Wave Direction (deg. TRUE)
250
200
150
100
50
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
Frequency (Hz)

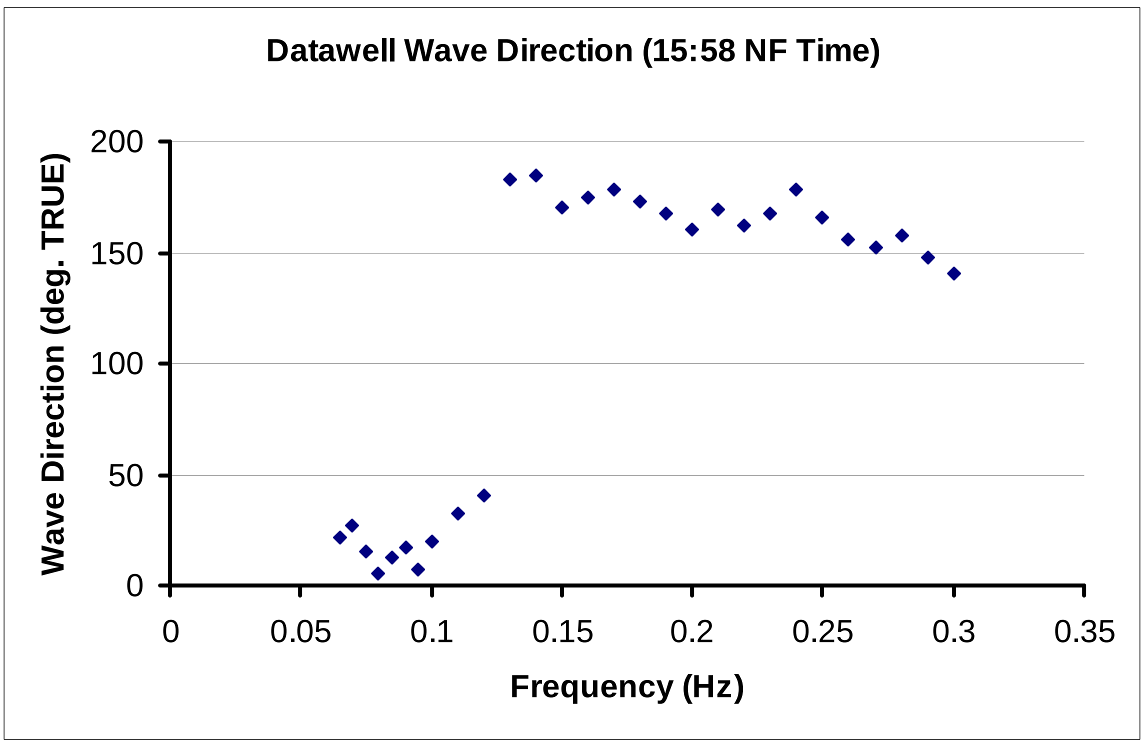

Datawell Spectral Density Data (14:58 NF Time)
S (m²/Hz)
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Frequency (Hz)


Datawell Wave Direction (14:58 NF Time)
Wave Direction (deg. TRUE)
200
150
100
50
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
Frequency (Hz)


Datawell Spectral Density Data (15:28 NF Time)
S (m^2/Hz)
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Frequency (Hz)

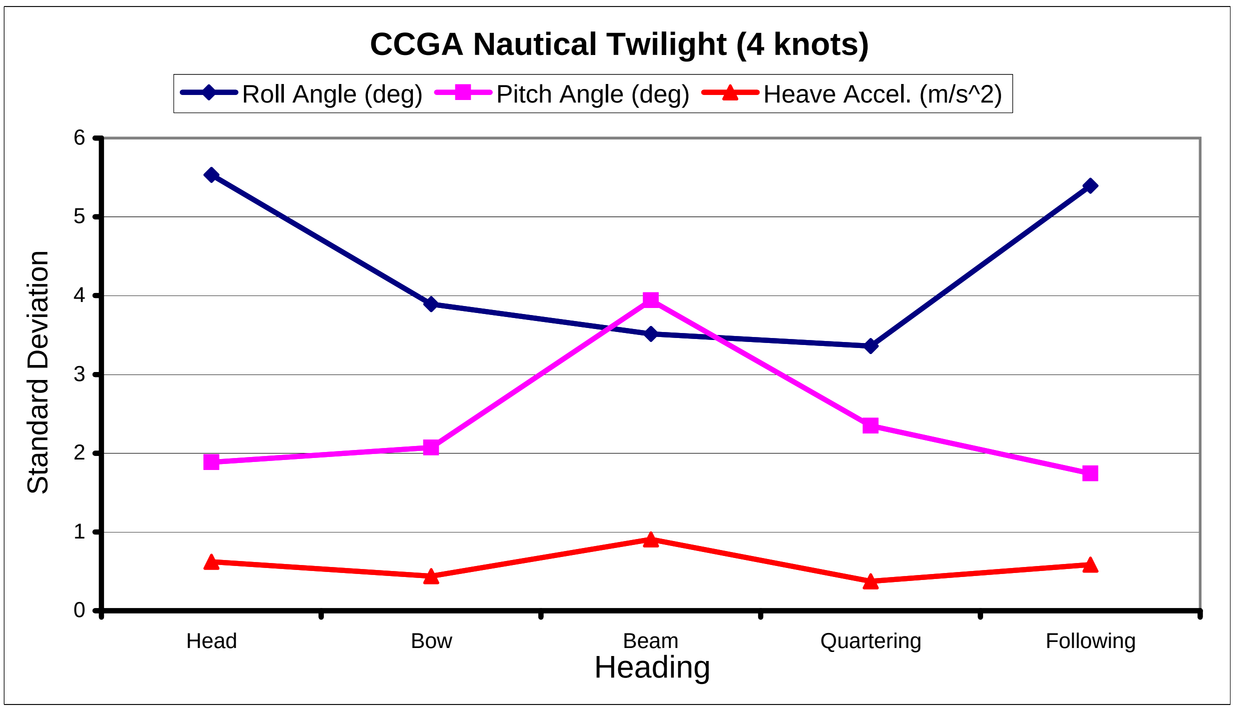

Datawell Wave Direction (15:28 NF Time)
Wave Direction (deg. TRUE)
200
150
100
50
0
-50
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
Frequency (Hz)

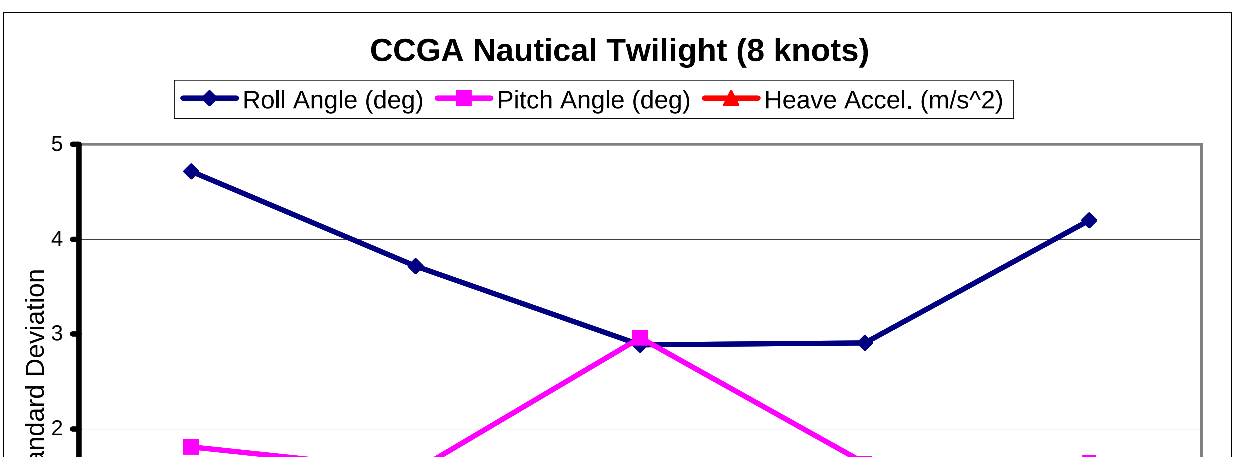

Datawell Spectral Density Data (15:58 NF Time)
S (m²/Hz)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Frequency (Hz)

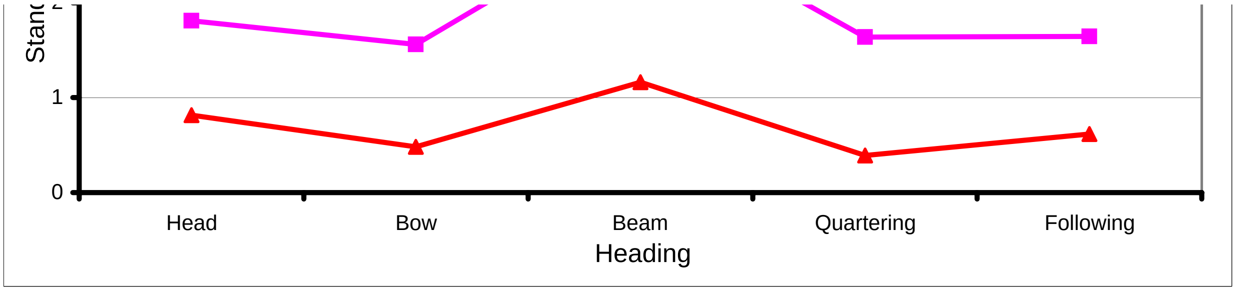

Datawell Wave Direction (15:58 NF Time)
Wave Direction (deg. TRUE)
200
150
100
50
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
Frequency (Hz)

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

Speed (kts)	Run Heading	Roll Angle (deg)	Pitch Angle (deg)	Yaw Angle (deg)	Surge Accel. (m/s2)	Sway Accel. (m/s2)	Heave Accel. (m/s^2)
0	Drift1	5.338	2.042	11.078	0.191	0.301	0.486
0	Drift2	5.619	2.347	9.460	0.242	0.304	0.509
4	Head	5.532	1.883	3.627	0.197	0.322	0.620
4	Bow	3.890	2.070	3.893	0.292	0.281	0.439
4	Beam	3.513	3.940	3.936	0.353	0.213	0.905
4	Quartering	3.359	2.347	2.808	0.345	0.199	0.374
4	Following	5.396	1.745	2.875	0.231	0.341	0.583
8	Head	4.714	1.809	2.469	0.216	0.331	0.817
8	Bow	3.715	1.561	2.854	0.220	0.290	0.481
8	Beam	2.887	2.961	1.637	0.293	0.232	1.165
8	Quartering	2.908	1.638	2.568	0.235	0.196	0.392
8	Following	4.196	1.646	2.132	0.232	0.311	0.618







Stand
0
1
Head
Bow
Beam
Quartering
Following
Heading