U.S. DEPARTMENT OF COMMERCE

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SERVICE

DATA ACQUISITION AND PROCESSING REPORT

Type of Survey	**Hydrographic**
Project No.	**M-I907-NF-16**
Registry No.	**H12935, H12936**

LOCALITY

State	**Puerto Rico**
General Locality	**Caribbean Sea**

2016

CHIEF OF PARTY

Timothy Battista, Mike Stecher

LIBRARY & ARCHIVES

DATE **April 2016**

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

H12935
H12936

HYDROGRAPHIC STYLE SHEET

INSTRUCTIONS – The Hydrographic Sheet should be accompanied by this form, filled in as completely as possible, when the sheet is forwarded to the Office.

FIELD No
NOAA Ship Nancy Foster

State	Puerto Rico
General Locality	Caribbean Sea
Sub-Locality	Southeast Coast of Puerto Rico, 10 NM North of Isla de Culebra
Scale	N/A
Date of Survey	April 7, 2016 to April 26, 2016
Instructions dated	N/A Project No. M-I907-NF-16
Vessel	NOAA Ship Nancy Foster
Chief of party	Timothy Battista
Surveyed by	NOAA Center for Coastal Monitoring and Assessment
Soundings by	Reson 7125-SV2, Kongsberg EM710
Graphic record scaled by	N/A
Graphic record checked by	N/A
Automated Plot	N/A
Verification by	N/A
Soundings in	Meters at MLLW
Remarks	All times are UTC

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ACRONYMS AND ABBREVIATIONS

BAG	Bathymetric Attributed Grid
BASE	Bathymetry Associated with Statistical Error
CCMA	Center for Coastal Monitoring and Assessment
CO-OPS	Center for Operational Oceanographic Products and Services
CTD	Conductivity Temperature Depth
CUBE	Combined Uncertainty and Bathymetry Estimator
DGPS	Differential Global Positioning System
FPM	Field Procedures Manual (April 2014)
GAMS	GPS Azimuth Measurement Subsystem
GPS	Global Positioning System
HIPS	Hydrographic Information Processing System
HSSD	Hydrographic Survey Specifications and Deliverables Manual (April 2012)
HSTP	Hydrographic Systems Technology Programs
HSX	Hypack Hysweep File Format
HTD	Hydrographic Surveys Technical Directives
HVF	HIPS Vessel File
IHO	International Hydrographic Organization
IMU	Inertial Motion Unit
MLLW	Mean Lower Low Water
NMEA	National Marine Electronics Association
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
OMAO	Office of Marine and Aviation Operations (NOAA)
POS/MV	Position and Orientation System for Marine Vessels
PPS	Pulse per second
ROV	Remotely Operated Vehicle
R/V	Research Vessel
SAT	Sea Acceptance Test
SBE	Smooth Best Estimate
SBET	Smooth Best Estimate and Trajectory
SVP	Sound Velocity Profiler
TPE	Total Propagated Error
TPU	Total Propagated Uncertainty
TSG	Thermosalinograph
USCRTF	U.S. Coral Reef Task Force
ZDA	Global Positioning System timing message
ZDF	Tide Zone Definition File

Data Acquisition and Processing Report
M-I907-NF-16 Caribbean Sea, Puerto Rico
April 2016
NOAA Ship Nancy Foster
Center for Coastal Monitoring & Assessment, Biogeography Branch
Lead Scientist, Timothy Battista

INTRODUCTION

In June 1998, the U.S. Coral Reef Task Force (USCRTF) was established by Presidential Executive Order 13089. The USCRTF mission is to lead, coordinate, and strengthen U.S. government actions to better preserve and protect coral reef ecosystems. The National Oceanic and Atmospheric Administration's (NOAA) Center for Coastal Monitoring and Assessment (CCMA) Biogeography Team is supporting the USCRTF mandate. The Biogeography Team completed its thirteenth year of an ongoing scientific research mission on board the NOAA Ship *Nancy Foster* from April 7th to April 26th, 2016.

This report applies to surveys H12935 and H12936 located in the Caribbean Sea near Puerto Rico and Isla de Culebra. These surveys were performed under project M-I907-NF-16, the objective of which was to collect a bathymetric dataset in waters greater than 10 meters with complete multibeam coverage, along with backscatter suitable for seafloor characterization in high-priority conservation areas. The delineation and identification of seafloor habitats within areas mapped during the mission was assisted by the use of an ROV with video and camera capabilities.

All references to equipment, software, and data acquisition and processing methods were valid at the time this document was prepared. Any deviations from these methods will be specifically addressed in the Descriptive Reports (DR) of the project surveys.

A. EQUIPMENT

Detailed descriptions of the equipment and systems, including hardware and software, used for bathymetric data acquisition and processing are listed in Table 1 below.

Table 1 NOAA Ship Nancy Foster Hardware

Hydrographic Systems Hardware Inventory M-I907-NF-16				
Equipment type	Manufacturer	Model	Serial #	Firmware
MBE Kongsberg	Kongsberg	EM710	240	N/A
Kongsberg TX Unit	Kongsberg	EM710	233/234	1.09
Kongsberg RX Unit	Kongsberg	EM710	173	1.11
MBE Reson	Reson	7125-SV2	18341313044	MR 7.1.1
Reson TX Unit	Reson	7125-SV2	2710007	N/A
Reson RX Unit	Reson	7125-SV2	2011032	N/A
Inertial GPS PCS	Applanix	POS/MV 320 V4	2249	5.03
IMU	Applanix	LN 200	447	N/A
DGPS	Trimble	DSM 132	224096283	3.0
SVP	Oceanscience	UCTD	PA-0252	3.10

SVP	SBE	19	0355	N/A
SVP	Reson	SVP 71	2711094	N/A

A1. SURVEY VESSEL

The NOAA Ship *Nancy Foster* (R352) is fifty-seven meters in length, has a beam of twelve meters, and draws approximately three meters of water. During the past 13 years numerous hydrographic surveying hardware and software installations have been implemented by NOAA's Office of Marine and Aviation Operations (OMAO) to make multibeam data acquisition a more integral component of the ship's research support.

Figure 1 NOAA Ship Nancy Foster

A2. MULTIBEAM SYSTEMS

The *Nancy Foster* is equipped with a Reson SeaBat 7125-SV2 dual frequency multibeam echosounder (MBE) capable of operating at 200 or 400 kHz and is integrated with a Reson SVP 71 sound velocity sensor. The 7125-SV2 MBE is mounted on the hull, and is located port of the keel, and forward of the reference point of the vessel. The 7125-SV2 was operated at 400 kHz for the duration of the M-I907-NF-16 cruise. The 7125-SV2 produced a 128-degree swath of 512 equiangular beams with an along-track beam width of 1.0 degrees and across-track beam width of 0.5 degrees.

For these surveys all 7125-SV2 data were acquired with the custom bracket selected in the hardware configuration with offsets values entered from the vessel survey. Range adjustments were made during acquisition as dictated by changes in water depth. Other sonar parameters were kept a constant to maximize backscatter quality. Hypack HYSWEEP was used to acquire all Reson MBE data in the HSX file format and backscatter in the 7K file format.

The *Nancy Foster* is also equipped with a deep-water Kongsberg EM710 MBE system. The EM710 MBE is permanently hull-mounted between two fiberglass hydrodynamic fittings starboard of the keel line. The EM710 replaces the obsolete EM1002, and was installed during a

drydock period in February of 2015. A Sea Acceptance Test (SAT) was performed and passed on the EM710 by Kongsberg and NOAA representatives on March 13, 2015. The EM710 is a 40-100 kHz system with a 140° swath consisting of 200 individually formed, electronically roll-stabilized 2° beams, with a maximum ping rate of 10Hz, depending on water depth. A combination of phase and amplitude detection was used, resulting in measurement accuracy practically independent of beam angle. The system is compensated in real-time for sound velocity changes at the transducer array, to assist the electronic beam steering capabilities with an additional hull mounted SVP-71.

All EM710 MBE data were acquired with Kongsberg's Seafloor Information System (SIS) software and logged in the .all format. Range adjustments and other sonar settings were made automatically by SIS during acquisition as dictated by changes in water depth.

A3. POSITION, HEADING and MOTION REFERENCE SYSTEMS

The *Nancy Foster* is outfitted with an Applanix Position and Orientation System for Marine Vessels (POS/MV) 320 Version 4, Global Positioning System (GPS) inertial system. The POS/MV was used to measure attitude, heading, heave, and position for the MBE system. The POS/MV is comprised of an Inertial Motion Unit (IMU), two dual frequency (L1/L2) Global GPS antennas, and a topside control unit.

A Trimble DSM132 differential beacon receiver acquired real-time corrections from a U.S. Coast Guard transmission station located at Isabela, Puerto Rico (295 kHz). The DSM132 provided DGPS corrections to the POS M/V to increase accuracy and precision.

Position, timing, heading and motion data were output to the Hypack and SIS acquisition systems using the POS/MV real-time ethernet option at 25 Hz. Additionally, using the ethernet logging controls, the POS/MV was configured to log TrueHeave™ and all of the raw observable groups needed to post process real-time navigation data. The POS/MV logged 13 megabyte files, which resulted in multiple files created per day. Position and orientation data from the POS/MV were displayed in real-time using Hypack and POSView software and continuously monitored during survey operations.

The POS/MV also provided time synchronization of MBE systems and data acquisition computers using a combination of serial and ethernet outputs. The Reson, SIS and Hypack acquisition computers were provided a Pulse Per Second (PPS) and National Marine Electronics Association (NMEA) ZDA date and time message to achieve synchronization with the POS/MV.

A position check between the POS/MV and DSM132 positioning system was performed while the vessel was secured and relatively motionless while tied up in San Juan, PR on April 6th, 2016. Logged position data from the POS/MV and DSM132 were compared to the vessel survey with satisfactory results.

In order to achieve further improved positional accuracy throughout the survey time period, an SBET (Smoothed Best Estimate of Trajectory) solution was derived during post-processing. This methodology employs Applanix's IN-Fusion SingleBase processing technique, the National Geodetic Survey's network of Continuously Operating Reference Stations (CORS), and final satellite ephemeris data. The tightly-coupled solution produces post-processed navigation, motion, and ellipsoidal height data with increased accuracy. For M-I907-NF-16, only the

navigation and attitude corrections were applied to the data, as a TCARI tidal solution was employed for vertical alignment.

A4. SOUND SPEED MEASURMENT SYSTEMS

A4.a UCTD

An OceanScience UnderWay CTD (UCTD) was the primary sound speed measurement instrument for this cruise. The UCTD provided CTD profiles while the vessel was underway off the aft deck with a tethered freefall CTD probe which is then retrieved with a powered level winding winch. After the UCTD was downloaded, the data was processed with UCast version 1.2 and converted and concatenated with Velocipy version 16.9.

On past cruises using the same UCTD sensor, independent cast comparisons have been carried out to ensure proper calibration of the unit. Given the identical methodology and instruments in use during M-I907-NF-16 as for the previous Caribbean mapping mission in 2015, no additional comparison was done during this mission. The results of the ray tracing uncertainty analysis between the UCTD and the SBE 19 on March 29th, 2015 is included below (Figure 2) for reference. The sound speed profiles derived from each CTD measurement are nearly identical. In this case, maximum outer beam refraction was estimated at a negligible 10cm at 500m of water depth. Current specification would allow for 2.8m in these depths (red bounds), less than 4% of the allowable refraction error was consumed in this comparison.

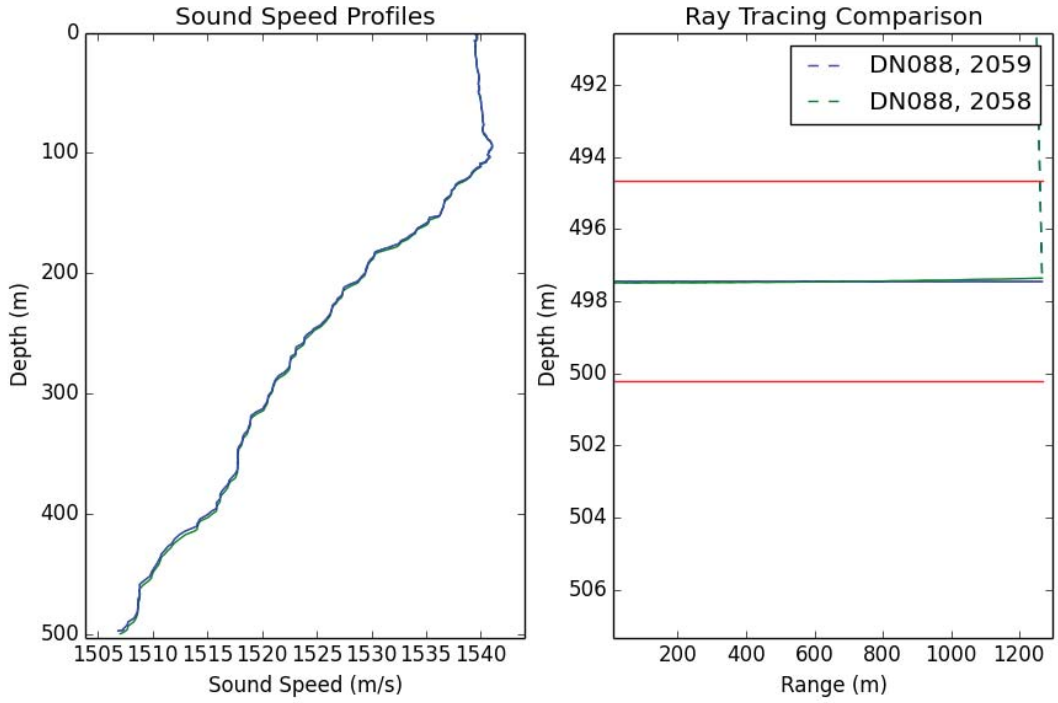


Figure 2 UCTD vs. SBE 19 Comparison Analysis

A4.b SBE 19

An SBE 19 Conductivity Temperature Depth (CTD) instrument for determining sound velocity

throughout the water column was used to QA/QC the UCTD and was available for backup if the primary UCTD failed. The vessel's hydraulic winch was rigged through the block of the port J-Frame davit, which provided a consistent rate of descent for acquisition of the SBE 19 data.

A4.c Reson SVP-71

A Reson SVP-71 sensor is mounted at each MBE transducer, real time values are input into both the 7125 SV-2 and EM710 topsides through serial communications. Sound speed values from the sensors were used in real-time during acquisition for beam steering and were also used to QC the sound speed values derived at the surface from the UCTD.

A5. ACQUISITION AND PROCESSING SYSTEMS

All acquisition and processing workstations are located in the Dry Lab of the *Nancy Foster*, are networked as a workgroup, and are interfaced with the ship's backup system. Coastal Oceanographics Hypack/Hysweep 2016 was used for 7125-SV2 bathymetric data acquisition and vessel navigation. The system provided precise time tagging of the sensor data and real-time data displays for quality control. Data was acquired in three formats: .RAW, .HSX and .7K. Kongsberg Seafloor Information System (SIS) software was used to acquire the EM710 bathymetric data in the .all format. A combination of the Geocoder implementation included with Hypack and Fledermaus were used to process the backscatter acquired by the 7125-SV2 and EM710.

Bathymetric survey data was converted and processed in Caris HIPS with modifications to the default Combined Uncertainty Bathymetric Estimator (CUBE) Parameters XML file. The default CUBE Parameters XML was replaced with the XML file issued to all NOAA hydrographic field units included with the Field Procedures Manual (FPM, 5/14). This updated XML file uses the resolution dependent maximum propagation distance values required in the Hydrographic Survey Specifications and Deliverables Manual (HSSD, 3/16). Processing methodology followed the standard Caris HIPS CUBE workflow. These steps include data conversion, filtering, sound velocity correction, tide correction, Total Propagated Uncertainty (TPU) calculation, TrueHeave application, merging, and editing.

Table 2 Acquisition and Processing Software

Hydrographic Systems Inventory	**Cruise# M-I907-NF-16**		**SOFTWARE**
Equipment type	**Manufacturer**	**Model**	**Software Version**
Inertial GPS PCS	Applanix	MV POSView	5.1.0.2
Navigation	Coastal Oceanographics	Survey	2016
Acquisition	Kongsberg	SIS	4.1.8
Acquisition	Coastal Oceanographics	Hysweep	2016
Processing	NOAA	Velocipy	16.9
Processing	CARIS	HIPS & SIPS	9.0.20
Processing	Fledermaus	FMGT	7.4.4
7k Control Center 7125	Reson	7125 SV2	FP 4
7k Control Center 7125	Reson	7K UI	6.1.0.3
7k Control Center 7125	Reson	7K Center	6.1.0.3

7k Control Center 7125	Reson	7K IO	4.2.0.5

A6. SURVEY METHODOLOGY

A6.a Mobilization

Mobilization of the *Nancy Foster* occurred in San Juan, Puerto Rico at the U.S. Coast Guard Pier on April 6th, 2016. Vessel offsets and TPU values used in the HIPS Vessel Files (HVF) were confirmed from the various vessel surveys performed on February 2006, February 2011 and March 2015. These vessel offsets and uncertainties are used in the HVF's for the 7125-SV2 and EM710.

A6.b Survey Coverage

Survey coverage was based on the survey limits of the M-I907-NF-16 Puerto Rico Mapping Project. No formal project instructions were provided for the project, but NOAA CCMA was provided with registry numbers and sheet extents from the Atlantic Hydrographic Branch. Sheets H12935 (Sheet 1) and H12936 (Sheet 2) were surveyed with line orientation appropriate for each of the survey boundaries, approximately parallel to contour or the adjusted orientations for encountered sea states. The survey project boundaries for H12935 were completed, along with an additional 36 nm of shelf edge to the west of the sheet area. Sheet H12936 was not completely surveyed; a 350 m-wide strip at the southern boundary wasn't completed due to time constraints.

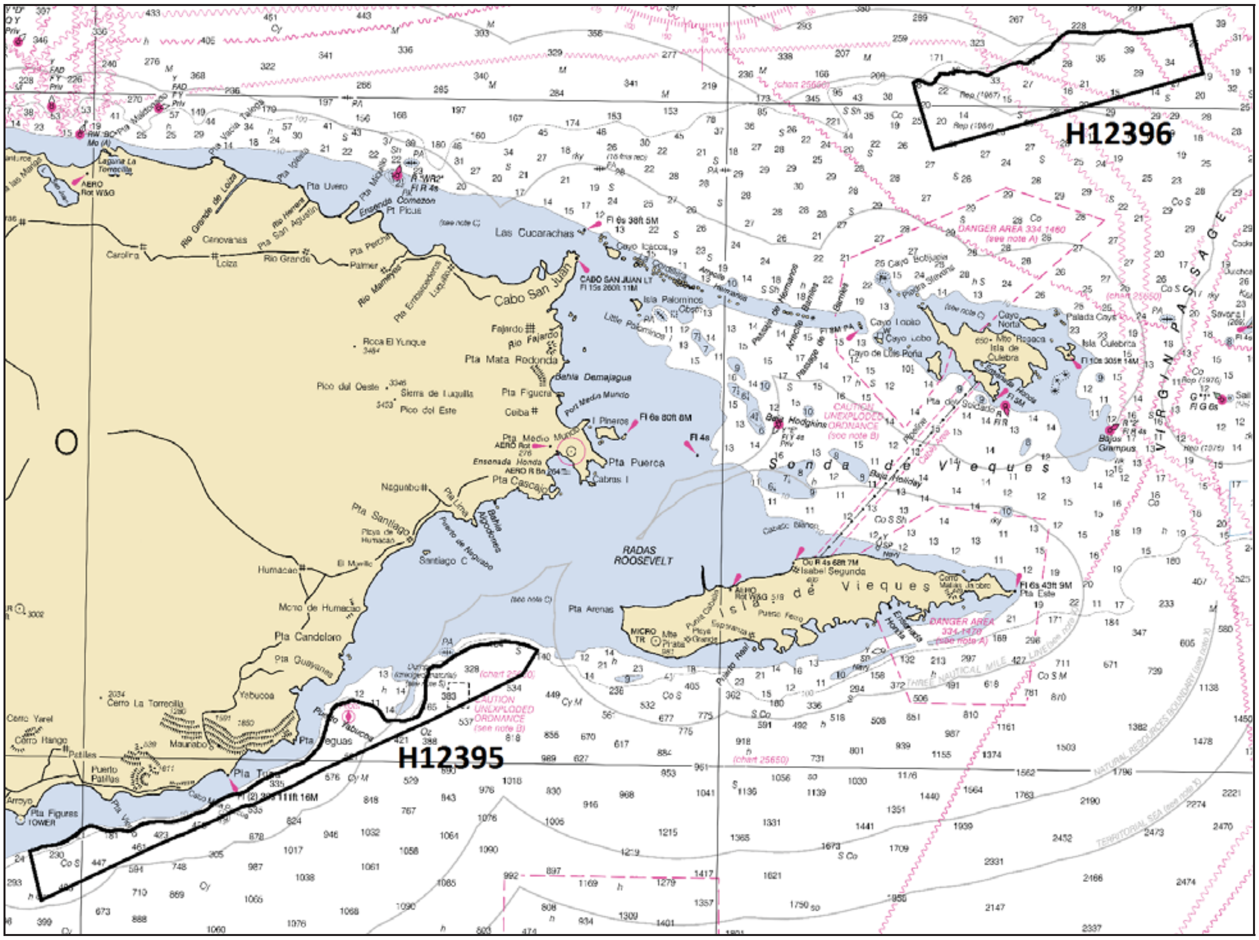


Figure 3 M-I907-NF-16 Sheet Layout

A6.c Multibeam Sonar Operations

Complete multibeam coverage was a requirement for this survey and MBE survey operations utilized the techniques defined by the HSSD. The 7125-SV2 was tuned to simultaneously maximize bathymetric and backscatter data quality by not over-saturating sonar returns by using Pydro's SATMON utility. The MBE was operated at different range scales throughout the survey by adjusting the depth range to obtain the best coverage in varying depths of water. Other parameters were left at a constant to maintain backscatter consistency.

Table 3 Typical Reson 7125-SV2 Sonar Settings

7125-SV2 Parameter	Value
Range	Variable, depth dependent
Gain	20 dB
Power	220 dB
Spreading	30 dB
Absorption	110 dB/km
Ping Rate	9-30 p/s
Pulse Width	33 µs

The EM710 is configured by Kongsberg to be a MBE system that is basically automatically tuned by the SIS acquisition system depending on water depths. The few operator selectable options included sector coverage (generally 55/55 except along steep slopes) swath mode (dynamic) and ping mode (auto).

A7. QUALITY ASSURANCE

Acquisition and processing methods followed systematic and standardized workflows as defined by the FPM. These procedures include, but are not limited to record and log keeping standards, software version management, and a multi-level review process.

B. QUALITY CONTROL

B1. Data Acquisition

B1.a Multibeam

The only incremental adjustments made during acquisition with the 7125-SV2 system involved the sonar range to ensure quality bathymetric and backscatter data. The EM710 system was closely monitored for optimized resolution while continuing to operate in autonomous mode. Vessel speeds were adjusted in accordance with the HSSD to ensure required along-track sounding density occurred with both sonar systems. Typical windows for monitoring raw sensor information included timing synchronization, surface-sound velocity, vessel motion, GPS quality, intensity, and satellite coverage.

B2. DATA PROCESSING

Data processing methodology followed the standard Caris HIPS CUBE workflow. A general flow diagram of the data processing pipeline is presented in Figure 4. This diagram graphically illustrates the general processing workflow from acquisition to delivery.

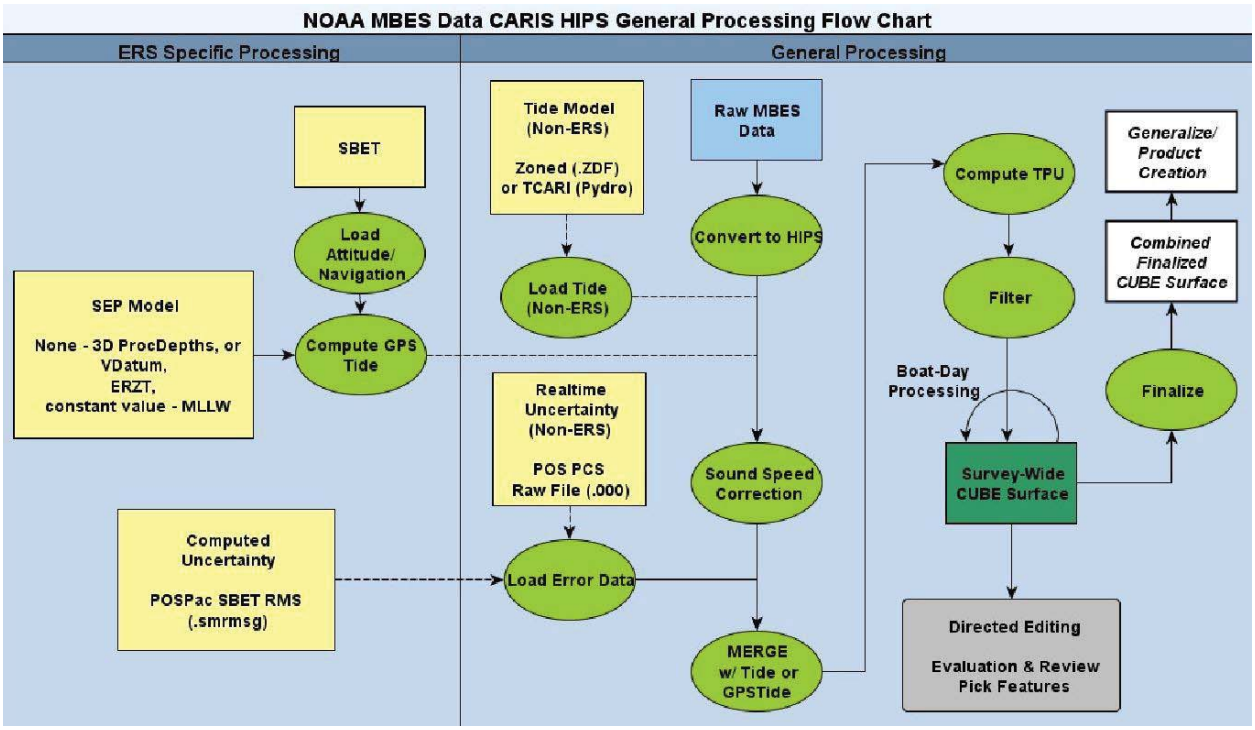


Figure 4 Flowchart of Data Acquisition and Processing Pipeline

B2.a Methodology Used to Maintain Data Integrity

The acquisition systems and survey protocols were designed with some redundancy to demonstrate that the required accuracy and precision was being achieved during the survey. Data integrity confirmation was performed through system comparisons and checks. A position confidence check was performed between the POSMV and DGPS system to confirm horizontal control. Sound speed profiles were computed for each of the sensors and compared to the hull mounted SVP-71 sensors. Frequent horizontal and vertical comparisons of mapped seafloor features with Caris between the 7125-SV2 and EM710 also promoted confidence between the two MBE systems and HVF configurations.

B2.b HIPS Conversion

MBE data were converted from HSX and ALL formats to Caris HDCS format using the Caris Conversion Wizard. Bathymetric data was organized in the typical Project Name, Vessel and Day of Year (DOY) format. During conversion ground coordinates (UTM NAD 83 20N) were selected with no data rejected or filtered during the conversion process. The Caris output window was monitored for failures during data conversion and none were observed.

B2.c Vessel Files

The reference point, as defined by the settings in the POSMV, is the EM710 transmit array, thus the motion and position data is output at the EM710. All offsets and patch values for the EM710 are compensated for in real-time with the POSMV, therefore the HVF EM710 offsets and patch values are zero. All offset and patch values for the 7125-SV2 HVF are in relation to the EM710

reference point. The HVF's in Table 4 contain all offsets and system biases for the 7125-SV2, as well as error estimates for TPU and waterline measurements for both the 7125-SV2 and EM710.

Table 4 HIPS Vessel Files

HIPS Vessel File	HIPS Converter	Sonar Type
NF7125-SV2_400khz_512_2016	Hypack	MBE
NF_EM710	Simrad	MBE

Sensor offset values were derived from various vessel offset surveys conducted by the IMTEC Group, Ltd.. The IMTEC primary GNSS lever arm to Reference Point offsets were compared to the Smoothed Best Estimate of Trajectory (SBET) data processed as part of the ellipsoid referenced waterline procedure discussed in section B2.d. The calibrated x,y,z values agree with the offsets currently entered into the POS/MV within reason for DGPS positioning accuracies. The reference point, as defined by the settings in the POS/MV, is the EM710 transmit array, thus the motion data entering the Reson 7125-SV2 are shifted by lever arm offsets from EM710 to Reson 7125-SV2. These x,y,z values (per the IMTEC Group report) were entered into the Reson 7125-SV2 HVFs.

The TPU values were entered into the HVF were based on current knowledge of the TPU/CUBE processing model. The manufacturers' published values were entered into the static sensor accuracy fields. Other values were either obtained from HTD 2007-10, calculated or estimated. TPU values for the *Nancy Foster* are listed in Table 5.

Table 5 Hydrographic Vessel File TPU Values

Manufacturer Accuracy Values for Total Propagation Uncertainty Computation M-I907-NF-16 HVFs	
Motion Sensor	POS/MV
Position System 1	POS/MV Model 320 V 4
Position System 2	DSM132
Gyro - Heading	
Gyro (°)	0.020
Heave	
Heave % Amplitude	5
Heave (m)	0.050
Roll and Pitch	
Roll (°)	0.020
Pitch (°)	0.020
Navigation	
Position Navigation (m)	1.00
Latency	
Timing Trans (s)	0.010
Nav Timing (s)	0.010
Gyro Timing (s)	0.010

Manufacturer Accuracy Values for Total Propagation Uncertainty Computation M-I907-NF-16 HVFs		
	Motion Sensor	POS/MV
	Position System 1	POS/MV Model 320 V 4
	Position System 2	DSM132
	Heave Timing (s)	0.010
	Pitch Timing (s)	0.010
	Roll Timing (s)	0.010
Measurement		
	Offset X (m)	0.002
	Offset Y (m)	0.002
	Offset Z (m)	0.002
Speed		
	Vessel Speed (m/s)	0.015
Draft and Loading		
	Loading	0.15
	Draft (m)	0.15
	Delta Draft (m)	0.030
Physical Alignment Errors		
Alignment		
	MRU align Stdev gyro	0.0
	MRU align roll/pitch	0.0
*	*All values given as 1 sigma.	

B2.d Static Draft

Three independent measurements of the waterline have been performed since the installation of the EM710 in March 2015, two of them utilizing the ellipsoid referenced waterline technique (developed by Glen Rice in 2011) and one of them simply measuring the draft marks while in port and referencing the observation to the vessel offset survey. Records of POSMV data were logged after installation in March 2015; for 3.9 hours on 3/18/15 while inport at Charleston, and 9.7 hours on 3/28/15, while inport at Crown Bay. The POSMV records were post processed in Applanix POSPac to obtain a SBET file which contains the vessel's NAD 83 ellipsoid heights. The correlating water levels from a nearby tide gauge were also obtained with water levels referenced to the NAD 83 ellipsoid. Then the time series are differenced to obtain a third time series of vertical offset from waterline to ship reference point, this procedure was provided by Mr. Rice in a python utility. The results of two ellipsoid referenced waterline measurements, performed in Charleston (left), and Crown Bay (right) are shown below (Figure 5).

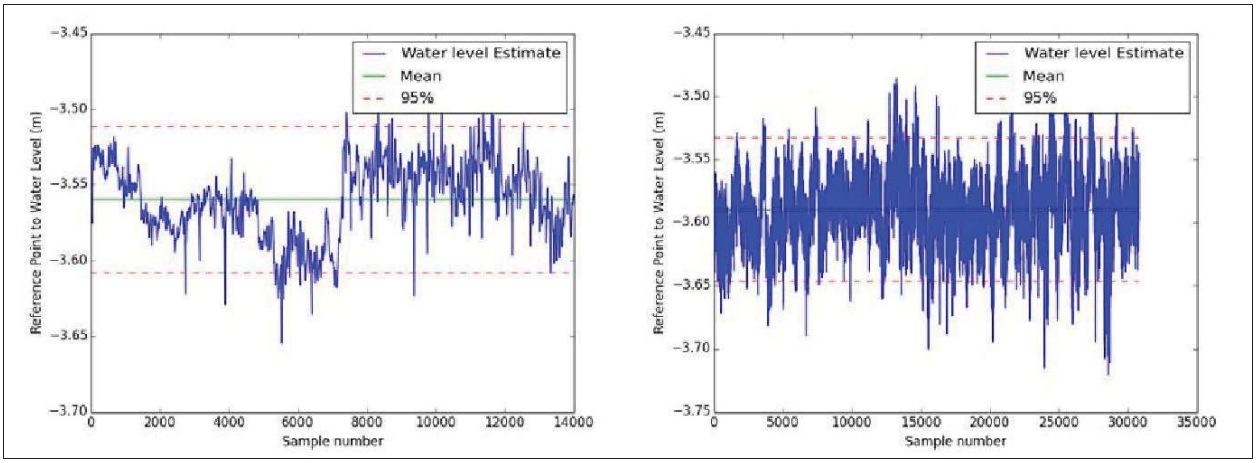


Figure 5 March 2015 ERS Waterline Measurement Results

The results are -3.56 +/ - 0.05m (Charleston), -3.59 +/ - 0.06m (Crown Bay), and -3.50 (draft mark observation referenced to EM710). The waterline value utilized during mapping operations and currently entered into SIS, the EM710 HVF, and the 7125-SV2 HVF is -3.56 m. This value is applied in real-time to the EM710 data via SIS, so therefore the waterline value in the EM710 HVF is set to not apply, and is only necessary for ray tracing if there is a need to reapply sound speed. The waterline value in the 7125-SV2 HVF is set to apply.

B2.e Sound Velocity

All sound speed profiles were concatenated and organized into one complete file for each sheet. Sound velocity casts were applied to each line using the nearest in distance within time (five hour) option in the Caris SVP correction routine. Velocity casts were taken at approximately four-hour frequency intervals with the UCTD throughout the survey sheets. Ray-tracing uncertainty analyses were performed periodically to ensure the four-hour sampling rate was sufficient to keep up with water column variability. Of the comparisons performed, the highest magnitude of refraction error between consecutive casts occurred in the example shown below. Here the estimated maximum outer beam refraction using a simulated 120° swath is 0.66 m, well

within the maximum allowable error attributable to refraction in this water depth, which is 1.34 m.

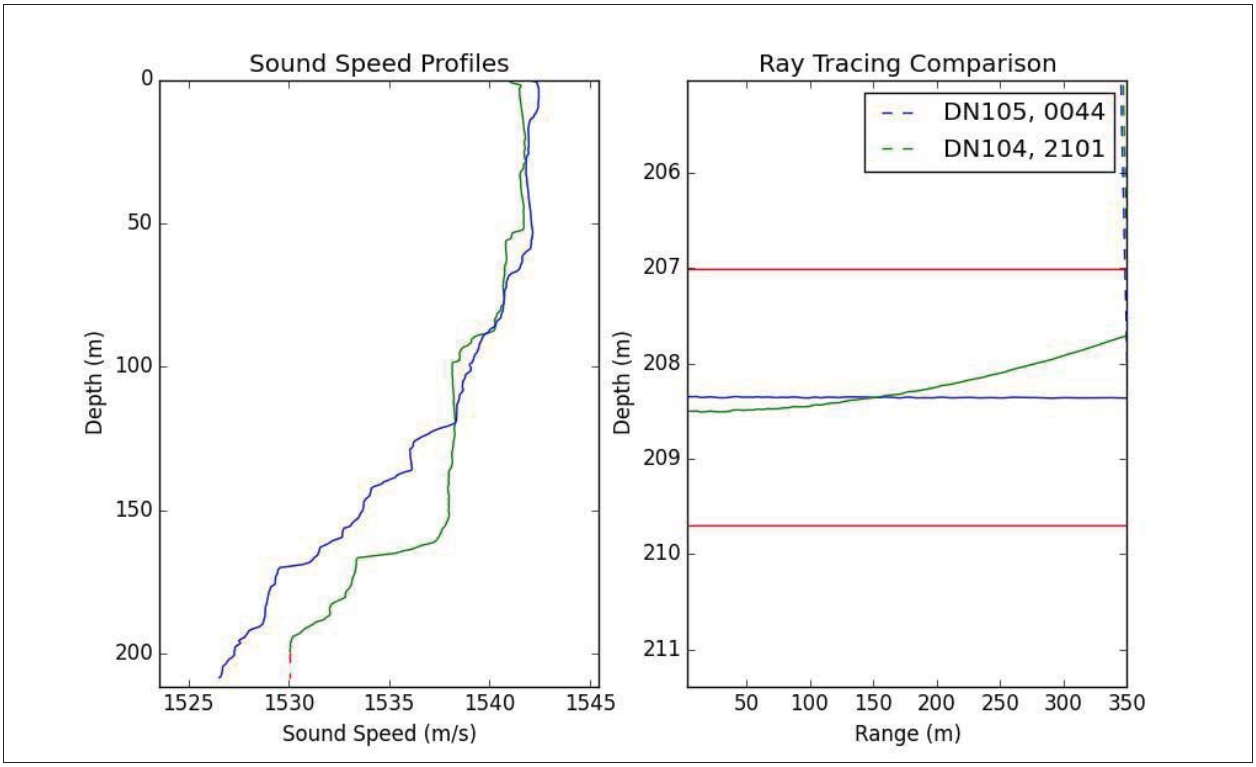


Figure 6 Ray-Tracing Uncertainty Analysis

B3. CARIS DATA PROCESSING

Below is a list of the general workflow for processing the MBE data. Several of the steps are interim processes, such as the water levels, SVP, merge and were re-applied as needed. The TPU was also re-computed as needed to reflect changes in the correctors.

1. Apply true heave
2. Load zero tide
3. Apply daily concatenated sound speed profiles
   - "Nearest in distance within time 5 hour"
4. Merge
5. Compute TPU
6. Filters applied based on the following criteria:
   - Reject soundings with poor quality flags (0,1,2)
7. Add data to field sheet:
   - CUBE surface of appropriate resolution for water depth per HSSD
     - Density & Local Disambiguation method
     - Advanced configuration using the 2010 NOAA XML File

8. SBET solutions applied to temporally-overlapping survey lines in post-processing, once final CORS station and ephemeris data become available
9. TCARI tide solution applied for post-processing vertical alignment, once final TCARI grid and water level data become available
10. Re-compute and review CUBE layers and edit accordingly
11. Data reviewed and fliers removed in Swath Editor and/or Subset Editor
12. Finalize surfaces with uncertainty from "Greater of the two"
    - Apply depth thresholds per HSSD requirements
13. Create TVU QC child layer and review for IHO compliance.

The CUBE surfaces were created using grid-resolution depth thresholds and resolution dependent maximum propagation distances for complete coverage surveys as specified in the 2016 HSSD. Multibeam data processing followed the standard HIPS workflow for CUBE editing except that the hypothesis surface was not edited; instead, fliers influencing the CUBE surface were rejected. Subset tiles were used to track the progress of processing activities. Surfaces were reviewed for excessive motion artifacts or systematic biases. All crosslines were manually reviewed for internal consistency between the datasets and comparison statistics were also computed using the HIPS QC Report tool.

Data were reviewed in HIPS 2D subset with the CUBE reference surface visible. Soundings rejected by quality filters were displayed during editing, and any feature removed by a filter was manually re-accepted. Fliers making the CUBE surface shoaler than expected by more than the allowable IHO vertical error were rejected.

The CUBE surfaces were reviewed to confirm where, and if, holidays greater than three nodes sharing adjacent sides in the surface, or data gaps over significant contacts may exist. The HIPS density layer of each grid was reviewed to confirm that the minimum sounding density of five soundings per node was achieved for 95 percent of nodes populated by mainscheme survey lines. After finalizing the CUBE surfaces, TVU QC child layers were created and reviewed for final International Hydrographic Organization (IHO) compliance.

B4. Final Bathymetric Processing

The finalized CUBE surfaces were generated using the "greater of the two" option for the final uncertainty value. Surfaces were reviewed in the 3D graphics window with an extreme vertical exaggeration to verify that all fliers have been removed from the surfaces. Thorough analysis determined that the 2m resolution CUBE surface is an accurate representation of the seafloor in the shallow regions for each survey sheet. The 2m surface honors the shoalest reliable soundings within 1/2 of the allowable TVU, therefore no designated soundings were used on either sheet.

The Raster Product Export function was then used on each finalized CUBE Depth surface and exported as individual Bathymetry Attributed Grid (BAG) files.

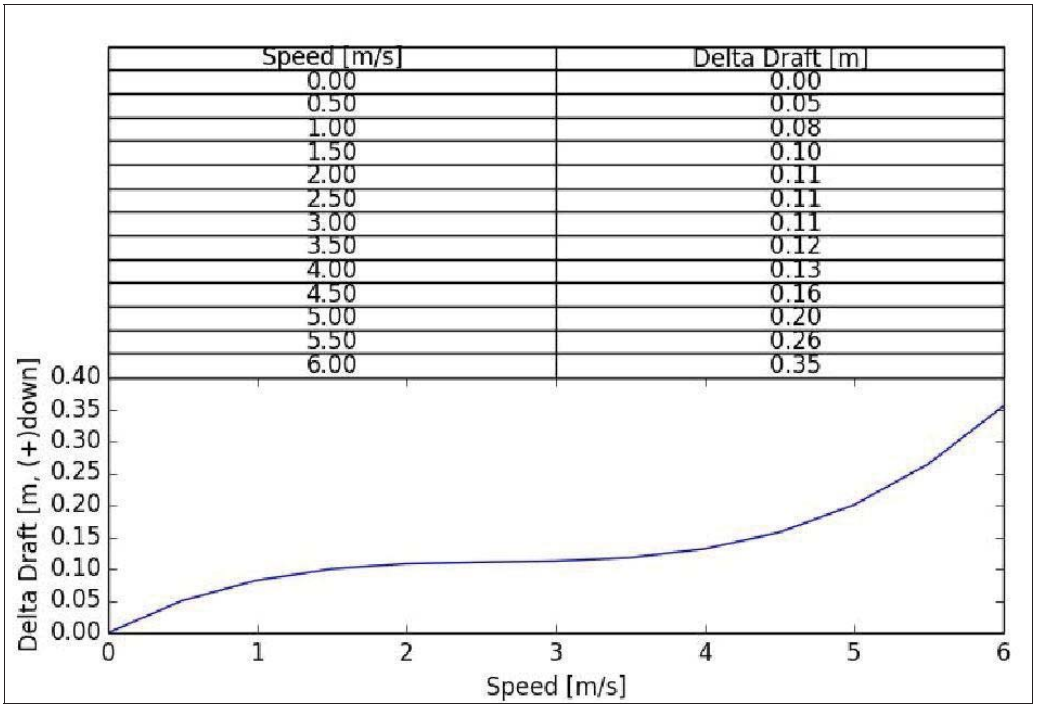
C. CORRECTIONS TO ECHO SOUNDINGS

C1. Static Draft

Please see section B2.d

C2. Dynamic Draft

An ellipsoid referenced dynamic draft procedure was conducted just south of St. Thomas, during calm seas on April 4th, 2015. This procedure requires POS/MV POSPac data while the ship is at rest and then at transitions of 2 knot increments up to top speed, moving for 2 minutes at each speed in a straight transect. Then the ship slows to rest, and repeats the procedure while moving back along the same transect. An SBET file was then created from the processed POS/MV data. The dynamic draft procedure, accessible via Pydro, incorporates the processed SBET and outputs adjustments of the vessel height as a function of speed. The results were entered into the dynamic draft entry for all HVF's onboard the ship and are shown in Figure 7.



Speed [m/s]	Delta Draft [m]
0.00	0.00
0.50	0.05
1.00	0.08
1.50	0.10
2.00	0.11
2.50	0.11
3.00	0.11
3.50	0.12
4.00	0.13
4.50	0.16
5.00	0.20
5.50	0.26
6.00	0.35

Figure 7 ERS Dynamic Draft Results

C3. LeadLine Comparisons

A lead line check was performed against the multibeam echosounder on April 6, 2016 (DN097) while the vessel was tied up alongside the pier in San Juan, Puerto Rico. The lead line reading of 33.35 ft (10.165 m) was taken ~6 m to port of the multibeam system in unconsolidated sediment. Digital data was logged simultaneously during the lead line procedure. The multibeam data was then converted and queried in Caris HIPS swath editor to confirm that the acoustic depths matched the lead line reading at this point 6 m across track to port. The lead line readings agreed

with the multibeam soundings within 0.10 m. This value is deemed adequate, considering the conditions that the comparisons were performed in. These observations were recorded in the acquisition log and are also included in Appendix II Echosounder Reports.

C4. Heave, Roll and Pitch Corrections

An Applanix POS/MV 320 v4 integrated dual frequency GPS and inertial reference system was used for the motion sensor for this survey. The POS/MV 320 is a 6-degree of freedom motion unit, with a stated accuracy of 0.05-meter or 5 percent for heave, 0.01 degrees for roll and pitch and heading. Real-time displays of the vessel motion accuracy were monitored throughout the survey with the MV POSView controller program. Manufacturer reported accuracies as published on the Caris HIPS TPU website (http://www.caris.com/tpu/) were entered into the HVF and used for TPU computations.

C5. Patch Test

The EM710 was patch tested on April 7th, 2016, and a patch test was performed for the Reson 7125-SV2 sonar system on April 14th, 2016. The EM710 patch values are entered into the POSMV, whereas the 7125-SV2 values are applied within the HVF file. The purpose of the patch tests was to measure alignment offsets between the IMU sensor and the multibeam transducers, while also determining time delays between the time-tagged sensor data. The patch test consisted of a series of lines run in a specific pattern, which were then used in pairs to analyze roll, pitch, and heading alignment bias angles.

Roll alignment was determined by evaluating the reciprocal lines run over a flat bottom. The pitch tests consisted of set of reciprocal lines located on a steep slope. The yaw error was determined by running parallel lines over the same slope separated by approximately four times water depth. Latency lines were run at varying speeds over a changing slope in the same direction. The roll, pitch and yaw lines were collected at approximately 7 knots, whereas the latency lines were run at 4 and 8 knots.

Selected pairs of lines were then analyzed in HIPS Calibration editor to measure the angular sensor bias values. Visual inspection of the data confirmed each adjustment. Final, patch tested values for the sonar systems – a summation of known measured rotation and current patch test values – are listed in Table 6.

Table 6 Patch Test Values

M-I907-NF-16 Patch Test Values				
	Pitch	**Roll**	**Yaw**	**Latency**
EM710	-1.066	-0.595	0.354	0.00
7125-SV2	-0.750	-0.370	-0.150	0.00

C6. Tide and Water Level Corrections

Existing water level station data was used in conjunction with tidal constituents and weighting functions contained within a TCARI (.tc) grid file overlaying the survey area and supplied by the

Center for Operational Oceanographic Products and Services (CO-OPS). This methodology was designed by the Office of Coast Survey (OCS) for the purpose of reducing bathymetry data relative to Mean Lower Low Water (MLLW) at selected coastal hydrographic survey areas. It incorporates spatially-interpolated amplitudes and phases of harmonic constants (the foundation for predicting astronomic tides), the relevant tidal datum (MLLW in this case), and residual water levels (the difference between predicted and observed tides) in order to derive tide reducers for the locations of the individual ship tracks overlaid on the TCARI grid.

The four water level stations used for sheets H12935 and H12936 were Lime Tree Bay, St. Croix, VI (9751401), Esperanza, PR (9752695), San Juan, PR (9755371), and Magueyes Island, PR (9759110). Following the survey completion, the preliminary TCARI grid (.tc) file was accepted as final by CO-OPS, and final verified water levels (relative to MLLW) were used in the final TCARI processing in Pydro. In addition, an uncertainty model is generated by propagating water level uncertainties, datum uncertainties, and TCARI grid vertical uncertainties, and this is included in the TPU computations for the final surfaces. Further tidal information is included in the associated Descriptive Reports (DRs) for H12935 and H12936.

C7. Sound Velocity Correction

Sound velocity casts were generally performed at four hour intervals during survey operations. After each cast the sound speed data was reviewed for outliers or anomalies that could impact data quality. Additionally, the sound speed measured by the UCTD at the surface was compared to the Reson SVP-71 for surface sound velocity agreement.

The sound speed correction was applied to each line using the nearest in distance within time (five hour) option in the HIPS SVP correct routine. All casts were concatenated into a sheet specific HIPS SVP file for each survey sheet with the associated time, position, depth, and sound speed information for each cast.

D. LETTER OF APPROVAL

The letter of approval for this report follows on the next page.

LETTER OF APPROVAL

M-I907-NF-16 DATA ACQUISITION AND PROCESSING REPORT

This report and the accompanying data are respectfully submitted.

Field operations contributing to the accomplishment of M-I907-NF-16 were conducted under my direct supervision with frequent personal checks of progress and adequacy. This report and associated data have been closely reviewed and are considered complete and adequate.

Mike Stecher

Digitally signed by Mike Stecher
DN: cn=Mike Stecher, o, ou=Solmar Hydro Inc, email=solmarhydro@gmail.com, c=US
Date: 2016.12.12 10:14:51 -08'00'

Appendix I: Vessel Reports

NOAA SHIP NANCY FOSTER (R-352)
SENSOR ALIGNMENT & ORTHOGONAL COORDINATE SURVEY
FEBRUARY-MARCH 2015

FINAL REPORT

March 17, 2015 - Rev "0"

Prepared By:

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CONTENTS

PROJECT OVERVIEW

Purpose

The purpose of this commentary is to summarize the procedures and analytical methods employed to perform the 3-D coordinate total station inspection that produced the data in this report for those unfamiliar with the equipment and process.

Dimensional data resulting from the inspection is included with the report.

General Comments

This report summarizes coordinate measurement data taken on the vessel NOAA Ship Nancy Foster February 12 thru March 5, 2015. The vessel was located in a dry dock at GMD Shipyard, Inc., Brooklyn Navy Yard, Brooklyn, NY.

Coordinate measurements were taken to characterize the vessel and create the required reference coordinate systems for reporting azimuth, pitch, roll and coordinate data.

Coordinate measurements were then taken to define elements and features as requested by NOAA representatives in support of the EM710 Multi-Beam Sounding system transducer installation.

Locations of existing draft marks were measured and recorded.

3-D Coordinate Measurement Equipment

A Sokkia NET 1200 enhanced electronic total station operated through a notebook computer running New River Kinematics Spatial Analyzer™ measurement and analysis software was utilized. This system measures 3-D spherical coordinates by recording an azimuth and zenith angle simultaneously with the near infrared distance coaxial with the telescope line of sight for each observation. Spatial Analyzer measurement and analysis software converts the spherical coordinate data to a Cartesian coordinate system that can be defined by the user. Measurements are made to either adhesive or kinematic targets that have a retro-reflective target face.

Temporary "benchmarks" or reference points were placed throughout the dry-dock area and on the vessel as required to allow for re-locating the instrument to a new position or "Station" and tie all of the data to the common coordinate system for comparison.

The measuring system used for this final inspection report is one of several owned by The IMTEC Group, Ltd. The NET 1200 total station, S/N 110554 was calibrated, traceable to N.I.S.T. and in accordance with A.N.S.I. Z-540-1, at the Sokkia USA Factory Service Center January 23, 2015.

Reference Coordinate Systems

The following parameters were used to define the reference coordinate system for reporting the survey data per Kongsberg representatives.

Survey data with respect to 2 additional coordinate systems was requested by NOAA representatives.

Kongsberg requested coordinate system:

Origin: Center of Granite Block: X=0.000, Y=0.000, Z=0.000 (intersection of etched lines)

Pitch: Pairs of points were surveyed at frames 20, 32, 40, 52, 60, 70 on main keel plate and frames 79, 88 and 95 on the skeg. A best-fit plane was derived using all pairs except those at frames 52 and 79 where the keel had a severe amount of distortion as compared to the rest of the points.

Roll: The 4 (port/stbd and fwd/aft) 12' draft marks were used to define the roll.

X Axis: Single points were taken at frames 10 and 107 on the centerline of keel and midpoints were constructed from the pairs of points used to define the keel plane. These points were then projected onto the keel plane and used to construct a best fit line to define the ship's heading (Azimuth).

Thus the coordinate system is depicted as shown:

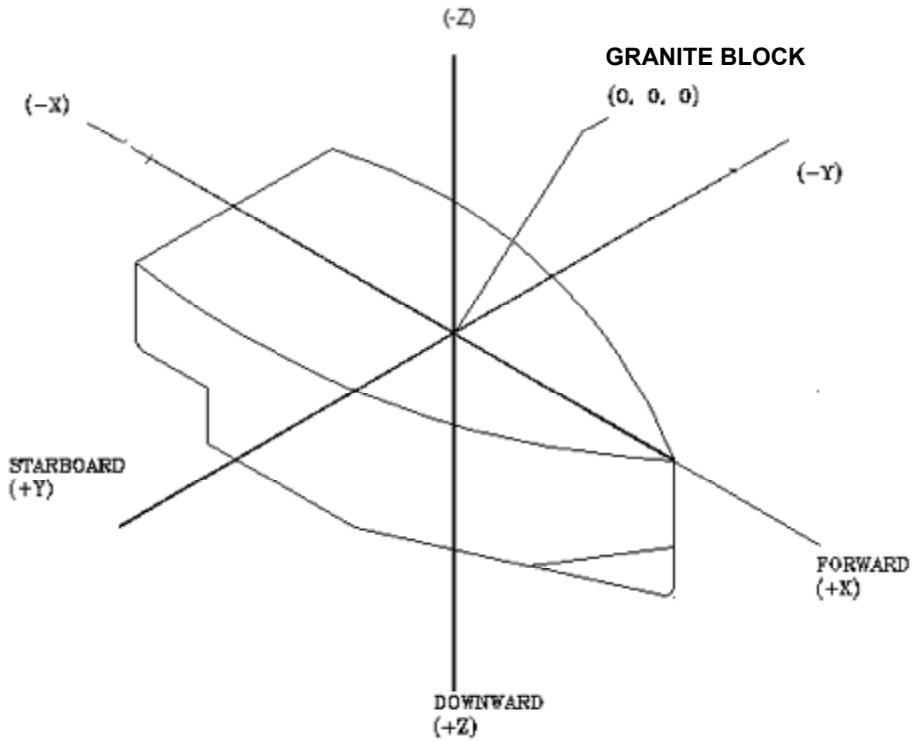


Figure 1 – Vessel Coordinate System

The first coordinate system requested by NOAA is defined as follows:

Origin: Center of Granite Block: X=0.000, Y=0.000, Z=0.000 (intersection of etched lines)

Pitch: Plane of Granite Block.

Roll: Plane of Granite Block.

X Axis: Etched Azimuth line on Granite Block.

Granite Block therefore completely defines the vessel coordinate system.

The second coordinate system requested by NOAA is defined as follows:

Origin: Center of EM710 TX Transducer Face: X=0.000, Y=0.000, Z=0.000

Pitch: Plane of EM710 TX Transducer frame

Roll: Plane of EM710 TX Transducer frame

X Axis: Line constructed from midpoints fwd/aft on EM710 TX transducer frame rails.

EM710 TX Transducer therefore completely defines the vessel coordinate system.

NOAA Representative requested that all survey data be presented in these two coordinate systems including the draft marks.

Measurement Procedure

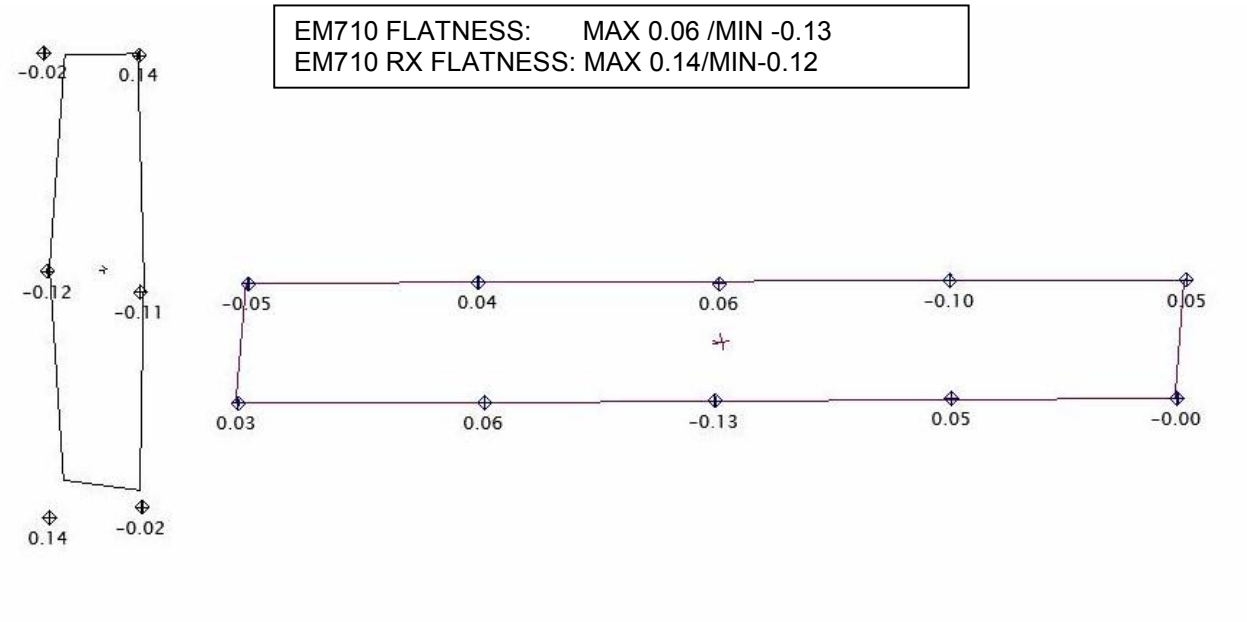
Adhesive targets with retro reflective target face were used throughout the survey as temporary benchmarks for relocating the instrument to new stations. Kinematic (a target with a known offset) retro reflective targets such as the RT-50M swivel targets were frequently used as a temporary benchmark.

The Sokkia NET 1200 total station operated through a notebook computer running Spatial Analyzer™ industrial measurement software was used to measure the targets and record observations.

EM 710TX and EM 710RX Transducers

After the transducer frames were installed, data points were surveyed at each of the bolt locations to determine overall flatness. With a tolerance of 0.20 mm, shim values were provided

to Kongsberg to meet the flatness requirement. After shims were added and bolts final torqued, the frames were again surveyed to document final flatness.



Final location (X, Y, Z), pitch, roll and azimuth of the Kongsberg transducer frames with respect to the vessel coordinate system are found in Tables 2 & 3.

Vessel Benchmarks and Navigation Elements

Existing benchmarks and elements were surveyed as part of this effort and values for each are reported in the vessel orthogonal coordinate system. The Benchmarks are summarized in Table 1 of this report. Vessel elements are summarized in Table 2.

The coordinates, azimuth & inclination of the Granite Block, IMU and Gyros were measured and recorded as shown in the Table 3. Draft Marks are summarized in Table 4.

TABLE 1- NOAA NANCY FOSTER SHIP SYSTEM BENCHMARK TABLE (METERS)			
BENCHMARK	**X**	**Y**	**Z**
AFT CUBE FACE	-35.9163	5.8001	-4.6643
AFT CUBE TOP	-35.9166	5.8315	-4.6973
AFT PORT BM	-37.8277	-5.2644	-3.8554
AFT STBD BM	-37.8198	5.2546	-3.8569
AFT TOW CTR	-43.2396	0.0046	-8.0539
C LAFT DECK	-37.8237	-0.0049	-3.8562
FLYING BRRIDGE CUBE FACE	6.4589	0.0073	-14.2725
FLYING BRIDGE CUBE TDC	6.5110	0.0295	-14.2819
FLYING BRIDGE PORT BM	4.6972	-5.6143	-14.2146
FLYING BRIDGE STBD BM	4.7002	5.5941	-14.1930
FWD MAST PUNCH MARK	16.1182	-0.0357	-8.5101
KEEL AFT BM	-1.7152	-0.0145	1.1048
KEEL FWD BM	2.7929	-0.0160	1.1113
MOON POOL BM	-21.9543	1.2146	-3.8048
SIDETOW AFT PUNCH	-28.6788	-5.8742	-4.3947
SIDETOW FWD PUNCH MARK	-25.5838	-5.8456	-4.2673
PORT PILOT DECK PUNCH	2.1572	-5.6605	-9.1247
STBD PILOT DECK PUNCH	1.9601	5.5828	-9.2587

TABLE 2- NOAA NANCY FOSTER SHIP SYSTEM ELEMENT TABLE (METERS)			
DESCRIPTION	**X**	**Y**	**Z**
SPEED LOG CTR	-9.6264	0.5552	1.0651
EK60 200 MHZ CTR	-8.0992	-1.5550	1.5586
BLANK CTR	-7.7548	-1.5565	1.5577
KNUDSEN 12KHZ CTR	-7.2156	-1.5576	1.5594
EK60 38MHZ CTR	-6.6074	-1.5611	1.5594
ADCP CTR	-6.0323	-1.5619	1.5636
EK60 120MHZ CTR	-5.5910	-1.5637	1.5641
MOON POOL CTR	-22.4801	1.2113	1.1040
RESON TX	-2.1772	0.3681	1.1069
RESON RX	-1.7294	0.5480	1.0986
KONGSBERG 710TX CTR	1.3635	1.8128	1.3684
KONGSBERG 710 RX CTR710	0.1572	1.9160	1.3857
PROJECTION LOW POINT FAIRING	-0.4741	1.9341	1.4112
FURUNO GP150 GPS-2 TDC	1.5816	-3.0001	-16.1387
FWD RAIL STBD SPARE GPS @ BASE	6.4324	3.3084	-15.2609
DP STBD @ BASE	0.9532	2.7917	-16.3507
DP PORT @ BASE	0.9292	-2.8209	-16.4127
POS/MV AFT GPS PHASE CTR	4.3203	-4.7241	-16.2864
POS/MV FWD GPS PHASE CTR	6.5803	-4.7410	-16.2964
POS/MV TRIMBLE TDC	5.4096	-4.6366	-16.3332
GP7000 TDC	2.4877	2.7110	-16.4113
FURUNO GP 37 GPS TDC	2.5427	-2.7591	-16.4250
GRANITE BLOCK CTR	0.0000	0.0000	0.0000
IMU TDC	0.7390	-0.0022	-0.1200
IMU CUBE FACE BM	1.6142	1.7532	-0.0386
IMU BM	-1.4672	0.2396	-0.1956
IMU FWD BM	3.3937	0.2352	-0.1935

TABLE 3-AZIMUTH,PITCH, AND ROLL W/R NOAA SHIP STSTEM, DECIMAL DEGREES						
ELEMENT	AZIMUTH		PITCH		ROLL	
	VALUE	DIRECTION	VALUE	DIRECTION	VALUE	DIRECTION
GRANITE BLOCK	0.06405	TO PORT	0.07856	BOW DOWN	0.07007	STBD DOWN
IMU	0.01747	TO PORT	0.17024	BOW DOWN	0.00615	STBD DOWN
710TX	0.16875	TO PORT	0.89562	BOW DOWN	0.34807	STBD DOWN
710RX	0.55717	TO PORT	0.70454	BOW DOWN	0.64005	STBD DOWN
VALEPORT SVP	-	-	2.22177	BOW DOWN	0.65100	STBD DOWN
REASON TX	0.80926	TO PORT	0.19948	BOW DOWN	0.39161	STBD DOWN
REASON RX	0.80926	TO STBD	0.55449	BOW DOWN	0.05421	STBD DOWN

TABLE 4- NOAA NANCY FOSTER DRAFT MARKS					
MARK	**Z**	**Ref**	**MARK**	**Z**	**Ref**
PORT AFT DM9	-9.1	-1.660	STBD AFT DM9	-9.1	-1.660
PORT AFT DM10	-10.0	-1.963	STBD AFT DM10	-10.0	-1.963
PORT AFT DM11	-11.0	-2.259	STBD AFT DM11	-11.0	-2.259
PORT AFT DM12	-12.1	-2.576	STBD AFT DM12	-12.1	-2.576
PORT AFT DM13	-13.0	-2.877	STBD AFT DM13	-13.0	-2.877
PORT FWD DM8	-8.0	-1.334	STBD FWD DM8	-7.9	-1.321
PORT FWD DM9	-9.0	-1.640	STBD FWD DM9	-9.0	-1.632
PORT FWD DM10	-10.0	-1.947	STBD FWD DM10	-10.0	-1.943
PORT FWD DM11	-11.0	-2.250	STBD FWD DM11	-11.0	-2.247
PORT FWD DM12	-12.0	-2.554	STBD FWD DM12	-12.0	-2.549
PORT FWD DM13	-13.0	-2.857	STBD FWD DM13	-13.0	-2.855
PORT FWD DM14	-14.0	-3.160	STBD FWD DM14	-14.0	-3.158
PORT FWD DM15	-15.0	-3.469	STBD FWD DM15	-15.0	-3.463
PORT PROJ DM8	-7.11	-0.757	STBD PROJ DM8	-7.07	-0.744
PORT PROJ DM9	-8.10	-1.058	STBD PROJ DM9	-8.07	-1.048
PORT PROJ DM10	-9.10	-1.363	STBD PROJ DM10	-9.07	-1.354
PORT PROJ DM11	-10.13	-1.675	STBD PROJ DM11	-10.09	-1.663
PORT PROJ DM12	-11.13	-1.981	STBD PROJ DM12	-11.09	-1.968
PORT PROJ DM13	-12.11	-2.281	STBD PROJ DM13	-12.09	-2.273
PORT PROJ DM14	-13.12	-2.586	STBD PROJ DM14	-13.08	-2.577

Z is Elevation above Keel measured in Feet

Ref is Height with respect to Granite Block measured in meters

Measurement Precision and Uncertainty

Uncertainties are reported to be:

Point to Point, any element or target within the vessel survey to another element or feature in the survey

$X, Y, \& Z \leq 1.5$ mm

Region to Region, i.e., GPS antenna to EM710 RX/TX features:

$X \leq 2.0$ mm

$Y \leq 2.0$ mm
$Z \leq 2.0$ mm

The angular measurement precision of the NET1200 is < 1 arc second in azimuth and zenith. There can be some error introduced by targeting. Random and systematic errors can be introduced by the working environment.

The expected angular precision of the survey is analyzed to be:

Azimuth, Pitch, Roll: ≤ 00° 00' 30"

PROJECT DATA

The required data is summarized in tabular form on the following pages. The units of measure for reporting are indicated on each table.

Table 1 reports the X, Y and Z, values for specified benchmarks in units of meters and in the final vessel coordinate system.

Table 2 reports the X, Y and Z, values for specified elements in units of meters and in the final vessel coordinate system.

Table 3 reports the Azimuth, Pitch and Roll of specified elements.

Table 4 reports the summarized data for the draft mark survey and is presented with Feet as the unit of measure to correlate with the specific draft mark number. Draft marks were measured for elevation only, and at the bottom of the weld. Draftmark elevations are reported above the best-fit keel as surveyed.

Appendix 1 is a copy of all 3 tables with the data presented with respect to the 1st coordinate system requested by NOAA: Granite Block as Origin and also defining Az, Pitch and Roll.

Appendix 2 is a copy of all 3 T ables with the data presented with respect to the 2nda coordinate system requested by NOAA: EM710 Tx Transducer Center as Origin and defining Az, Pitch & Roll.

Appendix 1 – NOAA Requested Coordinates wrt Granite Block

TABLE 1- NOAA NANCY FOSTER BENCHMARK TABLE W/R GRANITE BLOCK (METERS)			
BENCHMARK	**X**	**Y**	**Z**
AFT CUBE FACE	-35.916272	5.800141	-4.664265
AFT CUBE TOP	-35.916627	5.83149	-4.697301
AFT PORT BM	-37.827669	-5.264442	-3.855434
AFT STBD BM	-37.819771	5.254558	-3.856944
AFT TOW CTR	-43.239573	0.004598	-8.053891
CL AFT DECK	-37.82372	-0.004942	-3.856189
FLYING BRRIDGE CUBE FACE	6.45888	0.007309	-14.272523
FLYING BRIDGE CUBE TDC	6.511005	0.029505	-14.281894
FLYING BRIDGE PORT BM	4.697224	-5.61431	-14.214619
FLYING BRIDGE STBD BM	4.700203	5.594124	-14.193041
FWD MAST PUNCH MARK	16.118243	-0.035652	-8.510135
KEEL AFT BM	-1.71524	-0.014508	1.104821
KEEL FWD BM	2.792855	-0.01597	1.111258
MOON POOL BM	-21.954346	1.214577	-3.804787
SIDETOW AFT PUNCH	-28.678783	-5.874176	-4.394697
SIDETOW FWD PUNCH MARK	-25.583826	-5.845602	-4.267257
PORT PILOT DECK PUNCH	2.157231	-5.660526	-9.124689
STBD PILOT DECK PUNCH	1.960138	5.582815	-9.258711

TABLE 2- NOAA NANCY FOSTER ELEMENT TABLE W/R GRANITE BLOCK (METERS)			
DESCRIPTION	**X**	**Y**	**Z**
SPEED LOG CTR	-9.626399	0.555234	1.065054
EK60 200 MHZ CTR	-8.099244	-1.554993	1.558577
BLANK CTR	-7.754762	-1.556455	1.557728
KNUDSEN 12KHZ CTR	-7.215579	-1.55755	1.559416
EK60 38MHZ CTR	-6.607425	-1.561094	1.559423
ADCP CTR	-6.032253	-1.561932	1.563602
EK60 120MHZ CTR	-5.591048	-1.563732	1.564061
MOON POOL CTR	-22.480066	1.211263	1.103977
RESON TX	-2.177237	0.368131	1.106926
RESON RX	-1.72942	0.548047	1.098574
KONGSBERG 710TX CTR	1.36347	1.812773	1.368423
KONGSBERG 710 RX CTR710	0.157232	1.916027	1.385719
PROJECTION LOW POINT FAIRING	-0.474088	1.934089	1.411225
FURUNO GP150 GPS-2 TDC	1.581602	-3.000078	-16.138728
FWD RAIL STBD SPARE GPS @ BASE	6.408886	3.29468	-15.27371
DP STBD @ BASE	0.953155	2.791743	-16.350728
DP PORT @ BASE	0.929182	-2.820928	-16.412695
POS/MV AFT GPS PHASE CTR	4.320288	-4.72414	-16.286435
POS/MV FWD GPS PHASE CTR	6.580311	-4.740958	-16.296409
POS/MV TRIMBLE TDC	5.409574	-4.636594	-16.333162
GP7000 TDC	2.487728	2.711017	-16.411331
FURUNO GP 37 GPS TDC	2.542652	-2.759122	-16.425045
GRANITE BLOCK CTR	0	0	0
IMU TDC	0.739027	-0.002181	-0.120018
IMU CUBE FACE BM	1.614188	1.75317	-0.03857
IMU BM	-1.467211	0.239554	-0.195639
IMU FWD BM	3.393688	0.235238	-0.19347

TABLE 3-AZIMUTH,PITCH, AND ROLL W/R GRANITE BLOCK DECIMAL DEGREES						
ELEMENT	AZIMUTH		PITCH		ROLL	
	VALUE	DIRECTION	VALUE	DIRECTION	VALUE	DIRECTION
GRANITE BLOCK	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
IMU	0.02672	TO STBB	0.24875	BOW DOWN	0.06411	STBD DOWN
710TX	0.21197	TO PORT	0.97439	BOW UP	0.27725	STBD UP
710RX	0.60246	TO PORT	0.78256	BOW UP	0.71074	STBD UP
VALEPORT SVP	-	-	-2.14381	BOW DOWN	0.71937	STBD DOWN
REASON TX	0.21197	TO PORT	0.27828	BOW DOWN	90.32133	STBD UP
REASON RX	0.21197	TO PORT	0.63304	BOW DOWN	-90.01636	STBD UP

Appendix 2 – NOAA Requested Coordinates wrt EM710 TX Transducer

TABLE 1- NOAA NANCY FOSTER BENCHMARK TABLE W/R 710 TX (METERS)			
BENCHMARK	**X**	**Y**	**Z**
AFT CUBE FACE	-37.2797	3.9874	-6.0327
AFT CUBE TOP	-37.2801	4.0187	-6.0657
AFT PORT BM	-39.1911	-7.0772	-5.2239
AFT STBD BM	-39.1832	3.4418	-5.2254
AFT TOW CTR	-44.6030	-1.8082	-9.4223
CL AFT DECK	-39.1872	-1.8177	-5.2246
FLYING BRRIDGE CUBE FACE	5.0954	-1.8055	-15.6409
FLYING BRIDGE CUBE TDC	5.1475	-1.7833	-15.6503
FLYING BRIDGE PORT BM	3.3338	-7.4271	-15.5830
FLYING BRIDGE STBD BM	3.3367	3.7814	-15.5615
FWD MAST PUNCH MARK	14.7548	-1.8484	-9.8786
KEEL AFT BM	-3.0787	-1.8273	-0.2636
KEEL FWD BM	1.4294	-1.8287	-0.2572
MOON POOL BM	-23.3178	-0.5982	-5.1732
SIDETOW AFT PUNCH	-30.0423	-7.6869	-5.7631
SIDETOW FWD PUNCH MARK	-26.9473	-7.6584	-5.6357
PORT PILOT DECK PUNCH	0.7938	-7.4733	-10.4931
STBD PILOT DECK PUNCH	0.5967	3.7700	-10.6271

TABLE 2- NOAA NANCY FOSTER ELEMENT TABLEW/R 710 TX (METERS)			
DESCRIPTION	**X**	**Y**	**Z**
SPEED LOG CTR	-10.9899	-1.2575	-0.3034
EK60 200 MHZ CTR	-9.4627	-3.3678	0.1902
BLANK CTR	-9.1182	-3.3692	0.1893
KNUDSEN 12KHZ CTR	-8.5790	-3.3703	0.1910
EK60 38MHZ CTR	-7.9709	-3.3739	0.1910
ADCP CTR	-7.3957	-3.3747	0.1952
EK60 120MHZ CTR	-6.9545	-3.3765	0.1956
MOON POOL CTR	-23.8435	-0.6015	-0.2644
RESON TX	-3.5407	-1.4446	-0.2615
RESON RX	-3.0929	-1.2647	-0.2698
KONGSBERG 710TX CTR	0.0000	0.0000	0.0000
KONGSBERG 710 RX CTR710	-1.2062	0.1033	0.0173
PROJECTION LOW POINT FAIRING	-1.8376	0.1213	0.0428
FURUNO GP150 GPS-2 TDC	0.2181	-4.8129	-17.5072
FWD RAIL STBD SPARE GPS @ BASE	5.0689	1.4956	-16.6293
DP STBD @ BASE	-0.4103	0.9790	-17.7192
DP PORT @ BASE	-0.4343	-4.6337	-17.7811
POS/MV AFT GPS PHASE CTR	2.9568	-6.5369	-17.6549
POS/MV FWD GPS PHASE CTR	5.2168	-6.5537	-17.6648
POS/MV TRIMBLE TDC	4.0461	-6.4494	-17.7016
GP7000 TDC	1.1243	0.8982	-17.7798
FURUNO GP 37 GPS TDC	1.1792	-4.5719	-17.7935
GRANITE BLOCK CTR	-1.3635	-1.8128	-1.3684
IMU TDC	-0.6244	-1.8150	-1.4884
IMU CUBE FACE BM	0.2507	-0.0596	-1.4070
IMU BM	-2.8307	-1.5732	-1.5641
IMU FWD BM	2.0302	-1.5775	-1.5619

TABLE 3-AZIMUTH,PITCH, AND ROLL W/R 710 TX DECIMAL DEGREES						
ELEMENT	AZIMUTH		PITCH		ROLL	
	VALUE	DIRECTION	VALUE	DIRECTION	VALUE	DIRECTION
GRANITE BLOCK	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
IMU	0.02672	TO STBB	0.24875	BOW DOWN	0.06411	STBD DOWN
710TX	0.21197	TO PORT	0.97439	BOW UP	0.27725	STBD UP
710RX	0.60246	TO PORT	0.78256	BOW UP	0.71074	STBD UP
VALEPORT SVP	-	-	-2.14381	BOW DOWN	0.71937	STBD DOWN
REASON TX	0.21197	TO PORT	0.27828	BOW DOWN	90.32133	STBD UP
REASON RX	0.21197	TO PORT	0.63304	BOW DOWN	-90.01636	STBD UP

TOPCON SOKKIA

CERTIFICATE OF CALIBRATION

MODEL: NET1200

MANUFACTURER: Sokkia

SERIAL NO.: 110554 CERTIFICATE NO.: CI46742

This certifies that the above referenced instrument has been inspected and calibrated by the Topcon Sokkia Service Department. At the time of the completion of this service, Topcon Sokkia certifies that the above stated instrument meets or exceeds all factory specifications and tolerances for instrument parameters and performance of this instrument model. This certification is valid for a 12-month period from the calibration date shown below.

All distance measurement parameters were tested and adjusted using factory calibration jigs and with the 10 Meter Calibration Rail whose accuracy is traceable to the National Institute of Standards and Technology (NIST) via Mutual Recognition Agreement. All angle measurement parameters were tested with a NIST traceable optical collimation system, using accepted collimation and adjustment procedures. The quality system addresses and conforms to ANSI/NCSL Z540-1-1994 and ISO/IEC 17025-1999 (and, as a result ISO 9001-1994 or ISO 9002-1994). See individual sets of data for temperature and pressure.

This certificate shall not be reproduced without the written approval of Topcon Sokkia.

CUSTOMER NAME: IMTEC GROUP LTD (sf)-INDEPENDENCE

CUSTOMER ADDRESS: 19004 E. RINGO CIRCLE

CUSTOMER CITY/STATE/ZIP: INDEPENDENCE, MO 64057

DATE CALIBRATED: 1/23/2015 DATE RECALIBRATION DUE: 1/23/2016

SIGNED: Larry W. Tipton DATE: 1/23/2015

TITLE Service Technician

YES	NO	
____	X	Is this a new instrument?

Appendix II: Echosounder Reports

M-I907-NF-16
Patch Test Processing Log
Summary

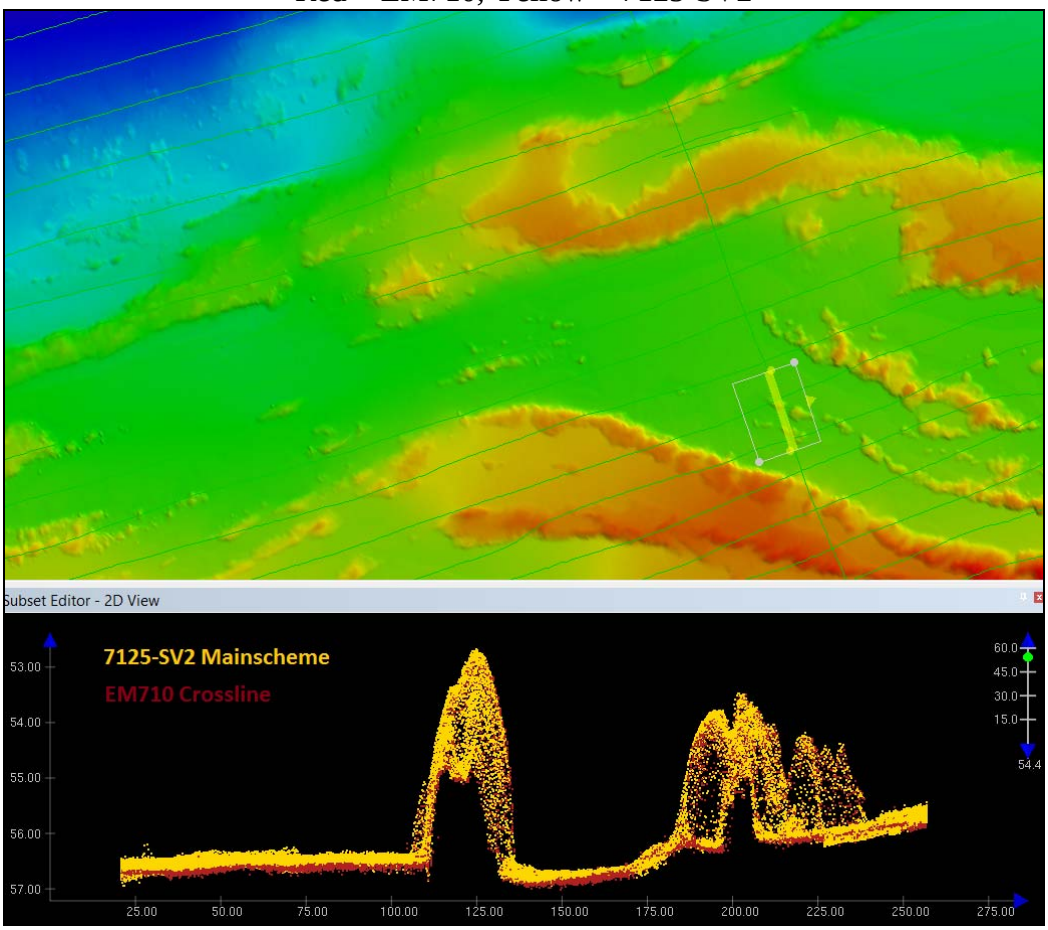
Nancy Foster 7125 SV-2 400kHz					
Acquisition Time		Final Values			
Day	Date	Latency	Pitch	Roll	Yaw
104	04/13/2016	0.000	0.90	-0.34	0.20

Nancy Foster EM710					
Acquisition Time		Final Values			
Day	Date	Latency*	Pitch ¥	Roll ¥	Yaw*
098	04/07/2016	0.000	-1.066	-0.595	-0.354

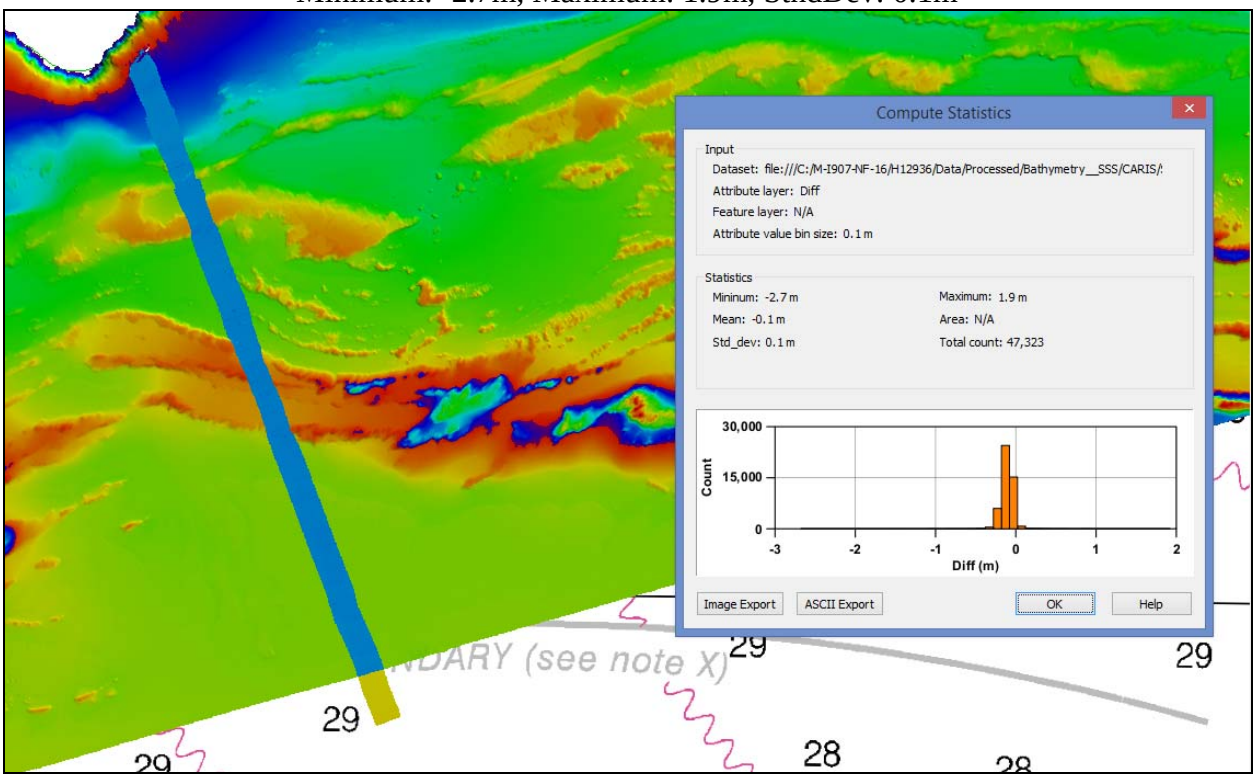
***Values entered into POSMV**

EM710 vs 7125-SV2 Comparisons

Subset Section of 7125-SV2 Mainscheme and EM710 Crossline
Red = EM710, Yellow = 7125-SV2



SV2 Mainscheme and EM710 Crossline
4m Cube Surface Comparison Statistics in approximately 40 meters of water
Minimum: -2.7m, Maximum: 1.9m, StndDev: 0.1m



Appendix III: Position and Attitude System Reports

Extract POS COnfig Version 1.0

November 14 2016 02:40 pm

Source Name: 092515_POSMV.nvm
Output File: 092515_POSMV.txt

Message 37 - Base GPS 1 Setup

Input Data Type Port 1 - Accept RTCM 1/9

Message 38 - Base GPS 2 Setup

Input Data Type Port 2 - Accept RTCM 1/9

Message 34 - COM Port Setup

Number of COM ports = 5
COM1 - Protocol: 19200,No Parity,8 data,1 stop,None
Input Selection: No Input
Output Selection: NMEA Message

COM2 - Protocol: 19200,No Parity,8 data,1 stop,None
Input Selection: No Input
Output Selection: Real-time Binary

COM3 - Protocol: 9600,No Parity,8 data,1 stop,None
Input Selection: Base GPS 1
Output Selection: NMEA Message

COM4 - Protocol: 115200,No Parity,8 data,1 stop,None
Input Selection: No Input
Output Selection: Real-time Binary

COM5 - Protocol: 9600,No Parity,8 data,1 stop,None
Input Selection: No Input
Output Selection: NMEA Message

Message 51 - Display Port Control

Number of groups selected for Display Port = 27
1 2 3 4 5 6 7 8 9 10 11 12
13 14 17 20 23 24 25 26 99 102 103 104
105 110 20000

Message 53 - Logging Port Control

Number of groups selected for Logging Port = 18
1 2 4 5 9 10 99 102 110 111 112 113 10001 10007 10008 10009 10011 10012 Logging Port Output Rate

50 Hz
AutoLog Select Disabled

Message 135 - NMEA Message Select

Number of Port 3
Assigned port number COM1
Update Rate Selection 1 Hz
Output Selection GGA HDT ZDA VTG
talker ID $GP
Roll Sense Port Up
Pitch Sense Bow Up
Heave Sense Heave Up
Assigned port number COM3
Update Rate Selection 1 Hz
Output Selection GGA HDT ZDA VTG SHR UTC
talker ID $IN
Roll Sense Port Up
Pitch Sense Bow Up
Heave Sense Heave Up
Assigned port number COM5
Update Rate Selection 1 Hz
Output Selection ZDA
talker ID $IN
Roll Sense Port Up
Pitch Sense Bow Up
Heave Sense Heave Up

Message 136 - Binary Message Select

Number of Port 2
Assigned port number COM2
Update Rate Selection 100 Hz
Output Selection SIMRAD-3000(TB)
Selected frame Sensor1
Roll Sense Port Up
Pitch Sense Bow Up
Heave Sense Heave Up

Assigned port number COM4
Update Rate Selection 50 Hz
Output Selection TSS
Selected frame Sensor1
Roll Sense Port Up
Pitch Sense Bow Up
Heave Sense Heave Up

Message 33 - Event Discrete Setup

Event 1 Trigger Positive edge
Event 2 Trigger Positive edge

Message 30 - Primary GPS Setup

GPS AutoConfig True

Message 31 - Secondary GPS Setup

GPS AutoConfig True

Message 24 - User Accuracy Specifications

User Attitude Accuracy 0.05
User Heading Accuracy 0.05
User Position Accuracy 2
User Velocity Accuracy 0.5

Message 52 - Real-time Data Port Control

Number of groups selected for Real-time Data Port = 6
3 7 10 20 102 104
Data Port Output Rate 50 Hz

Message 61 - Data Port Control

Number of groups selected for Data Port = 19
1 2 3 4 5 9 10 99 102 110 111 112
113 10001 10007 10008 10009 10011 10012
Data Port Output Rate 50 Hz

Message 20 - General Installation Parameters

Ref to IMU Lever Arm -0.606 -1.822 -1.487 [Wavemaster User => -0.615 -1.843 -1.414]
Ref to Pri GPS Lever Arm 5.473 -6.676 -17.541
Ref to Aux1 GPS Lever Arm 4.303 -6.568 -17.597
Ref to Aux2 GPS Lever Arm 0.000 0.000 0.000
IMU to Ref Mounting Angle -0.354 -1.066 -0.595
AutoStart Enabled
Multipath Low

Message 120 - Sensor Parameter Set-up

Sensor1 Ref Mount Angle 0.000 0.000 0.000
Sensor2 Ref Mount Angle 0.000 0.000 0.000
Ref Sensor1 Lever Arm 0.000 0.000 0.000
Ref Sensor1 Lever Arm 0.000 0.000 0.000
Ref to CoR Lever Arm 0.000 0.000 0.000

Message 121 - Vessel Installation Parameter Set-up

Ref to Vessel Lever Arm 0.000 0.000 0.000

Message 106 - Heave Filter Set-up

Heave Bandwidth 8.000
Heave Damping Ratio 0.707

Message 105 - Analog Port Set-up

Roll Scale 1.00
Pitch Scale 1.00
Heave Scale 1.00
Roll Sense Port Up
Pitch Sense Bow Up
Heave Sense Clockwise
Formula Select - TSS Trig
Analog Port Enabled True
Output Frame Sensor 1

Message 21 - GAMS Installation Parameters

Two Antenna Separation 2.257
Baseline Vector -2.256 0.028 -0.047
Heading Calibration Threshold 0.100
Heading Correction 0.000

Appendix IV: Sound Speed Sensor Reports

UCTD PROBE 0188 CALIBRATION REPORTS

Sea-Bird Electronics, Inc.

13431 NE 20th Street, Bellevue, WA 98005-2010 USA

Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0188
CALIBRATION DATE: 25-Feb-15

UCTD PRESSURE CALIBRATION DATA
FSR: 2900 psia S/N 2104556

COEFFICIENTS:

PA0 =	6.193513e-002	PTCA0 =	5.234471e+005
PA1 =	8.757408e-003	PTCA1 =	-1.024949e+001
PA2 =	6.185071e-011	PTCA2 =	4.558003e-001
PTEMPA0 =	-8.474853e+001	PTCB0 =	1.046316e+002
PTEMPA1 =	3.685918e-002	PTCB1 =	-2.847458e-003
PTEMPA2 =	6.196308e-007	PTCB2 =	0.000000e+000

PRESSURE SPAN CALIBRATION

PRESSURE PSIA	INST OUTPUT	THERMISTOR OUTPUT	COMPUTED PRESSURE	ERROR %FS
14.79	525145.0	2795.0	14.88	0.00
615.22	593609.0	2797.0	615.13	-0.00
1215.24	661993.0	2797.0	1215.25	0.00
1715.22	718910.0	2797.0	1715.19	-0.00
2315.09	787154.0	2797.0	2315.15	0.00
2915.00	855308.0	2798.0	2914.89	-0.00
2315.07	787158.0	2797.0	2315.19	0.00
1715.18	718916.0	2797.0	1715.24	0.00
1215.24	661989.0	2797.0	1215.22	-0.00
615.24	593610.0	2797.0	615.13	-0.00
14.78	525137.0	2796.0	14.81	0.00

THERMAL CORRECTION

TEMP ITS90	THERMISTOR OUTPUT	INST OUTPUT
32.50	3027.10	525337.00
29.00	2940.50	525274.22
24.00	2816.80	525202.49
18.50	2680.50	525154.73
15.00	2593.40	525138.14
4.50	2329.70	525151.03
1.00	2242.10	525177.97

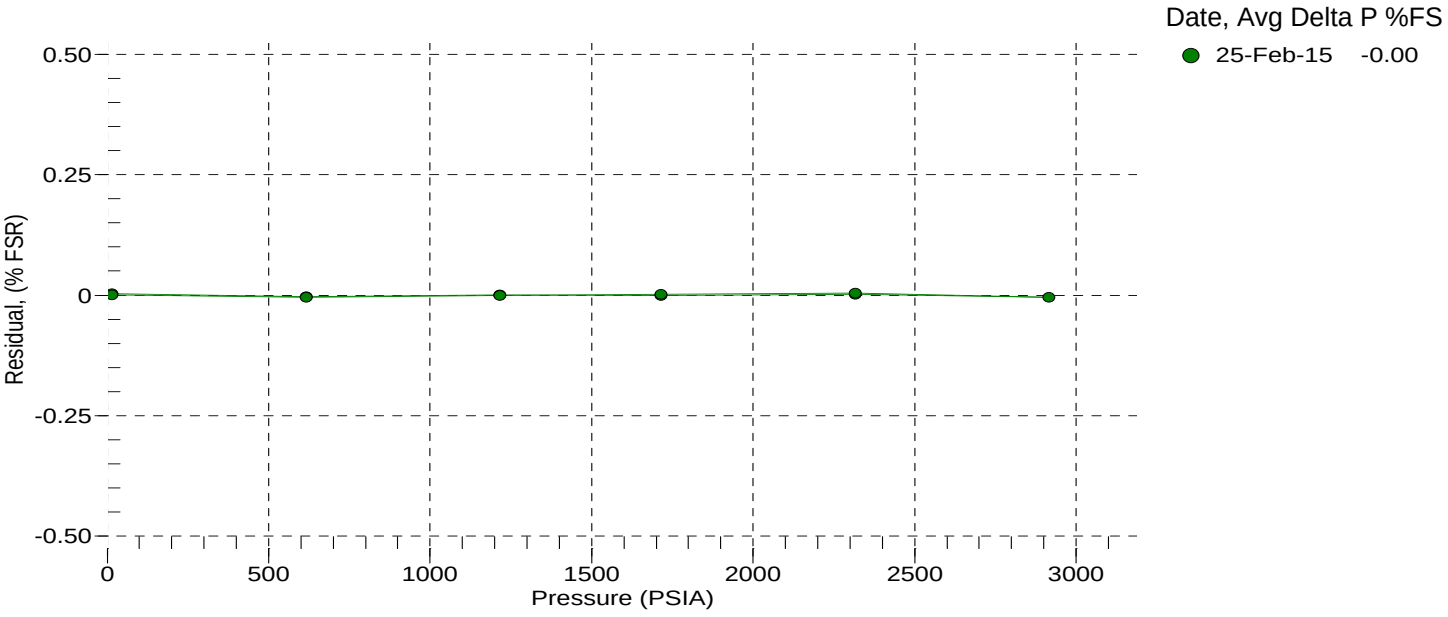
TEMP(ITS90)	SPAN(mV)
-5.32	104.65
34.51	104.53

y = thermistor output; $t = PTEMPA0 + PTEMPA1 * y + PTEMPA2 * y^2$

x = pressure output - $PTCA0 - PTCA1 * t - PTCA2 * t^2$

$n = x * PTCB0 / (PTCB0 + PTCB1 * t + PTCB2 * t^2)$

pressure (psia) = $PA0 + PA1 * n + PA2 * n^2$



Sea-Bird Electronics, Inc.

13431 NE 20th Street, Bellevue, WA 98005-2010 USA

Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0188
CALIBRATION DATE: 27-Feb-15

UCTD CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

```
g = -9.960715e-001
h =  1.419084e-001
i = -3.062575e-004
j =  4.532694e-005

CPcor = -9.5700e-008
CTcor =  3.2500e-006
```

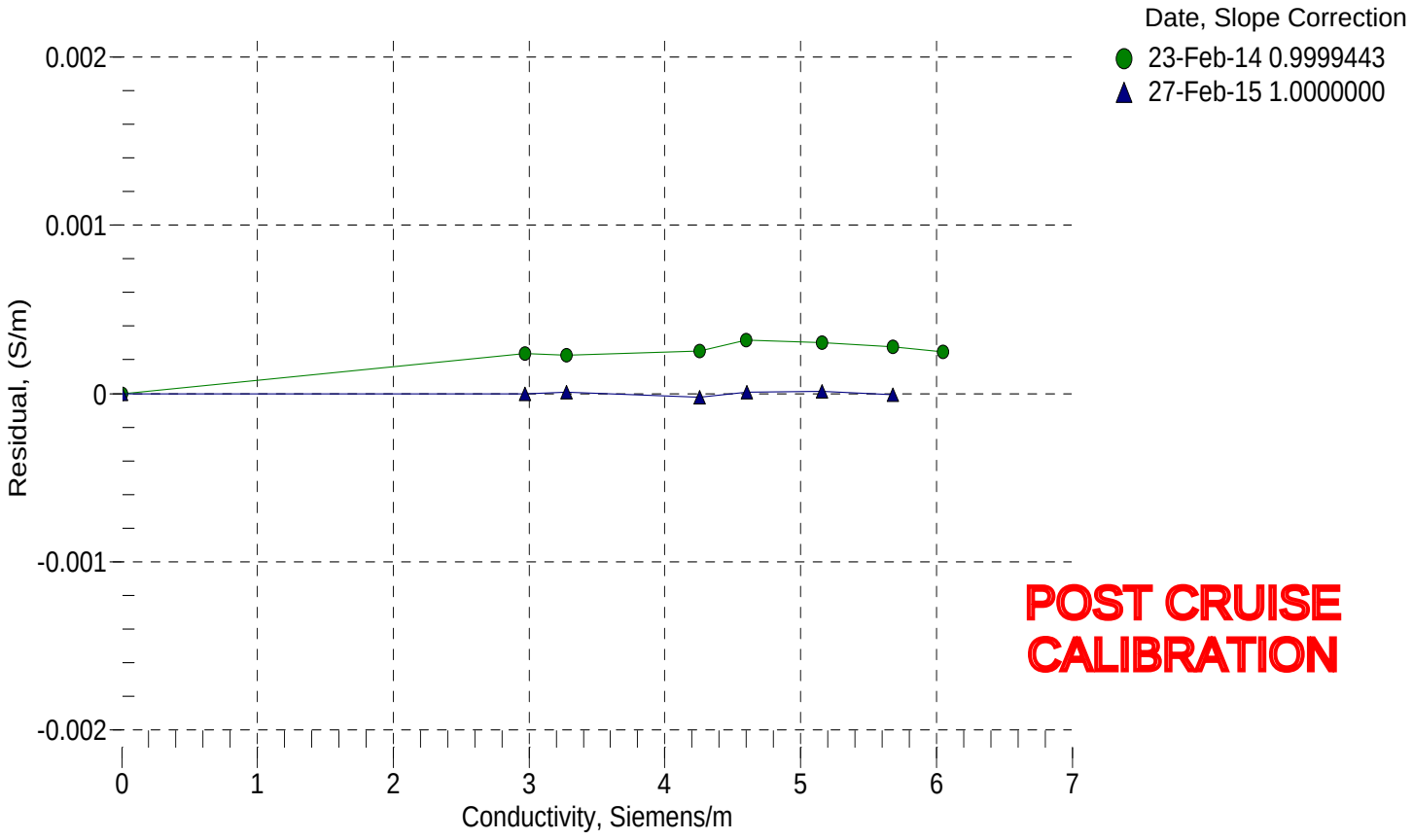
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (Hz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
22.0000	0.0000	0.00000	2653.98	0.0000	0.00000
1.0000	34.7519	2.97098	5293.81	2.9710	-0.00000
4.5000	34.7319	3.27755	5493.87	3.2776	0.00001
15.0000	34.6888	4.25762	6088.61	4.2576	-0.00002
18.5000	34.6795	4.60218	6284.04	4.6022	0.00001
24.0000	34.6692	5.15916	6587.34	5.1592	0.00001
29.0000	34.6634	5.68009	6858.48	5.6801	-0.00001
32.5000	34.6606	6.05190	7045.35	6.0518	-0.00013

f = INST FREQ / 1000.0

Conductivity = $(g + h * f^2 + i * f^3 + j * f^4) / (1 + \delta * t + \varepsilon * p)$ Siemens / meter

t = temperatur e[°C)]; p = pressure[decibars]; δ = CTcor; ε = CPcor;

Residual = instrument conductivity - bath conductivity



SEA-BIRD ELECTRONICS, INC.
13431 NE 20th St. Bellevue, Washington 98005 USA
Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

Temperature Calibration Report

Customer:	Ocean Science		
Job Number:	82436	**Date of Report:**	2/27/2015
Model Number	UCTD	**Serial Number:**	0188 UCTD

Temperature sensors are normally calibrated 'as received', without adjustments, allowing a determination sensor drift. If the calibration identifies a problem, then a second calibration is performed after work is completed. The 'as received' calibration is not performed if the sensor is damaged or non-functional, or by customer request.

An 'as received' calibration certificate is provided, listing coefficients to convert sensor frequency to temperature. Users must choose whether the 'as received' calibration or the previous calibration better represents the sensor condition during deployment. In SEASOFT enter the chosen coefficients. The coefficient 'offset' allows a small correction for drift between calibrations (consult the SEASOFT manual). Calibration coefficients obtained after a repair apply only to subsequent data.

'AS RECEIVED CALIBRATION' ☑ Performed ☐ Not Performed

Date: 2/27/2015 Drift since last cal: -0.00023 Degrees Celsius/year

Comments:

'CALIBRATION AFTER REPAIR' ☐ Performed ☑ Not Performed

Date: Drift since Last cal: Degrees Celsius/year

Comments:

SEA-BIRD ELECTRONICS, INC.
13431 NE 20th St. Bellevue, Washington 98005 USA
Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

Temperature Calibration Report

Customer:	Ocean Science		
Job Number:	82436	**Date of Report:**	2/27/2015
Model Number	UCTD	**Serial Number:**	0187 UCTD

Temperature sensors are normally calibrated 'as received', without adjustments, allowing a determination sensor drift. If the calibration identifies a problem, then a second calibration is performed after work is completed. The 'as received' calibration is not performed if the sensor is damaged or non-functional, or by customer request.

An 'as received' calibration certificate is provided, listing coefficients to convert sensor frequency to temperature. Users must choose whether the 'as received' calibration or the previous calibration better represents the sensor condition during deployment. In SEASOFT enter the chosen coefficients. The coefficient 'offset' allows a small correction for drift between calibrations (consult the SEASOFT manual). Calibration coefficients obtained after a repair apply only to subsequent data.

'AS RECEIVED CALIBRATION' ☑ Performed ☐ Not Performed

Date: 2/27/2015 Drift since last cal: +0.00196 Degrees Celsius/year

Comments:

'CALIBRATION AFTER REPAIR' ☐ Performed ☑ Not Performed

Date: Drift since Last cal: Degrees Celsius/year

Comments:

SEA-BIRD ELECTRONICS, INC.
13431 NE 20th Street Bellevue, Washington 98005 USA
Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

Conductivity Calibration Report

Customer:	Ocean Science		
Job Number:	82436	**Date of Report:**	2/27/2015
Model Number	UCTD	**Serial Number:**	0188 UCTD

Conductivity sensors are normally calibrated 'as received', without cleaning or adjustments, allowing a determination of sensor drift. If the calibration identifies a problem or indicates cell cleaning is necessary, then a second calibration is performed after work is completed. The 'as received' calibration is not performed if the sensor is damaged or non-functional, or by customer request.

An 'as received' calibration certificate is provided, listing the coefficients used to convert sensor frequency to conductivity. Users must choose whether the 'as received' calibration or the previous calibration better represents the sensor condition during deployment. In SEASOFT enter the chosen coefficients. The coefficient 'slope' allows small corrections for drift between calibrations (consult the SEASOFT manual). Calibration coefficients obtained after a repair or cleaning apply only to subsequent data.

'AS RECEIVED CALIBRATION' ☑ Performed ☐ Not Performed

Date: 2/27/2015 **Drift since last cal:** -0.00010 **PSU/month**

Comments:

'CALIBRATION AFTER CLEANING & REPLATINIZING' ☐ Performed ☑ Not Performed

Date: **Drift since Last cal:** **PSU/month**

Comments:

**Measured at 3.0 S/m*

Cell cleaning and electrode replatinizing tend to 'reset' the conductivity sensor to its original condition. Lack of drift in post-cleaning-calibration indicates geometric stability of the cell and electrical stability of the sensor circuit.

Sea-Bird Electronics, Inc.

13431 NE 20th Street, Bellevue, WA 98005-2010 USA

Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0188
CALIBRATION DATE: 23-Feb-14

UCTD TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS

a0 = 8.733824e-004
a1 = 2.732870e-004
a2 = -1.675584e-006
a3 = 1.752566e-007

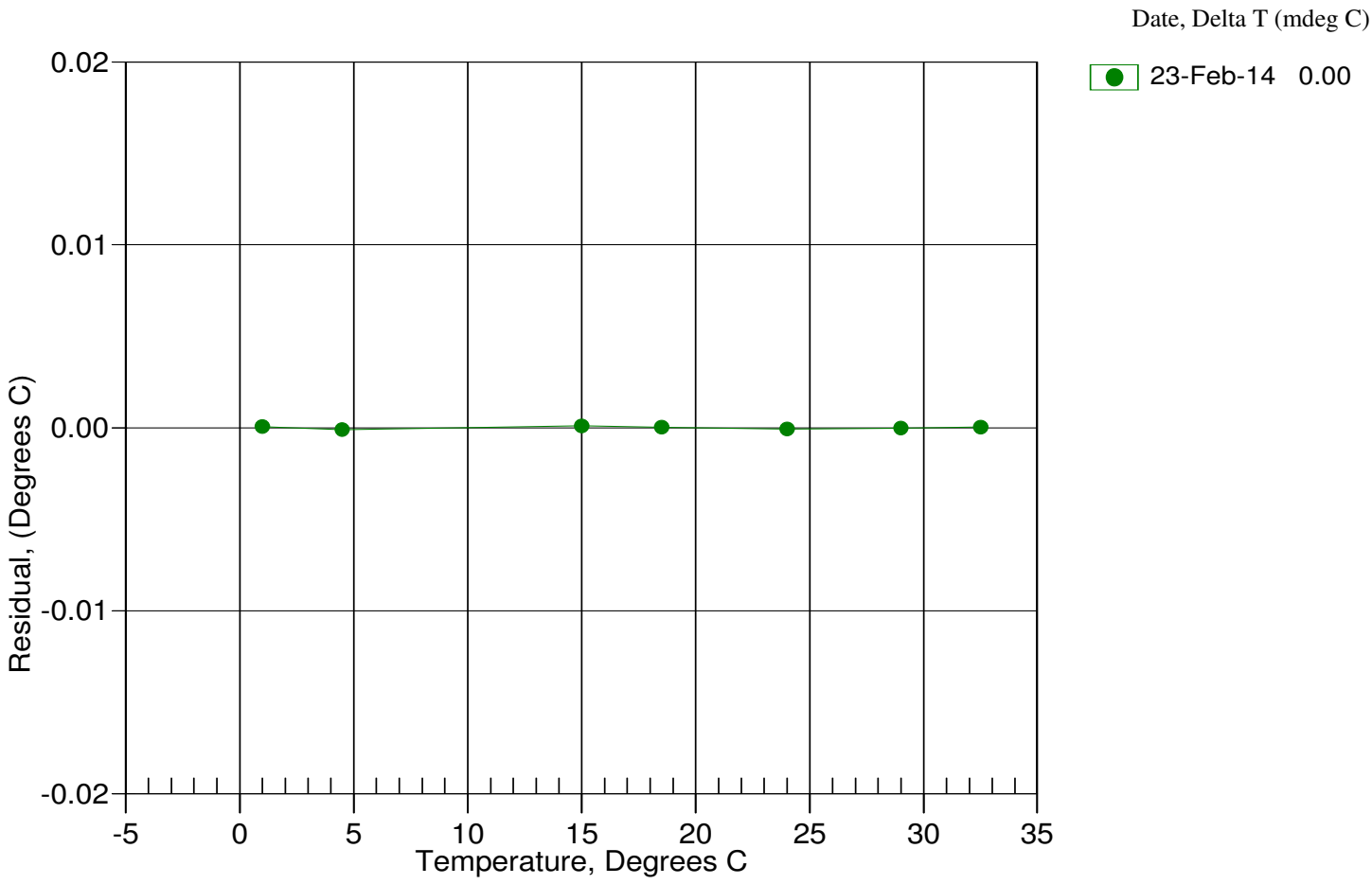
BATH TEMP (ITS-90)	INSTRUMENT OUTPUT(n)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
1.0000	789153.500	1.0001	0.0001
4.5000	700467.400	4.4999	-0.0001
15.0000	473348.900	15.0001	0.0001
18.5000	410664.000	18.5000	0.0000
24.0000	324415.900	23.9999	-0.0001
29.0000	257889.500	29.0000	-0.0000
32.5000	217348.300	32.5000	0.0000

MV = (n - 524288) / 1.6e+007

R = (MV * 2.295e+010 + 9.216e+008) / (6.144e+004 - MV * 5.3e+005)

Temperature ITS-90 = $1/\{a0 + a1[ln(R)] + a2[ln^2(R)] + a3[ln^3(R)]\} - 273.15$ (°C)

Residual = instrument temperature - bath temperature



Sea-Bird Electronics, Inc.
13431 NE 20th St. Bellevue, Washington 98005 USA
Website: http://www.seabird.com

Phone: (425) 643-9866
FAX: (425) 643-9954
Email: seabird@seabird.com

SBE Pressure Test Certificate

Test Date: **2/26/2014** Description **UCTD**

SBE Sensor Information:

Model Number: **UCTD**
Serial Number: **0188**

Pressure Information:

Pressure Sensor Rating (psia): **2900**
Housing Rating (psia): **2900**

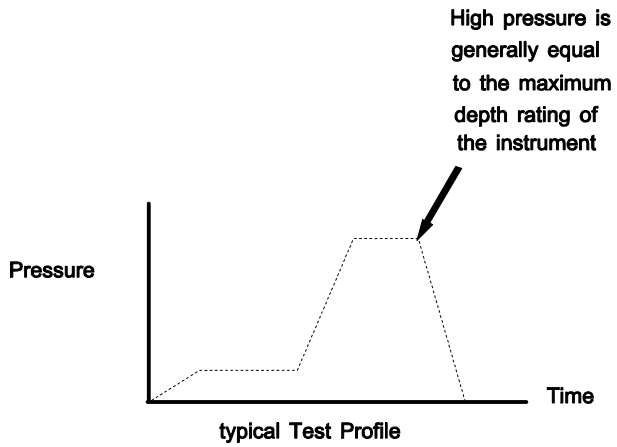
Pressure Test Protocol:

Low Pressure Test: **40** PSI Held For **15** Minutes

High Pressure Test: **2900** PSI Held For **15** Minutes

Passed Test: ☑

Tested By: sk



typical Test Profile

Sea-Bird Electronics, Inc.

13431 NE 20th Street, Bellevue, WA 98005-2010 USA

Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0188
CALIBRATION DATE: 20-Feb-14

UCTD PRESSURE CALIBRATION DATA
2900 psia S/N 2104556

COEFFICIENTS:

PA0 =	-4.541094e-002	PTCA0 =	5.234315e+005
PA1 =	8.755062e-003	PTCA1 =	-1.069398e+001
PA2 =	6.727080e-011	PTCA2 =	4.653616e-001
PTEMPA0 =	-8.530339e+001	PTCB0 =	1.046316e+002
PTEMPA1 =	3.728972e-002	PTCB1 =	-2.847458e-003
PTEMPA2 =	5.351464e-007	PTCB2 =	0.000000e+000

PRESSURE SPAN CALIBRATION

PRESSURE PSIA	INST OUTPUT	THERMISTOR OUTPUT	COMPUTED PRESSURE	ERROR %FSR
14.66	525109.0	2770.0	14.73	0.00
614.99	593576.0	2777.0	614.83	-0.01
1214.96	661959.0	2778.0	1214.86	-0.00
1714.88	718888.0	2780.0	1714.85	-0.00
2314.80	787137.0	2780.0	2314.85	0.00
2914.74	855287.0	2781.0	2914.61	-0.00
2314.72	787140.0	2782.0	2314.88	0.01
1714.82	718892.0	2781.0	1714.89	0.00
1214.88	661968.0	2780.0	1214.93	0.00
614.91	593583.0	2782.0	614.88	-0.00
14.67	525113.0	2783.0	14.72	0.00

THERMAL CORRECTION

TEMP ITS90	THERMISTOR OUTPUT	INST OUTPUT
32.50	3027.70	525317.70
29.00	2941.10	525254.50
24.00	2816.90	525183.24
18.50	2680.90	525133.96
15.00	2593.50	525118.54
4.50	2329.90	525135.75
1.00	2242.50	525161.77

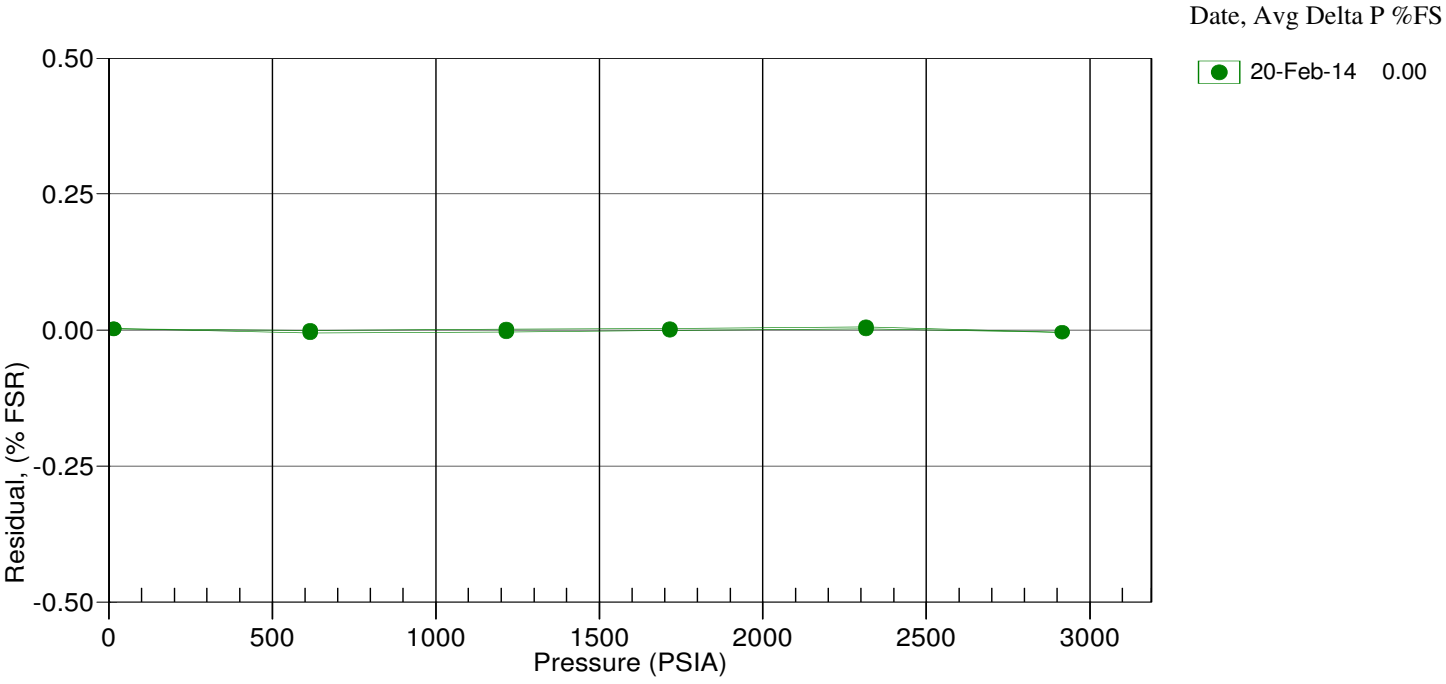
TEMP(ITS90)	SPAN(mV)
-5.32	104.65
34.51	104.53

y = thermistor output; $t = PTEMPA0 + PTEMPA1 * y + PTEMPA2 * y^2$

x = pressure output - $PTCA0 - PTCA1 * t - PTCA2 * t^2$

$n = x * PTCB0 / (PTCB0 + PTCB1 * t + PTCB2 * t^2)$

pressure (psia) = $PA0 + PA1 * n + PA2 * n^2$



Underway-CTD (UCTD)

Conductivity, Temperature & Pressure Recorder

Instrument Configuration:

Serial Number	UCTD-0188
Firmware Version	3.10
Interface Type	Bluetooth / RS-232C (9600, 8, N)
Conductivity Range	0-7 S/m
Pressure Sensor	2000 dBar, S/N 2104556
Maximum Depth	**2000 meters**

Sea-Bird Electronics, Inc.

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SENSOR SERIAL NUMBER: 0188
CALIBRATION DATE: 23-Feb-14

UCTD CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

```
g = -9.960845e-001
h =  1.419510e-001
i = -3.238576e-004
j =  4.687114e-005

CPcor = -9.5700e-008
CTcor =  3.2500e-006
```

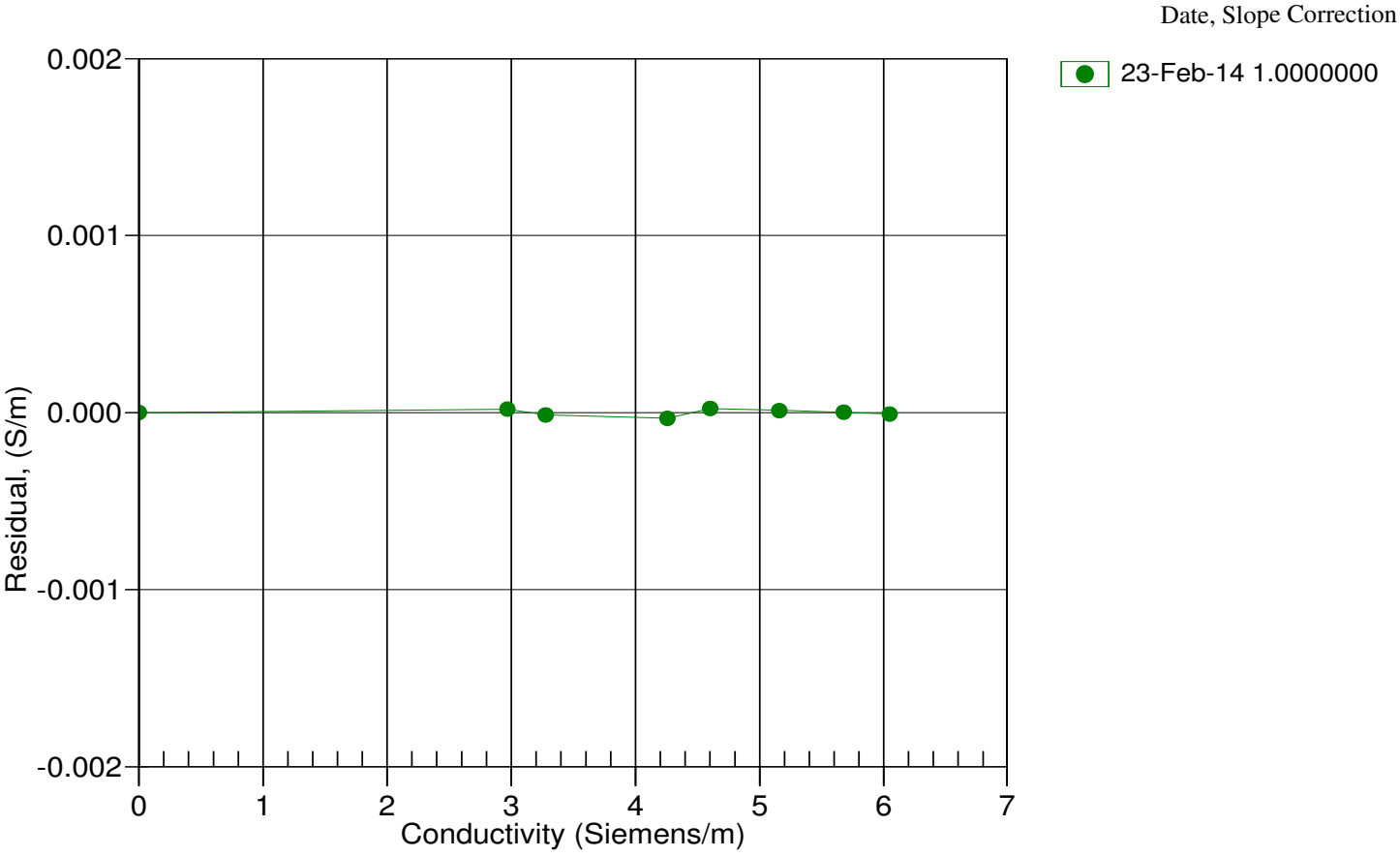
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (Hz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
22.0000	0.0000	0.00000	2653.93	0.0000	0.00000
1.0000	34.7409	2.97013	5293.40	2.9702	0.00002
4.5000	34.7200	3.27653	5493.36	3.2765	-0.00001
15.0000	34.6752	4.25613	6087.91	4.2561	-0.00003
18.5000	34.6641	4.60035	6283.20	4.6004	0.00002
24.0000	34.6515	5.15681	6586.25	5.1568	0.00001
29.0000	34.6434	5.67718	6857.14	5.6772	0.00000
32.5000	34.6377	6.04836	7043.78	6.0484	-0.00001

f = INST FREQ / 1000.0

Conductivity = $(g + hf^2 + if^3 + jf^4) / (1 + \delta t + \varepsilon p)$ Siemens/meter

t = temperature[°C)]; p = pressure[decibars]; δ = CTcor; ε = CPcor;

Residual = instrument conductivity - bath conductivity



SBE 19Plus CALIBRATION REPORTS

Sea-Bird Electronics, Inc.

13431 NE 20th Street, Bellevue, WA 98005-2010 USA

Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0355
CALIBRATION DATE: 07-Jan-15

SBE 19 PRESSURE CALIBRATION DATA
FSR: 1450 psia S/N 2651317 TCV: -140

QUADRATIC COEFFICIENTS:
PA0 = 8.557892e+002
PA1 = -2.390758e-001
PA2 = -2.881441e-008

STRAIGHT LINE FIT:
M = -2.300211e-001
B = 7.746006e+002

PRESSURE PSIA	INST OUTPUT (N)	COMPUTED PSIA	ERROR %FS	LINEAR PSIA	ERROR %FS
14.73	3515.0	15.08	0.02	-33.92	-3.36
314.97	2263.0	314.61	-0.02	254.06	-4.20
615.04	1010.0	614.29	-0.05	542.28	-5.02
915.04	-249.0	915.32	0.02	831.88	-5.74
1214.99	-1503.0	1215.06	0.00	1120.32	-6.53
1464.97	-2547.0	1464.53	-0.03	1360.46	-7.21
1214.98	-1504.0	1215.29	0.02	1120.55	-6.51
914.91	-250.0	915.56	0.04	832.11	-5.71
614.98	1008.0	614.77	-0.01	542.74	-4.98
315.00	2261.0	315.09	0.01	254.52	-4.17
14.73	3506.0	17.24	0.17	-31.85	-3.21

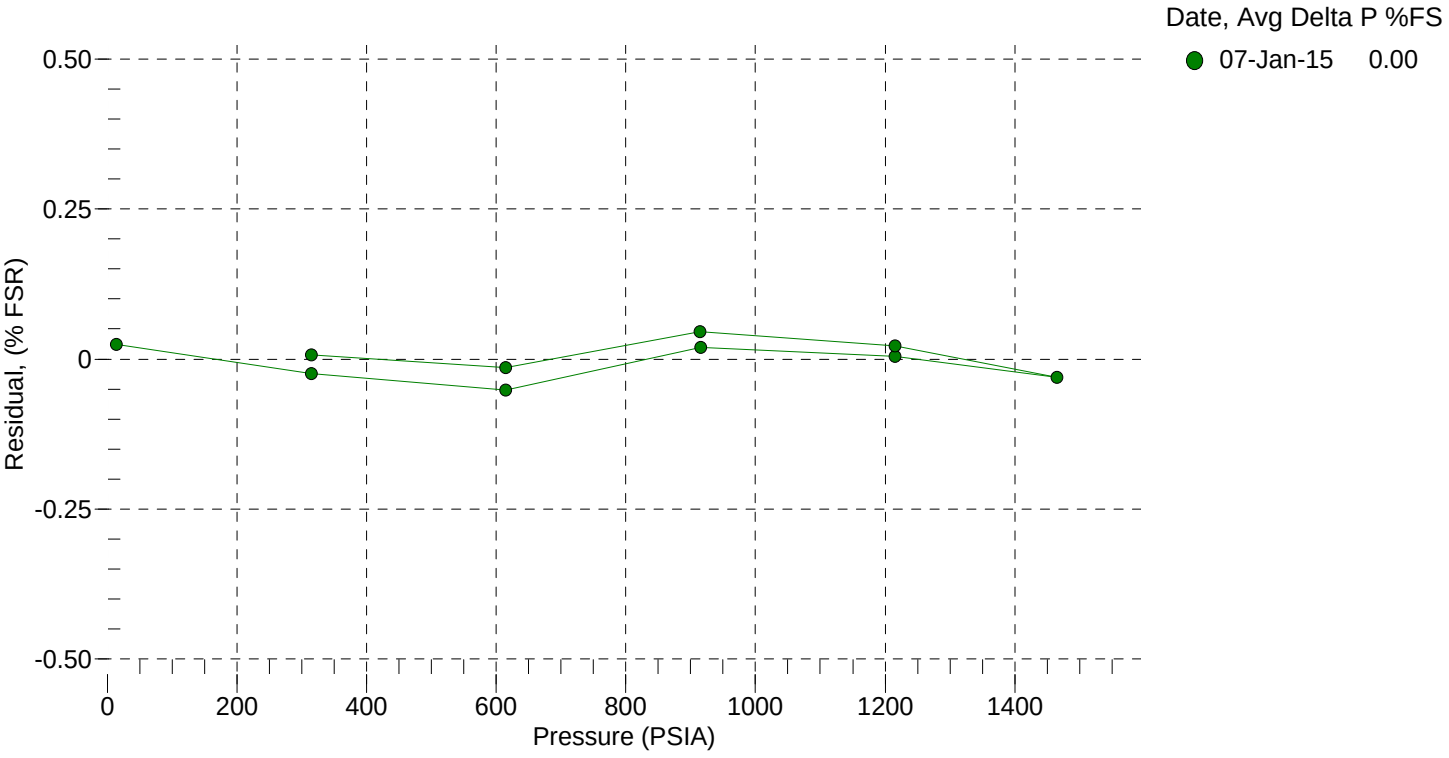
Straight Line Fit:

Pressure (psia) = M * N + B (N = binary output)

Quadratic Fit:

pressure (psia) = PA0 + PA1 * N + PA2 * N^2

Residual = (instrument pressure - true pressure) * 100 / Full Scale Range



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SENSOR SERIAL NUMBER: 0355
CALIBRATION DATE: 10-Jan-15

SBE 19 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

```
g =  -4.11865548e+000
h =   4.90925625e-001
i =   1.36555792e-003
j =  -2.91397376e-005

CPcor = -9.5700e-008 (nominal)
CTcor =  3.2500e-006 (nominal)
```

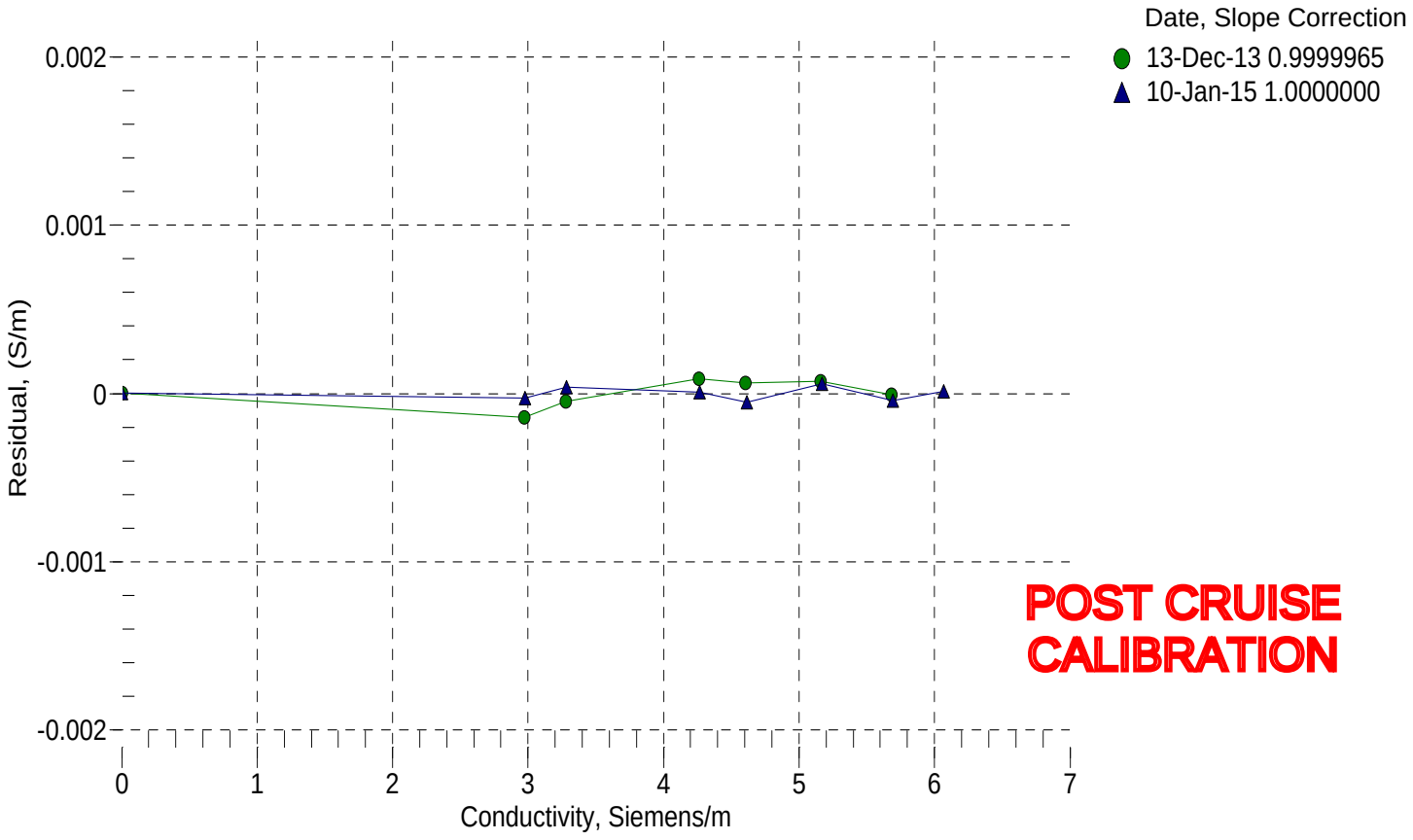
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
22.0000	0.0000	0.00000	2.88563	0.00000	0.00000
1.0000	34.8388	2.97770	8.23195	2.97768	-0.00003
4.5000	34.8195	3.28500	8.59440	3.28504	0.00004
15.0000	34.7778	4.26739	9.66066	4.26740	0.00001
18.5000	34.7689	4.61276	10.00809	4.61271	-0.00005
24.0000	34.7585	5.17098	10.54525	5.17104	0.00006
29.0000	34.7532	5.69315	11.02350	5.69310	-0.00004
32.5000	34.7499	6.06572	11.35235	6.06573	0.00001

f = INST FREQ / 1000.0

Conductivity = $(g + h * f^2 + i * f^3 + j * f^4) / (1 + \delta * t + \varepsilon * p)$ Siemens / meter

t = temperatur e[°C)]; p = pressure[decibars]; δ = CTcor; ε = CPcor;

Residual = instrument conductivity - bath conductivity



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Conductivity Calibration Report

Customer:	Atlantic Marine Center		
Job Number:	82553	**Date of Report:**	1/12/2015
Model Number	SBE 19-02	**Serial Number:**	192523-0355

Conductivity sensors are normally calibrated 'as received', without cleaning or adjustments, allowing a determination of sensor drift. If the calibration identifies a problem or indicates cell cleaning is necessary, then a second calibration is performed after work is completed. The 'as received' calibration is not performed if the sensor is damaged or non-functional, or by customer request.

An 'as received' calibration certificate is provided, listing the coefficients used to convert sensor frequency to conductivity. Users must choose whether the 'as received' calibration or the previous calibration better represents the sensor condition during deployment. In SEASOFT enter the chosen coefficients. The coefficient 'slope' allows small corrections for drift between calibrations (consult the SEASOFT manual). Calibration coefficients obtained after a repair or cleaning apply only to subsequent data.

'AS RECEIVED CALIBRATION' ☑ Performed ☐ Not Performed

Date: 1/10/2015 **Drift since last cal:** 0.0000 **PSU/month***

Comments:

'CALIBRATION AFTER CLEANING & REPLATINIZING' ☐ Performed ☑ Not Performed

Date: **Drift since Last cal:** **PSU/month***

Comments:

**Measured at 3.0 S/m*

Cell cleaning and electrode replatinizing tend to 'reset' the conductivity sensor to its original condition. Lack of drift in post-cleaning-calibration indicates geometric stability of the cell and electrical stability of the sensor circuit.

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Pressure Test Certificate

Customer	Atlantic Marine Center
Job Number	82553
Date	2/20/2015
Technician	JK

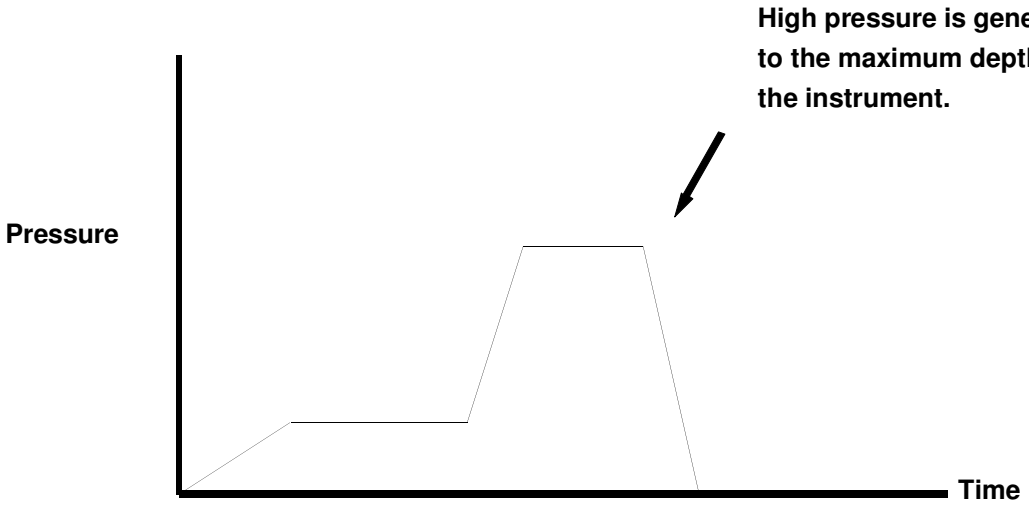
Serial Number	192523-0355	
Low Pressure (PSI)	50	PSI
Time (Minutes)	15	Minutes
High Pressure (PSI)	2900	PSI
Time (Minutes)	30	Minutes

Pass ☑

Fail ☐

Comments

Installed a new 2900 psi Kistler pressure sensor. Replaced the main piston "O"-Rings.



Typical Test Profile

SEA-BIRD ELECTRONICS, INC.
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Temperature Calibration Report

Customer:	Atlantic Marine Center		
Job Number:	82553	**Date of Report:**	1/12/2015
Model Number	SBE 19-02	**Serial Number:**	192523-0355

Temperature sensors are normally calibrated 'as received', without adjustments, allowing a determination sensor drift. If the calibration identifies a problem, then a second calibration is performed after work is completed. The 'as received' calibration is not performed if the sensor is damaged or non-functional, or by customer request.

An 'as received' calibration certificate is provided, listing coefficients to convert sensor frequency to temperature. Users must choose whether the 'as received' calibration or the previous calibration better represents the sensor condition during deployment. In SEASOFT enter the chosen coefficients. The coefficient 'offset' allows a small correction for drift between calibrations (consult the SEASOFT manual). Calibration coefficients obtained after a repair apply only to subsequent data.

'AS RECEIVED CALIBRATION' ☑ Performed ☐ Not Performed

Date: 1/10/2015 Drift since last cal: -0.00045 Degrees Celsius/year

Comments:

'CALIBRATION AFTER REPAIR' ☐ Performed ☑ Not Performed

Date: Drift since Last cal: Degrees Celsius/year

Comments:

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SENSOR SERIAL NUMBER: 0355
CALIBRATION DATE: 10-Jan-15

SBE 19 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

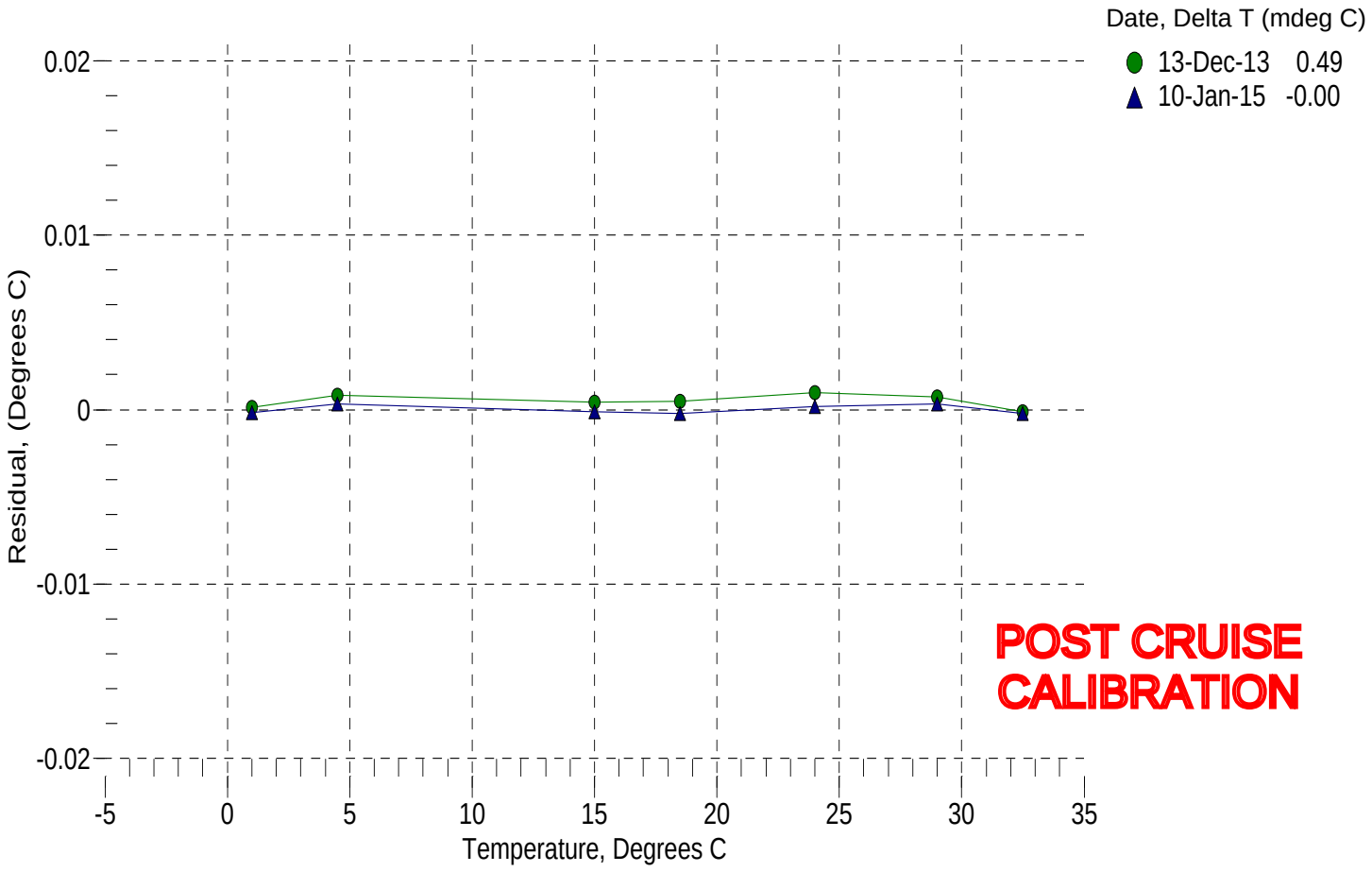
ITS-90 COEFFICIENTS:

```
g =  4.15716009e-003
h =  5.80871704e-004
i =  8.05399070e-008
j = -2.47557798e-006
f0 =  1000.0
```

BATH TEMP (ITS-90)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
1.0000	2411.327	0.9998	-0.00018
4.5000	2612.311	4.5003	0.00031
15.0000	3285.884	14.9999	-0.00013
18.5000	3535.174	18.4998	-0.00024
24.0000	3953.314	24.0002	0.00016
29.0000	4362.393	29.0003	0.00031
32.5000	4665.681	32.4998	-0.00023

Temperature ITS-90 = $1/\{ g + h[ln(f_0/f)] + i[ln^2(f_0/f)] + j[ln^3(f_0/f)]\} - 273.15$ (°C)

Residual = instrument temperature - bath temperature



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SENSOR SERIAL NUMBER: 0355
CALIBRATION DATE: 20-Feb-15

SBE 19 PRESSURE CALIBRATION DATA
FSR: 2900 psia S/N 4632581 TCV:

QUADRATIC COEFFICIENTS:
PA0 = 1.729174e+003
PA1 = -4.779822e-001
PA2 = -3.350831e-007

STRAIGHT LINE FIT:
M = -4.784895e-001
B = 1.728115e+003

PRESSURE PSIA	INST OUTPUT (N)	COMPUTED PSIA	ERROR %FS	LINEAR PSIA	ERROR %FS
14.73	3578.3	14.52	-0.01	15.94	0.04
592.21	2377.9	590.69	-0.05	590.32	-0.07
1171.84	1166.8	1171.01	-0.03	1169.81	-0.07
1746.22	-37.7	1747.19	0.03	1746.15	-0.00
2323.08	-1246.3	2324.36	0.04	2324.46	0.05
2900.05	-2450.0	2898.22	-0.06	2900.41	0.01
2324.05	-1247.8	2325.08	0.04	2325.17	0.04
1746.30	-38.0	1747.34	0.04	1746.30	-0.00
1169.30	1172.1	1168.47	-0.03	1167.28	-0.07
592.16	2377.6	590.83	-0.05	590.46	-0.06
14.73	3573.2	16.97	0.08	18.38	0.13

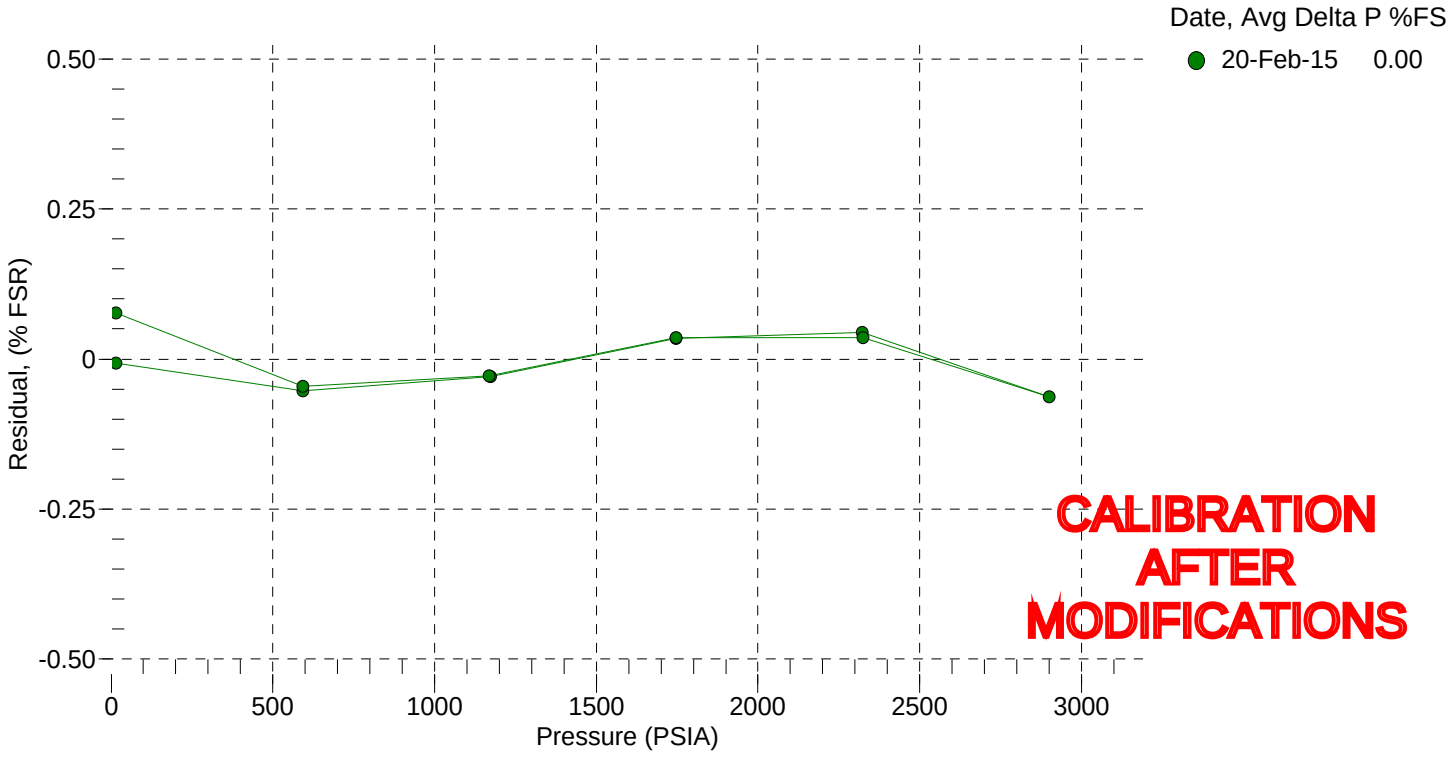
Straight Line Fit:

Pressure (psia) = M * N + B (N = binary output)

Quadratic Fit:

pressure (psia) = PA0 + PA1 * N + PA2 * N^2

Residual = (instrument pressure - true pressure) * 100 / Full Scale Range



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SENSOR SERIAL NUMBER: 0188
CALIBRATION DATE: 27-Feb-15

UCTD TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:

```
a0 =  8.756901e-004
a1 =  2.725671e-004
a2 = -1.599503e-006
a3 =  1.725281e-007
```

BATH TEMP (ITS-90)	INSTRUMENT OUTPUT	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
1.0000	789180.200	1.0001	0.0001
4.5000	700487.700	4.4999	-0.0001
15.0000	473355.300	15.0001	0.0001
18.5000	410667.600	18.5000	0.0000
24.0000	324416.100	23.9999	-0.0001
29.0000	257885.200	29.0000	0.0000
32.5000	217343.700	32.5000	0.0000

MV = (n - 524288) / 1.6e+007

R = (MV * 2.295e+010 + 9.216e+008) / (6. 144e+004 - MV * 5.3e+005)

Temperature ITS-90 = $1/\{a0 + a1[ln(R)] + a2[ln^2(R)] + a3[ln^3(R)]\} - 273.15$ (°C)

Residual = instrument temperature - bath temperature