BGM-3 Gravimeter Best Practices Manual

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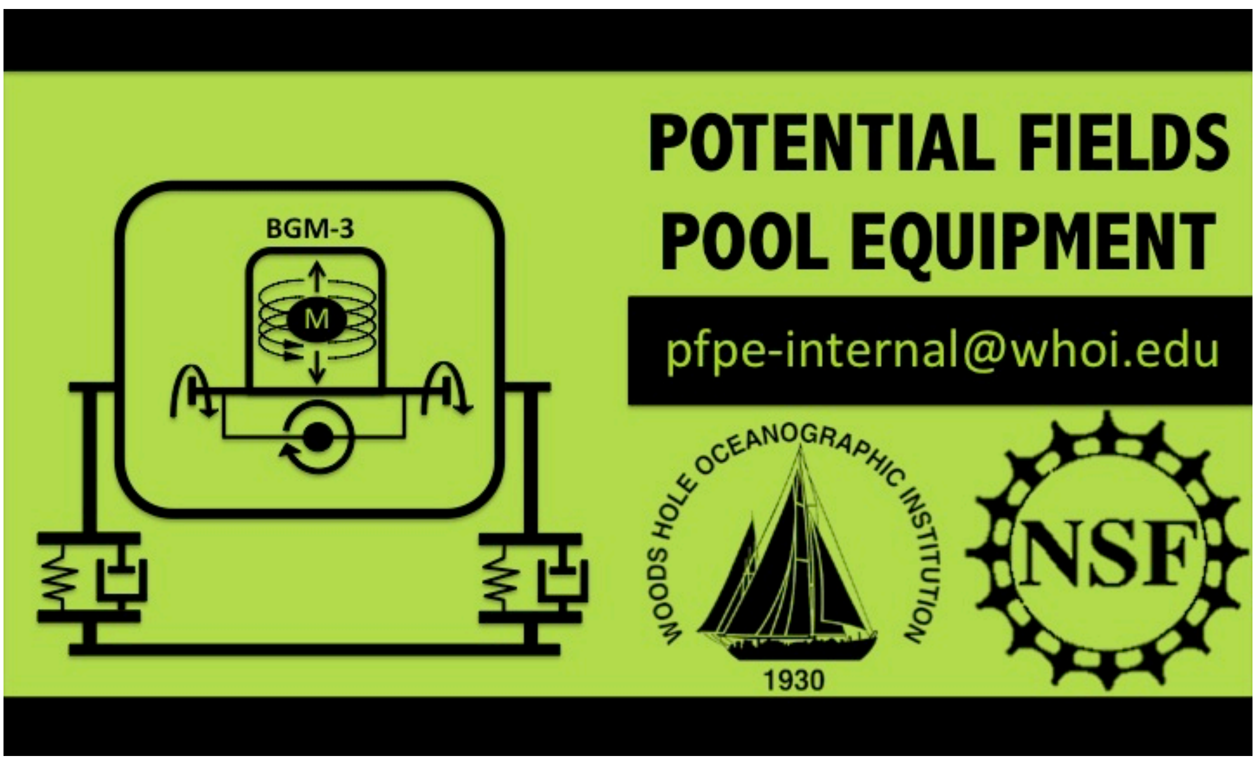

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1 System Overview and Component Descriptions

The BGM-3 consists of a force feedback accelerometer mounted on a stabilized platform. The first Bell Aerospace BGM-3 Marine Gravimeter system made available for academic use was installed on the R/V Robert D. Conrad in February 1984 by Robin E. Bell and Anthony B. Watts.

In late 2006, through a NSF equipment grant, the Woods Hole Oceanographic Institution (WHOI) acquired used BGM-3 gravimeters equipment from Fuguro Internarional, a commercial survey company. The intent of the project was to implement 5 permanent BMG-3 installations on UNOLS research vessels, and 2 systems that could be temporarily installed on other ships of opportunity on an as-needed basis.

Today, the Potential Fields Pool Equipment (PFPE) maintains a total of 9 BGM-3 gravimeters on ships including all of the UNOLS global and ocean class research vessels, and all of the U.S. Polar research vessels.

The BGM-3 Gravimeter is an extremely power sensitive system, and great care must be taken to ensure that the sensor remains powered up in order to remain operational. Even momentary power loss can result in very expensive and time consuming repairs.

Figures 1-5, below depict all of the major components of the system:

- Figure 1. Typical shipboard installation of BGM-3 Gravimeter
- Figure 2. Sensor Electronics Front Panel
- Figure 3. Control Power Supply (CPS) Front Panel
- Figure 4. Stabilization Table with top cover removed
- Figure 5 – Data Buffer Reset button and LED's

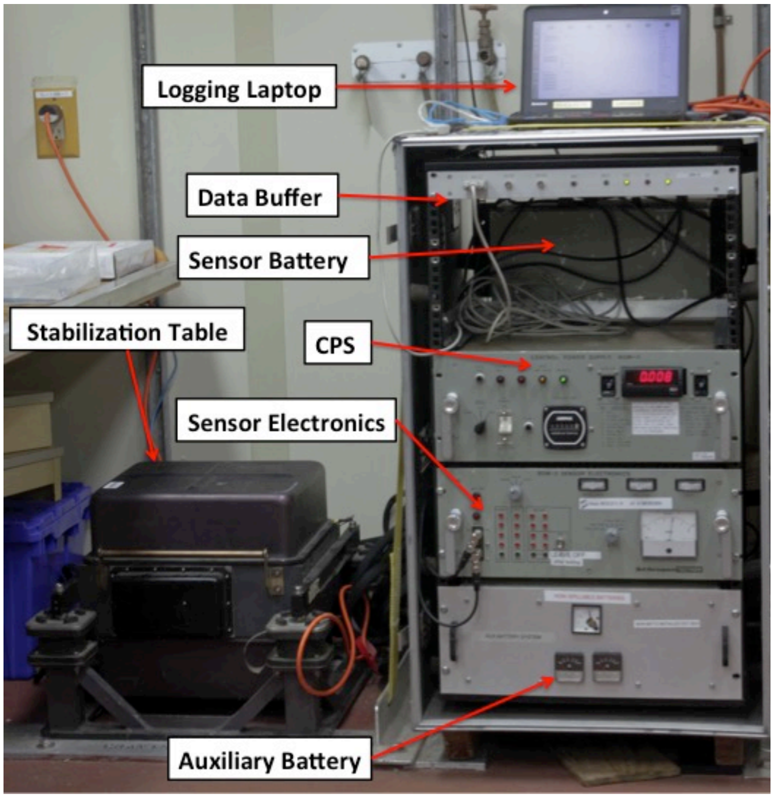

Figure 1. Typical shipboard installation of BGM-3 Gravimeter

1.1 Typical Operational State

When in its normal functional operations mode, the BGM-3 gravimeter includes components noted in Figure 1. The first place to look for a quick health check is the analog meter on the front panel of the Sensor Electronics case. There you can check the sensor voltage (ELEX V) which should read ~29 Volts. Another quick health check is the green **Operate** LED in the middle of the Control Power Supply (CPS) panel, and the DNV lights on the data buffer, the CPS, and the laptop GravGui are either not illuminated (LEDs) or are showing green (GUI).

If the Battery Low light on the Sensor Electronics front panel is ever illuminated, very serious damage could occur. When a system is being transported it should register an absolute minimum of 20 Volts DC, and any time a sensor is this low on power it requires immediate attention. FIX PER RANDY AND STEFANO'S COMMENTS

1.2 Sensor and Sensor Electronics

The sensor unit (seen below in section 1.4) consists of a proof mass suspended in an electromagnetic field. This is surrounded by a series of insulating ovens, which keep the sensor at a stable temperature. The sensor itself is the most delicate part of the system and must always be handled with great care. When moving the sensor it is best to always keep it orientated vertically, and to be gentle. Since the sensor unit is so sensitive to such subtle vertical accelerations, extra care should be taken when putting the sensor down, and to always avoid letting it drop even very short distances.

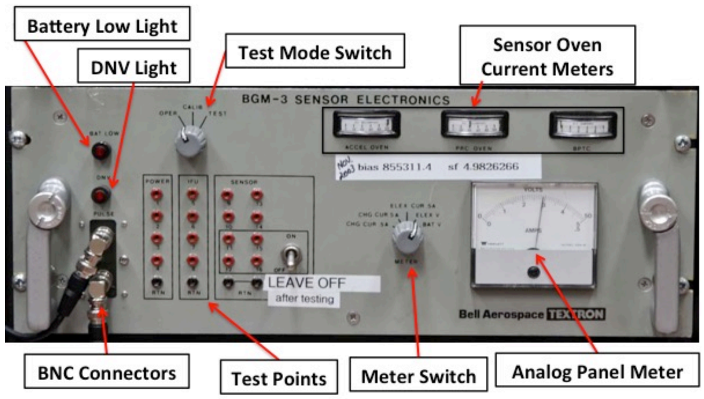

Figure 2. Sensor Electronics Front Panel

The sensor itself is permanently hard wired to the Sensor Electronics. The electronics in the chassis provides a constant electrical current, which keeps the proof mass floating. Any damage to the sensor's cabling could result in accidental power loss. At all times, at least two separate and redundant power sources (either battery packs or clean 115VAC wall power) should be plugged into the sensor electronics.
As shown in Figure 2, the Sensor Electronics front panel has an analogue panel meter on the lower right side, with a selector knob to toggles between:
CHG CUR .5A - Charge current, fine 0 to .5 amp scale
CHG CUR 5A - Charge Current, coarse 0 to 5 amp scale
ELEX CUR .5A -Current drawn by the sensor, 0 to .5 amps
ELEX V -Voltage going to the sensor, 0 to 50 Volt scale
BAT V -Battery Voltage, 0 to 50 Volt scale

At all times during normal operation (while plugged into wall power) the **ELEX V** should read about 29 volts ± 1 volt.

Along the top of the Sensor Electronics there are analog readouts for the 3 ovens labeled ACCEL OVEN, PRC OVEN, and BPTC OVEN. These gauges display cyclical readings, and are a good indicator that the sensor has power and is stable.

On the left hand side of the sensor electronics are the sensor's test points. These are to be used with an external digital multimeter. Instructions for taking readings on these test points are explained in Section 2.1.3.

Acceptable values for all sensor electronics readouts are described in Section 2.1.

On the far left hand side of the Sensor Electronics are two BNC connectors that allow the it to communicate the sensor's raw data feed to the data buffer.

1.3 Control Power Supply (CPS)

The Control Power Supply (CPS) is what drives the gimbaled gyro-stabilized leveling table by taking feedback from the table's axis specific (pitch/roll) accelerometers and gyroscopes to automatically compensate for the ship's pitch and roll. Actively counter-acting all horizontal accelerations allows the sensor to accurately isolate and measure only the vertical accelerations (and thus gravity). The CPS is not involved with the basic power supply to the sensor; it only interacts with the gimbaling table.

The CPS has an ON/OFF switch on the lower left hand side, which acts as a power switch to the stabilization table. 5 LED read outs in the upper left indicate whether the platform is operating correctly (Green OPERATE light), and give some insight as to the potential failure mode if the platform is not operating correctly.

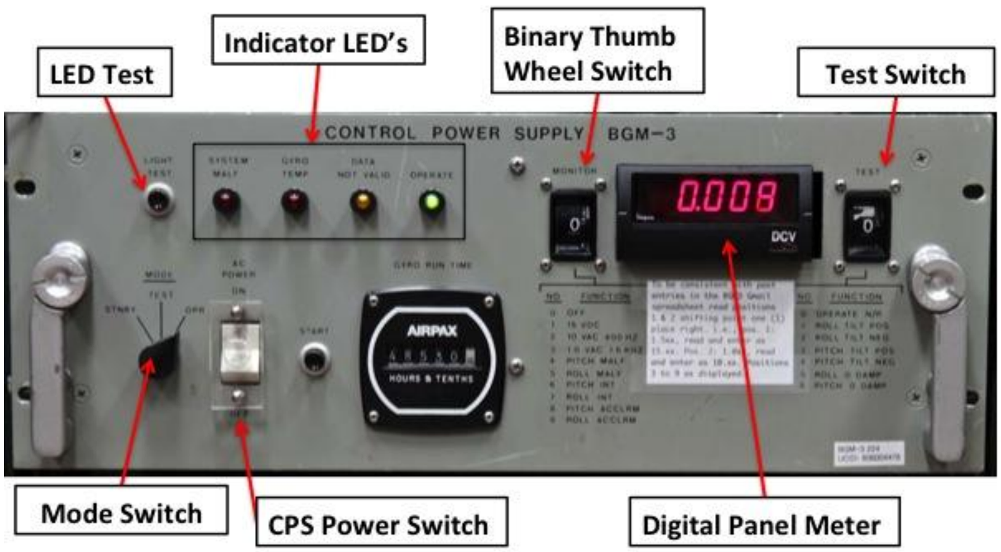

Figure 3. Control Power Supply (CPS) Front Panel

The CPS also has a Digital Panel Meter (DPM) on the upper right side (shown in Figure 3). This panel helps in doing quick assessments of the table's power supplies and gyroscopes (described in section 2.1.1), and it also facilitates running in-port tests for tuning the stabilization table (described in sections 4.2 and 4.3)

1.4 Stabilization Table

The stabilization table (Figure 4) is the platform on which the sensor sits while in operation. As described in Section 1.3, the table is gimbaled on the ship's pitch and roll axes and compensates for the ship's motion. The stabilization table is typically firmly bolted to a welded plate somewhere close to the ship's roll axis, and as close to its center-line as possible. Two large cables connect the CPS to the Stabilization table. The stabilization table may also be referred to as the "(double) gimbaled table", "sensor table", "sensor platform" or simply "table" or "platform".

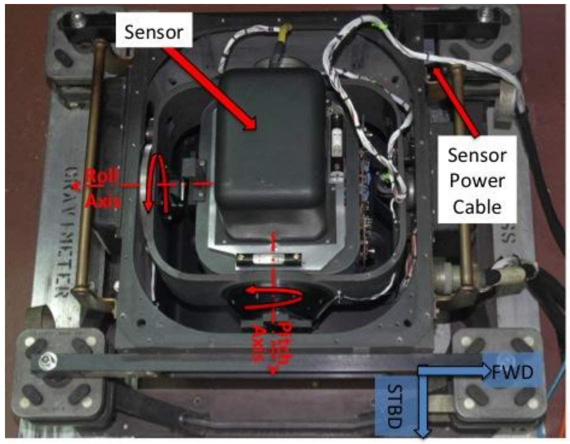

Figure 4. Stabilization Table with top cover removed

1.5 Batteries and Uninterrupted Power Supplies

In order to ensure a consistent and redundant supply of power to the sensor, at least one or two battery packs must remain attached to the system at all times regardless of access to clean 120VAC power. These emergency battery packs are preferably plugged into a separate (emergency) shipboard power circuit and are designed to keep the system powered for about 24 hours in the occurrence of a 120VAC power loss.. It is also preferable to use a commercially available rack mounted Uninterrupted Power Supply (UPS) which plugs into a clean (regulated) 115 Volts AC socket.

1.6 Data Buffer

The LDEO BGM-3 interface buffer is a frequency counter with an RS-232 output.
It is specifically intended to measure the gravity field-dependent frequency of pulses emitted by the BGM-3. The time base of the measurement is a 4 Hz signal generated by the BGM-3 from the same reference oscillator that is modulated by the gravity measurement.

Figure 5 – Data Buffer Reset button and LED’s

This interface was originally designed in the mid 1980s by Joseph Stennett at Lamont-Doherty Earth Observatory of Columbia University. The interface was developed to replace the large collection of interface hardware that was delivered as part of the original equipment of the Bell BGM-3 Marine Gravity Meter that was installed on the R/V Conrad. Separate batches of buffers have been made in 1998 and 2007

Revision history and additional operation information is documented in the complete BGM-3 Interface Manual which should be included with each BGM-3 unit.
THERE SHOULD BE MENTION THAT THESE DOCUMENTS ARE ITAR CONTROLLED… NO?

1.7 Computing and Software

PFPE is in the process of equipping every sensor with a new PC-based, LINUX laptop with a gravimeter dedicated software program developed at WHOI. This software automates much of the tedious hand calculations for in-port tests, and provides an ability to easily check the status of the system and its functionality.

1.7.1 WHOI "GravGui"

The WHOI-designed graphical user interface (GUI) has a real time auto-scaling display of gravity values plotted over a 90 second interval. Along the top of the display are series of 7 artificial LED's that toggle between red and green indicating:

- RDS – verifies Raw Data Stream from sensor electronics via Data Buffer see section 1.8 for further information
- FDS – verifies Filtered Data Stream from Data Buffer
- GPS – Verifies connection to ship's GPS data
- DNV – Mimics Data Not Valid light on Data Buffer
- DEP – Depth – Verifies feed of ship's depth data
- HDG – Heading – Verifies feed of ship's heading data
- LINK – Verifies correct operation of the filtering/IO/logging code

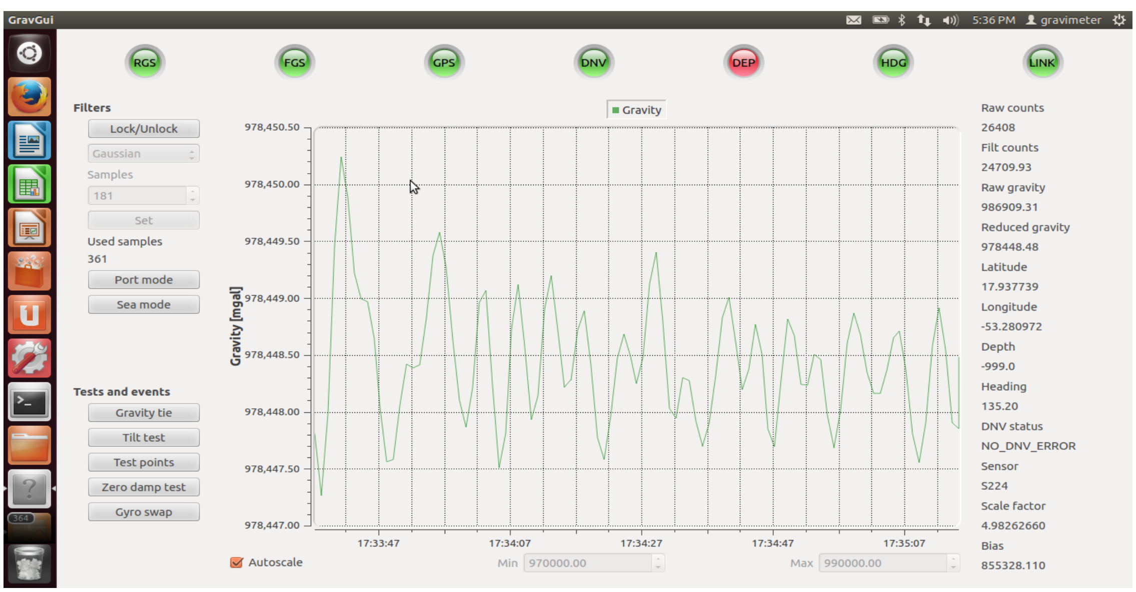

Figure 6. GravGui main page

On the right side of the screen it displays raw gravity values, reduced gravity values, the sensor's GPS co-ordinates, ship's heading, sensor serial number, DNV status, scale factor and bias. The left hand side shows lockable filters, it how many samples are used in the filtered data, and it has options for Port Mode vs. At Sea mode.

1.7.2 GravGui Functions

At the lower left hand corner of the GUI (Figure 6), a series of buttons labeled "Tests and events" is displayed. Using those buttons, the user has the option of selecting Gravity Tie, Land Tie, Tilt Test, Test Points, Zero Damp Test, and Gyro Swap. The software typically automatically saves all of this information, in .pdf format (and .xml for gravity tie) for documentation and archiving purposes.

1.7.3 Data Formats

Raw Gravity Strings (RGS)

The Raw Gravity String (RGS) is created at the native rate of the gravimeter (e.g., for a BGM3, it is created once a second) and uses the MOST RECENT navigation and depth data. **The gravity logging program (gravlog) does not attempt to resolve the asynchronis data streams.** Consequently, the navigation and depth data will be older than the gravity measurements. The nav data uses GPS and should be less than a second old; depending on the site depth, the depth data maybe a few seconds old. The timestamps of the nav and depth data are included in the RGS, enabling the user to resolve the age of the measurement.
For both the nav and depth measurements, ONLY THE BEST AVAILABLE MEASUREMENT IS LOGGED IN THE RGS. On any given vessel, multiple sensors may be obtaining nav and depth data, and gravlog decides which sensor to use based on a prioritization table, the "age" of the measurement, and other metrics. It is not uncommon for the source of the measurement to change during a cruise. GravLog automatically switches to the best available sensor and uses that "best measurement" in the RGS. For both depth and nav, a source field is included that indicates the source of the obtained measurement.

The data format for the RGS is:
RGS YYYY/MM/DD hh:mm:ss.sss raw_gravity gravity_unixtime counts scale_factor bias gravimeter_model gravimeter_serial_number
NAV: latitude longitude number_of_satelites GPS_unixtime GPS_source
DEPTH: depth depth_unixtime depth_source
dnv_status maggie_data_string
Where: raw_gravity — is the UNFILTERED measured gravity in *MGALS*
counts — is the counts measured by the gravimeter (e.g., for a BGM3, the value transmitted from the data buffer)

2 Gravity software

2.1 Overview

TO BE WRITTEN?

2.2 Using the software for calibration and testing

TO BE WRITTEN?

2.2.1 Test and calibration matrix

Test or event type	Location to execute	When	Purpose	Reports location
Tilt test	In port	Every 2-3 months, or after changing a gyroscope. Execute this after the zero damp test is in spec	CPS System tuning	/data/gravity/eng/
Zero damp test	In port	Every 2-3 months, or after changing a gyroscope	CPS System tuning	/data/gravity/eng/
Test points	In port	Every port stop, not simultaneously to a gravity tie or land tie	Systems health check	/data/gravity/tp/
Land tie	In port	As necessary to support gravity ties	Pre-Calibration; determine the mGal gravity value at the pier where the ship is docked	/data/gravity/lt/
Gravity tie (ship-to-shore tie)	In port	Every port stop if possible or every 2-3 months, and before a geophysics cruise	Calibration; determine the gravimeter bias offset. May require a land tie to be executed before this	/data/gravity/gt/
Gyro swap	N/A	When a gyroscope is changed	Create a record of gyroscope change with serial numbers	/data/gravity/gs/

2.2.2 Ship to Shore Gravity tie instructions

A gravity tie is executed to determine the bias (offset), in mGal, of the gravimeter, allowing the user to relate the sensor's relative gravity measurement to a known and accurate benchmark site which is considered stable and has been surveyed in by a very precise land based gravimeter. As such, doing a gravity tie requires the gravity value of an established gravity station where the ship is docked. The software includes a database of known, trusted gravity stations that will be expanded over time. If the ship's docking location does not have a station in the database, contact pfpe-internal@whoi.edu for a search in an extended database. If no gravity station exists at the ship's exact docking location, a land tie is required before executing the gravity tie, to determine the gravity value of "station A" at the ship pier. A gravity tie takes exactly one hour of time, but it is mostly automated in the software. Instructions to use the gravity tie interface are:

1. Click the "Gravity tie" button on the GUI to open the gravity tie interface
2. Click the "new test" button on the new window
3. Select from the database the gravity station at the ship's exact docking location. NOTE: if a land tie had to be executed to determine the value of the gravity at the ship, in the database dropdown menu select "Other – Other – Other", then fill the fields with a reference ID to the land tie executed, and in the "mGal at pier" field enter the gravity value of station A that was determined at the end of the land tie procedure
4. Click the "Start recording" button. A progress percent indicator will display and the window will start plotting and buffering filtered counts from the system
5. Go immediately outside the ship, and measure the height difference (in feet and inches) between station A and the gravimeter location on the ship. Enter the value in the "Water height to pier 1" field in the gravity tie GUI window
6. At 50% progress for the gravity tie, go outside the ship, and measure the height difference (in feet and inches) between station A and the gravimeter location on the ship. Enter the value in the "Water height to pier 2" field in the gravity tie GUI window
7. At 100% progress for the gravity tie, go outside the ship, and measure the height difference (in feet and inches) between station A and the gravimeter location on the ship. Enter the value in the "Water height to pier 3" field in the gravity tie GUI window
8. If a land tie was executed to determine the "mGal at pier" field of this window, check the "Land tie used" checkbox
9. When the progress indicator shows "COMPLETE!", press the "Compute Bias" button. The new bias will be displayed to the right of the button
10. Compare the new bias to the old bias. The old bias is reported also in the GUI main window in the "Bias" field in the bottom right corner. If the new bias looks acceptable (i.e. is consistent with historical bias drift rate of the system), click the

"Accept" button on the gravity tie window. This will generate a report and update the software to use the new bias. After clicking "Accept", verify that the "Bias" field in the bottom right corner of the GUI main window is now the new bias

NOTES:

a) If the software detects a system malfunction or a "data not valid" flag during the gravity tie, the gravity tie will automatically abort and the abort reason will be displayed on the gravity tie window. In this case, the system malfunction or "data not valid" should be investigated before restarting the gravity tie again

2.2.3 Land tie instructions

A land tie is executed (and necessary) if no established gravity stations are available immediately next to (i.e., within 50m) where the ship is docked. The purpose of a land tie is to determine the gravity value (in mGal) at the location where the ship is docked (station A – new station), using: a) information from a land gravity meter and b) the gravity value of a known and well established gravity station (station B – known station).

Figure 7. James Kinsey – WHOI, taking a reading with the LaCoste and Romberg Model G in Halifax Nova Scotia while installing a BGM-3 on the Canadian Coast Guard Ice Breaker Louis St. Laurent

When a land tie is required, a technician should use a land meter to record:

1) The time (and reading from the land gravimeter) at station A (repeated three times)
2) The time (and reading from the land gravimeter) at station B (repeated three times)

3) The time (and reading from the land gravimeter) at station A again (repeated three times)

When this data has been collected, the "Land Tie" button on the GUI opens a window to determine the value of the gravity at the pier (station A). Instructions to use the land tie interface are:

1. Click the "Land tie" button on the GUI to open the land tie interface
2. Click "NEW" to start a new land tie
3. Enter the first set of three land meter readings and times for station A in the first station A block
4. Enter the set of three land meter readings and times for station B in the station B block
5. Enter the second set of three land meter readings and times for station A in the second station A block
6. In the "Database – section B" block, select the appropriate ship, and the gravity station used for station B from the database. If the station B you used is not in the database, select "Other – Other – Other" and enter all the information required to fill out this block, including the "mGal at pier" field. ***NOTE***: this "mGal at pier" field is NOT the value of the gravity at the pier where the ship is docked, but the value of the gravity of station B (known station)
7. In the "New Station – station A" section, enter the latitude and longitude of the new station (A) that you are establishing (i.e., from a handheld GPS receiver), assign a name to the new station and use the text box below to enter any note that can help in better identify the location of the station (for example, indicate distances from bollards, from pier ends, from easily recognizable landmarks, etc…). These notes are useful to locate again the new station in the future
8. In the "Additional information" section, enter the name(s) of the personnel who used the land meter for this land tie and/or filled out the information in the land tie window. Enter the land meter temperature recorded during the readings in the field, and select the serial number of the land meter used. The software automatically uses the appropriate calibration table for the particular land meter S/N to compute the reading-to-mGal conversion
9. Click "COMPUTE" to compute the value of the gravity at station A. The computed value will be displayed to the right of the "COMPUTE" button
10. If the value computed is acceptable, click the "ACCEPT" button to generate and save a report

2.2.4 Test points checks instructions

1. Click "Test points" in the GUI main window
2. Click "New test" in the new window that appears
3. Complete the "Ship", "Personnel" , "Port", "Wind sea" and "Swell" fields

4. Ensure that the Sensor DNV light is off, and the CPS “Data not valid” light is off
5. Use a volt meter to measure the 16 sensor test points on the front of the sensor electronics rack unit. The grounds are different for groups of test points, the engraved boxes show the pairing of grounds with the correspondent test points. Test points 11,12,15,16 require to turn the switch next to them to the ON position before taking their measurements. *Make sure to turn that switch to OFF after taking those measurements and that after doing this the Sensor “DNV” light on the front of the sensor electronics rack unit turns off*. Enter the values read for the 16 test points in the GUI window (Sensor TP 1-16)
6. Switch the “Monitor” selector of the CPS through all its positions and record the values indicated on the CPS Digital Panel Meter on the GUI window (CPS TP 1-9)
7. Record in the GUI window the maximum values reached by the three meters indicators on the front of the sensor electronics rack unit, and check the corresponding checkbox to indicate if the indicators are cycling or not.
8. Cycle the “Meter” selector on the front of the sensor electronics rack unit between the “Bat V”, “Elex V”, “Elex Curr”, “Chg Curr” positions and record on the GUI window the readings from the analog panel meter.
9. Click “Check ranges” on the GUI window. The GUI will display in green the values that are within specification and in red the values that are out of specification. If a value is out of specification, e-mail pfpe-internal@whoi.edu.
10. Click “Save report” and verify that the GUI displays “Saved OK”.

2.2.5 Tilt test instructions

11. Click “Tilt test” in the GUI main window
12. Select the axis to test (pitch or roll)
13. Click “Initialize tilt test”
14. Complete the “Ship”, “Personnel” and “Port” fields
15. If not already, set the CPS switch in “Test” mode
16. Follow the instructions on the window and set the appropriate CPS monitor and test dial numbers
17. After stabilization in the plot’s indicated gravity (about 6 minutes) press the G1 button to record the gravity value
18. Follow the new instructions on the window and set the appropriate CPS monitor and test dial numbers
19. After stabilization in the plot’s indicated gravity (about 6 minutes) press the G2 button to record the gravity value
20. Press “Determine action and generate report”
21. Follow the instructions on the window and execute the eventual corrective action it recommends

When the tilt tests are finished and no other CPS tests need to be executed, set the CPS switch in “OPR” mode and verify that after about 7 minutes the “data not valid” light turns off and the “operate” light turns green.

2.2.6 Zero-damp test instructions

3. Click “Zero-damp test” in the GUI main window
4. Select the axis to test (pitch or roll)
5. Click “Initialize Zero-damp test”
6. Complete the “Ship”, “Personnel” and “Port” fields
7. If not already, set the CPS switch in “Test” mode
8. Follow the instructions on the window and set the appropriate CPS monitor and test dial numbers
9. When the Digital Panel Meter value crosses zero (from negative sign to positive sign) click “Start zero-damp test”
10. When the Digital Panel Meter value crosses zero again (from negative sign to positive sign, after one period of the oscillation) click “First zero-crossing”
11. When the Digital Panel Meter value crosses zero again (from negative sign to positive sign, after two periods of the oscillation) click “Second zero-crossing”
12. When the Digital Panel Meter value crosses zero again (from negative sign to positive sign, after three periods of the oscillation) click “Third zero-crossing”
13. When the Digital Panel Meter value crosses zero again (from negative sign to positive sign, after four periods of the oscillation) click “Last zero-crossing”
14. Press “Determine action and generate report”
15. Follow the instructions on the window and execute the eventual corrective action it recommends

When the tilt tests are finished and no other CPS tests need to be executed, set the CPS switch in “OPR” mode and verify that after about 7 minutes the “data not valid” light turns off and the “operate” light turns green.

3 Troubleshooting and Repairs

It can not be stressed enough that the first step in any troubleshooting should be to contact **pfpe-internal@whoi.edu** . If you are unsure what the cause of the failure might be, and need help describing the symptoms the following sections will help guide you through preliminary information gathering which can help the group at WHOI diagnose your problem.

3.1 Where to Start?

3.1.1 Checking the Sensor Electronics

The primary concern with the BGM-3 is to ensure that there is still power to the sensor. Check the sensor voltage by turning the panel meter dial on the sensor electronics case to the '**ELEX V**' position and reading the voltage on the panel meter. The voltage should be approximately 28V. Leave the panel meter dial in the '**ELEX V**' position. Also see if the Low Battery light is on. If so, immediately notify the ship's technician.

3.1.2 CPS Digital Panel Meter (DPM) values

If the sensor itself appears healthy, but the DNV light is illuminated then the next thing to check is the Digital Panel Meter (DPM) on the Control Power Supply (CPS).
The CPS has 9 test values that are read via the DPM and the binary thumb wheel switch. The exact format of the DPM varies — see Appendix C for more information. The table below lists the CPS test points and the expected values. It is often the case that the decimal point on the DPM should be ignored.

Position	Function	Expected Value	Deviation
1	15 VDC Power Supply	15 vdc	±1 vdc
2	10 VAC 400HZ Supply	10.00 vdc	±1 vdc
3	1.0 VAC 1.6KHZ Supply	1.00 vdc	±0.1 vdc
4	Pitch Gyro Malfunction	0.00 vdc	±0.1 vdc
5	Roll Gyro Malfunction	0.00 vdc	±0.1 vdc
6	Pitch Gyro Integral Value	0.00 vdc	±3 vdc
7	Roll Gyro Integral Value	0.00 vdc	±3 vdc
8	Pitch Accelerometer Value	0.00 vdc	±0.2 vdc
9	Roll Accelerometer Value	0.00 vdc	±0.2 vdc

Figure 8. DPM Functions and Expected Values

If the laptop provided with the system is running updated GravGui software, this process can be logged automatically along with other measurements described in the following sections. On the lower left side of the GravGui's main page there is a widget button labeled "Test Points". Clicking this will open a new window where you can input the value for each test point, and the TP# will automatically turn green if the value is within specification, or it will turn red if the value is outside the acceptable range. At the end of the test, a button on the lower right hand side will automatically generate a time-stamped report in .pdf format.

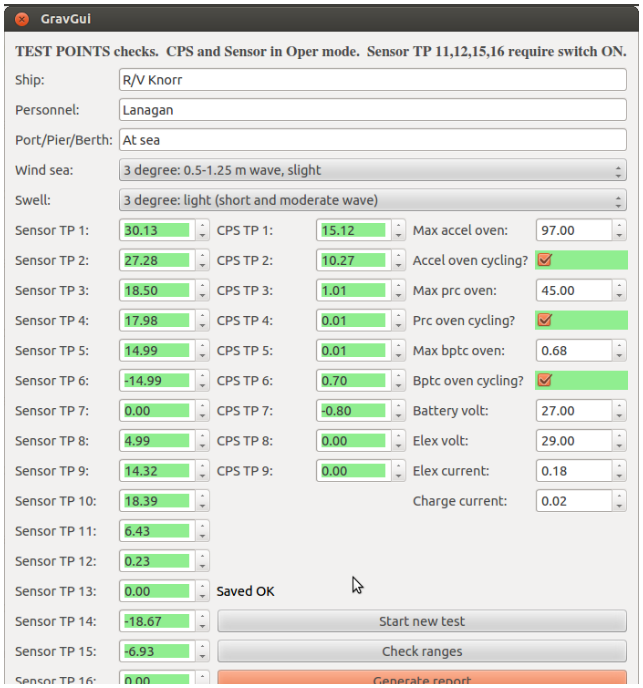

Figure 9. GravGui Test Points Checks

3.1.3 Sensor Electronics Test Point Voltages

The test point jacks are located on the left side of the Sensor System chassis front panel. The black TP jacks under the main TP group are ground points for the VOM low side probe. These measurements are to be made using a standard digital volt/ohm meter. DC voltage accuracy is between 0.01 and 0.05 percent, which is quite adequate for these measurements. The table below lists the test points with the expected values followed by a reasonable expected plus and minus range value. For example, TP 1 with a measured value below 27 vdc or above 33 vdc should be taken as an indication of an incipient problem. Deviations from these values should be noted and the measurements repeated a few hours later. If deviations last more then a few hours, contact pfpe-internal@whoi.edu

Test Point	Expected Value	Deviation
1	30VDC	±0.5VDC
2	22 vdc	0.25 vdc
3	18.5 vdc	0.25 vdc
4	18 vdc	0.25 vdc
5	15 vdc	0.25 vdc
6	-15 vdc	0.25 vdc
7	skip	skip
8	5 vdc	0.1 vdc
9	14.2 vdc	0.25 vdc
10	18.4 vdc	0.5 vdc
11	6.4 vdc	0.25 vdc
12	0 vdc	0.5 vdc
13	skip	skip
14	-18.6 vdc	0.5 vdc
15	-6.8 vdc	0.5 vdc
16	skip	skip

Figure 11. Sensor Electronics Test Points and Expected Values

Important Note: Test points 11, 12 and 15 are grouped by a border with an ON/OFF switch. To make those measurements that switch must be temporarily turned on. Note also that the Sensor Electronics chassis DNV indicator turns on at that time. Always return the switch to the off position at the completion of the test.

3.1.4 Sensor Ovens Currents

Directly above the Sensor Electronics panel meter are the current meters for 3 internal ovens that keep the sensor at a stable temperature. The indicating needle normally moves cyclically. Expected values for current draw are shown in the table below:

Measurement	Expected Value
PRC Current	≈ 40 mA
ACCL Current	≈ 100 mA
BPTC Current	≈ 0.7 A

Figure 12. Sensor Oven Currents and Expected Values

3.1.5 Restarting the CPS

Occasionally, a simple cycling of the power switch on the CPS case can help resurrect the stabilization table, and turn a DNV light or a Gyro Temp light off. After turning the CPS power switch off, wait approximately one minute before powering it back up.

3.1.6 Observe operational conditions

In adverse sea states the stabilization table can struggle to keep up with the ship's motion. This often results in a failure to keep the sensor level enough to give reliable data and can trigger the table to become dis-erected and/or trigger the DNV light to become illuminated. The best thing to in this situation is to wait out the storm and try again once the sea state abates. If the table is failing to erect in a rough sea state the table should be secured with zip ties through the designated slots on the corners of the table.

3.2 Common Issues

The following items tend to have finite lifespans, and will occasionally require repair or replacement. Good functional descriptions of the following components can be found in the Operations and Maintenance Manual, Stabilized Table subsystem, Section 4.''

Note: Before replacing any of the boards or power supplies turn the CPS off and unplug it from AC power. The chassis must be pulled out far enough to remove the top cover. For PS replacement the CPS must be removed from the rack.

3.2.1 Gyro Failure

Due to the constant duty cycle and high RPMs of the gyroscopes, failure is only a matter of time. Despite retrofitting most gyros with long life bearings, we still only expect to get a finite number of hours out of each gyro before it needs to be sent back to the manufacturer (US Dynamics) for refurbishment. The exact time between failures is highly circumstantial and still under investigation.

Typical symptoms include a failure to erect the stabilization table, DNV lights on the CPS, Gyro Temp lights on the CPS, high pitched whining (louder than usual), and out of spec Pitch/Roll MALF values on the CPS monitor points 4 and 5 (see section 2.1.1). Replacing a gyro requires a step-by-step disassembly and re-assembly of the stabilization table and is discussed in section 2.3.1.

3.2.2 Stabilization Board Failure

Stabilization (often abbreviated as Stab) board failure is not often encountered. The typical symptom mimics a gyro failure; however, the Stab board is always suspect if repeated bad values for Monitor Positions 4 and 5 interchange, and are not consistently on Position 4 or 5.

3.2.3 Gyro Board Failure

Gyro Board failures are also not frequent. The typical Gyro Board failure is encountered when adjustment to one or more of the Pots (tilt test or zero damp test) do not result in any change.

3.2.4 Control Board Failure

Control Board failure is usually demonstrated by a blank display screen or values that are way out of specification. The display (Digital panel Meter or DPM) could also be the problem here.

3.2.5 Mother Board Failure

Mother Board failure is the most common failure of the 4 boards within the CPS. It is usually due to faulty or sticky relays on the board, not allowing the electronics to erect the stabilization table. Occasionally wildly bad values are seen on the DPM.

3.2.6 PS1 or PS2 Power Supply Failures

PS1 and PS2 provide the 28 VDC power for the entire CPS. A consistent value greater than 110 will typically be seen on the DPM, regardless of the Mode setting on the CPS or the Monitor Position. A common handheld DVM can be used to observe the 28VDC power during the startup sequence directly on each power supply. Often the PS will show 28V initially but then drop off when the load is applied.

3.3 Common Repairs

There are several common repairs that must be made at sea in order to keep the BGM-3 operational. Several of these common repairs have been documented both in traditional instructional text formats and more recently in video format that will be distributed amongst the pool of BGM-3 users the end of 2015.

3.3.1 Gyro Replacement

Changing out gyros can be a fairly complicated task for a first timer without the guidance of a more experienced technician. Special care must be taken to handle all gyros very gently and avoid dropping or knocking them during replacement.

An instructional video for this procedure is now available, and should be included with each BGM-3. For traditional text format, follow the instructions below:

1) Turn off the CPS electronics (the same electronics you were getting the CPS values from) using the on/off switch.

2) You need to remove the sensor from the table. Unfasten the screws holding the top cover of the stabilization and remove the cover. You'll see the sensor (a black cube) on the middle of the double-gimbaled table. There is a cable running from the sensor out of the table case to the sensor electronics case. Inside the case, this cable is dressed with tie-

wraps. Note how it is dressed (I recommend taking a photo) and then remove tie-wraps. Unscrew the sensor from the table and place the sensor somewhere safe near the electronics rack. Note that you can NOT unplug the cable from the sensor --- you must leave it plugged in.

3) Unplug the CPS cables from the table. There are 2 cables with large connectors (i.e., greater than 1" in diameter). Unplug them.

4) Remove the table from the pedestal. There are 4 bolts, one on each corner of the table that connect it to the pedestal mounted on the deck. Remove the bolts. You can now remove the table from the pedestal. You might want to move the stabilization table to a bench or table to avoid unnecessary bending over.

5) Turn the stabilization table over such that bottom cover is facing up. Remove this cover. You will now see 2 gyros (Figure 5-3 in attached). One is the roll gyro; the other the pitch gyro. You can tell which is which by (a) looking at the mounting bracket for the gyro and seeing if it says or (b) looking at the label near where the connector connects to the table. Label J3 is for the pitch gyro; J4 for roll.

6) Unplug the gyro. This is a pain. Get a long, thin flat head screwdriver. You need to slowly back the screws on the connector off --- i.e., turn one screw a little, then the other screw a little and then back to the first screw. This will slowly back the connector off. This may take a while, be patient.

7) Remove the screws holding the gyro in place. Note the alignment of the old gyro as you want to use the same alignment with the new gyro.

At this point note the serial numbers on the old gyro and on the new gyro. Send those serial numbers to pfpe-internal@whoi.edu when you're done with the swap.

8) Install the new gyro. Mount it and then screw in the connector.

9) Now put the table back together again. Attach the bottom cover and mount the table on the pedestal. Put the sensor on the table and dress the sensor cable (see your notes from step 2 and figure 5-5 in attached). Once you've dressed the cables rock the sensor along both axes of the double gimbaled table to ensure that the sensor cable has sufficient slack and does not get pinched). Then plug the CPS cables back in. I recommend you leave the top cover off for the moment so you can observe the table during power up.

10) Now restart the CPS. Set the CPS monitor to position 2. Should be at 0V initially and after ~1 minute go to 10V. You'll start to hear a "whining" sound from the table --- this is the gyros spinning up to 13000 rpm (these are old school spinning mechanical gyros). After a few minutes the table should start to automatically level and, after 8 minutes, the DNV light will go off. If all goes smoothly, then place the top cover back on (note the gap on one side of it for the sensor cable). You're done. Congrats!

11) If you still get a gyro error, first check your work. If it's still bad, then most likely you swapped out the wrong gyro or the spare is bad (we test all of the gyros at WHOI for 24 hours prior to shipping them so this is unlikely). In this case, verify you swapped out the right gyro; if not, swap out the right gyro. If it still doesn't work use the other spare.

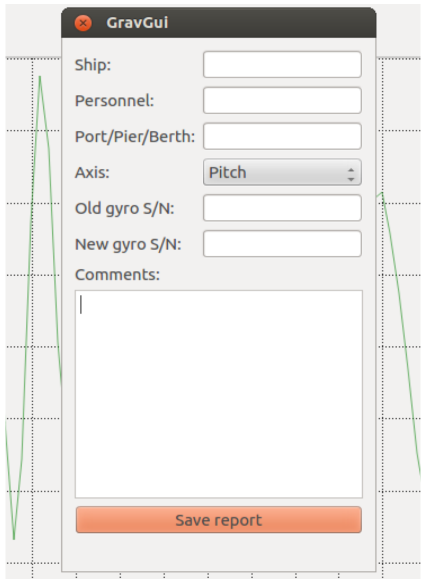

Figure 13. GravGui Gyro Swap Widget

It is important to document the gyro swap. In the GravGui there is a widget to assist in this documentation. The widget takes inputs for old and new gyro serial numbers, which axis they were on, and automatically generates a report that will allow WHOI engineers to determine the mean time between failures.

3.3.2 Stabilization board replacement

An instructional video for this procedure will be available in early 2016, and should be included with each BGM-3. For traditional text format, follow the instructions in the actual BGM-3 Gravimeter.

3.3.3 Gyro Board Replacement

An instructional video for this procedure will be available in early 2016, and should be included with each BGM-3. For traditional text format, follow the instructions in the actual BGM-3 Gravimeter.

3.3.4 Control Board Replacement

An instructional video for this procedure will be available in early 2015, and should be included with each BGM-3. For traditional text format, follow the instructions in the actual BGM-3 Gravimeter.

3.3.5 Mother Board Replacement

An instructional video for this procedure will be available in early 2015, and should be included with each BGM-3. For traditional text format, follow the instructions in the actual BGM-3 Gravimeter.

3.3.6 PS1 or PS2 Replacement

An instructional video for this procedure will be available in early 2016, and should be included with each BGM-3. For traditional text format, follow the instructions in the actual BGM-3 Gravimeter.

Link to Instructional Videos
https://drive.google.com/drive/u/0/folders/0B8-3WOlqZ4BDNC1ZQzlBM1ZnNUE

4 At Sea Maintenance

4.1 Routine Science Checks

When the gravity data is a crucial component of the cruise, the following checks should be done on every watch. These checks are the responsibility of the science party and not the shipboard technicians. Under no circumstances should the science party touch the gravimeter.

1) CPS Monitor Points – described in section 2.1.2
2) Sensor Power Checks – described in section 2.1.1
3) Sensor Ovens Checks – described in section 2.1.3

4.2 Daily Checks – In Passing

For a non gravity specific cruise, it is a good practice for the onboard science technicians to check the gravimeter daily in passing to check that there are no DNV lights, Battery Low light, or other obvious alarms. It is also good to quickly check that the GravGui is running, data is logging, and that the ELEX V is at 29 V.

4.3 Weekly Test Point Checks

For non gravity specific cruises, there are additional checks that should be done on a weekly basis. This is easily accomplished by using the GravGui widget for "Test Points". This widget is found on the lower left hand side of the main GravGui screen, and clicking it should open a new window which prompts the user to input values for various test points and monitor values. These measurements are described in sections 2.1.1, 2.1.2, 2.1.3, and 2.1.4.

Once completed the test results should be saved and automatically time stamped and stored locally on the laptop. An onshore repository for all of these documents is being developed to allow the pfpe personnel to access this information for long term troubleshooting.

5 Spare Parts

Every BGM-3 installed in the field comes equipped with a set of spare parts in order to reduce down time and to promote continuous data acquisition. As described in section 2.2, several components of this system are assumed to have finite lifespans even with normal conditions. In anticipation of these failures, PFPE sends out spares in an attempt to keep all BGM-3's as operational as possible.

5.1 Standard Spares Supplied

The standard set of spares typically supplied by PFPE includes

1) 2 Gyroscopes
2) 1 Stabilization Board
3) 1 Gyroscope Board
4) 1 Control Board
5) 1 Mother Board
6) 1 PS1 / PS2 power supply
7) misc. Power Supplies

5.2 Spares Kept at WHOI/PFPE

The following spares are typically kept at WHOI and can be sent out upon request:

1) Data buffers
2) Battery Charging boards
3) Cables
4) Entire CPS units
5) Accelerometers
6) Digital panel Meters

5.3 Spares for Gravity Specific Cruises

For cruises with specific gravity surveying objectives, especially those which may be out or not conveniently resupplied for extended periods of time may be sent out with additional spares kits.

6 ITAR Regulations

Several components on the BGM-3 Gravimeter have other uses in defense applications, and thus fall under the control of the International Traffic in Arms Regulations or ITAR. When shipping the BGM-3 overseas, or operating the BGM-3 on foreign flagged vessels special written permission and licensing must be obtained from the US Department of State.

ITAR is a set of United States government regulations that control the export and import of defense-related articles and services on the United States Munitions List (USML).[1] These regulations implement the provisions of the Arms Export Control Act (AECA), and are described in Title 22 (Foreign Relations), Chapter I (Department of State), Subchapter M of the Code of Federal Regulations. The Department of State Directorate of Defense Trade Controls (DDTC) interprets and enforces ITAR. Its goal is to safeguard U.S. national security and further U.S. foreign policy objectives.

For practical purposes, ITAR regulations dictate that information and material pertaining to defense and military related technologies (for items listed on the U.S. Munitions List) may only be shared with U.S. Persons unless authorization from the Department of State is received or a special exemption is used.[3] U.S. Persons (including organizations) can face heavy fines if they have, without authorization or the use of an exemption, provided foreign (non-US) persons with access to ITAR-protected defense articles, services or technical data.[4]

7 Shipping Procedures

The BGM-3 gravimeter sensor requires continuous power and, in consequence, special care must be taken when shipping the sensor. Each BGM-3 is equipped with sufficient batteries to power the sensor (but not the stabilization table) for approximately 30 hours allowing the sensor to be shipped anywhere in the Continental United States by overnight air freight.

7.1 Receiving the BGM-3 Sensor

When receiving the sensor container it is important to verify the state of the sensor and plug the sensor in immediately upon arrival. When the sensor arrives, immediately follow this procedure:

1) Remove the front cover from the shipping container. Figure 4.1 shows a typical layout of the sensor container with the location of indicator lights and the current meter shown.

2) On the sensor electronics, check if the 'BAT LOW' light is lit (Figure 4.2, right). If so, make a note of it and inform the shipping party and PFPE.

3) On the sensor electronics, check the main sensor voltage by turning the panel meter dial (Figure 4.3) to the 'ELEX V' and recording the voltage. Then turn the dial to the 'BAT V' and record the voltage. Both voltages should be above 20V.

4) Record the voltage on the auxiliary battery voltage meter.

5) Plug the power cable at the back of the shipping container into a 120V power outlet!

6) If the 'Low Battery' light was lit, it should now be off. In addition the 'ELEX V' should be in the range of 29-30V.

7) Turn the panel meter dial to the 'CHG CUR 5A' position. Record the amperage on the panel meter. Return the panel meter dial to the 'ELEX V position.

8) Record the current on the auxiliary battery current meters. They should both indicate that the auxiliary battery is drawing power and charging.

The meter should be checked daily to ensure it is powered. This is best done by checking the 'ELEX V' levels. *If the 'Low Battery' light ever comes on, check power immediately and notify pfpe-internal@whoi.edu*

Figure 14: The BGM-3 sensor in its shipping case. The auxiliary battery is at the bottom of the case; the primary sensor battery above it (in the rear); and the sensor electronics above it. The sensor is in the shipping bracket behind the black panel at the top of the case.

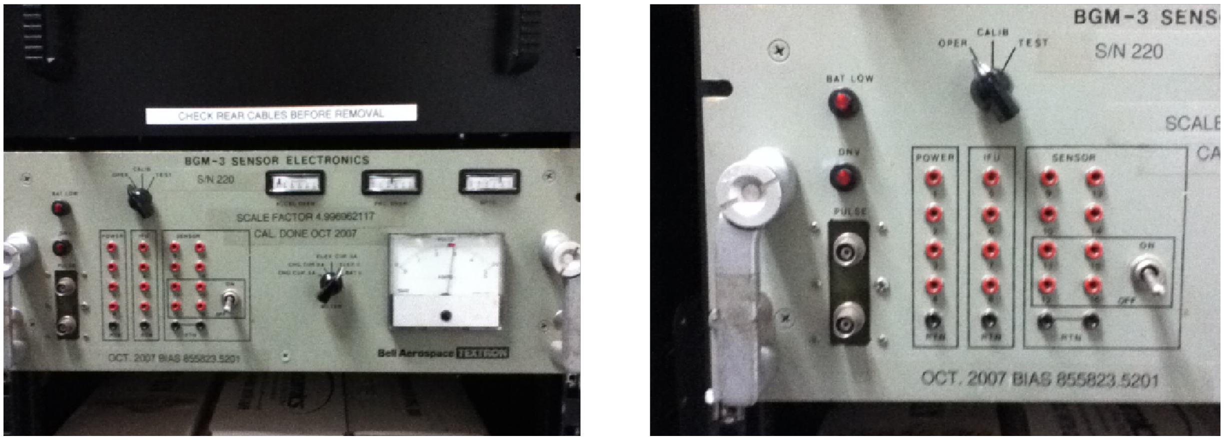

Figure 15: Left: Front of the sensor electronics case. The sensor test points are on the left side of the case. The panel meter is on the right side. Right: Close up of the left side of sensor electronics drawer. When receiving a sensor, always check the battery low light before plugging in the sensor. If it is lit, notify pfpe-internal@whoi.edu immediately.

Figure 16 Close up view of the sensor electronics panel meter and control switch.