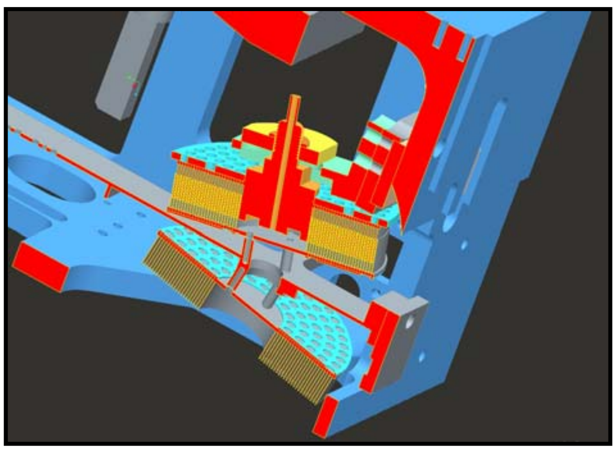
Model 'S' Air Sea Dynamic Gravity Meter System II



INSTRUCTION MANUAL

March 2006

(Version 1.7 Software)

Micro-g LaCoste
1401 Horizon Avenue

Lafayette, Colorado 80026 USA

TEL: (303)-828-3499

FAX: (303)-826-3288

E-Mail: info@microglacoste.com

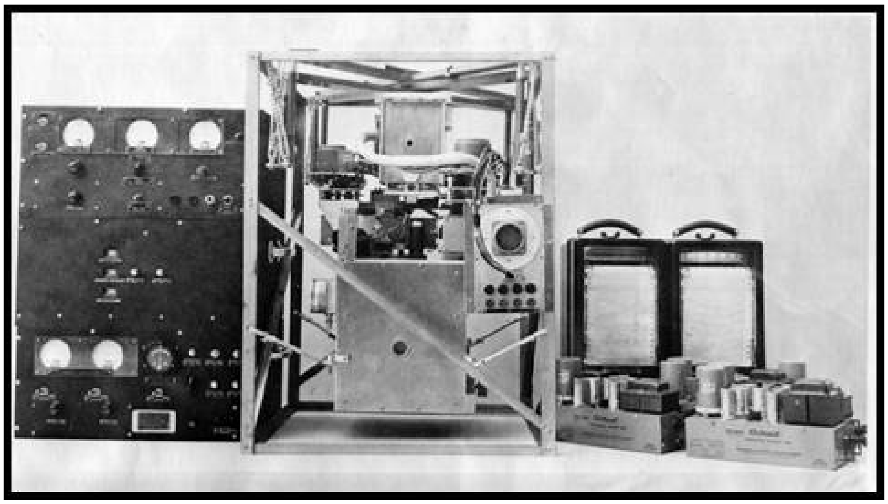
Website: www.microglacoste.com

TABLE OF CONTENTS

1 INTRODUCTION

1.1 HISTORY OF THE AIR-SEA GRAVITY METER

LaCoste & Romberg instruments were first used for marine gravity measurements from submarines about 1955. Known as the "Gimbal Meter", this S-meter had brass, fixed air-dampers and a 96 TPI (threads-per-inch) measuring screw. Gimbal Meter numbers S-1 to S-19 were built through 1965 (S-10 was skipped).



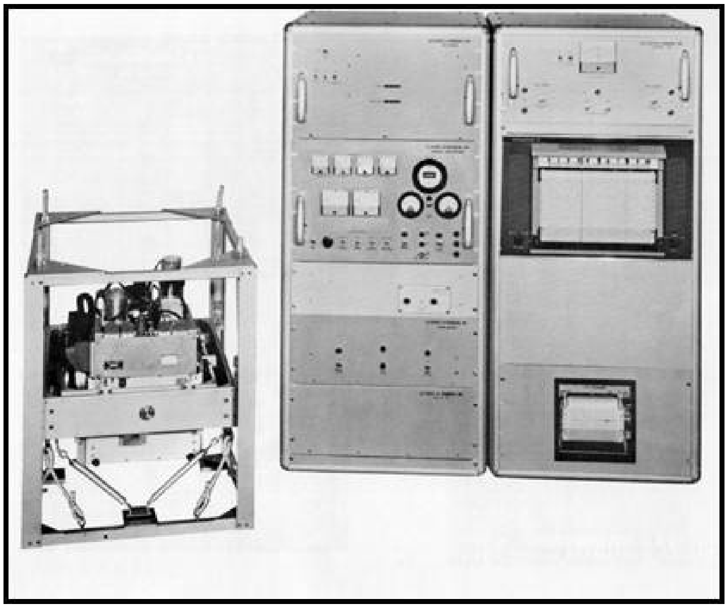
LaCoste & Romberg Gimbal Meter

The first 14 of the 18 Gimbal Meters were used at sea by the U.S. Navy, oceanographic research institutions, and some exploration companies.

Gimbal meters S-16, 17, and 18 were sold to GSI as meters only, and were later converted to stable platform meters.

Gimbal meter S-6 was also flown extensively by the U.S. Air Force starting in 1958 (Thompson and LaCoste, 1960) to test the possibility of making airborne gravity measurements.

The stable platform S-meter was designed in the early 1960's. A key element in the stable platform design was the selection of high-quality torque motors to be driven by the gyroscopes. A great deal of effort also went into perfecting the air-damper design. The beam was redesigned to be much stiffer, and cross-wires were added to allow the meter to function with significant horizontal accelerations. The optical "chopper" system was still used as the beam position transducer.



S-20 was the first installed stable-platform meter, sold in 1965 to GMX Corp. of Houston.

The control system consisted of two 19-inch racks about six feet high! Data were recorded on a paper chart and processed by hand calculations.

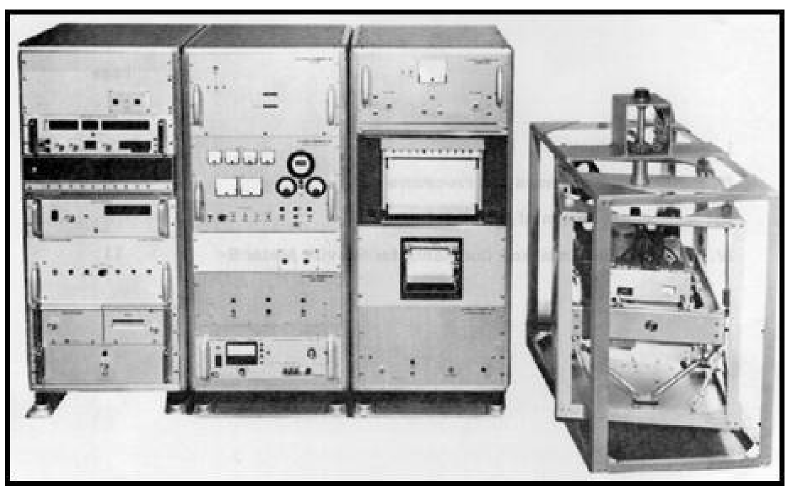
The first "Auto Reader" was implemented. This is a combination beam-nuller unit and analog computer used to combine the spring tension and total correction information.

Many existing Gimbal Meters were converted to Stable Platform meters at this time. Starting with S-23 the fixed air-damper was changed from brass to aluminum to eliminate problems with fungal growth inside the damper.

The gimbal meters and older S-Meters (20 through 33, 35, 37) required a one-inch travel of the measuring screw to produce world-wide range. Starting with meter S-34 in 1968, the S-Meter's lever system was altered so that one half-inch travel of the measuring screw would give world-wide range. The measuring screw was changed from 96 TPI to 184 TPI to maintain the same accuracy.

This change increased the actual meter range from 12,000 to 20,000 mGal, although only the middle 12,000 mGal of range (from 4,000 to 16,000 counter units) are calibrated. The most important result of this change was that a single calibration factor could be used over the half-inch travel of the measuring screw, whereas older S-Meters required a calibration table.

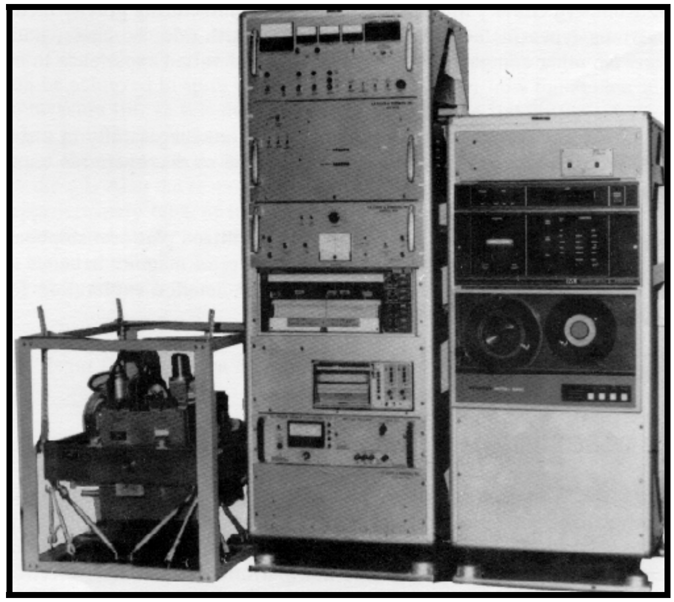
The 70's also produced growing interest in using the stable platform for inertial navigation by adding a third axis (Valliant and LaCoste, 1976). A total of 10 three-axis systems were built from 1972 to about 1980. The control systems consisted of three large racks of equipment. Interest in the three-axis system declined later, although a few systems are still in use today.

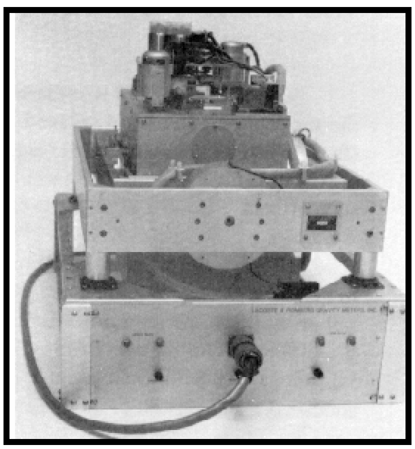


About 1972 the Auto Reader was upgraded to electronic computing from computing via mechanical servos. The first data-acquisition systems were added in the early 70's to replace the paper strip chart records with magnetic tape.

Non-Linear Systems manufactured an early digital data-acquisition system, followed by the Monitor Labs 9400 system which became the most common in use throughout the world.

These were replaced by the Design Enterprises 6400 systems, soon followed by "Hybrid" systems with a computer-controlled nuller in use until the introduction of the digital SEASYS control system in 1990.





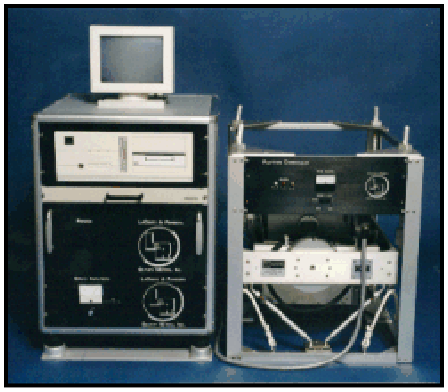
The Straight Line (SL) sensor was introduced in 1981. Meters SL-1, SL-2, and SL-3 were delivered between 1981 and 1987. The SL meters are not affected by vibration, and therefore do not require the type of shock-mounting used with S-meters.

Although the SL-meter successfully eliminated the cross coupling corrections required for S-meters, it was more expensive to build and required a very long time for the drift to settle down after manufacturing.

Dr. LaCoste did not believe the SL-sensor justified the added expense for most applications, and the S-meter sensor remained the most popular.

Very strong demand for S-meters continued, and by 1983 sensors had been built through serial number S-115. However, a dramatic drop in geophysical exploration budgets about 1982 marked the end of demand for S-meters for some time. Many completed sensors were not installed in stable platforms until years later.

The first CPI system was installed in November 1984 in S-115. An unusual feature is that the CPI capacitor plates are at the rear of the beam where the total beam motion was less than half of that at the front of the meter. Most S-meters have now been converted from the optical beam-sensing system to the CPI system, eliminating one more device requiring manual adjustments.



The "SEASYS" digital control system was introduced in 1990, with software recording data at 10-second intervals.

SEASYS 2 (1995) recorded unfiltered data at one-second intervals. An Absolute Encoder was integrated to record the Spring Tension value. The maximum Spring Tension Slew Rate was increased to 600 CU per minute.

About the same time, the "Mini-Console" was designed for customers needing a compact installation, such as on board an aircraft.

An industrial-quality single board computer, compact gyro power supply, dual torque motor amplifier module, and flat-panel display all reduced the size of the control system. AIRSEA 3 software recorded the Beam Position at 10 Hz, and integrated new Fiber Optic Gyros (FOGs).

Validation of the software and FOGs was done during an 10,000-km Airborne Gravity Survey of the French and Swiss Alps in February 1998 (Verdun, 2002).

Air-Sea System II was introduced in 2002.

Over twenty new and upgraded systems have been delivered to mid-2005.

Micro-g LaCoste continue to manufacture new meters and upgrade earlier systems with modern digital control systems.

1.2 TERMINOLOGY

BEAM POSITION:

The Mass attached to the Beam has a range of motion of approximately 1 mm. The end-of-motion points are referred to as the Top Stop and the Bottom Stop. Beam position is most commonly measured in Volts as the output of a Capacitance Position Indicator (CPI) system. Typical values are -5 Volts at the Bottom Stop, +5 Volts at the Top Stop, and 0 Volts at the Center (clamped) position.

BEAM SCALE FACTOR:

The factor used to convert Beam Velocity to Counter Units (also known as K-Factor).

BEAM VELOCITY:

Beam Velocity is determined from Beam Position, and is proportional (almost) to the instantaneous imbalance between the Spring Tension and Gravity. As a rough approximation, the Beam Velocity is 1 Nanometer per second per mGal of imbalance.

COUNTER UNITS:

Abbreviated as "CU", these are units of the "Counter" on the meter lid, and represent the Spring Tension value.

EYEPIECE DIVISION:

Abbreviated as "E.D." or "EPD", this term is used by meter builders (during the assembly and test process) to specify Beam Position. The Bottom Stop is approximately -50 EPD and the Top Stop +50 EPD. The term originates from viewing the Beam through the eyepiece, and reading the position from the divisions on the reticule.

SPRING TENSION:

Abbreviated as "ST", Spring Tension is the upward force exerted by the Zero-Length Spring to balance the downward pull of gravity on the gravity meter mass. ST is measured in Counter Units, and ranges from 0 to 20,000 CU (12,000 CU on older meters).

ST TRACKING:

The process by which the control system slowly but constantly adjusts the Spring Tension in order to keep the Beam Position near the midpoint, i.e. zero volts.

1.3 THEORY OF OPERATION

The Micro-g LaCoste Air-Sea gravity meter (Model S) consists of a highly damped, spring type gravity sensor mounted on a gyro stabilized platform with associated electronics for obtaining gravity readings.

The original theory behind the Micro-g LaCoste Air-Sea gravity meter system is given in LaCoste (1967). Valliant (1992) also describes many details of theoretical and practical interest. The reader is referred to these articles for details which are not repeated here.

The Model S gravity meter has a calibrated range without resetting of 12,000 mGals. The sensor is calibrated at our test range in Cloudcroft, New Mexico which has a gravity difference of about 240 mGal (Valliant, 1991). Each gravity meter is then laboratory tested on several testing machines which subject it to various combinations of horizontal and vertical accelerations ranging up to ± 100,000 mGals.

The Model S sensor incorporates a hinged beam supported by a zero-length spring. Damping of the large vertical accelerations due to the ship's motion is achieved through the use of air dampers.

The gravity sensor is maintained level in spite of ship motions by means of a stabilized platform. However, the vertical accelerations of the ship make it impractical to keep the beam constantly nulled. Therefore, it is necessary to read the gravity sensor when the beam is in motion.

Mathematical analysis shows that this can be done with a spring type gravity sensor by making use of the position of the beam, its velocity, and its acceleration. Furthermore if the beam is highly damped, the acceleration term can be neglected; and if the gravity sensor has a very high sensitivity, the position term can be neglected.

Both of these conditions exist in the Model S gravity meter; it is very highly damped as has been mentioned, and it is made very sensitive by using a "zero-length-spring" to support the beam. (A zero-length-spring is a spring whose unstretched length is zero.) Accordingly, the Model S gravity meter can be read without nulling it by making use of the beam velocity in addition to the spring tension.

The basic equation for doing this is:

$g = S + kB' + CC$

where g = the gravity meter reading

S = the spring tension

k = a constant which is a function of the average beam sensitivity and the damping

B' = the beam velocity = (dB/dt)

CC = Cross Coupling corrections

By mounting the gravity meter sensor on a stabilized platform, we eliminate the effect of tilting caused by the roll and pitch of the ship. The platform is held on a horizontal plane by a pair of gyroscopes feeding signals to torque motors. The accuracy required, 1 mGal for horizontal accelerations of 0.1 g, is satisfied if good gyros are used and the platform is working correctly.

The operation of the stabilized platform is as follows. The gyro output is amplified by the torque motor amplifier, and connected to the torque motor, which makes the platform follow the gyro output. However, this first feedback loop requires a reference signal since the gyro may have some drift. Also, the reference line may not be vertical to begin with, and gyros tend to remain fixed in space.

This vertical reference signal is provided by mounting an accelerometer on the platform and is used as a second feedback loop. If the accelerometer does not read level, a signal is sent to the gyro to precess. The corresponding output is fed to the torque motor to bring the platform vertical.

It is possible to use various functions of the accelerometer outputs to precess the gyro. The gyro which controls the L & R stable platform is torqued by the sum of the output plus the integral of the output of the accelerometer.

This Proportional-Integral Feedback algorithm produces a stable platform that performs like a damped pendulum. The period of the platform is made long compared to the period of the ocean waves by properly adjusting the integral of the accelerometer outputs that precess the gyros.

In order to make the system function automatically the gravity meter mass is approximately nulled by a slow acting feedback loop which obtains its input from the displacement of the mass. A motor operates a micrometer screw to vary the pull of the spring in the gravity meter, i.e. to control the "spring tension". The gravity meter reading must be determined from the velocity of the mass and the spring tension. This computation is performed automatically by the computer.

1.4 SPECIFICATIONS

SENSOR:

RANGE:	12,000 mGal (worldwide)
DRIFT:	3 mGal per month or less
TEMPERATURE SETPOINT:	46° to 55°C

STABILIZED PLATFORM:

PLATFORM PITCH:	± 22 degrees
PLATFORM ROLL:	± 25 degrees
PLATFORM PERIOD:	4 to 4.5 Minutes
PLATFORM DAMPING:	.707 of Critical

CONTROL SYSTEM:

RECORDING RATE:	1 Hz
SERIAL OUTPUT:	RS-232
ADDITIONAL I/0:	Ambient Temp, Sensor Temp, Sensor Pressure

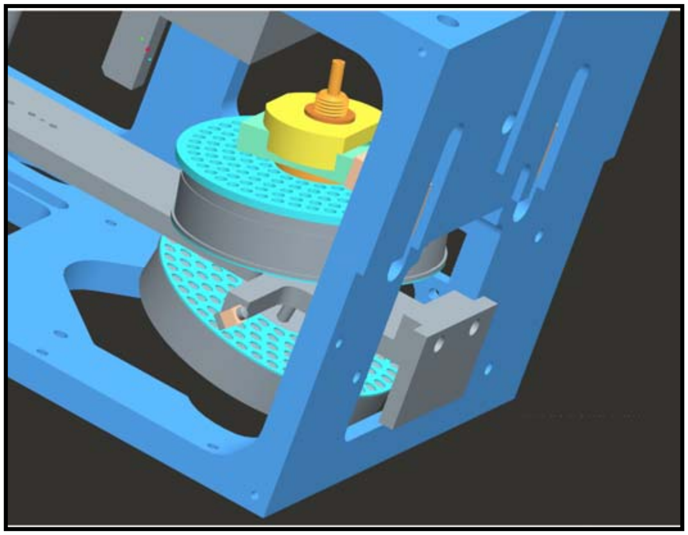
SYSTEM PERFORMANCE:

RESOLUTION:	0.01 mGal
STATIC REPEATABILITY:	0.05 mGal
ACCURACY AT SEA:	1.0 mGal or better
(Based upon crossing point analysis)	
ACCURACY IN LABORATORY:	
50,000 mGal Horizontal Acceleration	0.25 mGal
100,000 mGal Horizontal Acceleration	0.50 mGal
100,000 mGal Vertical Acceleration	0.25 mGal

MISC:

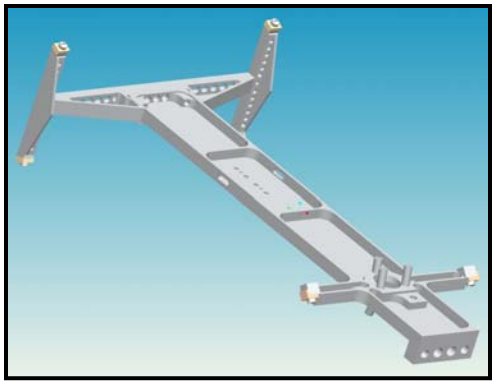
OPERATING TEMPERATURE:	0°C to 40°C
STORAGE TEMPERATURE:	-30°C to 50°C
POWER REQUIREMENTS (INTO UPS)	240 watts average, 450 watts max 80-265 VAC, 47-63 Hz
DIMENSIONS:	71 x 56 x 84 cm (28 x 22 x 33 in)
WEIGHT:	Meter: 86 kg (190 lbs) UPS: 30 kg (65 lbs)

2 GRAVITY SENSOR

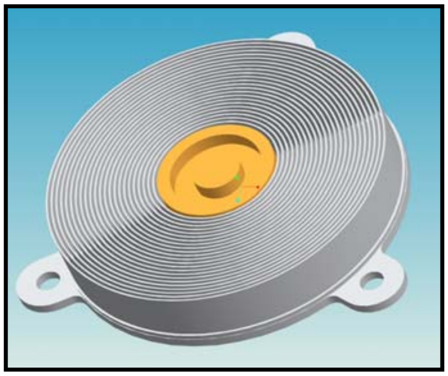


CAD drawing illustrating Beam with Top and Bottom Dampers, and Mass attached to Beam.

Beam

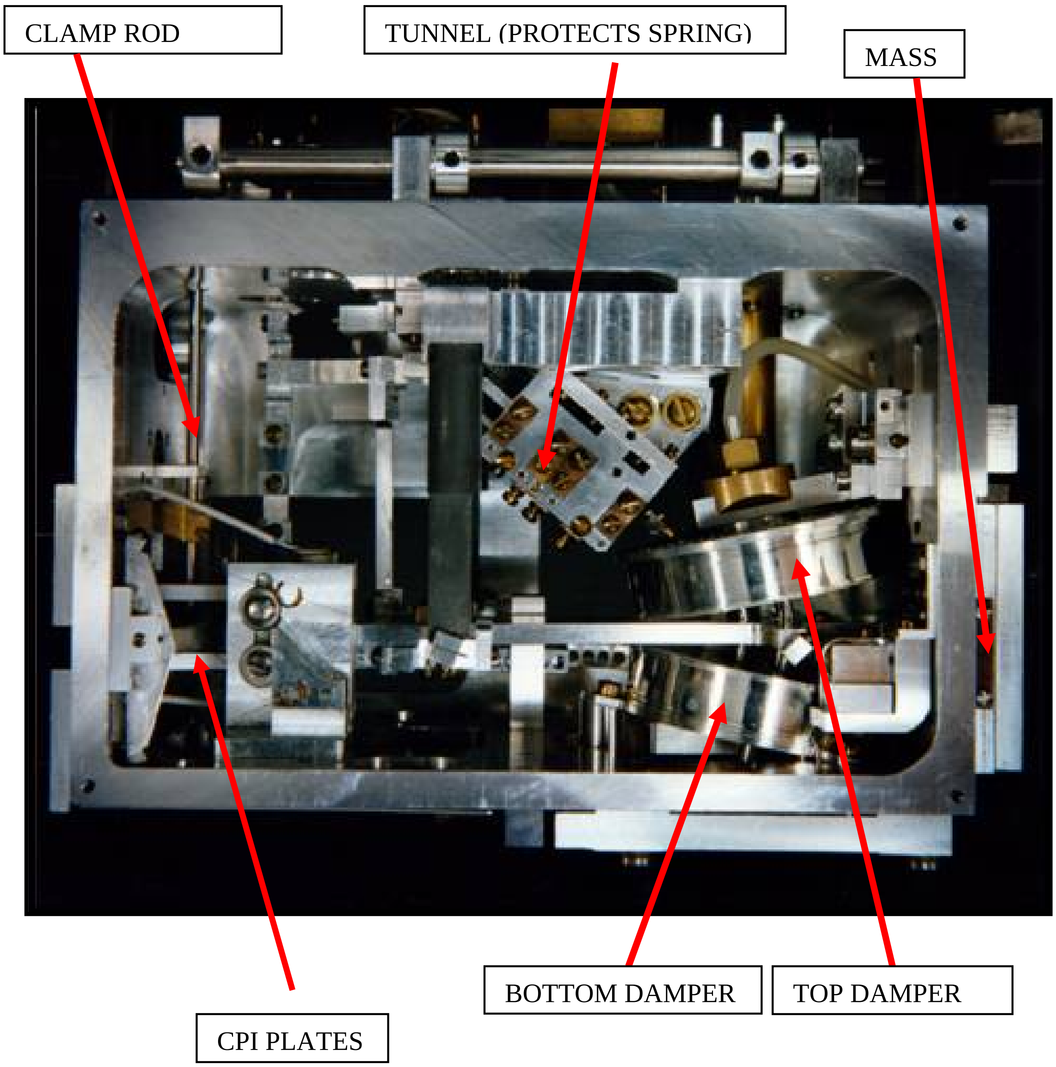


Dampers



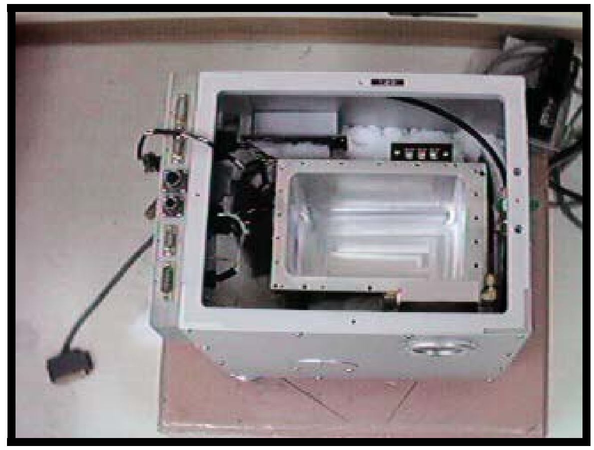
Photograph of the inside of the S-meter sensor. The Zero-Length Spring and Mass are not visible in this side view.

Note the plastic hose coming out of the top damper. The beam slew motor pumps air into or out of the damper to move the heavily damped beam.



2.1 INTERNAL COMPONENTS

2.1.1 HEATER BOX



The heater box is an aluminum box inside the sensor unit and is not normally visible. The box sits on 3 solid PVC mounts which attach it to the outer aluminum box of the sensor unit.

The heater box has a resistive-wire winding, through which approximately 15 VAC is applied. Two thermistors installed at opposite corners of the heater box form a bridge circuit which is used to control the meter temperature.

2.1.2 THERMAL CUT-OUT SWITCH

If the meter overheats, a bi-metallic thermal cutout switch will protect it from any damage. The failure which caused the overheating must be corrected, and the meter must cool down before the operator can proceed with the power up.

The thermal cutout switch is located on the side of the meter heater box, and opens at a factory selected temperature of approximately 65°C. After cutting out, it will take a few hours before it cools enough (to about 35°C) to reset.

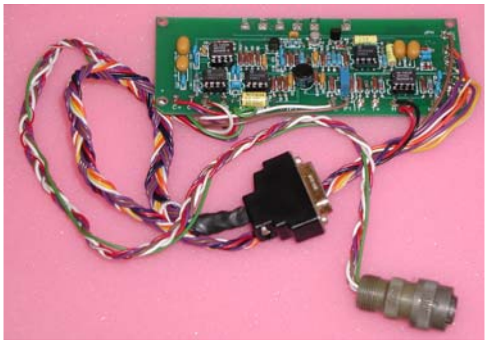
2.1.3 PROPORTIONAL HEATER BOARD (ASM503P)

Air-Sea meters manufactured since 1995 use a proportional heater system. This controller cycles the heater current at a faster rate than previous circuitry. A Flashing LED located on the Meter Junction Box indicates cycling of the heater current.

The Proportional Heater Board (ASM503P) located inside the Meter Junction Box. It can be replaced after removing 4 screws and two connectors. Remember to use the existing standoffs for the spare card when installing a replacement. The heater circuitry is powered by 28 VAC.

2.1.4 BEAM POSITION SENSOR

2.1.4.1 CPI CARD (ASM500)



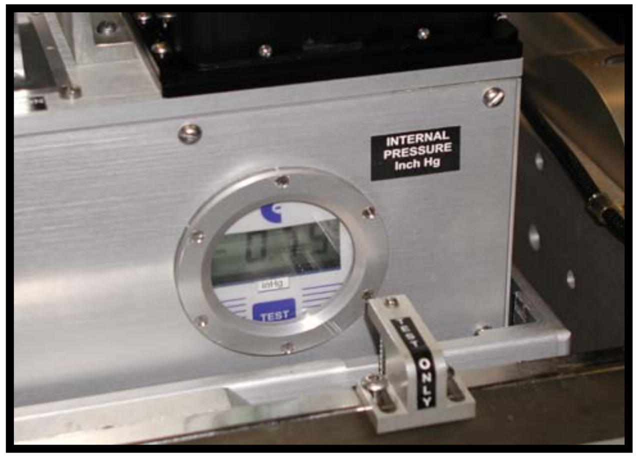
This card transforms the beam position into a DC Voltage, based upon the capacitance between the beam and two fixed plates inside the gravity sensor.

The card is mounted inside the gravity sensor box. The output range is from -5 VDC to + 5 VDC.

2.1.5 POWER SUPPLY ±15VDC

This Acopian power supply is located inside the Gravity Sensor Unit. It provides power to the CPI board, the Accelerometers, Meter Temperature Sensor and the Meter Pressure Sensor.

2.1.6 DIGITAL PRESSURE GAUGE



A Digital Pressure Gauge (on the side of the Sensor Box) indicates internal pressure inside the gravity sensor in inch-Hg (inches of Mercury).

The pressure reading is displayed on the Air-Sea II software Main Screen, and recorded to the daily ENVIRONMENT (.ENV) data file at 10 second intervals.

If the software display value does not agree with the pressure gauge reading, they can be synchronized by changing the variable:

"Pressure_offset=x.xx"

in the Hardware Configuration File ("ASII_hw.ini").

Air-Sea System II sensors are filled with dry nitrogen, and then leak-tested at the factory. It is important to note that **ALL METERS DO LEAK**, although at a very slow rate when properly sealed.

INTERNAL PRESSURE and GRAVITY READING:

There will be approximately **7 mGals DECREASE** in apparent gravity for every **1 inch-Hg INCREASE** in internal pressure. This is due to floatation effect on the gravity test mass, since density changes with pressure. Assuming the maximum leak rate specification of 0.03 inch-Hg per day, we could expect leakage of up to 1-inch Hg per month! This would appear as meter drift of 7 mGals/month.

INTERNAL PRESSURE and METER TEMPERATURE:

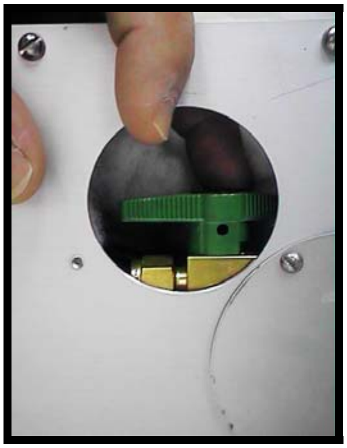
Internal Pressure increases approximately 3 inch-Hg as the meter heats up from ambient (i.e. 20° C) to operating temperature (i.e. 50° C). Likewise, the pressure will decrease approximately 3 inch-Hg when the meter goes cold.

Consider the situation of transporting a meter without heating power available:

As the meter goes cold, a 3-inch Hg pressure **differential** is created, which will increase the leak rate. Outside air will continuously leak into the under-pressured sensor. When the meter is back at operating temperature, it will now be up to 3 inch-Hg HIGHER PRESSURE THAN BEFORE. It could require months to come back to atmospheric pressure through slow leakage from the over-pressured sensor! This is a typical case where pressure equalization is required.

2.1.7 PRESSURE EQUALIZATION VALVE

A round port on the sensor provides access to the pressure equalization valve. It is easier to operate the valve if the sensor is removed from the stabilized platform bucket.



PRESSURE EQUALIZATION:

This procedure should be performed if the meter has been off heat for more than a few hours. This is usually the case when the meter is transported to a new location.

The purpose is to minimize any internal/external pressure difference, and thereby minimize the leakage rate and resulting "apparent" meter drift.

- Bring the meter up to operating temperature for 24 hours.
- Rotate the valve handle 90° Counter-Clockwise to open the valve and equalize the internal and external pressure.
- After 15 minutes, close the valve. This allows enough time for the nitrogen/air inside the meter to reach a stable temperature before sealing. The change in pressure when first opening the valve could cause some adiabatic heating/cooling.
-

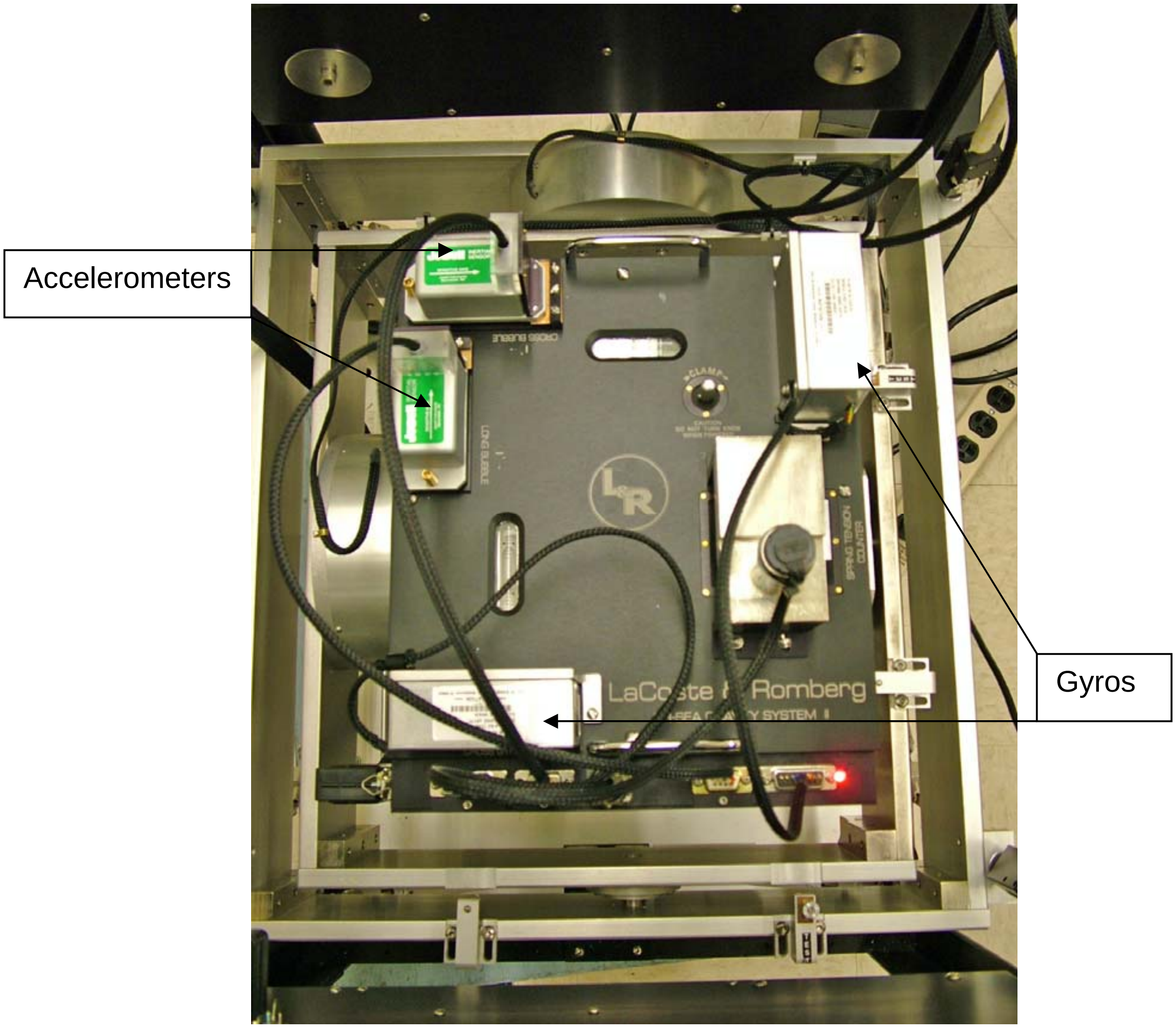
2.1.8 LEVEL LAMPS

The level lamps are mounted on brackets beneath the bubble levels. Wires from both brackets run to a 5-pin Amphenol connector, which connects to a mating connector from the Meter Junction Box, and the power source for the Beam Lamp is connected in parallel. All Air-Sea System II sensors have 12 Volt "LED Packs". There are two LED Packs on each level bracket. They are removed by pushing up on the LED pack from the inside of the bracket with a screwdriver.

2.1.9 BEAM LAMP

For older systems, a 12-volt lamp is located behind the round plate with three screws on the side of the gravity sensor unit. Since 1995, the bulbs have been replaced with a 12 Volt LED. This LED has a much longer life than an electric bulb. However, the replacement procedure is a little more complex. The entire side panel of the meter must be removed first. Unsolder the 820-ohm resistor on one side of the lamp, and the wire on the other side. Replace the LED and re-solder the connections.

2.2 SENSOR LID COMPONENTS



Here you see the sensor lid viewed from above. Two single-axis gyros are in the upper right and lower left corners. The two accelerometers are in the upper left corner.

2.2.1 FIBER OPTIC GYROS

Air-Sea System II sensors have fiber-optic gyros (FOGs) installed. These solid-state gyros reduce the chance that an operator will be required to change a gyro at sea. The FOG has no moving parts, and is constructed with surface mount electronics.

The FOG is based on the Sagnac effect. A light beam is split and sent in both directions through a coil of special fiber optic material. The rotation rate of the coil is determined by the difference in time taken by the two light beams to pass through the coil in opposite directions.

NOTE: The Fiber Optic Gyro assembly has no user-serviceable parts, and should never be opened by the customer. Doing so will void the warranty.

2.2.1.1 SINGLE-AXIS FIBER OPTIC GYRO (KVH DSP-3000)

Performance

Bias Stability:	1°/hr
Angle Random Walk (noise):	0.08 °/SQR(Hour)
Rotation Rate Maximum:	±500°/s
Instantaneous Bandwidth:	100 Hz
Turn-on Time:	<5 sec

Environmental

Operating Temperature:	-40°C to +75°C
Storage Temperature:	-50°C to +85°C
Shock:	90 G, 11 ms half-sine
MTBF:	55,000 hours

2.2.2 HORIZONTAL ACCELEROMETERS

Two horizontal accelerometers are mounted on the sensor lid. Cables attached to the accelerometers are plugged into the 9-pin connectors on the Meter Junction Box.

The accelerometer mounts have fine pitch adjustment screws which are used to adjust the accelerometers (and the stabilized platform) to level.

Correct leveling of the gravity meter unit can be checked by means of the bubble levels on top of the gravity sensor unit.

Range	±0.2 G
Full Scale Output	7.50 V
Scale Factor	37.5 Volts/G
Natural Frequency	>25 Hz
Damping Ratio	4.2 to 5.2

2.2.3 ARRESTMENT KNOB

The clamping, or arrestment, is now done by an internal DC motor. The meter is clamped or unclamped from a software control on the main display.

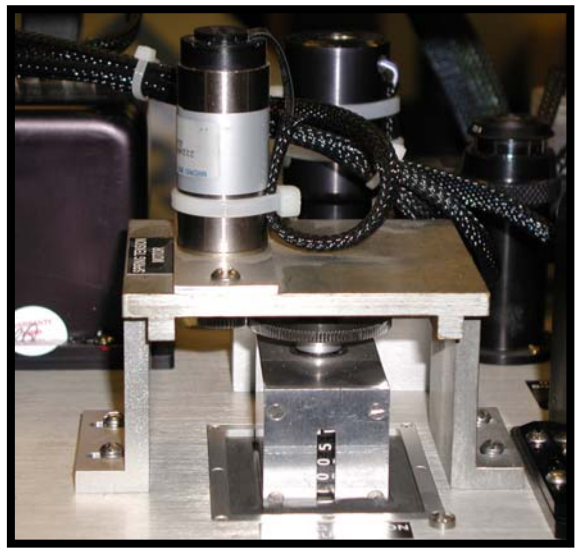
In case of malfunction, the meter can be clamped by hand. However, The POWER MUST BE OFF, or the resistance of the motor will be such that the gear train could be damaged.

Turn the knurled arrestment knob fully clockwise to clamp, and fully counter-clockwise to unclamp the beam.

2.2.4 BUBBLE LEVELS

The bubble levels have a scale factor of approximately 60 arc-seconds per bubble division, and have been adjusted to level at the factory. Level lamps are located beneath the levels. These can be turned on with the switch located on the bottom of the meter junction box. Heat from the lamps can cause the bubble position to change, so use the lamp for only a short period of time.

2.2.5 SPRING TENSION COUNTER



The Spring Tension Counter is part of the gear box attached to the sensor below the lid. The Counter has a gear on top, which meshes with a gear attached to the Spring Tension DC motor mounted on a bracket above the counter.

When the sensor lid is installed, the engagement of the gears should be checked to ensure that there is a small amount of backlash to permit smooth operation.

2.2.6 SPRING TENSION DC MOTOR

The Spring Tension DC motor contains a relative encoder. As the motor rotates, pulses from the encoder are accumulated by the Counter Board in the Control Module.

This is a very reliable method of encoding the Spring Tension, but it is standard practice for the operator to verify that the physical counter matches the software counter each day while on survey.

If the motor/counter gears are ever disengaged (i.e. if the sensor lid is removed), or the Counter Board is changed (i.e. when changing to Spare Control Module), the software counter must be re-synchronized to the physical counter using the “SET” pull-down menu option described in the SOFTWARE chapter.

Standard gear configuration is a 40-tooth gear on the ST Motor and a 120-tooth gear on the ST Counter. Typical maximum speed is 200-250 CU/minute with these gears. As a special option, 80-tooth gears can be installed on both the ST Motor and ST Counter. This will produce speeds of about 700 CU/minute, which may be useful for airborne survey when making turns where the Eotvos effect can be 2000 mGal or greater.

If using 80-tooth gears, the parameter “Ratio” must be changed from 0 to 1 in the Hardware Configuration file, i.e.

```
[Encoder]

Ratio=0  "// 0 Standard 40/120 gear, 1 Airborne 80/80"
```

2.2.7 EYEPIECE

Although the eyepiece is primarily used while building and testing the sensor, you can observe the beam crosshair directly when looking into the eyepiece, and confirm that the Beam is at the Reading Line, bottom stop, top stop, etc. The Beam Lamp must first be turned on with the small toggle switch located on the bottom of the Meter Junction Box.

The eyepiece has been removed from the lid starting with meters in 2004. To use the eyepiece to view the beam, the lid must be removed and the eyepiece temporarily installed.

2.2.8 BEAM SLEW MOTOR - 110 VAC

This black three-phase 110 VAC motor is mounted on the sensor lid close to the eyepiece. The motor drives an air pump which is connected through a plastic hose directly to the top damper inside the gravity sensor. This allows the operator to push the beam to any position between the top and bottom stop.

It is primarily used during the Beam Gain adjustment procedure to push the beam to the Top Stop. When the sensor lid is installed, a check on the engagement of the gears must be made to ensure a small amount of backlash to permit smooth operation.

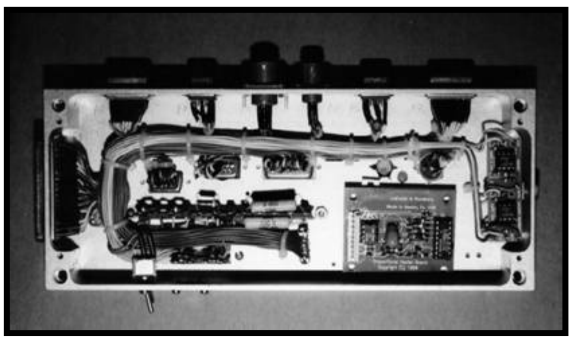
2.2.9 BEAM SLEW MOTOR – 5 VDC

Starting in 2004, a much smaller and quieter DC motor has replaced the old 110 VAC three-phase motor on new meters. This new motor is installed beneath the lid. Upgraded meters still use the AC beam slew motor.

2.2.10 METER JUNCTION BOX (ASM303P)

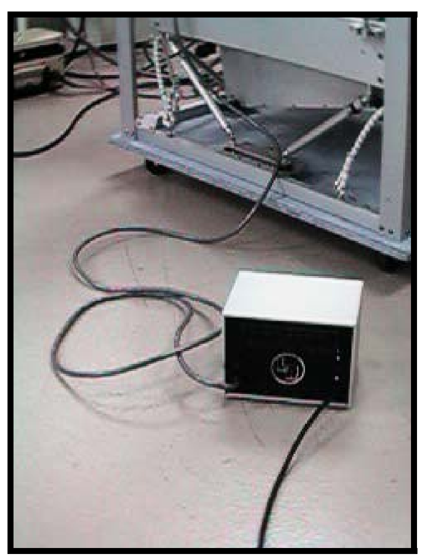
This aluminum box mounted on the end of the gravity sensor unit provides a junction point to collect all the signals from the sensor and distribute those signals through to the control cable.

On the top edge are two 9-pin D connectors for the accelerometers, two 15-pin D connectors for the gyros, and two Bendix connectors to go to the Beam Slew Motor and the Spring Tension DC Motor on the sensor lid.



There are 4 connectors on the BACK of the Meter Junction Box, i.e. the side that mounts onto the gravity sensor unit. These connections are a 9-pin D-connector to the ± 15 Volt Power Supply, a 15-pin D-connector to the CPI card, a 5-pin Amphenol connector to the lamps, and a 9-pin D-connector to the meter heater windings and the thermistors.

2.3 AUXILIARY POWER SUPPLY (Optional Accessory)



The Auxiliary Power Supply is used to keep the meter on heat when the control console is not available. It provides 12 VAC for the lamps and 24 VAC for the heater.

A switch on the front panel selects between 115 and 230 VAC input power.

The 50-pin D-connector from the Auxiliary Power Supply plugs directly into the side of the Meter Junction Box (on gravity meter sensor) where the P1 Control cable is connected during normal operation.

3 STABILIZED PLATFORM AND FRAME

The gravity sensor unit is mounted on a stabilized platform which is controlled by two torque motors to maintain a stabilized vertical. The torque motors produce rotation about two approximately horizontal axes that are approximately perpendicular to each other. Since there is no essential difference between the operation of the long and cross direction feedback loops, the operation about only one axis is described below.

There are two feedback loops for each torque motor. In one loop, the gyro output is fed through a torque motor amplifier to the torque motor, thereby nulling the gyro output. Since a nulled gyro output corresponds to stabilization in space, this feedback loop stabilizes the platform in space. However, this stabilization in space does not ensure verticality of the reference line on the platform for the following reasons:

(1) The reference line might not have been vertical to begin with,

(2) The gyros have some drift, and

(3) The earth rotates and gyros tend to remain fixed in space.

In order to attain verticality, a second feedback loop is employed. In this loop each accelerometer output is fed to a gyro precessor. The output of the gyro precessor is a function of the accelerometer output which slowly precesses the corresponding gyro to maintain verticality of the reference line.

It is possible to use various functions of the accelerometer output to precess the gyro. The function used in the Micro-g LaCoste stabilized platform is the sum of the accelerometer output plus a constant multiplied by it's integral. This combination makes the platform behave like a damped pendulum, whose period is determined by the integral term and whose damping is determined by the other term.

The damping of Micro-g LaCoste stabilized platforms is always set at 0.707 times critical (U.S. Patent No. 3,474,672). The reason for choosing this amount of damping is that it minimizes the gravity meter error due to ship motion for any chosen period of the platform. Accordingly, this optimum damping makes it possible to attain adequate gravity meter accuracy with a shorter stabilized platform period than otherwise. The shorter platform period reduces time lost after the ship makes a turn. The period of the Micro-g LaCoste stabilized platform is normally set to approximately 4 minutes. This period is long compared to the common periods of motion encountered at sea.

3.1 STABILIZED PLATFORM

3.1.1 SENSOR BUCKET

This aluminum box rotates about the long axis. The long torque motor is attached directly to the side of the bucket.

The sensor bucket holds the gravity sensor unit with three screws inserted from underneath. Elongated mounting holes allow some motion in the long direction for balancing. A small weight is located on a bar along the bottom of the bucket. This movable weight balances the sensor in the long axis direction.

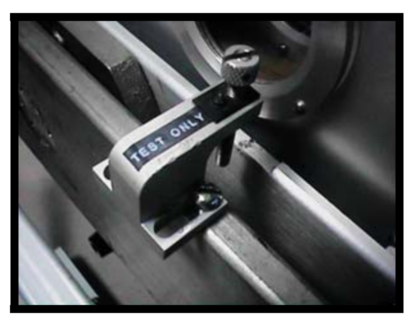
Rubber bumpers are installed on all the sides of the bucket to absorb shocks from hitting the limits.

3.1.2 INNER GIMBAL RING

The Inner Gimbal Ring rotates about the cross axis, and is attached directly to the cross axis torque motor. A small weight is located on a bar attached to the inner gimbal ring at the end opposite the cross torque motor. This movable weight balances the sensor in the cross axis direction.

3.1.3 OUTER GIMBAL RING

The Outer Gimbal Ring holds the Inner Gimbal Ring. These two rings should NOT be separated from each other when shipping. The assembly is quite heavy, and should be handled carefully to prevent damage to the motor bearings.



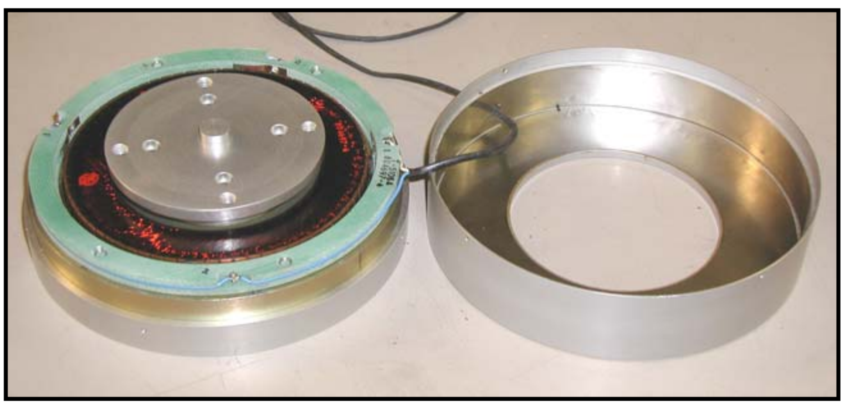
There are clamps on the Outer Gimbal Ring that are marked "TEST ONLY". They are used for holding the platform level without using gyros during factory testing.

NEVER use the clamps when shipping the meter, as they will most certainly be damaged, and could damage the torque motor bearings as well!

3.1.4 TORQUE MOTORS

Two Torque Motors are mounted inside cylindrical aluminum housings attached to the platform. The Long Torque Motor is located between the inner gimbal ring and the sensor bucket. The Cross Torque Motor is located between the inner and outer gimbal ring.

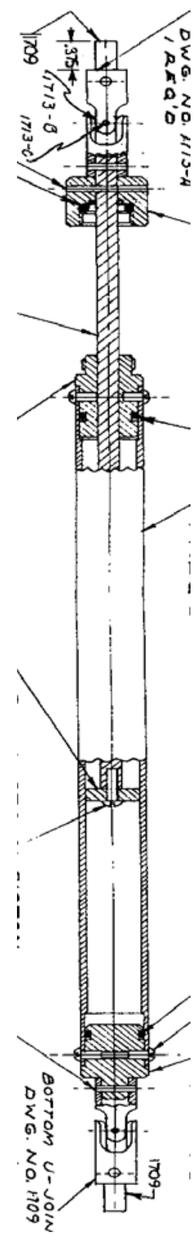
The motors are generally problem-free, except that the bearings should be replaced as part of standard factory service (every 5 to 10 years). They may require earlier replacement if the stabilized platform is routinely operated during very rough weather conditions at sea.



3.2 FRAME

The Frame provides suspension of the Outer Gimbal Ring through both the Oil Shock Absorbers and Shock Cords.

3.2.1 OIL SHOCK ABSORBERS



There are eight oil-filled shock absorbers connecting between the underside of the outer gimbal ring and the base of the frame. They are designed to damp out long period motion.

The oil shock absorbers are mounted on rubber "Lord" brand mounts to damp out high frequency vibration.

They should be filled about 2/3 of the way up (2 inches or 5 centimeters from top) with 50-weight motor oil.

<u>The shock absorbers must be removed</u>

<u>from the frame before shipping!!</u>

3.2.2 SHOCK CORDS

UPPER CORDS:

Four cords suspend the inner frame from the outer frame above it.

LOWER CORDS:

Four more looped cords attach from the base of the outer frame to the corners of the inner frame. Their function is to dampen external motion before reaching the stable platform.

WARNING: The looped shock cords MUST be in place during survey to prevent shock damage to the meter.

3.2.3 CONTROL CABLE (P1)

This cable connects the Meter Junction Box (on the sensor) to the Control Module.

There are 50 conductors, with DB-50 connectors and a mounting bracket on each end of the cable.

Control Cable P1 is 52 inches long.

1	RG174U ctr.	Beam signal	26	NC	
2	Shield	Beam return	27	NC	
3		Long - Accelerometer return	28	NC	
4		Beam Slew Motor	29		Cross - Accelerometer output
5		Beam Slew Motor	30		Long - Accelerometer output
6		28VAC input for heater	31		Gyro - Cross up/down CH1
7		28VAC return for heater	32		Gyro - Cross Data CH1
8		Beam Slew Motor	33	NC	
9		(+5V) Clamp Motor	34		Cross - Accelerometer return
10		Clamp Motor return	35		Analog Ground
11		Clamp Motor Pot pin3	36		Analog Ground
12		Clamp Motor Pot pin1	37		Analog Ground
13		Clamp Motor Pot pin2	38		Analog Ground
14		Acopian (+15V)	39		Digital Ground
15		Acopian (-15V)	40		Chassis Ground
16	NC		41		Meter Pressure Signal
17		(+5V) Spring Tension Motor	42		Gyro - Long up/down CH2
18		(+5V) Spring Tension Motor return	43		Gyro - Long Data CH2
19		Spring Tension Encoder VDD	44		Meter Temperature Signal
20		Spring Tension Encoder CH A	45	NC	
21		Spring Tension Encoder CH B	46	NC	
22		Spring Tension Encoder GND	47		28VAC Return for gen 1 FOG
23	NC		48		28VAC Input for gen 1 FOG
24		120 VAC Hot	49		(-5v) for gen 2 FOG
25		120 VAC Neutral	50		(+5v) for gen 2 FOG

3.2.4 POWER CABLE (P100)

This cable connects the Power Module to the Control Module. There are 37 conductors, with DB-37 connectors on each end. The connectors are keyed so they cannot be installed incorrectly.

All power and ground wires are 20 AWG

Signal and AC wires are 24 AWG

Rubidium Clock signal is RG-174U Coax

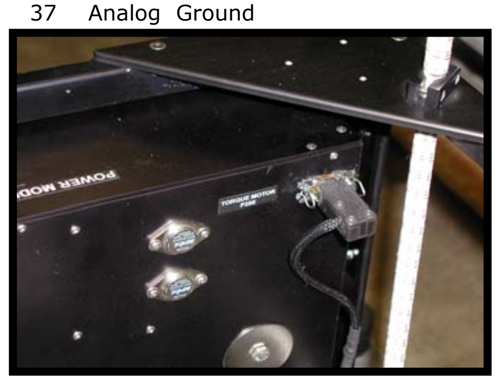
Power Cable P100 is 32 inches long

1	pin 4 beam slew
2	pin 5 beam slew
3	pin 1 beam slew
4	pin 2 beam slew
5	pin 3 beam slew
6	TS-1 120 VAC Neutral
7	FOG transformer
8	FOG transformer
9	PS (+5V)
10	TS-1 120VAC Hot
11	TS-1 120VAC Neutral.
12	PS (+5V)
13	PS (+5V)
14	PS (-5V)
15	PS (-5V)
16	Analog Ground
17	Analog Ground
18	Analog Ground
19	PS (+12V)
20	PS (-12V)
21	Analog Ground
22	Analog Ground
23	Rubidium Clock Signal
24	Rubidium Clock Return
25	L- Torque (LIN)
26	X- Torque (XIN)
27	Analog Ground
28	Heater Transformer
29	Heater Transformer
30	Chassis Ground
31	PS (+5V)
32	PS (+5V)
33	PS (+5V)
34	Analog Ground
35	Analog Ground
36	Analog Ground
37	Analog Ground

3.2.5 TORQUE MOTOR CABLE (P200)

This cable connects the torque motors to the Power Module. The cable is soldered to each of the torque motors and disconnects at the back of the Power Module.

	P200	
1	Blue	Cross Output
2	Blue	Cross Output
3		
4	Brown	Long Output
5	Brown	Long Output
6	Purple	Analog Ground
7	Purple	Analog Ground
8	Purple	Analog Ground
9	Purple	Analog Ground



3.3 UPS BASEPLATE WITH AIR-SHOCKS

3.3.1 UPS BASEPLATE

3.3.2 AIR-SHOCK MOUNTS

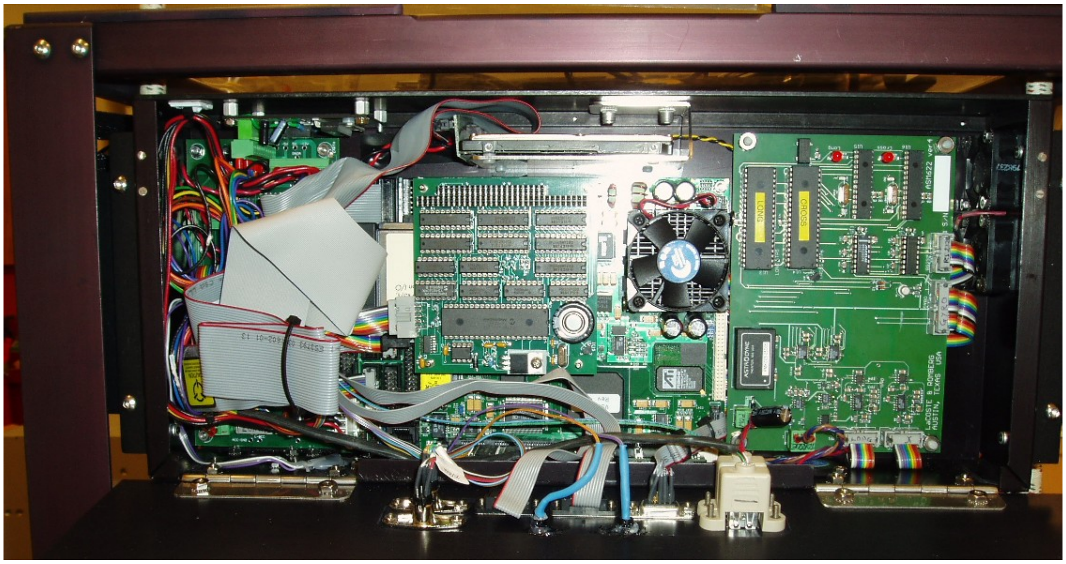
New S-meters are now equipped with Air Shock Mounts.

Each shock mount has a maximum weight rating of 100 lbs, and maximum pressure of 60 PSI.

These mounts should be inflated to approximately 30-35 PSI for optimum shock absorbing. A normal bicycle or car tire pump and gauge can be used to inflate the shock mounts.

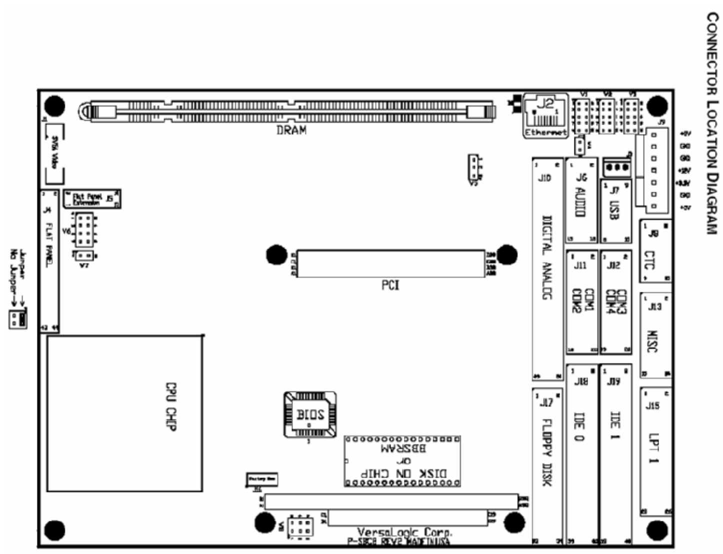
4 DIGITAL CONTROL SYSTEM

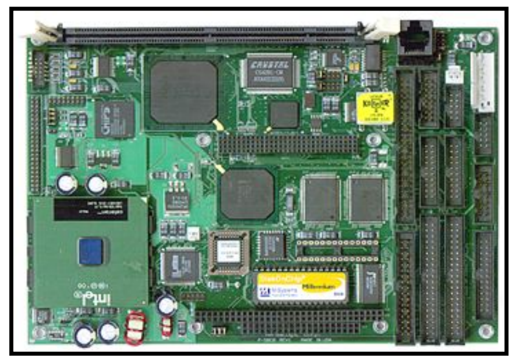
4.1 CONTROL MODULE



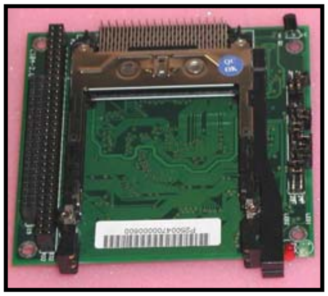
4.1.1 PC-104 CPU

The CPU is a Versalogic Model VSBC-8k, a PC-104 industrial CPU with Pentium III processor.



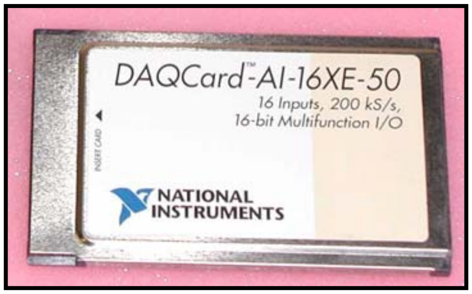


4.1.1.1 PCMCIA DRIVER BOARD



This PC/104 PCMCIA driver board plugs directly into the CPU board and provides two PCMCIA accessory card slots.

4.1.1.2 A/D CARD



This 8-channel 16-bit Analog-to-Digital PCMCIA card digitizes voltage output from the Accelerometers, Beam Position Sensor (CPI), Meter Temperature Sensor, Ambient Temperature Sensor, and Meter Pressure Sensor.

The card is installed in the lower slot of the PCMCIA Driver Board, and is configured as Device 1 using the National Instruments "Measurement and Automation" software tool.

4.1.1.3 D/A CARD

This 8-channel 16-bit Digital-to-Analog PCMCIA card generates analog voltages to drive the Torque Motors, Spring Tension DC motor, and the Clamp/Unclamp motor.

The card is installed in the upper slot of the PCMCIA Driver Board, and is configured as Device 2 using the National Instruments "Measurement and Automation" software tool.

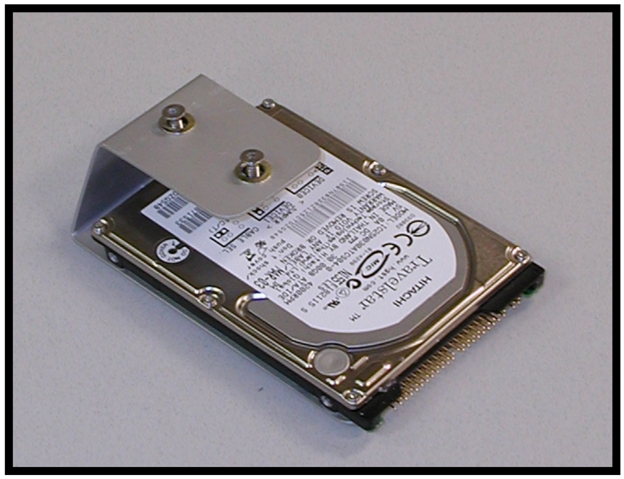
4.1.1.4 COUNTER BOARD

This PC-104 board reads the encoder built into the Spring Tension DC Motor. The current Spring Tension value is stored in non-volatile memory on this board. The Counter Board is installed on top of the PCMCIA Driver Board.

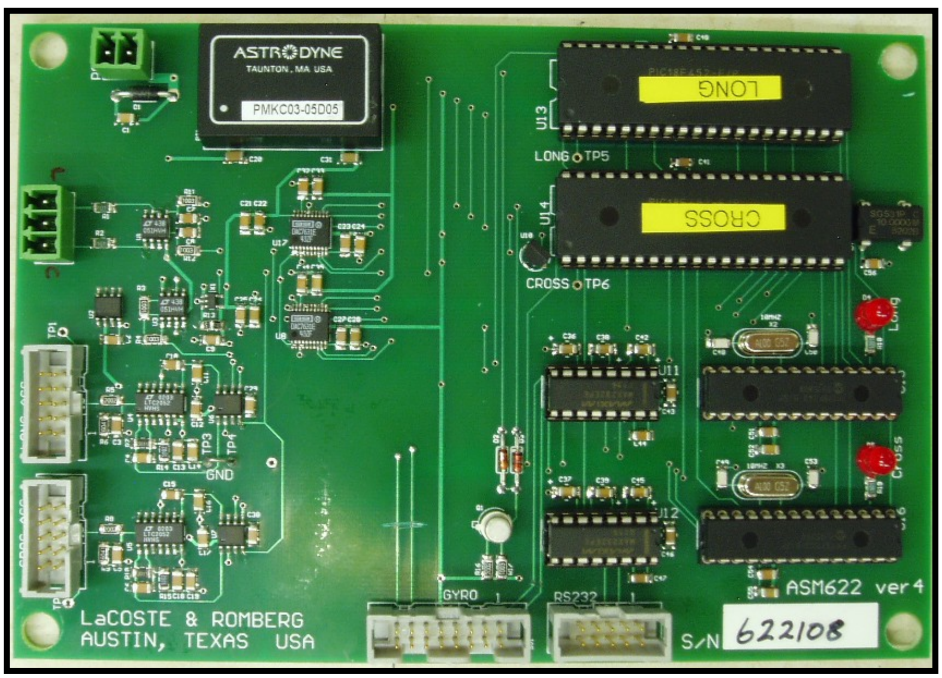
4.1.2 HARD DISK DRIVE

The system has a 20 GB hard disk drive, which can store more than 1000 days of data.

It is installed in a special mounting bracket to absorb shock.



4.1.3 PLATFORM CONTROLLER BOARD (ASM 622)



The Stabilized Platform is controlled by a pair of boards located in the center of the Control Module.

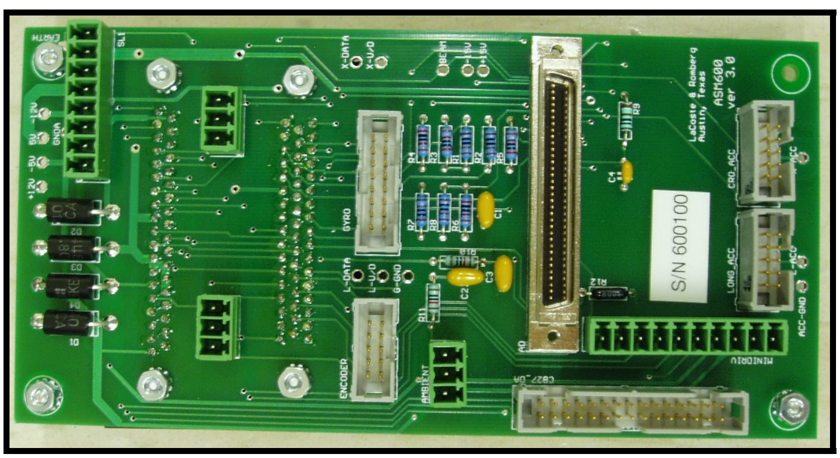
The boards plug together and contain all the electronics necessary to read the platform signals, perform the calculations, and to level the platform.

4.1.4 DC MOTOR CONTROLLER BOARD (ASM 601)

The DC Motor Controller Board amplifies the motor control signals from the D-A card. These signals drive the Spring Tension and clamp/unclamp motors.

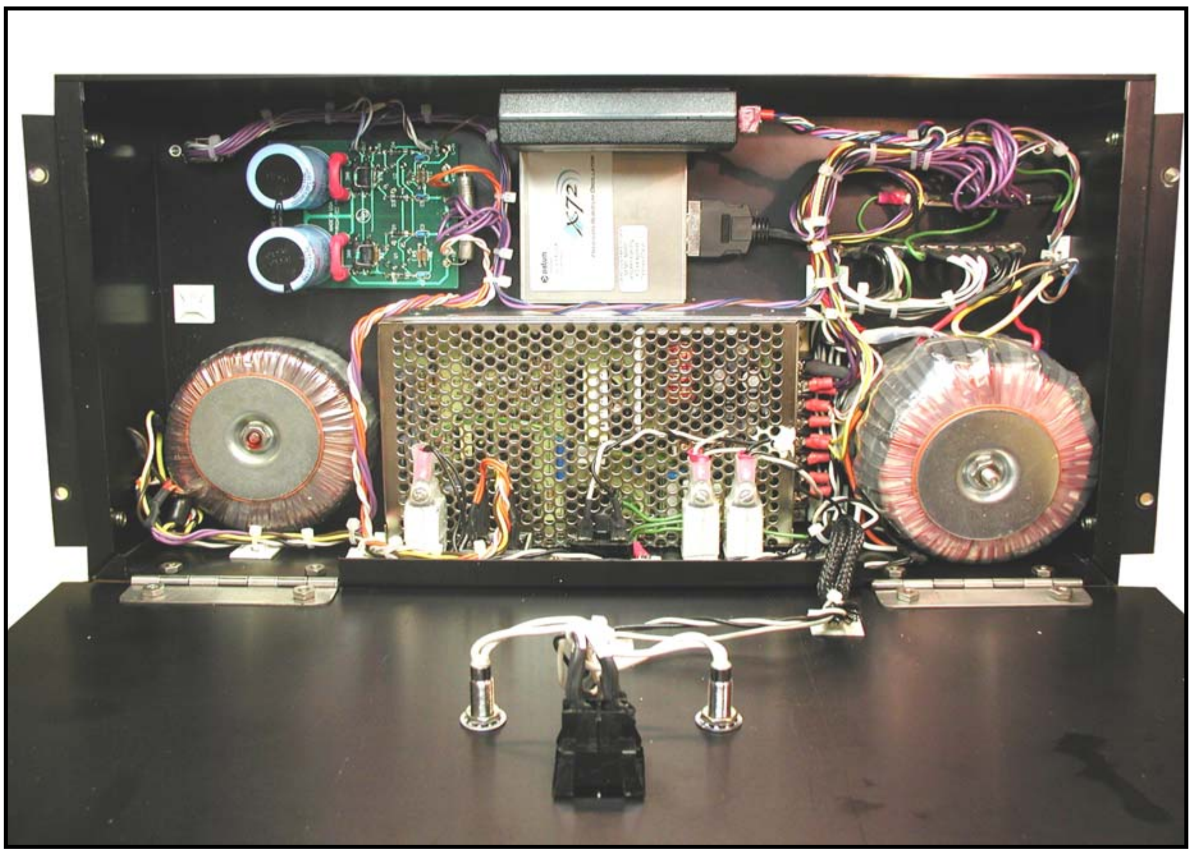
The board is located in the top of the Control Module. It is coated with a special heat conductive paste.

4.1.5 CONNECTION BOARD (ASM 600)

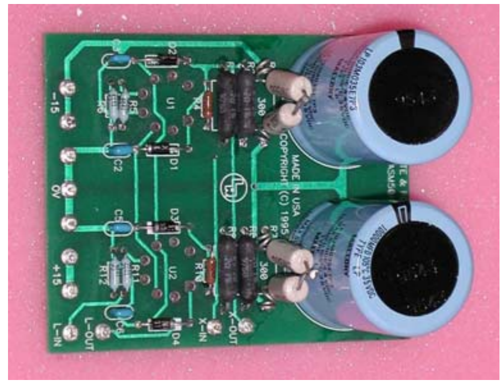


This board collects and distributes system signals within the Control Module.

4.2 POWER MODULE



4.2.1 DUAL-CHANNEL TORQUE MOTOR AMPLIFIER



This unit amplifies the torque motor voltage signal to generate the current required to operate the torque motors on the stabilized platform.

There is a circuit breaker on the bottom of the Power Module which cuts the power to the Torque Motors.

4.2.2 QUAD POWER SUPPLY

The Quad power supply provides ±12 and ±5 VDC for the system.

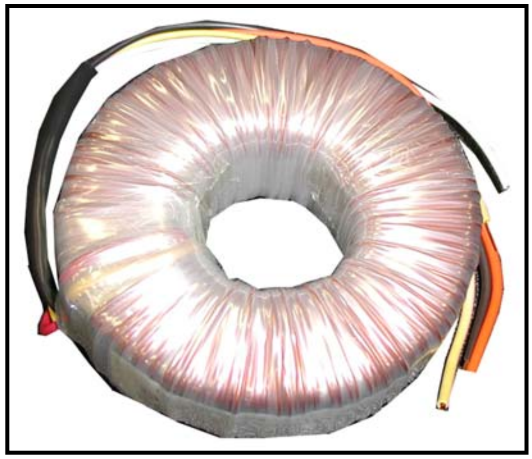
4.2.3 RUBIDIUM CLOCK

This precision oscillator provides a stable time base for data acquisition. The 10-MHz output is used to drive the 16-bit digitizer which samples voltages at 2 KHz.

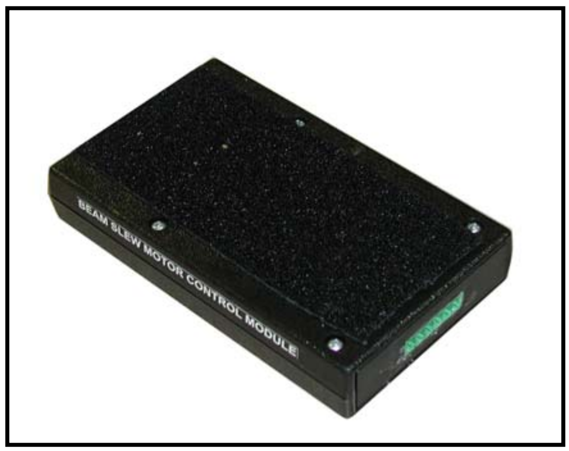
The Rubidium Clock is extremely stable, i.e. one part in one billion, over both time and a wide range of ambient temperatures (-40° C to + 85°).

The drift rate of the clock is therefore only 2 or 3 milliseconds per MONTH!

4.2.4 TOROID TRANSFORMERS



4.2.5 BEAM SLEW MOTOR RELAY CARD



	Beam Slew PCB	
1		pin 3 P100 Gnd
2		pin 4 P100
3		pin 5 P100
4		pin 1 P100 Slew Down
5		pin 2 P100 Slew Up
6	Black	120VAC Hot

5 SOFTWARE

5.1 OVERVIEW

AIR-SEA II software is a fully automated system for controlling the Micro-g LaCoste Air-Sea Gravity Meter and its stable platform. The system self starts upon power application, and can operate largely unattended.

DIGITIZATION:

The software controls two PCMCIA devices which serve as A-to-D and D-to-A converters. The gravity meter beam signal and two accelerometer outputs are sampled at 2 kHz by the 16-bit A/D converter. The Beam Position is sampled by two channels, increasing the effective conversion to 22 bits for that signal.

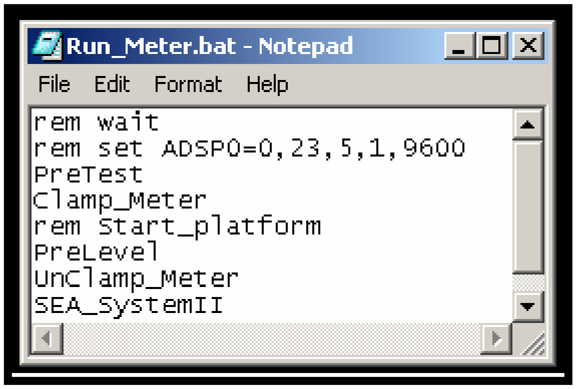
SYSTEM TIMING:

Data sampling is controlled by a computer interrupt derived from the 10 MHz Rubidium Clock. This extremely stable frequency source is also used for both the system clock and time-stamping of data records.

SYSTEM FUNCTIONS:

- Communicate with the DSP Platform Controller.
- Sample and process Accelerometer signals to derive a voltage to be sent to the torque motors to level the platform.
- Adjust the Spring Tension at 10 second intervals with a DC motor.
- Filter the data appropriately.
- Compute Total Correction and Gravity.
- Compute the cross-coupling correction and five cross-coupling monitors.
- Scale the data according to the gravity meter scale factor.
- Output data to the hard disk and serial port.
- Provide menu selections for the operator to communicate with the system.

5.2 START-UP SEQUENCE



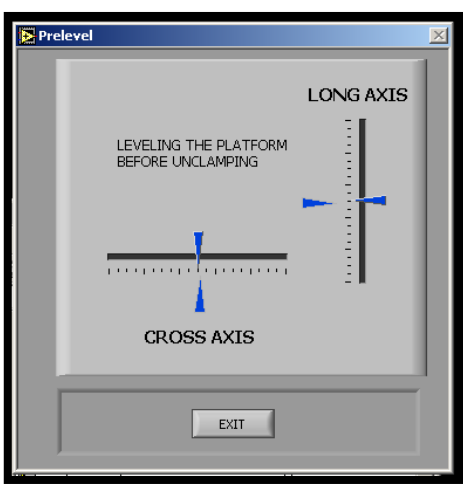
BATCH FILE: “Run_Meter.bat”

When the Power Module power switch is turned on, the CPU will boot up the Windows 2000 Professional operating system. A shortcut in STARTUP then executes the following batch file:

SELF-TEST:

This routine then checks six system power supply voltages and reports with a “check” in the box if the voltage is OK.

It also reports the platform controller status as OK with a checkbox.



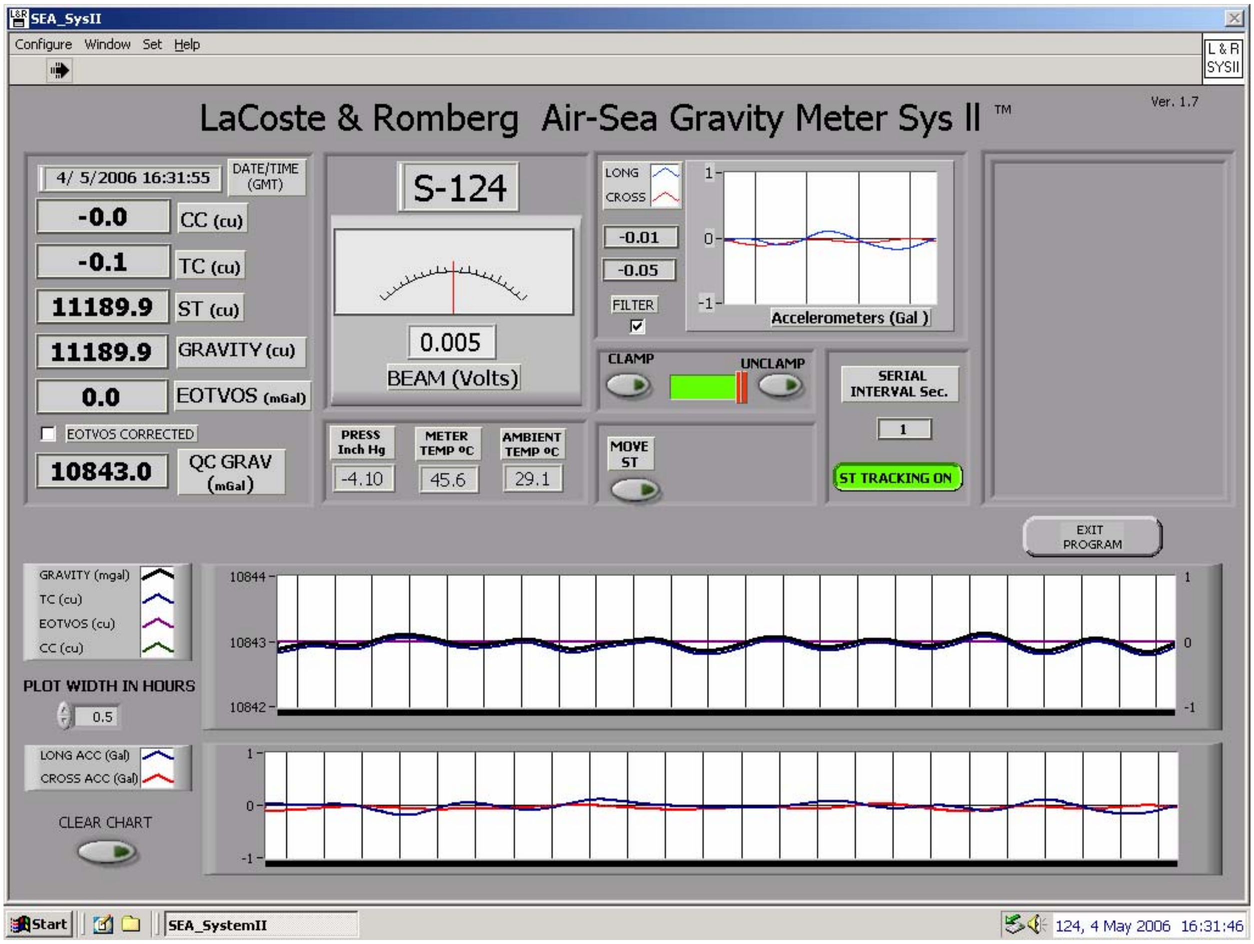
Pre-Level:

This routine will level the meter in both cross and long direction, and then unclamp the meter.

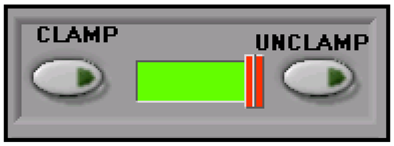
When this is complete, the final command in the batch file, SEA_SystemII.exe, starts the main executable program.

5.3 USER INTERFACE

5.3.1 MAIN SCREEN (Version 1.7)



5.3.1.1 MAIN SCREEN CONTROLS



CLAMP-UNCLAMP CONTROL

Allows the user to clamp or unclamp the beam. The button changes color to indicate the beam clamp status. Red indicates CLAMPED, Green indicates UNCLAMPED.

MOVE SPRING TENSION CONTROL

This control allows the user to move the Spring Tension to a new value.

When you click the “MOVE ST” button, the following sub-screen appears.

Type the desired ST value into the “MOVE TO“ numerical box (or use up-down arrow keys), and press GO.

An Exit button allows abort of MOVE ST request.

SERIAL INTERVAL (SECONDS)

Indicates the Serial Data Output Rate

SPRING TENSION TRACKING CONTROL

Toggles ON/OFF the Spring Tension control loop.

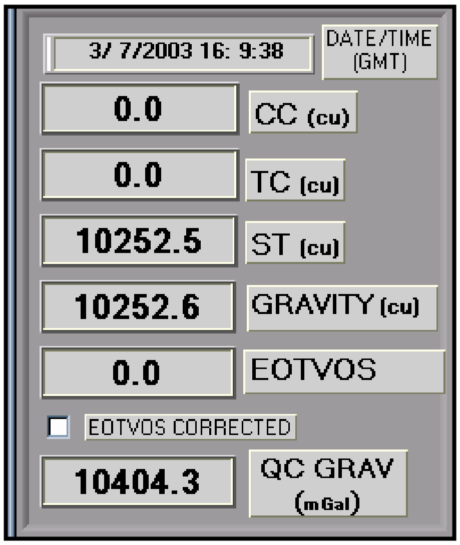
Red indicates that the tracking is OFF, Green indicates tracking is ON.

EXIT PROGRAM

Exits the program and clamps the beam. A confirmation window appears to prevent accidentally exiting the program.

5.3.1.2 DIGITAL STATUS

This window provides numerical information on the current state of the system.



DATE/TIME: Day, Month, Year, Hour, Minute, and Seconds

CC: Cross Coupling Correction in Counter Units (CU), QC filtered

TC: Total Correction in Counter Units (CU), QC filtered

ST: Spring Tension in Counter Units (CU)

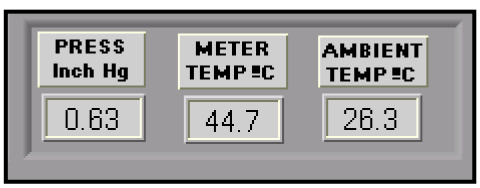
GRAVITY: Gravity in Counter Units (CU), QC filtered

EOTVOS: Eotvos Correction in mGal, QC filtered

EOTVOS CORRECTED CHECKBOX: The Eotvos correction checkbox cannot be changed from the main screen. It is set within the Gravity Correction Control under the "Configuration" pull-down menu.

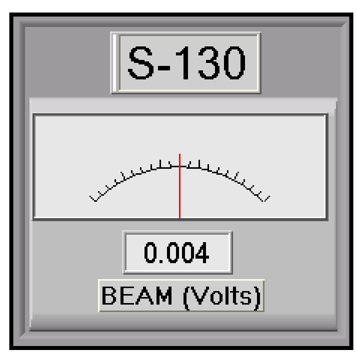
QC GRAVITY: QC Gravity (Eotvos corrected if checked) in mGal, QC filtered

5.3.1.3 ENVIRONMENT STATUS



This panel indicates the Meter Pressure, Meter Temperature, and Ambient Temperature.

5.3.1.4 BEAM POSITION GALVANOMETER



This indicator shows the Beam Position represented as a voltage, with -5 volts at the **"Bottom Stop"** and +5 volts at the **"Top Stop"**, covering the full range of motion of the Gravity Meter Beam.

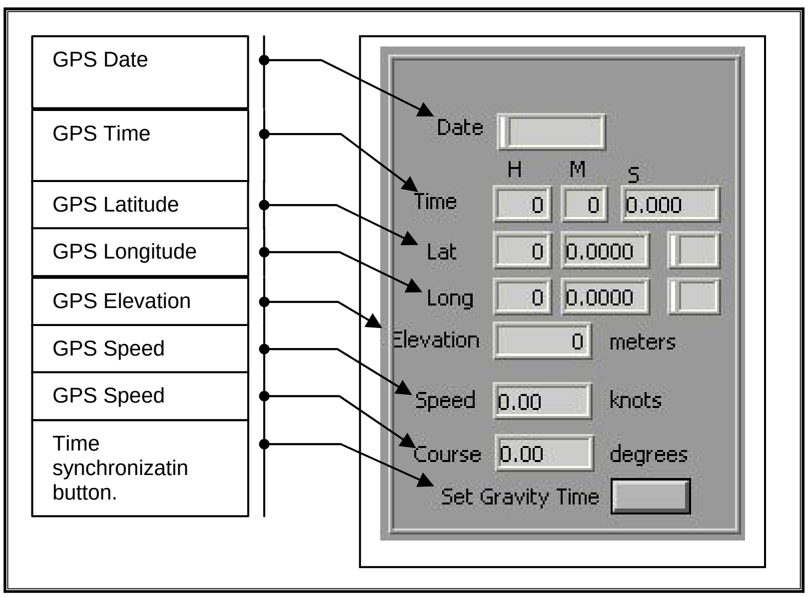
5.3.1.5 GPS DISPLAY

The GPS window is displayed when the program starts, provided that GPS input is detected. If no GPS data is detected, the window will not open. If GPS input is connected to the Control Module front panel connector AFTER the software is running, it will not be recognized until the program is re-started.

The default baud rate for GPS input is 4800 baud, and is controlled by the Hardware Configuration File parameter:

GPS_Baud=4800

This can be changed to suit the specific GPS unit, i.e. 9600 baud is also a common setting.



The GPS interface depends upon a collection of three NMEA0183 data strings.

The strings are:

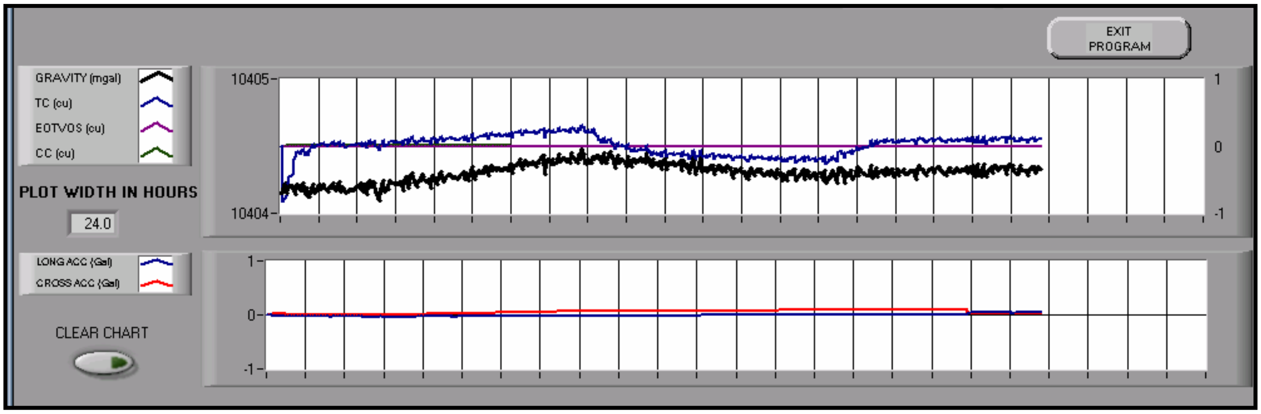
GLL – provides position information

RMC – provides date, time, course and speed information

GGA – provides elevation information.

The GPS interface expects all three messages to be present.

5.3.1.6 MAIN STRIP CHART



UPPER CHART

Gravity (QC filtered) is plotted in mGal according to the **left-side scale.**

TC, Eotvos, and CC are plotted against the **right-side scale**, centered about zero.

LOWER CHART

Filtered Accelerometer values plotted in gals

PLOT WIDTH IN HOURS

Adjusted by Software Configuration File parameter:

Plot_hours=x or onscreen in v 1.7

CLEAR CHART

Clears all data from main Strip Chart

5.3.1.7 HORIZONTAL ACCELEROMETER STRIP CHART

This chart indicates the horizontal accelerometer outputs, scaled in Gals, both on the chart and as digital values.

Filter Checkbox

The Filter Checkbox allows the user to toggle between filtered (QC filter) and unfiltered accelerometer data.

X-axis

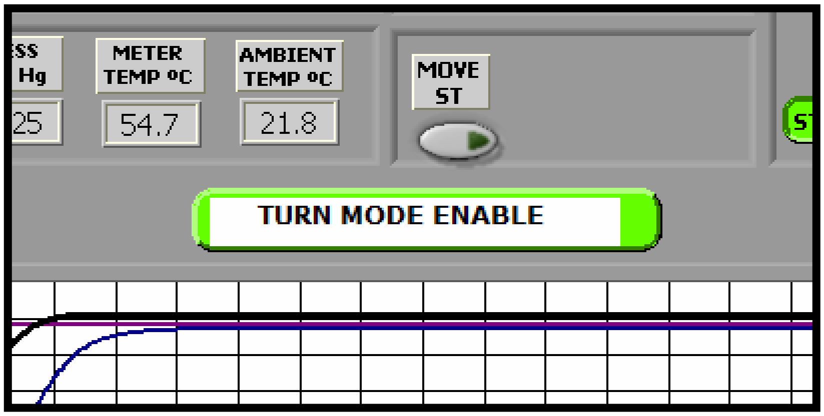
The window displays 1024 samples.

With 0.5 second updates, the chart will show about 8.5 minutes of data.

Y-axis

The Y-axis has a variable scale. The units are Gal and the display will automatically adjust to the data (autoscale ON). The user can override the automatic scaling by selecting the value with the mouse and typing the desired scale.

5.3.1.8 TURN MODE



Purpose:

Enabling TURN MODE at the end of a survey line starts a sequence of procedures to minimize recovery time to normal data acquisition after the turn is complete.

TURN MODE ENABLE
(WARNING – THIS WILL INTERRUPT NORMAL DATA ACQUISITION)

1) Upon pressing TURN MODE ENABLE, the Turn Button will display (FLASHING RED):

NOW IN TURN MODE
METER CLAMPED - PLATFORM PERIOD 30 SECS – ACCELEROMETER INPUTS DISABLED
PRESS HERE TO EXIT TURN MODE (When On Line and Level)

2) Operator should now MOVE ST to expected Counter Value at next SOL (Start of Line).

3) Upon pressing EXIT TURN MODE, the Turn Button will display (FLASHING RED):

EXITING TURN MODE – WAIT 30 SECONDS
METER CLAMPED – ACCELEROMETERS ON – PLATFORM PERIOD 4 MINUTES

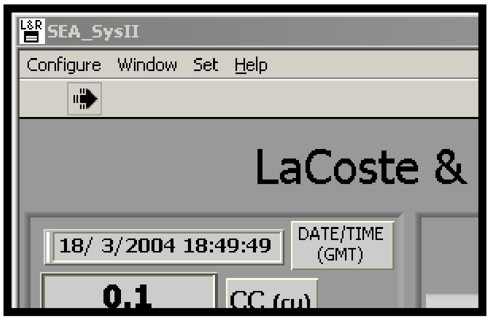
4) After 30 Seconds, the Turn Button will display (FLASHING RED):

EXITING TURN MODE – UNCLAMPING

5) After unclamping, Turn Button will display original message:

TURN MODE ENABLE
(WARNING – THIS WILL INTERRUPT NORMAL DATA ACQUISITION)

5.3.2 PULL-DOWN MENUS



Four Pull-Down menus are available for various operations as follows:

CONFIGURE

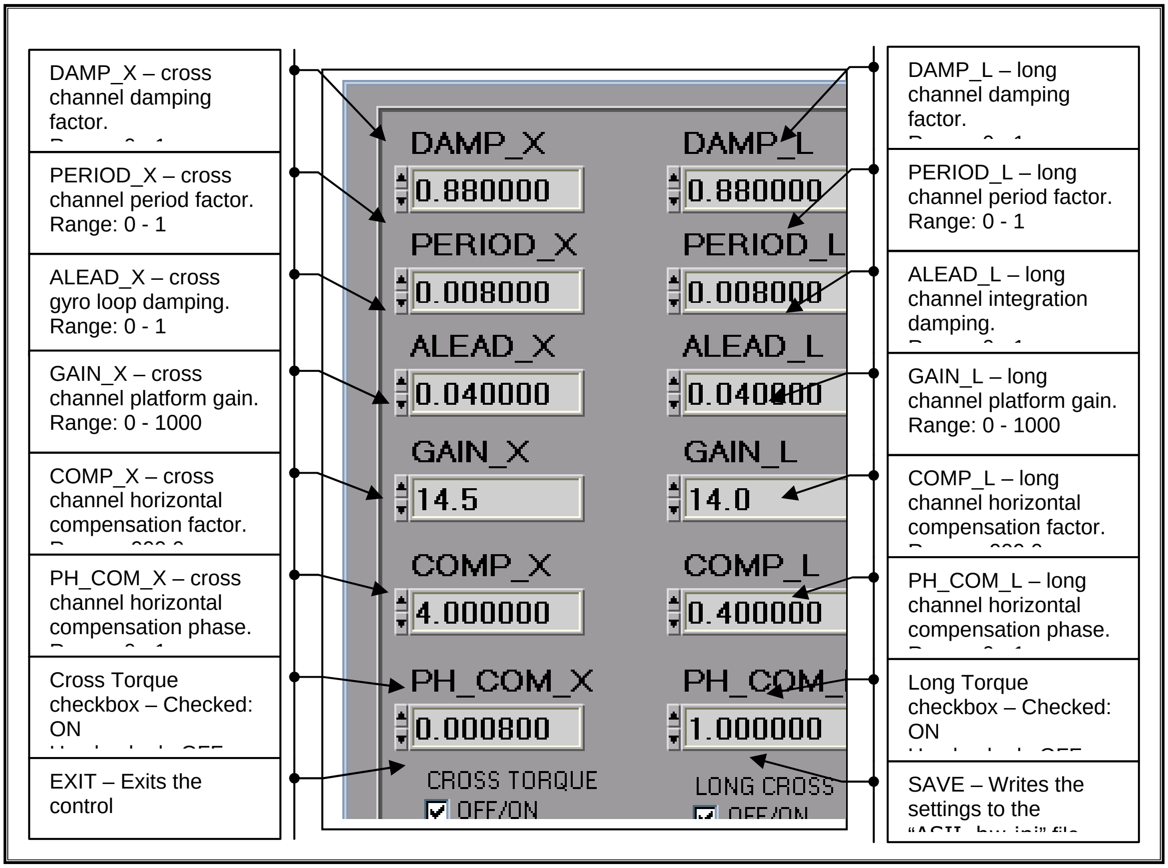
WINDOW

SET

HELP

5.3.2.1 "CONFIGURE" PULL-DOWN MENU

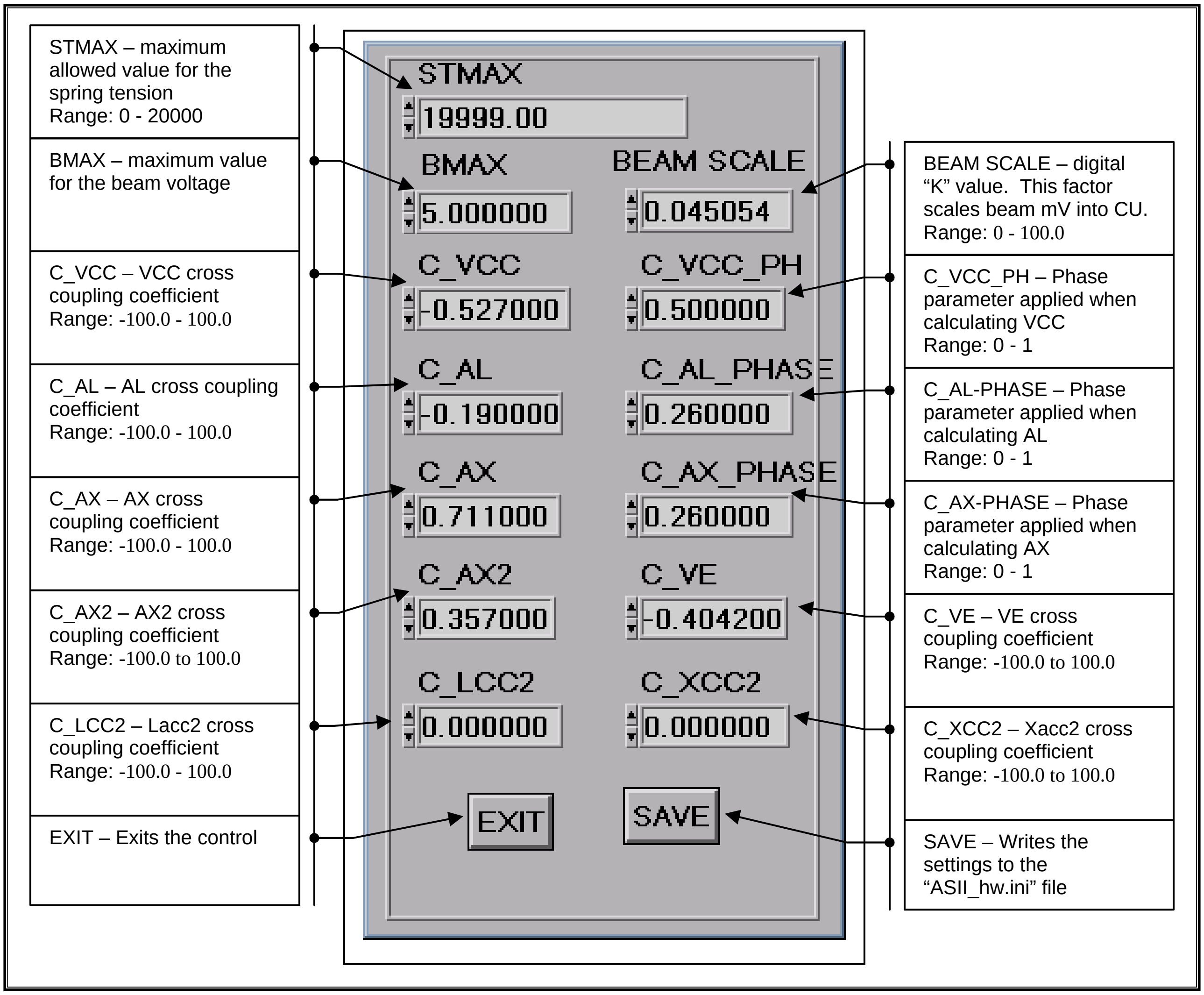
5.3.2.2 "PLATFORM" CONFIGURATION / TORQUE MOTOR CONTROL



Item	Description	Range
Damp_X	Sets the cross axis damping	0 to +1
Period_X	Sets the cross axis period	0 to +1
Alead_X	Sets the cross axis gyro loop damping	0 to +1
Gain_X	Sets the cross axis gain	0 to 1000.0
Comp_X	Sets the cross axis compensation	-999.0 to 999.0
PH_Com_X	Sets the cross axis compensation phase	0 to 1
Cross Torque Checkbox	Toggles cross torque motor on/off	
Damp_L	Sets the long axis damping	0 to +1
Period_L	Sets the long axis period	0 to +1
Alead_L	Sets the long axis gyro loop damping	0 to +1
Gain_L	Sets the long axis gain	0 to 1000.0
Comp_L	Sets the long axis compensation	-999.0 to 999.0
PH_Com_L	Sets the long axis compensation phase	0 to 1
Long Torque Checkbox	Toggles long torque motor on/off	
Save	Writes the settings to "ASII_hw.ini" hardware configuration file.	
Exit	Exits the control	

WARNING – The values in the table should not be changed. The values are determined by platform testing and incorrect operation of the meter can result if they are incorrectly adjusted!

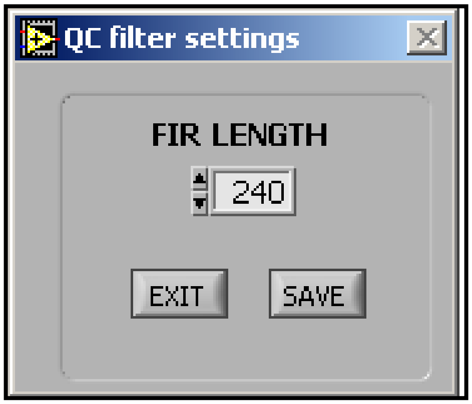
5.3.2.3 "CROSS COUPLING" CONFIGURATION CONTROL



Item	Description	Range
STMAX	Maximum Allowed Spring Tension Value	0 to 20000
BMAX	Maximum Beam Voltage	5.0
C_VCC	VCC cross coupling coefficient	-100.0 to 100.0
C_AL	AL cross coupling coefficient	-100.0 to 100.0
C_AX	AX cross coupling coefficient	-100.0 to 100.0
C_AX2	AX2 cross coupling coefficient	-100.0 to 100.0
C-VE	VE cross coupling coefficient	-100.0 to 100.0
BEAM SCALE	Sets the digital k factor	0.0 to 100.0
C_VCC	VCC phase coefficient	0 to +1
C_AL	AL phase coefficient	0 to +1
C_AX	AX phase coefficient	0 to +1
C_LCC22	LACC2 cross coupling coefficient	-100.0 to 100.0
C_XCC22	XACC2 cross coupling coefficient	-100.0 to 100.0
Save	Writes the settings to "ASII_hw.ini" configuration file	
Exit	Exits the control	

WARNING – The values in the table should not be changed. The values are determined by laboratory cross coupling tests. Incorrect calculation of the gravity can result if they are incorrectly adjusted!

5.3.2.4 QC FILTER CONTROL



This controls the FIR filter applied to the data on the Main Screen. The filter is applied to the Cross Coupling (CC), the Total Correction (TC), corrected and uncorrected Gravity, the Eotvos correction, and the two horizontal accelerometers. The user must restart the program for any change in the filter to take effect.

<u>FIR LENGTH:</u> FIR Filter length, in seconds.

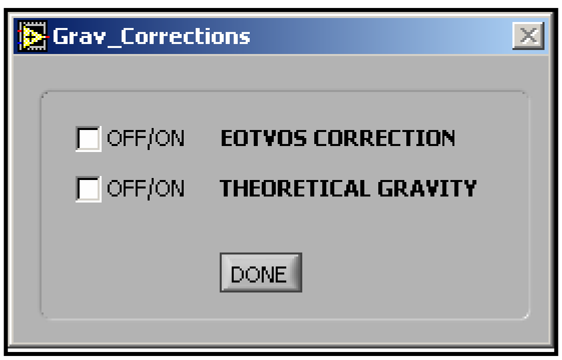
Default=180 seconds, i.e. 3-minute delay

<u>EXIT:</u> Exit without saving to file

<u>SAVE:</u> Exit and save to "ASII_sw.ini" software configuration file

5.3.2.5 GRAVITY CORRECTIONS CONTROL

This control toggles whether the gravity data is corrected for Eötvös effects and latitude changes. Both the Eötvös and latitude corrections require a GPS input.



<u>Eotvos Correction Checkbox:</u>

Toggles whether QC gravity has the Eotvos correction applied. Checked applies the correction.

<u>Theoretical Gravity Correction Checkbox:</u>

Toggles whether QC gravity has a Latitude correction applied. Checked applies the correction.

<u>Done:</u> Exits the control and writes the settings to the "ASII_sw.ini" software configuration file.

The Eötvös formula used is:

$E_{corr} = 7.503 \bullet V \bullet \cos(\varphi) \bullet \sin(\alpha)$, where

V = velocity over ground in knots,

φ = latitude,

α = heading from North.

The Latitude correction is approximated by

$L_{corr} = 978031.846 * (0.005278895 * \sin^2 \varphi + 0.000023462 * \sin^4 \varphi)$

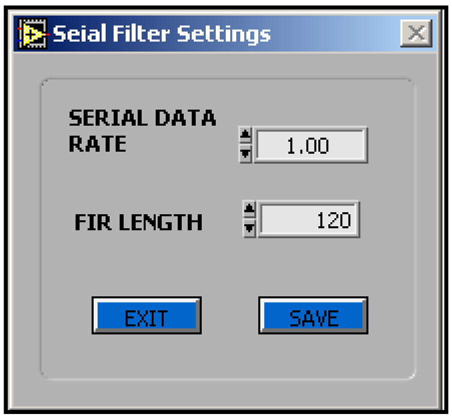
This formula drops the constant term so that the calculation is sensitive only to the change in gravity from the equator to the poles. At the equator, the correction is 0.0 while at the poles it is 5185.87 mGal.

5.3.2.6 RECORDING/OUTPUT RATE CONTROL

The serial data output rate and amount of filtering applied can be adjusted. The filter applied is a FIR filter with Exact Blackman window.

The FIR filter is applied to all values within the DAT string except for the time stamp and the gravity value. The time stamp is normal, unfiltered time while the gravity data has the QC filter applied.

Since the time has not been filtered and the balance of the data has been filtered, the data is not "zero phase". Processing of the data will have to account for the filter lag.



SERIAL DATA RATE:
Time in seconds between data records.

FIR LENGTH:
FIR filter Length (in seconds) applied to the data records.

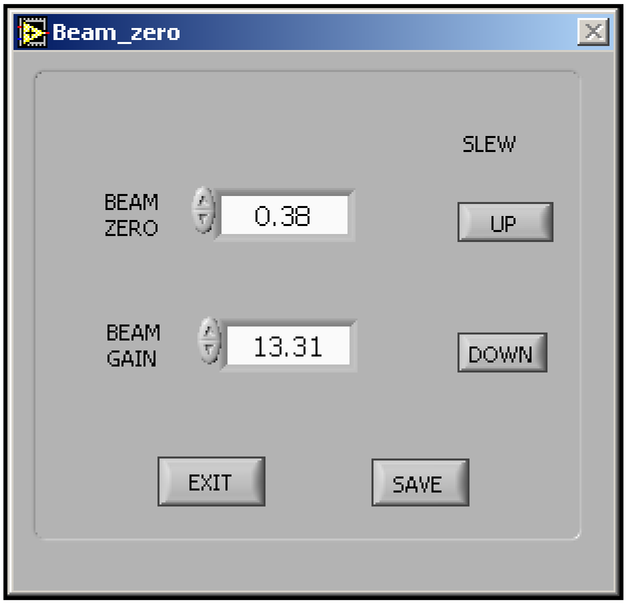
Default = 1 second
i.e. record "raw" data with filtering to be applied later by data processor.

EXIT: Exits the control

SAVE: Writes the settings to the "ASII_sw.ini" Software Configuration File.

5.3.2.7 BEAM ZERO/GAIN (and BEAM SLEW MOTOR CONTROL)

The Beam Zero/Gain Control is used to calibrate the range of the beam voltage, and control the action of the Beam Slew Motor.



BEAM ZERO CONTROL: Adjust the beam zero value so that beam position reads 0.0 volts ±10 mV while the beam is clamped.

BEAM GAIN CONTROL: Adjust the beam gain value so that beam position reads 5.0 volts ±10 mV with the beam at the top stop.

SLEW UP: Pushes the beam to the top stop using the Beam Slew Motor. Button turns red while the motor is ON.

SLEW DOWN: Pushes the beam to the bottom stop using the Beam Slew Motor. Button turns red while the motor is ON.

EXIT: Exit without saving

SAVE: Saves beam zero/gain settings to the “ASII_Hw.ini” hardware configuration file

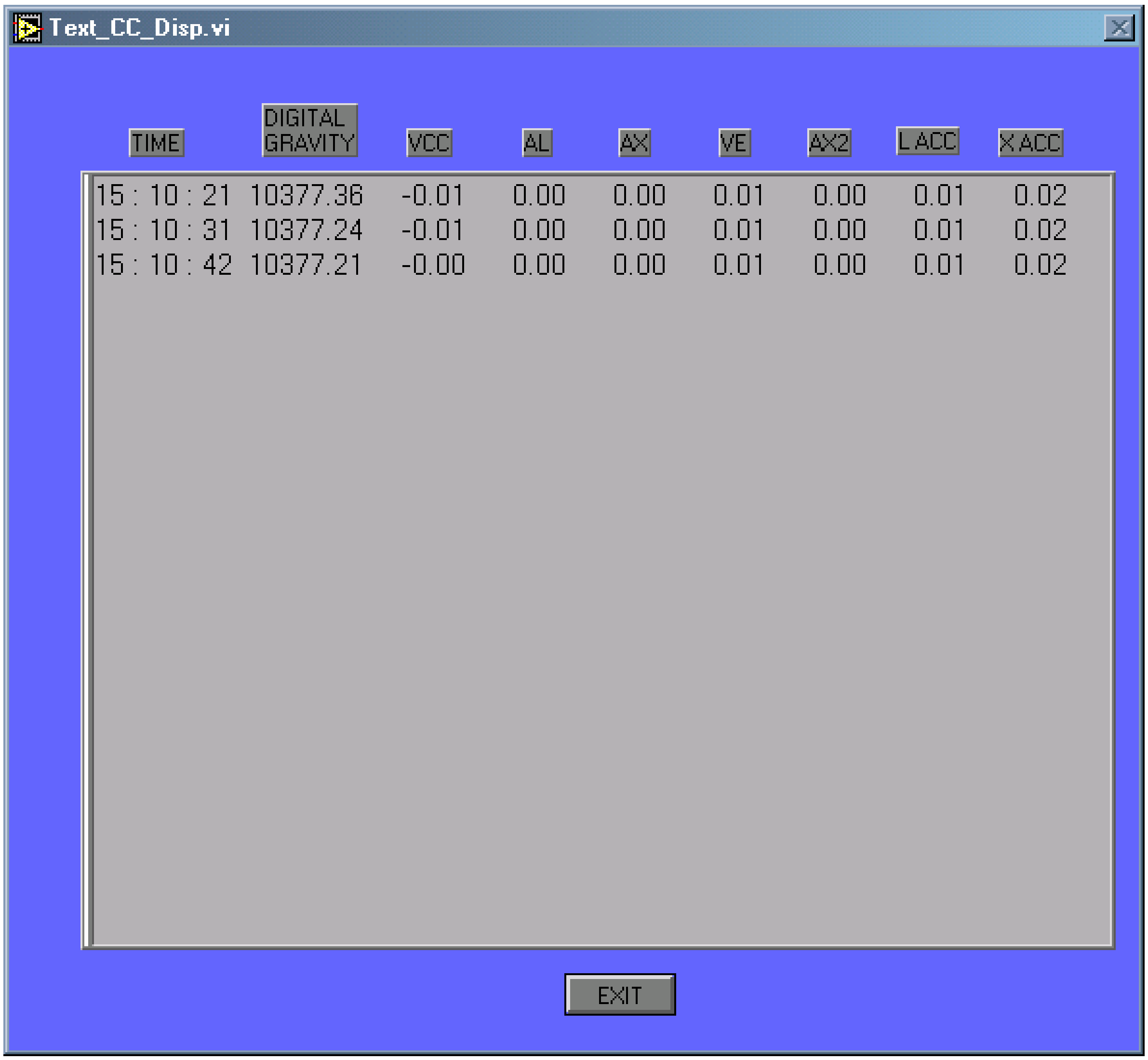
5.3.2.8 "WINDOW" PULL-DOWN MENU

5.3.2.9 "CROSS COUPLING" WINDOW

This menu option activates a text display of the Cross Coupling values.

The display shows Time, Gravity (QC filtered), the five cross coupling monitors VCC, AL, AX, VE, AX2, and the two horizontal accelerometers LACC, XACC.

This display is primarily used during the cross coupling tests at L&R.

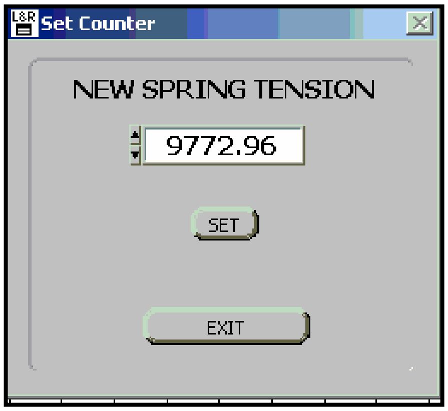


5.3.2.10 "GRAVITY" WINDOW

This text display is used to view numerical data rather than graphical data. The display shows Time, Digital Gravity (5 min filtered), Filtered Gravity (QC filtered), Spring Tension, Cross Coupling, Raw Beam, and Total Correction.

5.3.2.11 "SET" PULL-DOWN MENU

5.3.2.12 SET COUNTER



Use this option to synchronize the control software with the actual Spring Tension Counter value indicated on the Meter Sensor.

This procedure must ALWAYS be done when swapping between Primary and Spare Control Modules, because the latest Spring Tension position information is stored in the Counter Board in the Control Module.

5.3.2.13 "HELP" PULL-DOWN MENU

SHOW CONTEXT HELP

If this option is selected, placing the mouse on a control or indicator will bring up a small window with HELP information about that feature.

5.3.3 WARNING SCREENS

5.3.3.1 LEVEL WARNING

After an initial delay from startup of 500 seconds (8.3 min), the software checks the filtered accelerometer outputs every 10 seconds.

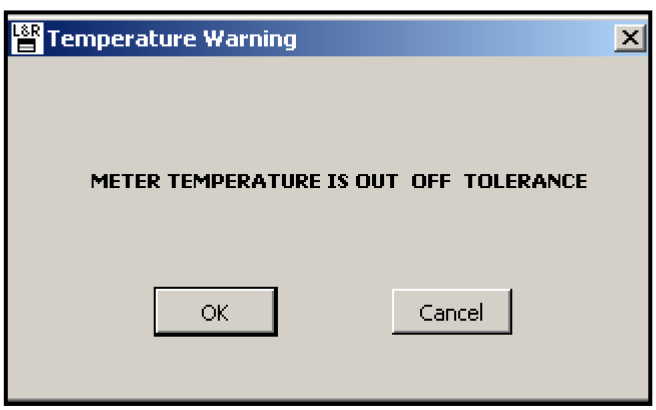
This check is only performed if the "Level_check" parameter in the Hardware Configuration File is set to TRUE, i.e.

Level_check=True

If the values exceed ±1 Gal, this warning window will appear and the ST TRACKING is turned OFF.

5.3.3.2 TEMP WARNING

After an initial delay from startup of 500 seconds (8.3 min), the software checks the meter temperature every 10 seconds.



This check is only performed if the "Temp_check" parameter In the Hardware Configuration File is set to TRUE, i.e.

Temp_check=True

If the values exceed ±1 °C from the setpoint entered into the Hardware Configuration File, i.e.

"Temp_Setpoint=47.1"

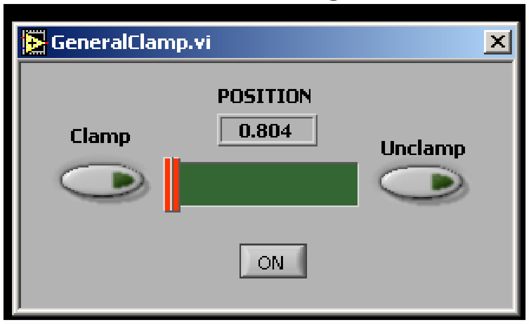
this warning window will appear and the ST TRACKING is turned OFF.

5.3.4 CLAMP-UNCLAMP MOTOR POSITION UTILITY

A stand-alone VI (Virtual-Instrument) named "Clamp_Unclamp.exe" is provided with the system software.

This software utility is used to check the output voltage across the "position potentiometer", which is mechanically linked to the clamp-unclamp DC motor.

The "POSITION" indicator on the instrument panel indicates the voltage drop across the potentiometer. The voltage is used as a relative indicator of position.



The Hardware Configuration File contains two parameters which control operation of the CLAMP or UNCLAMP commands on the AIRSEA II control software main panel.

[Clamp]

Clamp_pos=0.822

Unclamp_pos=3.37

To determine the correct values for the two positions:

1) Exit main control software, and load "Clamp_Unclamp.exe" utility software.
2) Turn the Arrestment Knob manually to the CLAMP position, i.e. clockwise to end of the mechanical range of motion. (Although the label on the lid says only turn manually with Power Off, this procedure requires manually turning with the Power On – just turn slowly and carefully without too much force.)
3) Observe indicated "POSITION". Add .02 to this reading; this will be the initial value for "Clamp_pos" parameter.
4) Turn Arrestment Knob manually to the UNCLAMP position, i.e. counter-clockwise to end of the mechanical range of motion.
5) Observe indicated "POSITION". Subtract .02 from this reading; this will be the initial value for "Unclamp_pos" parameter.
6) Close Clamp_Unclamp.exe" utility software. Enter the two parameters into Hardware Configuration File, and save. Start "Clamp_Unclamp.exe" utility software again.
7) Test both CLAMP and UNCLAMP functions. If the "LIGHT" on either CLAMP or UNCLAMP button remains on, it means the motor is still on, and is trying to reach a position which is beyond the mechanical range of the arrestment. Adjust the two parameters as necessary for smooth and complete operation.
8) Start AIR-SEA II main control software and test both CLAMP and UNCLAMP functions again. If you encounter a "TIMEOUT" error this indicates a position parameter is still outside the mechanical range of motion.

5.4 FILES

Air-Sea System II files are installed in the “AIRSEAII” directory under the root directory. This directory contains the following files and subdirectories:

Executable Files

Clamp_Meter.exe –	Subroutine to Clamp the Beam
Clamp_Unclamp.exe –	Utility to monitor Clamp-Unclamp Position Pot Voltage
Diag21k.exe –	Sends parameters to the DSP Platform Controller
Platform_test.exe –	Auxiliary program called by batch file
Pretest.exe –	System Test Module
Prelevel.exe –	Level the platform before starting SEA_SystemII.exe
SEA_SystemII.exe–	Main Executable program
Start_platform.exe –	Starts the Platform Controller
UnClamp_meter.exe –	Subroutine to Unclamp the Beam
Wait.exe –	Delay program to allow for computer boot time
Write_counter.exe –	Set a Spring Tension value into the Counter Board

Driver Files

daqdrv –	Drivers for the PCMCIA Data Acquisition Cards
serpdrv –	Drivers for Serial Port
PLATFORM.21K –	Platform Controller Configuration File

Text Files

SelfTest.ini -	created by PreTest.exe
Commands.txt –	text file for Platform Controller initialization

Subdirectories

Data –	data and environment files
Configuration –	meter-specific files
ASII_hw.ini –	Hardware Configuration File
ASII_sw.ini –	Software Configuration File

Batch File

Run_Meter.bat -	This batch file is set to run at start up of the computer. It starts the meter and runs the necessary programs.

5.4.1 HARDWARE CONFIGURATION FILE (ASII_Hw.ini) **EXAMPLE ONLY**

```
[Meter]
Meter_Number=S-110

[Meter_Abs_Calibration]
Meter_Cal=False

[Meter_Table]
Coef0=0
Coef1=0.9978
Coef2=0
Coef3=0

[Beam]
BeamScaleFactor=3.838000
Beamgain=13.740000
Beamzero=0.020000

[SpringTension]
ST_Max=19990.000000
Backlash=0.05
Tracking=1.0

[CrossCoupling]
Vcc=-0.660000
Vcc_phase=0.450000
Al=0.269000
Al_phase=0.250000
Ax=0.305000
Ax_phase=0.300000
VE=0.200000
Ax2=-0.570000
Xcc2=0.000000
Lcc2=0.000000

[Platform]
Cross_Damping=550.000000
Cross_Periode=0.100000
```

```
Cross_Lead=0.150000
Cross_Gain=60.000000
Cross_Comp=-0.015000
Cross_Phcomp=1.000000
Long_Damping=550.000000
Long_Periode=0.100000
Long_Lead=0.150000
Long_Gain=50.000000
Long_Comp=-0.015000
Long_Phcomp=0.008000

[Clamp]
Clamp_pos=0.822
Unclamp_pos=3.37

[Serial_ports]
GPS_Port=1
GPS_Baud=4800
Datalog_Port=2
Datalog_Baud=9600
[Sensor]
Level_check=False
Temp_check=False
Temp_Setpoint=47.1
Pressure_offset=-1.18
[Gyro]
Gyro_type=2
[Encoder]
Ratio=0
```

5.4.2 SOFTWARE CONFIGURATION FILE (ASII_Sw.ini) **EXAMPLE ONLY**

```
[Accelerometer]
Cross_offset=-0.0555
Long_offset=-0.0588
Cross_DSP_Setpoint=-400
Long_DSP_Setpoint=-500

[Printer]
Printer=0
Printer_secdiv=240

[Corrections]
Eotvos=0
Theoretical_Grav=0

[File]
File_Save_Period=1.0

[Filter]
Filter_Type=1
Filter_Length=120
QC_Filter_Length=180

[Serial]
Serial_log_rate=1.000000

[Recording]
10Hz=False

[windows]
Plot_Window=FALSE
Plot_hours=1
GPS_Window=TRUE
Grav_precision=0
Level_precision=0
Turn_button=False
```

5.4.3 DATA FORMATS

Air-Sea System II has two types of data records, with File Extensions ".DAT" and ".ENV".

File Names are automatically generated from Year, Day of Year, and Meter Number.

i.e.	2003_188_S-133.DAT	DAILY SIZE = approx 16.5 MB
	2003_188_S-133.ENV	DAILY SIZE = approx 1 KB

Fields in each record are Comma-Separated Variables (.CSV style for direct import into spreadsheet, etc.).

Fields are normally fixed width as listed below. If a field overflows, the width is expanded to meet the required width, altering the column definitions after that field.

5.4.3.1 DATA RECORD (.DAT FILE)

The Data Record has 21 comma separated fields, recorded once per second.

Example:

```
$DAT,2003/ 6/29, 0: 0: 0.55,180,10262.40,10262.18,  -10501.98,   -0.00,
0.00,    0.00,    0.00,    0.00,    0.01,    0.02,   -0.00,    0.12,
0.00,   0.00000000,   0.00000000,  0.000,   0.000,
$DAT,2003/ 6/29, 0: 0: 1.55,180,10262.40,10262.18,  -10410.72,   -0.00,
0.00,    0.00,    0.00,    0.00,    0.01,    0.02,    0.01,    0.09,
0.00,   0.00000000,   0.00000000,  0.000,   0.000,
$DAT,2003/ 6/29, 0: 0: 2.55,180,10262.40,10262.18,  -10277.42,   -0.00,
0.00,    0.00,    0.00,    0.00,    0.01,    0.02,    0.00,    0.12,
0.00,   0.00000000,   0.00000000,  0.000,   0.000,
$DAT,2003/ 6/29, 0: 0: 3.55,180,10262.40,10262.18,  -10487.27,   -0.00,
0.00,    0.00,    0.00,    0.00,    0.01,    0.02,    0.00,    0.11,
0.00,   0.00000000,   0.00000000,  0.000,   0.000,
$DAT,2003/ 6/29, 0: 0: 4.55,180,10262.40,10262.18,  -10507.16,   -0.00,
0.00,    0.00,    0.00,    0.00,    0.01,    0.01,   -0.00,    0.07,
0.00,   0.00000000,   0.00000000,  0.000,   0.000,
$DAT,2003/ 6/29, 0: 0: 5.55,180,10262.40,10262.18,  -10457.47,   -0.00,
0.00,    0.00,    0.00,    0.00,    0.01,    0.01,   -0.00,    0.08,
0.00,   0.00000000,   0.00000000,  0.000,   0.000,
$DAT,2003/ 6/29, 0: 0: 6.55,180,10262.40,10262.18,  -10394.30,   -0.00,
0.00,    0.00,    0.00,    0.00,    0.01,    0.01,   -0.00,    0.09,
0.00,   0.00000000,   0.00000000,  0.000,   0.000,
$DAT,2003/ 6/29, 0: 0: 7.55,180,10262.40,10262.18,  -10442.79,   -0.00,
0.00,    0.00,    0.00,    0.00,    0.01,    0.02,   -0.00,    0.09,
0.00    0.00000000    0.00000000   0.000    0.000
```

DATA RECORD Field Descriptions:

DATA FIELD	START COLUMN	FIELD WIDTH	UNITS	FILTERING	
				HARD DISK DATA	SERIAL OUT DATA
ID	1	4	"$DAT"	N/A	N/A
DATE	6	10	YYYY/MM/DD	N/A	N/A
TIME	17	11	HH:MM:SS.SS	N/A	N/A
DAY OF YEAR	29	3	DDD	N/A	N/A
GRAVITY	33	8	CU	QC FILTERED	QC FILTERED
SPRING TENSION	42	8	CU	1-SEC AVERAGE	SERIAL FILTER
BEAM POSITION	51	11	Volts x 750,000	1-SEC AVERAGE	SERIAL FILTER
VCC	63	8	See Appendix	1-SEC AVERAGE	SERIAL FILTER
AL	72	8	See Appendix	1-SEC AVERAGE	SERIAL FILTER
AX	81	8	See Appendix	1-SEC AVERAGE	SERIAL FILTER
VE	90	8	See Appendix	1-SEC AVERAGE	SERIAL FILTER
AX2	99	8	See Appendix	1-SEC AVERAGE	SERIAL FILTER
XACC2	108	8	See Appendix	1-SEC AVERAGE	SERIAL FILTER
LACC2	117	8	See Appendix	1-SEC AVERAGE	SERIAL FILTER
CROSS ACCEL	126	8	GAL	1-SEC AVERAGE	SERIAL FILTER
LONG ACCEL	135	8	GAL	1-SEC AVERAGE	SERIAL FILTER
EOTVOS CORR	144	8	MGAL	1-SEC AVERAGE	SERIAL FILTER
LONGITUDE	153	13	DEGREES	1-SEC AVERAGE	SERIAL FILTER
LATITUDE	167	13	DEGREES	1-SEC AVERAGE	SERIAL FILTER
VELOCITY	181	8	KNOTS	1-SEC AVERAGE	SERIAL FILTER
HEADING	189	8	DEGREES	1-SEC AVERAGE	SERIAL FILTER

5.4.3.2 ENVIRONMENT RECORD (.ENV FILE)

The Environment Record contains information about system conditions during data acquisition. It is written to the Hard Disk and Serial Port every 10 seconds.

Example:

```
%ENV,2003/ 6/30, 0: 0: 6.43,181,S-132/V1.0,    0.15,   46.37,
24.43,1.020809E-1, 0.00000, 0.08000, 0.00000, 0.00000, 0.00000,   1, 180
%ENV,2003/ 6/30, 0: 0:16.43,181,S-132/V1.0,    0.15,   46.37,
24.41,1.020809E-1, 0.00000, 0.08000, 0.00000, 0.00000, 0.00000,   1, 180
%ENV,2003/ 6/30, 0: 0:26.43,181,S-132/V1.0,    0.15,   46.37,
24.39,1.020809E-1, 0.00000, 0.08000, 0.00000, 0.00000, 0.00000,   1, 180
%ENV,2003/ 6/30, 0: 0:36.43,181,S-132/V1.0,    0.15,   46.37,
24.39,1.020809E-1, 0.00000, 0.08000, 0.00000, 0.00000, 0.00000,   1, 180
%ENV,2003/ 6/30, 0: 0:46.43,181,S-132/V1.0,    0.15,   46.37,
24.39,1.020809E-1, 0.00000, 0.08000, 0.00000, 0.00000, 0.00000,   1, 180
%ENV,2003/ 6/30, 0: 0:56.43,181,S-132/V1.0,    0.15,   46.37,
24.39,1.020809E-1, 0.00000, 0.08000, 0.00000, 0.00000, 0.00000,   1, 180
%ENV,2003/ 6/30, 0: 1: 6.43,181,S-132/V1.0,    0.15,   46.37,
24.39,1.020809E-1, 0.00000, 0.08000, 0.00000, 0.00000, 0.00000,   1, 180
%ENV,2003/ 6/30, 0: 1:16.43,181,S-132/V1.0,    0.15,   46.37,
24.40,1.020809E-1, 0.00000, 0.08000, 0.00000, 0.00000, 0.00000,   1, 180
%ENV,2003/ 6/30, 0: 1:26.43,181,S-132/V1.0,    0.15,   46.37,
```

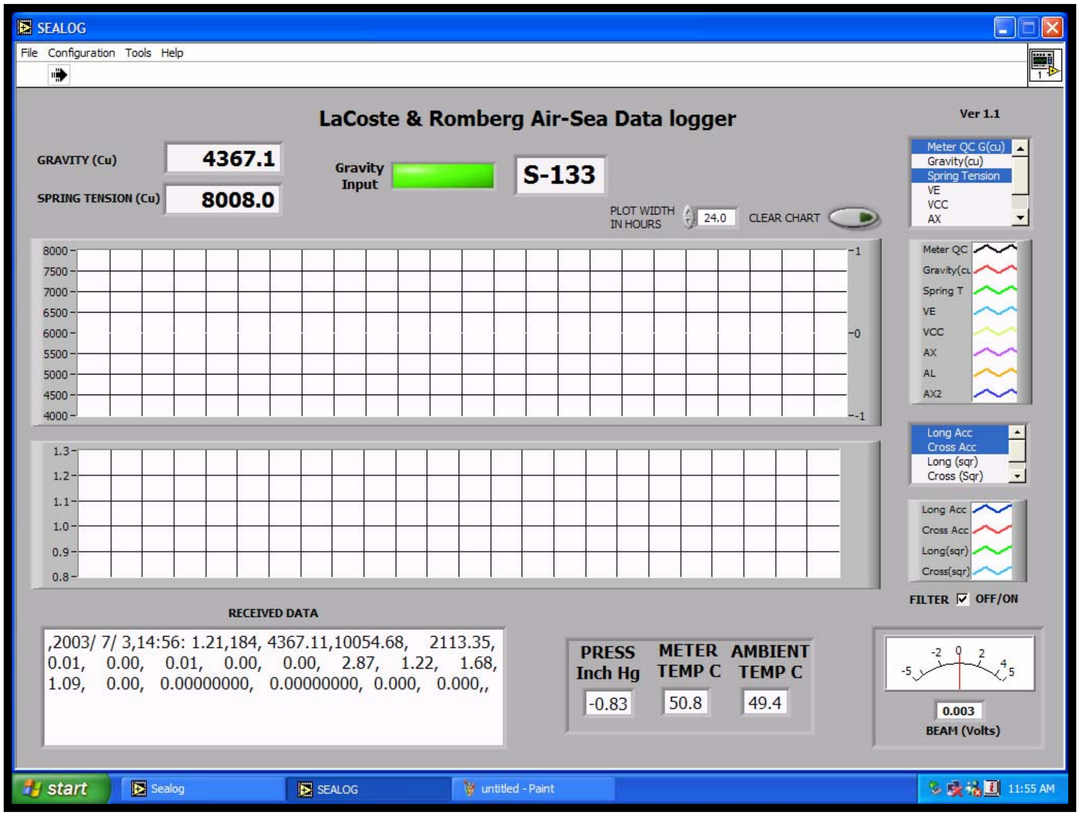
NAME	START COL	WIDTH	UNITS	FILTERING
ID	1	4	"$ENV"	n/a
DATE	6	10	YYYY/MM/DD	n/a
TIME	17	11	HH:MM:SS:SS	n/a
DAY OF YEAR	29	3	DDD	
METER ID	33	10	Meter/Software ID	n/a
METER PRESSURE	44	8	inch-Hg	2-minute avg
METER TEMP	53	8	ºC	2-minute avg
AMBIENT TEMP	62	8	ºC	2-minute avg
K-FACTOR	71	11		
VCC COEFF	83	8		
AL COEFF	92	8		
AX COEFF	101	8		
VE COEFF	110	8		
AX2 COEFF	119	8		
SERIAL FILT LENGTH	128	4	seconds	n/a
QC FILT LENGTH	133	4	seconds	n/a

6 "SEALOG" DATA LOGGING SYSTEM (v 1.1)

The optional SEALOG data logging system consists of a laptop with SEALOG software installed. Data from the AIR-SEA II system can then be logged and monitored from a remote location away from the actual gravity meter installation site.

A serial cable is provided to connect from the "DATA OUT" connector on the front of the Control Module, to the serial port on the laptop computer.

A continuous-form printer is also provided to produce strip chart records of the gravity data.



SEALOG Software Screen.

6.1.1 NUMERICAL INDICATORS

GRAVITY (CU): Filtered Gravity

SPRING TENSION (CU): Filtered Spring Tension Value

RECEIVED DATA: This window shows a real-time sequence of the data strings as received from the Gravity Meter through the serial cable.

ENVIRONMENT: This panel indicates the Meter Pressure, Meter Temperature, and Ambient Temperature.

6.1.2 GRAPHICAL INDICATORS

GRAVITY INPUT: indicates Red or Green depending if gravity data is being received OK from the gravity meter via the serial cable/serial port.

GRAVITY STRIP CHART (Upper Graph): Plots 1 to 8 Gravity-related variables as selected in the selection window. Color of plotted data indicates data type according to legend.

ACCELEROMETER STRIP CHART (Lower Graph): Plots 1 to 4 Accelerometer-related variables as selected in the selection window. Color of plotted data indicates data type according to legend.

BEAM POSITION: This indicator shows the Beam Position represented as a voltage, with -5 volts at the **"Bottom Stop"** and +5 volts at the **"Top Stop"**, covering the full range of motion of the Gravity Meter Beam.

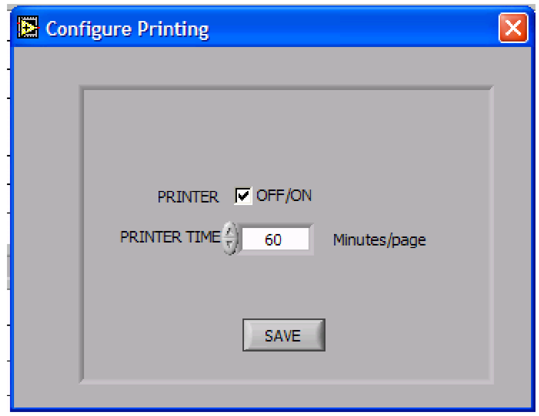
6.1.3 CONTROLS

PLOT WIDTH IN HOURS: Change the time scale with the up/down arrow keys to the left of the window

CLEAR CHART: Press to clear the strip charts on the computer display.

6.1.4 PULL DOWN MENUS

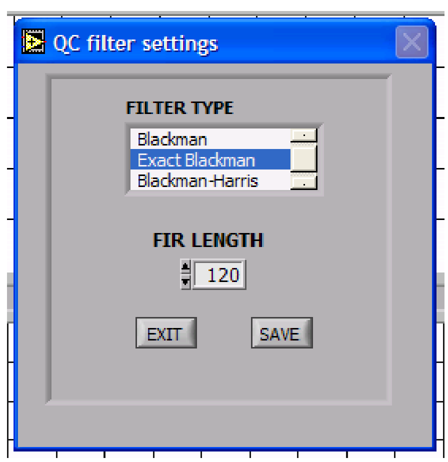
6.1.4.1 "FILE" MENU



6.1.4.2 "CONFIGURATION" MENU

6.1.4.3 "TOOLS" MENU

6.1.4.4 "HELP" MENU



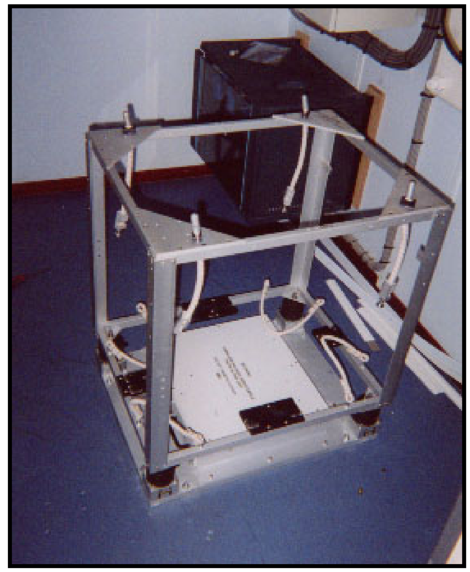
6.1.5 DATA FILES

7 INSTALLATION

7.1 ASSEMBLY

- Install the Stabilized Platform (Gimbal) into the Frame as follows:
- First orient the Stabilized Platform correctly: the end with the Cross Torque Motor must be towards the end of the Frame where the Power Module will be installed. (The Power Module and Control Module have different mounting hole patterns).
- Suspend the Stabilized Platform from the shock cords hanging from the top of the Frame. The "pivot screw" at the end of each upper shock-cord is inserted into the matching bracket on the Outer Gimbal Ring.
- Place lower shock-cord loops (in the bottom of the Frame) into the hooks on the underside corners of the Outer Gimbal Ring. (These should be loose, not tight as you might expect. If they are tight, they will transmit vibration from the Frame to the Platform).
- Install the eight oil-filled shock absorbers between the corners of the Outer Gimbal Ring to the bracket on each side of the Frame bottom.
- Mount the Gravity Sensor into the bucket of the Stabilized Platform. Three hex-head screws are inserted from the bottom of the bucket. Slide the meter around in the Bucket until it is approximately balanced, then tighten the three screws.
- Balance the meter using the movable weights on the Stabilized Platform.
- Mount Power Module and Control Module to the Frame.
- Attach Torque Motor Cable (P200) to the Power Module P200 connector (rear).
- Attach Control Cable (P1) to P1 connector on the back of the Control Module and P1 connector on the Meter Junction Box (on Sensor).
- Attach Power Cable (P100) to both the Power Module and Control Module.
- Mount the Frame to the UPS/Power Conditioner base plate using bolts into the Air-Shock mounts.

7.2 SHIPBOARD INSTALLATION



The meter should be mounted as near as possible to the center of motion of the ship. Generally, this means that the meter should be installed on the centerline, near mid-ship and at or near the waterline.

Install the meter in an air-conditioned (temperature stable) room if possible.

7.3 AIRCRAFT INSTALLATION

S-110 mounted in a Twin Otter aircraft, with the primary and spare mini-console control systems in the 19-inch rack in the background.

7.4 VIBRATION

The meter should be installed as far as possible from sources of vibration, such as the engine room. Air Sea System II meters are equipped with air shock mounts which isolate the meter from vibration.

7.5 WELDING

NEVER perform any welding near the gravity meter. The high currents produced by arc-welding can magnetize the meter and require factory servicing to demagnetize.

7.6 AC POWER SUPPLY

The system has an integrated UPS/Power Conditioner that provides clean isolated 115 VAC power. It is important to use the UPS system to avoid potential power problems.

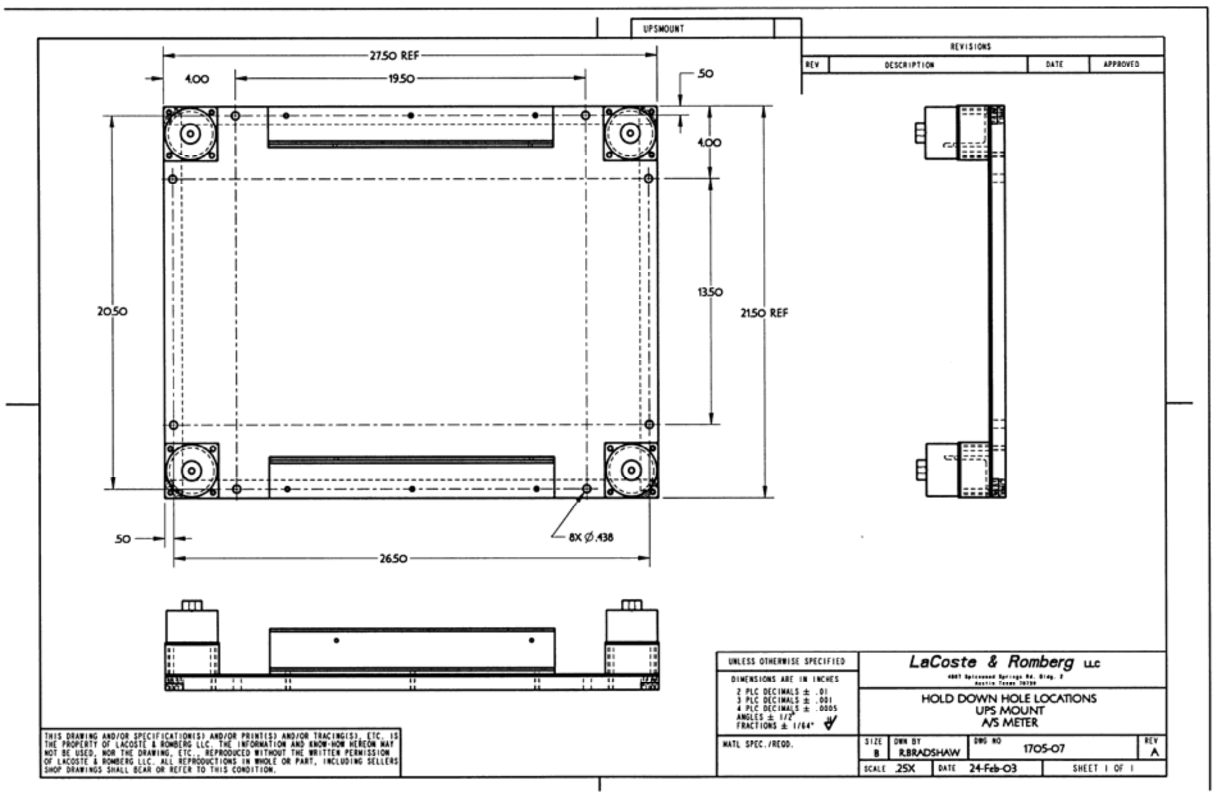
7.7 STANDBY POWER

The recommended procedure is to ALWAYS keep the meter on heat.

When not collecting data use the Auxiliary Power Supply provided with the system.

7.8 BASEPLATE MOUNTING and CLEARANCE

Eight mounting holes are provided, two on each side of the UPS/ base plate assembly. The meter can be mounted to the deck of the ship by bolting through these holes.



Alternately, a sheet of plywood can be cut to the dimensions of the frame, and then the meter is bolted to the plywood. Industrial Velcro strips can be used to hold the wood to the deck of the ship or aircraft.

Sufficient clearance should be provided so that a technician can move around all sides of the system for testing or maintenance.

8 CHECKS and ADJUSTMENTS

8.1 BEAM ZERO and BEAM GAIN ADJUSTMENT

BEAM ZERO ADJUSTMENT

Clamp the beam.

Select "Beam Zero/Gain" from the "Configuration" pull-down menu.

Observe the "BEAM" value displayed (in Volts) on the Beam Position Galvanometer.

Adjust BEAM ZERO value (up/down arrows) until the Beam Position value reads 0.000 Volts ±10 mV.

PRESS EXIT (without saving to config file) or SAVE (saving new values to config file).

BEAM GAIN ADJUSTMENT

Unclamp the beam.

Select "Beam Zero/Gain" from the "Configuration" pull-down menu.

Turn the Beam Slew Motor ON by pushing the "UP" button. The Beam will now quickly move to the "Top Stop" position, i.e. about 5 volts.

Once the Beam Position Voltage stops changing, stop the Beam Slew Motor by pushing the "UP" button again.

Observe the "BEAM" value displayed (in Volts) on the Main Screen galvanometer.

Adjust BEAM GAIN value (up/down arrows) until the Beam Position value reads 5.000 Volts ±10 mV.

PRESS EXIT (without saving to config file) or SAVE (saving new values to config file).

Example: Beam Zero/Gain Setting:

Primary Control Module:

Beam Zero = 6.01, clamped = 0.000 v

Beam Gain = 14.69, top stop = 4.999 v

Spare Control Module:

Beam Zero = 6.04, clamped = 0.001 v

Beam Gain = 14.69, top stop = 4.998 v

8.2 K-CHECK: VERIFYING THE BEAM SCALE FACTOR

The Beam Scale Factor (often referred to as the "K" factor) is a number which varies from about 1.0 to 3.0 depending upon the damping characteristics of the meter. The K-Factor converts the beam velocity from arbitrary units to counter units.

The Beam Scale Factor for your meter is documented in the "ASII_hw.ini" configuration file discussed in this manual.

The "K" factor can be verified by the following procedure:

- Allow Air-Sea System II to stabilize to Still (static) Reading
- When Total Correction reads nearly zero, switch OFF Spring Tension tracking
- Move Spring Tension +30 CU.
- After approximately 5 minutes the Total Correction should read -30 CU ± 5%.
- Move Spring Tension -60 CU.
- After approximately 5 minutes the Total Correction should read +30 CU ± 5%.

EXAMPLE K-Check:

Primary Control Module:

SR = 10249.7	
ST = 10250.0	TC = -0.4
ST = 10279.8	TC = -30.7
ST = 10219.7	TC = 30.4

Spare Control Module:

SR = 10250.0	
ST = 10050.0	TC = 1.0
ST = 10279.7	TC = -30.5
ST = 10220.2	TC = 30.6

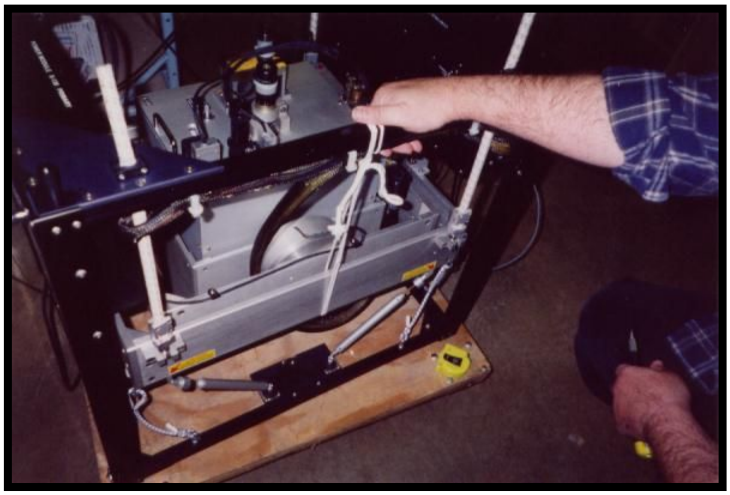
The important value to check here is that the DIFFERENCE between the two Total Correction readings should be 60 CU. If these appear to be incorrect, carefully re-check the Beam Zero and Gain adjustment as described above.

If the condition persists, it will be necessary to change the "K" factor stored in the Configuration data file. Adjust the "K" factor according the formula below.

$K(new) = (\Delta ST / \Delta TC) * K(old)$, where $\Delta ST = ST1 - ST2$ and $\Delta TC = TC2 - TC1$

8.3 ADJUSTING THE SHOCK CORDS

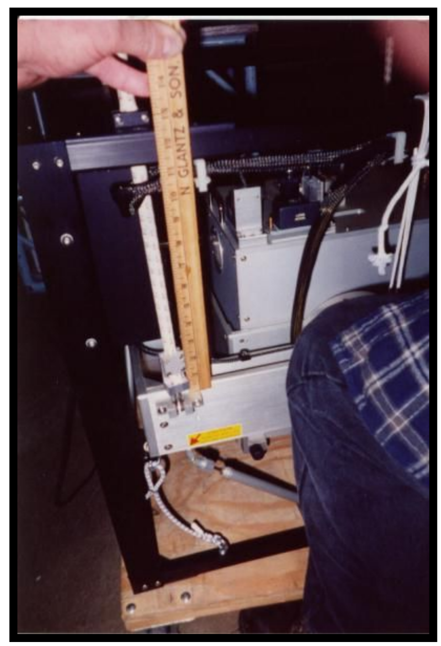
Over time, the vertical shock cords can stretch, and the suspended outer gimbal needs to be raised back to the correct operating position.



The smaller looped cords can also come loose from the hooks on the underside of the outer gimbal.

To raise the gimbal, the clamp on each vertical shock cord above it must be adjusted one by one.

First, use a piece of rope tied to the frame to support a corner of the gimbal beneath it. This should remove tension from the vertical shock cord at that corner.



Loosen the metal clamp on the top of the vertical cord, and pull the top cord up high enough to place some tension on the looped cord beneath. When correctly adjusted, the distance between the top surface of the "pivot screw mount" (holding the bottom of the vertical cord) and the bottom of the upper frame crosspiece should be approximately 11 inches (28 cm).

Re-tighten the top clamp after adjusting the shock cord height.

As a check, observe the resting position of the oil-shock absorbers, which should be roughly mid-way in their operating range. Approximately 1 to 1.5 inches of the brass rod should be visible.

8.4 ACCELEROMETER ADJUSTMENT

The accelerometers may occasionally need adjusting, especially after removing/installing the sensor lid.

If you need to adjust an accelerometer level, first gently tap on top of the accelerometer to remove any hysteresis before making the adjustment.

The label on the accelerometer shows which way to turn the brass screw in order to move the bubble level in a desired direction.

Wait 5 to 10 minutes before making each adjustment due to the 4-minute response time of the accelerometer feedback loop.

Keep repeating the adjustment until the bubble level is centered.

WARNING: Do not try to adjust the accelerometer at sea!

8.5 BUBBLE LEVEL ADJUSTMENT

This procedure is complex, and should normally only be done at the factory, or by very experienced users. It consists of setting the Long Level (Sensitivity), Cross Level, and Reading Line.

A user can quickly check if the Long Level (Sensitivity) is roughly correct by observing the meter reading when at +10 E.D. and – 10 E.D.

The reading should not change dependent on the beam position.

9 OPERATIONS

9.1 STARTUP PROCEDURE

- Connect the Power Cord from one of the six UPS Outlets to the Power Module AC Power input (located underneath). Fasten retaining clip to Power Cord.

- Connect Keyboard, Mouse, and Monitor to connectors on front of Control Module.

- Connect the UPS/Power Conditioner to local AC Power (80 to 280 VAC).

- Turn on UPS by pushing toggle switch on front to the right.

- Turn on Main Power Switch on the front of Power Module.

9.2 TIME SYNCHRONIZATION

As a special option, Micro-g LaCoste can provide software and a compact low-cost 12-channel PPS-output GPS receiver. The software and GPS unit work together to set the clock in the Control Module CPU to GPS time ± 0.1 sec or better.

The Time Synchronization procedure is as follows:

1) The synchronization software is run separately before starting the main Air-Sea II control software. Exit the Air-Sea II software if already running.

2) Once the PC clock is synched to GPS time, close the synchronization software.

3) Start the Air-Sea II control software.

4) The Air-Sea II control software will read the PC Clock once. Master time is then continuously incremented from the 10 MHz output of the Rubidium oscillator in the Power Module. The stated accuracy of this oscillator is < ±5 E-11 over one day.

9.3 DAILY CHECKS

Internal Pressure

Spring Tension Synchronization

Visual Inspection

9.4 IN-PORT CHECKS

Still Reading

Beam Zero/Gain Check

K-Check

Check Accelerometer Levels

Dock-to-Water Height

9.5 SHUTDOWN PROCEDURE

- EXIT Air-Sea II SOFTWARE with button on Main Screen. This clamps the meter.

- Turn Off Windows 2000 Operating System using SHUT DOWN Icon via START BUTTON.

- Next Window: Select SHUTDOWN (not RESTART), wait for Windows 2000 to close.

- Turn Off Main Power switch on Power Module. This cuts power to the Platform Controller, so Platform will now move freely.

Connect Auxiliary Power Supply if desired, or leave system as is but verify that meter heating system is still operating, i.e. flashing LED on Meter Junction Box.

10 DATA PROCESSING

10.1 NOTES ON QC FILTER

MAIN PROGRAM QC FILTER

should be set to 180 or 240 seconds, and is applied to the:

1) "QC GRAVITY" number on the screen
2) Accelerometer data on the screen.
3) "Gravity" number in the Main Program Hard Disk
4) "GRAVITY" number sent out the serial port.

"GRAVITY" number is NOT affected by the Serial Out Filter Setting.

With the exception of "GRAVITY" number, all other data recorded to the hard disk by the MAIN PROGRAM are always raw 1-sec averages, and this does not change.

MAIN PROGRAM SERIAL OUT FILTER

Should be set to 1 second, so that all data going out to SEALOG is unfiltered 1-second data (except QC GRAVITY number as explained above).

It is important to only record raw data so that a data processor specialist can re-compute the data with a different filter later if they wish to try some special technique.

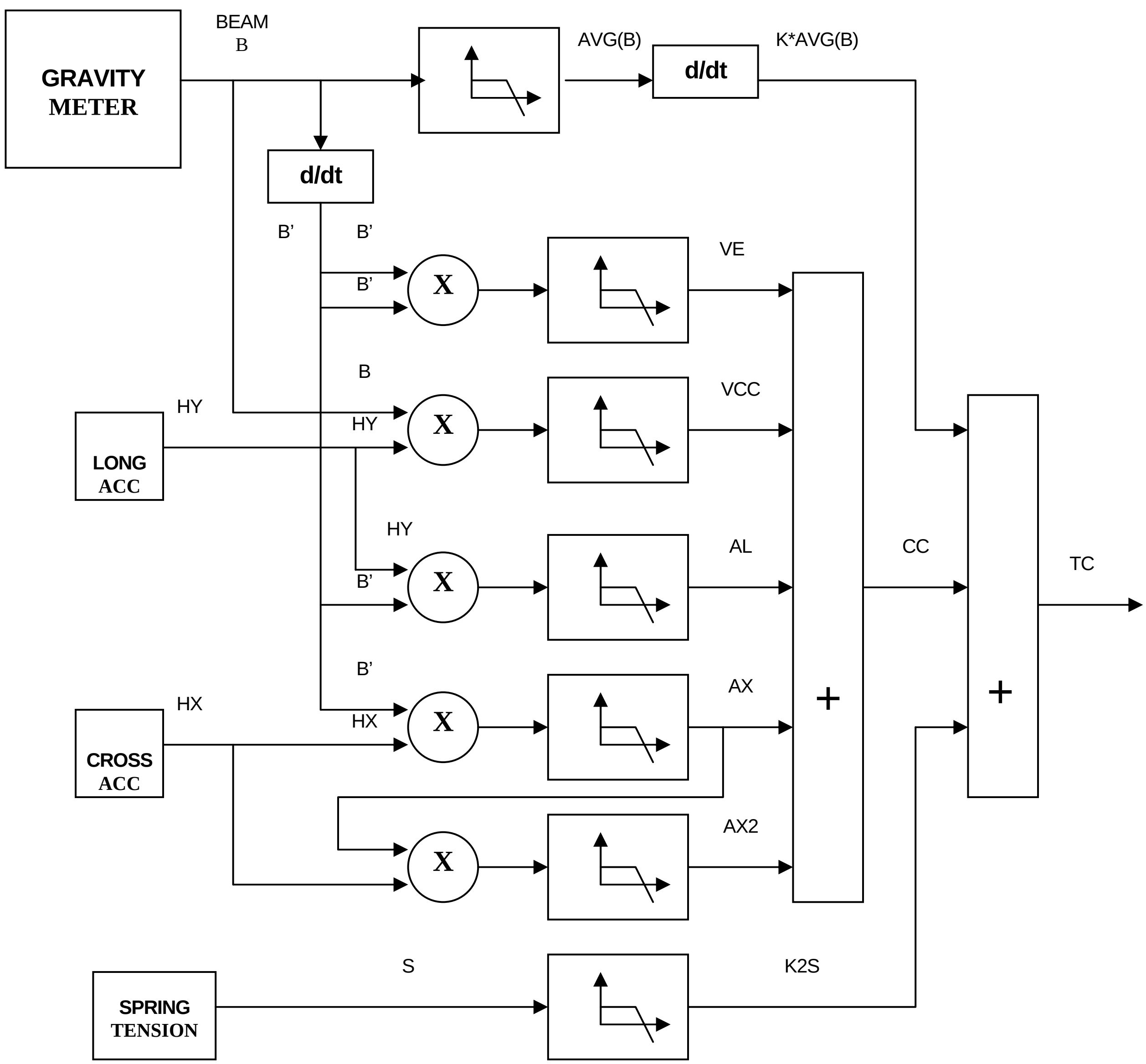
SEALOG QC FILTER

SEALOG records exactly what is sent out by the MAIN PROGRAM, with no extra filtering.

The only data that is affected by SEALOG QC FILTER is what is plotted on the screen of the laptop computer.

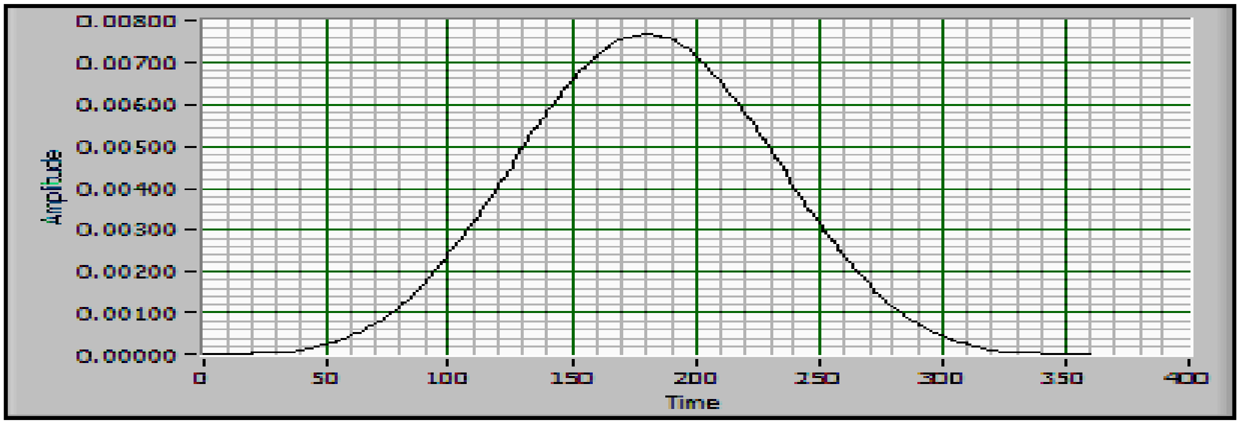
If SEALOG QC FILTER and MAIN QC FILTER are both set the same, the plots on both screens should then appear the same.

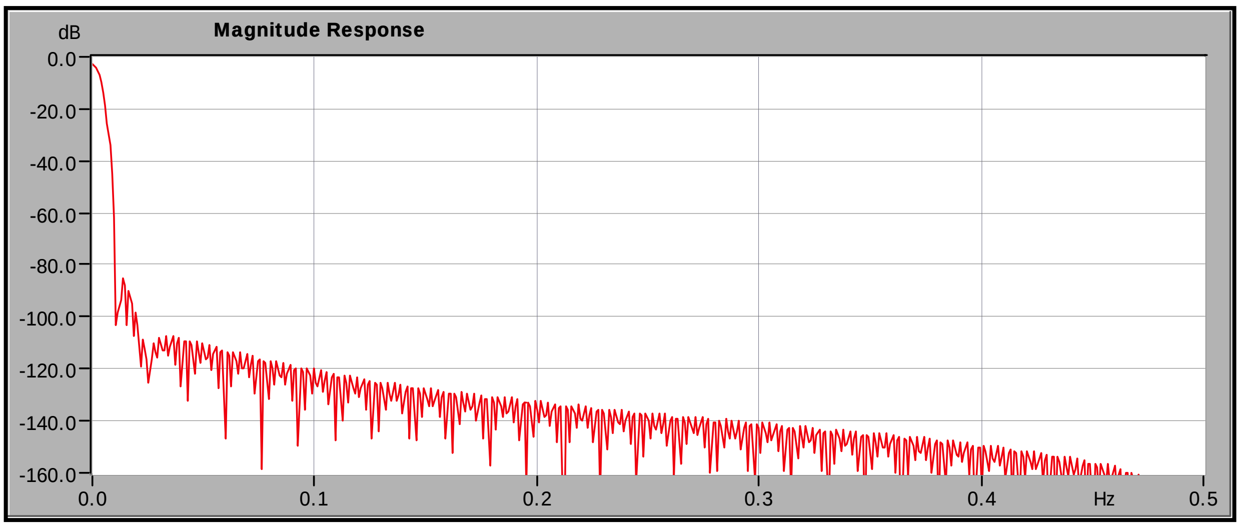
10.2 GRAVITY CALCULATION



10.3 QC FILTER – EXACT BLACKMAN WINDOW

The QC Filter is a Low-pass FIR Filter with an Exact Blackman Window. The default setting for the filter is "3-minute" (180 seconds), which actually has 361 coefficients that are applied to 6 minutes of data. You can set another value, i.e. 240 seconds, using the QC Filter Pull-Down Menu.





10.4 FILTER DELAY

Some users will re-compute gravity from the raw (1-sec) Spring Tension, Beam Velocity and Cross Coupling values, and use their own filtering procedures. However, if you use the filtered "QC Gravity (in CU)" values recorded by Air-Sea II software, you must consider the delay of the applied FIR filter. The time delay of the "3-minute" (180-second setting) FIR filter is 3 minutes.

For example, if surveying a test grid to determine crossing point repeatability, you would first determine the "crossing point time" for both intersecting lines. Then extract the data points from the file at time = crossing point time + 3 minutes, and apply Eotvos correction.

10.5 RECOMPUTING GRAVITY FROM RAW DATA

Gravity(cu)=((Beam(k-1)-Beam(k))*BEAM_SCALE+ST+CC

Where

Gravity(cu)= Gravity in meter counter units

With

CC=VE_Coeff*VE+VCC_Coeff*VCC+AX_Coeff*AX+AL_Coeff*AL+AX2_Coeff*AX2

Note that the BEAM_SCALE is read from the XXX.ENV file.

This BEAM scale is automatically set by the meter to adjust to different output data rates. That means if data output serial data rate from 1 to 0.1 samples/sec the BEAM_SCALE factor is automatically set to the correct value so ((Beam(k-1)-Beam(k))*BEAM_SCALE equals gravity in CU.

All the needed variables and constants are located in the two files xxx.dat and xxx.env

Var name in formula	**Var name in file**	**File type**
Beam	Beam	xxx.dat
BEAM_SCALE	Digital K	xxx.env
VE	VE	xxx.dat
VE_Coeff	VE coefficient	xxx.env
VCC	VCC	xxx.dat
VCC_Coeff	VCC coefficient	xxx.env
AX	AX	xxx.dat
AX_Coeff	AX coefficient	xxx.env
AL	AL	xxx.dat
AL_Coeff	AL coefficient	xxx.env
AX2	AX2	xxx.dat
AX2_Coeff	AX2 Coeff	xxx.env

10.6 SCALING DATA TO MILLIGALS

Although the ASII Software Main Screen shows QC Gravity in mGals, ALL recorded data remain in CU (Counter Units).

New Meters with Single Coefficient:

in this case the table will look like:

The data must be scaled to mGals by applying the "meter factor", which is the "Coef1" specified in the Hardware Configuration File (ASII_hw.ini).

```
[Meter_Table]
Coef0=0
Coef1=0.9978
Coef2=0
Coef3=0
```

Older Meters with Calibration Tables:

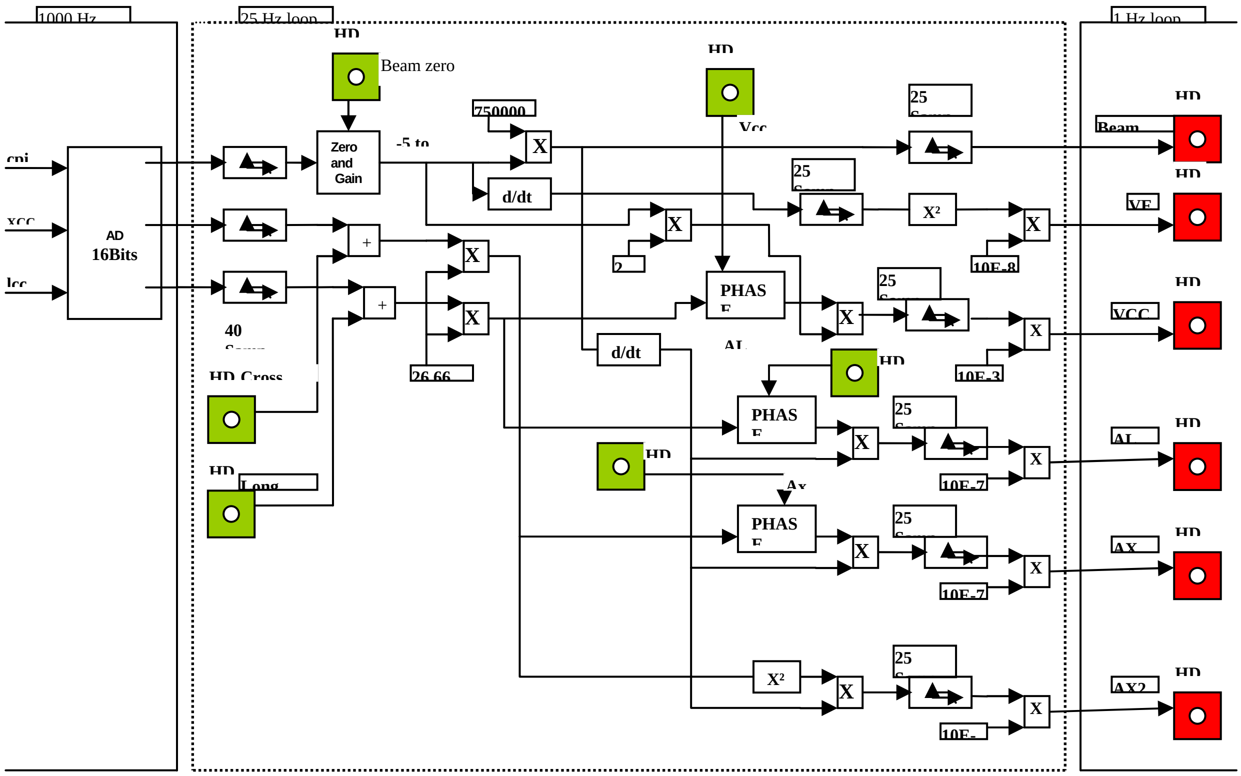
These calibration tables have been fitted using a 3rd-order polynomial.

```
[Meter_Table]
Coef0=1.19765809
Coef1=1.01159477
Coef2=4.96327378e-7
Coef3=-1.90807205e-11
```

The formula to obtain Spring Tension in mGal from Spring Tension in CU:

ST(mGal)=Coef0+Coef1*ST+Coef2*ST^2+Coef3*ST^3

10.7 COMPUTATION OF MONITORS



The phase shift blocks are calculated as:

$$OUT = VE\_PHASE \cdot (IN - OUT(k-1)) + OUT(k-1)$$

The z transform of the phase shift block will be

$$T(z) = \frac{VE\_PHASE}{1 + (VE\_PHASE - 1) \cdot z^{-1}}$$

Numerical calculation of the monitors

The three input signals are:

Beam Position:

The CPI voltage sampled at 1 KHz filtered with a 40-sample running average filter. The computer represents the beam position with a number in the range (-5 to 5). This value is found after the block Bean zero and Gain in the block diagram.

Xcc:

The Cross Accelerometer voltage sampled at 1 KHz filtered with a 40-sample running average filter. The computer represents the beam position with a number in the range (-10 to 10).

Lcc:

The Long Accelerometer voltage sampled at 1 KHz filtered with a 40-sample running average filter. The computer represents the beam position with a number in the range (-10 to 10).

$$Beam\_1Hz = 25RAVG[750000 \cdot Beam]$$

$$VE = 10^{-8}\left[25RAVG\left[\frac{dBeam}{dt}\right]\right]^2$$

$$VCC = 10^{-3} \cdot 25RAVG[(2.5 \cdot Beam) \cdot Phase\_shift(26.66 \cdot 10^3 \cdot Lcc)]$$

$$AL = 10^{-7} \cdot 25RAVG\left[750000 \cdot \frac{dBeam}{dt} \cdot Phase\_shift(26.66 \cdot 10^3 \cdot Lcc)\right]$$

$$AX = 10^{-7} \cdot 25RAVG\left[750000 \cdot \frac{dBeam}{dt} \cdot Phase\_shift(26.66 \cdot 10^3 \cdot Xcc)\right]$$

$$AX = 10^{-12} \cdot 25RAVG\left[750000 \cdot \frac{dBeam}{dt} \cdot (26.66 \cdot 10^3 \cdot Xcc)^2\right]$$

11 SERVICE

11.1 FACTORY SERVICE

Micro-g LaCoste recommend that the Air-Sea meter be returned to our factory for periodic testing and servicing.

The meter should be serviced every 5 to 8 years depending upon use.

The “GENERAL SERVICE” includes the following procedures:

Sensor:	Clean and adjust Measuring Screw
	Overhaul Gearbox
	Replace Seals
	Adjust Sensor for Optimum Performance
	Leak Test, fill with Dry Nitrogen
Platform:	Replace Torque Motor Bearings
	Service Oil Shock Absorbers
	Service Oil Shock Absorber Mounts
	Replace Upper and Lower Shock Cords
System:	Complete Testing and Adjusting

11.2 FACTORY TRAINING

A three-day factory training program is available to customers.

The program includes:

DAY 1:	ORIENTATION
	IDENTIFICATION OF SYSTEM COMPONENTS
	Air-Sea System II SOFTWARE MENUS
	BEAM ZERO AND GAIN ADJUSTMENT
DAY 2:	COMPLETE DISASSEMBLY (READY FOR SHIPPING)
	RE-ASSEMBLY
	TESTING AFTER RE-ASSEMBLY
	INSTALLATION AND OPERATION
	DOWNLOADING DATA
	GYRO REPLACEMENT
	TROUBLESHOOTING
DAY 3:	DATA PROCESSING INTRODUCTION
	QUALITY CONTROL
	OTHER SPECIAL TOPICS

11.3 FIELD SERVICE

As always, troubleshooting requires careful observation of the symptoms, and an understanding of the system function to determine which part has failed, or which device is out of adjustment. Swapping parts is the most obvious technique, but sometimes the process of changing components can cause additional problems.

If you are not confident about diagnosis of the problem, contact Micro-g LaCoste for advice. Be prepared to give a clear description of the symptoms.

Remember, the most difficult problems are often caused by connectors. Check that every connector is screwed or locked into place, and no cables are cut or pinched.

11.3.1 RECOMMENDED SPARE PARTS KIT

SPARE CONTROL MODULE

SPARE POWER MODULE

SPARE GYRO (optional)

SPARE SHOCK CORDS

MOLDED CASE for SPARE PARTS

11.3.2 INSTALLING SPARE POWER MODULE

DISCONNECT POWER BEFORE SWAPPING MODULES!!

After the module is replaced, the Beam Zero/Gain adjustment should be performed, followed by a K-Check procedure.

If you experience any problem with clamping, it may be because the 5V supply is not producing exactly the same voltage as the other power module. This voltage is applied across a potentiometer used to indicate the position of the arrestment shaft. Refer to the software utility “CLAMP-UNCLAMP MOTOR POSITION UTILITY” for more details.

11.3.3 INSTALLING SPARE CONTROL MODULE

DISCONNECT POWER BEFORE SWAPPING MODULES!!

When the new module is in place, you must re-synchronize the Spring Tension Counter.

After the module is replaced, the Beam Zero/Gain adjustment should be performed, followed by a K-Check procedure.

11.3.4 INSTALLING SPARE FIBER OPTIC GYRO (FOG)

11.3.4.1 SINGLE AXIS FOG

Simply remove the problem FOG and install the spare unit. The arrow on the cover of the gyro indicates the AXIS of ROTATION that the gyro is sensitive to. The arrow should point towards the OUTSIDE of the gravity meter sensor box.

At first, align the FOG parallel to the edge of the gravity meter, and tighten the four screws. The elongated screw holes on the FOG allow a small amount of rotation of the FOG; the alignment procedure is as follows.

Cross Gyro Alignment: Switch OFF the LONG torque motor with the Torque Motor Control Checkbox (located under "Configuration" – "Platform" pull-down menu).

Tilt the sensor by hand in the long direction. The tilting motion should be slow and even. Observe the cross level bubble as the platform is being tilted. The bubble should remain level throughout the range of motion of the long axis. If not, the gyro should be rotated to a position that minimizes the motion of the cross level bubble with the long tilt. This may require several attempts. Be patient and do not rush the tilting procedure.

Facing the front of the platform, the cross bubble level will be in front of you. As you tilt the platform towards you (the front), the bubble will move to the left or right. The cross gyro now needs to be rotated a very small amount (less than one degree). Loosen the screws holding the gyro to the lid. Rotate the gyro in the same direction that the bubble moved, and retighten the screws.

Long Gyro Alignment: Repeat the procedure tilting the meter about the cross axis. Switch the long torque motor ON and the cross torque motor OFF. Face the side of the meter with the long bubble level closest to you. From this position, tilt the platform towards you, again observing if the bubble moves towards the left or right. Again, a small rotation of the gyro in the same direction the bubble moved should bring it closer to being aligned.

NOTE: Aligning the cross gyro in port may be difficult because of the roll of the ship at dockside. One solution is to rotate the stable platform 90° to perform the cross gyro alignment.

12 TRANSPORTATION

12.1 PACKING

- Disconnect all AC Power at BOTH the Power Module and UPS/Power Conditioner.
- Check by hand that Sensor is CLAMPED!
- Remove Sensor from the Bucket with three hex-head bolts underneath the Bucket. Pack in Sensor Box with 5-6 inches foam on all sides.
- Remove Oil Shock Absorbers, wrap in plastic bag to contain any oil leakage, and tape to inner leg of Frame (with tops UP!).
- Disconnect P1, P100, and P200 cables. Protect connectors with bubble-pack.
- Disconnect Monitor, Keyboard, and Mouse from Control Module.
- Remove Power and Control Modules from Frame.
- Remove Platform from Frame. **DO NOT** Clamp Bucket to Platform with "TEST ONLY" Clamps. Pack in Platform Box or Platform-Frame Case.
- Remove UPS (with base plate) from Frame. Pack in UPS Box.
- Pack Frame in Frame Box or Platform-Frame Case.
- Bubble-wrap Modules and Accessories and pack inside Frame Box or UPS Case.

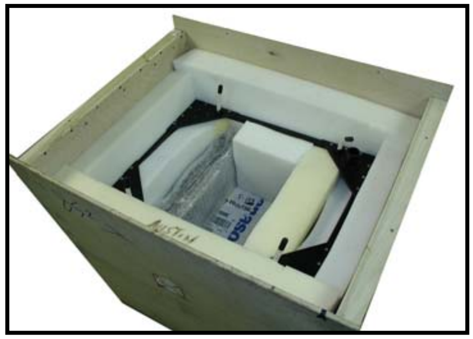
12.2 WOOD SHIPPING CRATES

Wood Shipping Crates are standard for packing the Air-Sea System II. This is suitable for users who will permanently install the gravity meter on a ship, and do not plan to move the meter frequently. The wood crates should be kept, in case the meter has to return to the factory for service.

12.2.1 SENSOR BOX

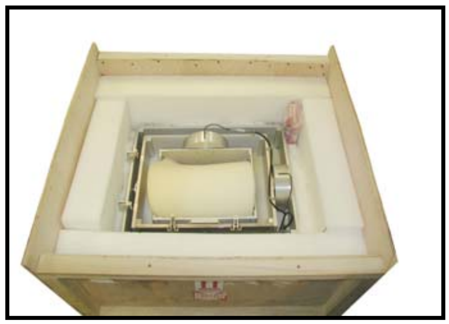
At least 8 inches of foam on ALL sides of the sensor is recommended. In this picture, the foam has been cut to leave room for the Auxiliary Power Supply. This allows quick start of putting sensor on heat as soon as this box is opened at the destination.

12.2.2 FRAME BOX



There is room in the Frame Box for the Power/Control Modules and various accessories. The UPS and base frame may also be shipped attached to the frame.

12.2.3 PLATFORM BOX



The Platform (Gimbal) is quite heavy, yet must be packed carefully to avoid damage to the torque motor bearings.

12.2.4 UPS BOX

The UPS is also heavy, so may be shipped in its own box.

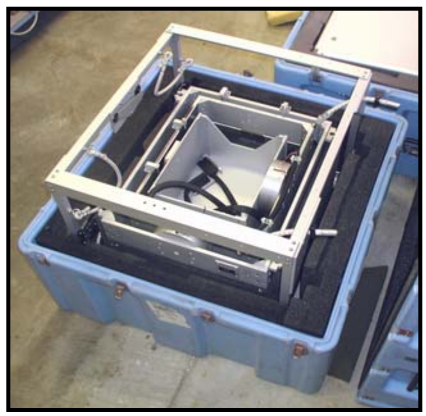
12.3 SHIPPING CASES

Molded Polyethylene Resin Shipping Cases are available as an option. These are a good choice if the system will be transported frequently, i.e. for contractors/researchers who utilize various aircraft or ships.

12.3.1 SENSOR CASE

12.3.2 FRAME-PLATFORM CASE

There are two variations of this case; both contain the Frame and Platform together in one case.



The first style has hard foam in the bottom half which fits the Platform. The Frame is turned on its side and dropped in around the platform.

The second style keeps the Platform installed in the Frame, and the Frame is packed upright. Hard foam supports in the bottom protect the Platform torque motors.

12.3.3 UPS/ACCESSORIES CASE

The UPS with Base-plate fits into this case. There is additional room for accessories.

13 FACTORY TESTS

This chapter contains information which we hope is of interest, but is NOT intended to give instructions sufficient for the user to perform or interpret the tests!

13.1 SENSOR TESTS

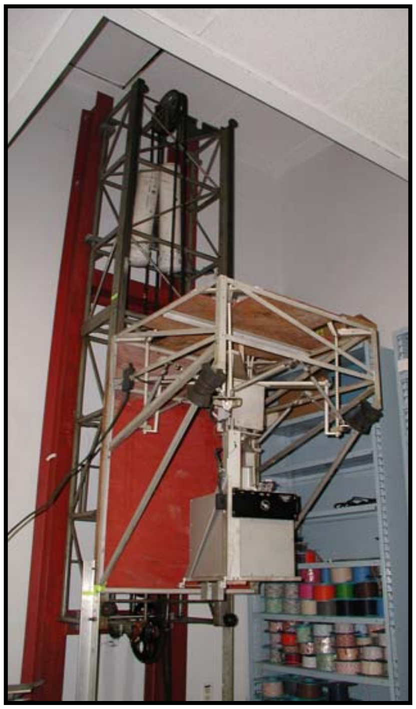
13.1.1 CROSS COUPLING TEST

The sensor is placed on a special motion table which produces a ±50K mGal "Ramp" motion which produces a strong cross-coupling effect. The dampers are adjusted until the observed CC is <10 CU in both the Long and Cross direction.

<u>Example:</u>	AL:	Difference = +2.0 CU
	AX:	Difference = +7.5 CU

Note that these are RAW cross coupling effects before correction in software, and do NOT represent the error that would be in the final data under such accelerations at sea.

13.1.2 VERTICAL ERROR TEST



The Vertical Motion machine is used to produce vertical accelerations for testing the sensor. For example, 48 inches of vertical motion at 0.2 Hz produces ±96K mGal.

The Vertical Error ("VE") test measures sensor error due to these vertical accelerations. VE is first measured at ±50K mGal acceleration with only the top damper installed. The sensor is then tested with both dampers installed at ±100K mGal acceleration.

The dampers are adjusted so that VE < 4 CU. Note that these are RAW VE effects before correction in software, and do NOT represent the error that would be in the final data under such accelerations at sea.

13.1.3 DRAG TEST

If the gravity meter dampers touch each other anywhere over the range of Beam motion, this is referred to as a "DRAG". The "Drag Test" verifies that the dampers do not interfere with each other from the Bottom Stop (-50 ED) to the Top Stop (+ 50 ED).

The test is performed by moving the Beam to the bottom stop, and then adding 5 mGal to the Spring Tension. The slight imbalance will cause the Beam to move from the Bottom Stop to Top Stop over a period of 10-15 hours. The test is then reversed from Top to Bottom stop.

The "Beam Recorder" is a computer test station used to monitor and plot the Beam Velocity in CU during the Drag Test. If there is a drag, it will be apparent as a change in Beam Velocity on the Beam Recorder plot. If a drag is detected, the dampers are adjusted until the drag is eliminated.

13.1.4 TILT TEST

6000 mGal Tilt Test

90 degree Tilt Test

13.1.5 LEAK TEST

Air-Sea System II sensors are filled with dry nitrogen, and then leak-tested at the factory.

The leak test includes both a **Pressure Test** and **Vacuum Test** at ±5 PSI relative to external pressure (±5 PSI is approximately equal to ±10 inch-Hg).

Sensors typically show leak rates of 0.01-0.02 inch-Hg/day, and must be less than 0.03 inch-Hg/day under both Pressure and Vacuum to pass.

It is important to note that ALL METERS DO LEAK, although at a very slow rate when properly sealed.

13.2 PLATFORM TESTS

13.2.1 PLATFORM GAIN, PERIOD AND DAMPING

Adjust parameters DAMP_X, DAMP_L, PERIOD_X, PERIOD_L, GAIN_X, GAIN_L

13.2.2 PLATFORM HORIZONTAL COMPENSATION

±50K Horizontal Acceleration

±90K Horizontal Acceleration

Determines Parameters COMP_X, COMP_L, PH_COM_X, PH_COM_L

13.2.3 VE TEST

Determines Parameters C_VE

13.2.4 AL/AX TEST

Determines Parameters C_AL, C_AL_PHASE, C_AX, C_AX_PHASE

13.2.5 AX2 TEST

Determines Parameters C_AX2

13.2.6 VCC TEST

Determines Parameters C_VCC, C_VCC_PH

13.3 SYSTEM TESTS

13.3.1 WAVE MOTION TEST

The entire meter is placed on this table, which produces a vertical circular motion of approximately ±50K mGal acceleration.

A Static Reading is obtained first. Then Dynamic Readings are made with the table in circular motion.

The table can rotate, and Dynamic Readings are made in 8 different directions, simulating the effects of wave motion coming from different directions.

		NORTH		
	+0.4	-0.2	0.0	
WEST	+0.9		+0.4	EAST
	+0.4	+0.1	+0.1	
		SOUTH		

The differences between the Dynamic Readings and the Static Reading are then plotted in a “box” as Error in CU.

13.3.2 CALIBRATION

Once the meter has passed all Sensor and Platform tests, it is loaded in a vehicle and driven to the Rocky Mountain Calibration Line outside Denver, Colorado.

This range consists of a large number of precisely known absolute gravity stations. The meter is normally tested at two stations, Golden DA and either RMCL 260 or Echo Lake. These stations provide a range of at least 260 milligals.

Calibration Example:

Rocky Mountain Calibration Line (RMCL)

Bottom Average:	10823.70 CU
Top Average:	10561.80 CU
Observed Difference:	261.90 CU
Known Difference:	260.40 mGal
Calibration Factor:	0.9943 mGal/CU

13.3.3 VIBRATION SENSITIVITY TEST

We present our vibration sensitivity results using a scientifically designed vibration test table and three Micro-g LaCoste Air-Sea gravity meters. The test vibration was applied through the testing table to the base or mounting plate of the meter, thus letting the meter, gimbal, shock cords, and air dampers work as a system. Our testing shows that when vibration is applied to the meter with an amplitude larger than found in aircraft or ships, the resulting change in the gravity reading is insignificant.

We also modeled the theoretical transfer function of the system formed by the meter, gimbal, gimbal suspension, and shock absorbers. The outputs of these models confirm our testing results that noise is highly attenuated by the meter suspension.

Vibration testing tools.

Every meter is tested using our vibration equipment to determine its vibration sensitivity. The shock absorbers' optimum pressure is set individually for each meter. The set of tools comprising our vibration test lab include:

VIBCO Adjustable Vibration Table.

2x ICS 3022-002 accelerometer.

Tektronix TDS 460 Oscilloscope.

National instruments DAQCard-AI-16E50.

Labview data analysis package.

Figure 1 Typical vibration testing setup.

Micro-g LaCoste Sensor Vibration Sensitivity Test.

The purpose is to find and correct any meter with an abnormal sensitivity to vibration in any direction. We are interested in finding at which frequencies the sensor has resonances. The test procedure to perform this test is as follows:

The meter is mounted on the vibration table with the air shocks removed. An accelerometer is located on the base plate. The amplitude of the excitation vibration is recorded. For this test a very large RMS value of excitation is used because we want the vibration transmitted through the low pass system formed by the gimbal and shock cords to be large enough to excite any possible resonances in the sensor itself. A range of frequencies are swept through and the results recorded.

The results are:

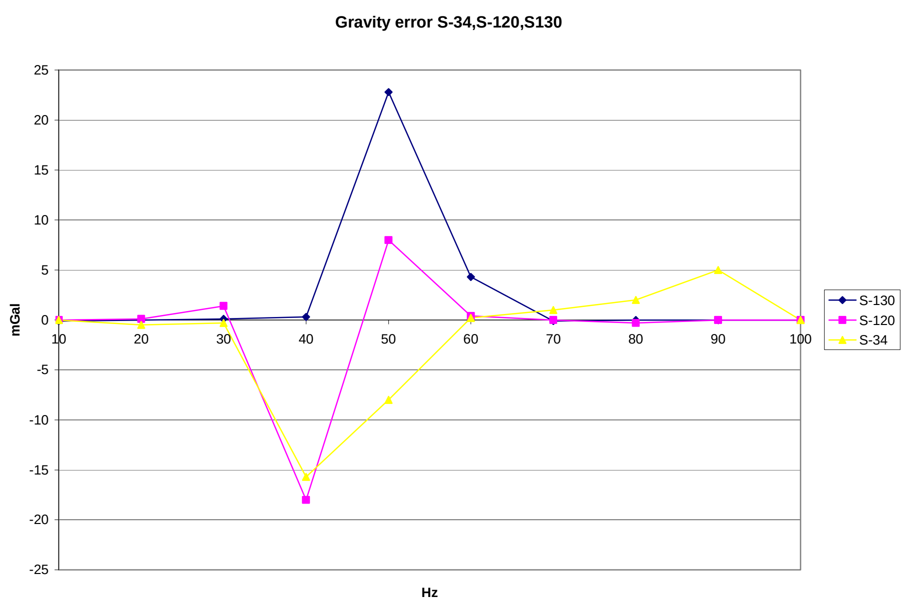
10 to 20 Hz. No significant errors in gravity were found in this range of frequencies for any of the three meters. The applied vibration amplitude was 100 mg (milli-g) RMS.

20 to 60 Hz. We found errors as large as 20mGal at approximately 40 Hz for the worse case and the average error was 17 mGal. The applied vibration amplitude was 200 mg RMS. In this range the meters show their maximum sensitivity to vibrations. We suspect the meter spring has its main resonance in this range. Other possible sources of resonances in this range would be in the screw lever system arms.

60Hz to 100 Hz. In this range smaller errors were found; 5 mGal in the worse case and 0.5 mGal for most of the meters tested. The applied vibration amplitude was 500 mg RMS.

The next figure shows the results for three different meters with the air shock absorbers removed and when vibration larger than is found on planes or boats is applied to the base plate.

Figure 2 Error of gravity reading vs. frequency when applying large vibrations with no air shocks.



Air Shock Mount Optimum Pressure Test.

The shock mounts used below the Micro-g LaCoste meter frame are air filled. The shocks can be pressurized in the range of 0 to 60 psi. Our testing shows there is a correlation between the pressure in these shocks and how well the shock absorber performs in absorbing vibration. The purpose of this test is to find the optimum air pressure for the shock absorbers. The procedure to perform this test is as follows:

The meter is mounted on the vibration table with the air shocks installed. An accelerometer is located on the base plate. Three shock absorber pressures are tested with a range of frequencies and the results recorded.

0 psi. The system behaves as if no air shocks were used (too stiff).

25 to 35 psi. The performance of the air shocks is optimum and negligible errors are obtained.

50 psi. The performance of the air shocks degrades and an error of up to 5mGal may appear (too stiff again).

The next figure shows the error in gravity at different frequencies for three different pressures on the shocks for meter S-130. Results are similar for other meters.

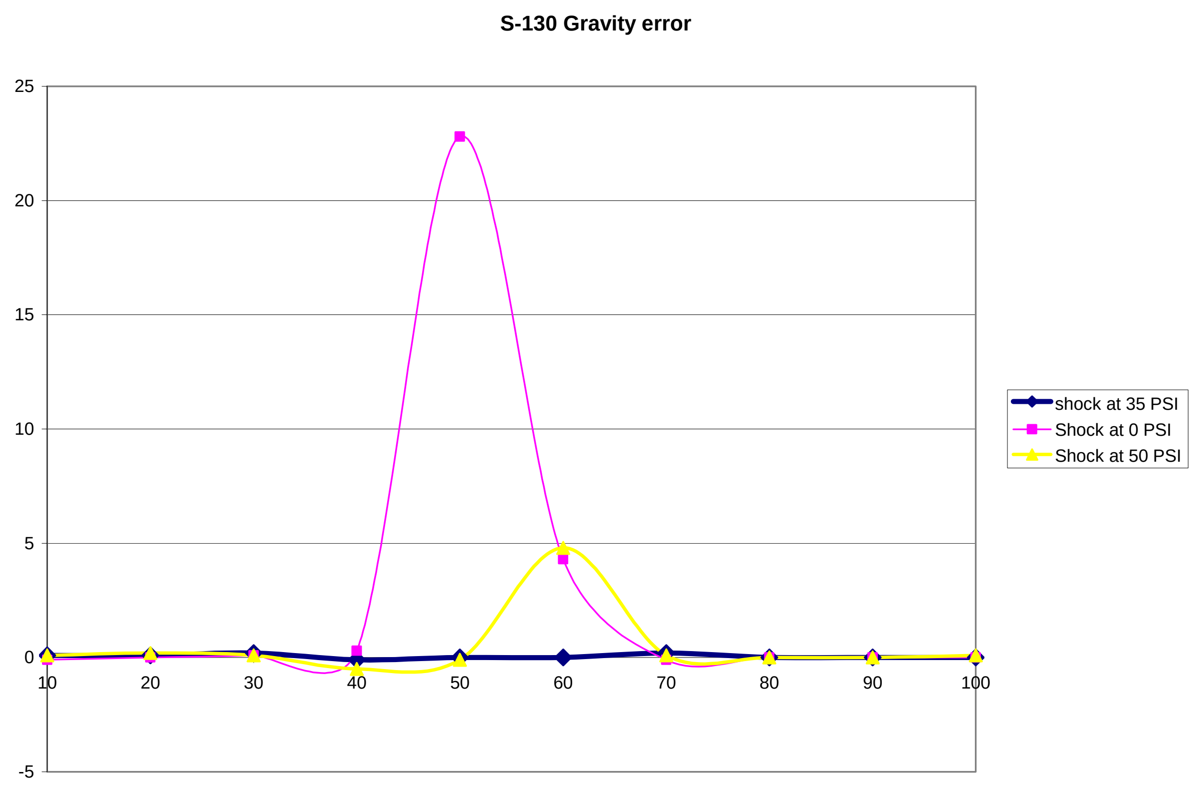


Figure 3 Gravity errors at different pressures and frequencies.

Every new meter or serviced meter is tested and a optimum shock pressure found. Once the optimum pressure is known a label is applied to the meter frame with the optimum range of pressures. Note that the vibrations applied during the test have amplitudes larger than would normally be found in real surveys.

Results with optimized air shock absorbers.

The meter is tested again on the vibration table with the same level of vibration as before but with the shock absorbers installed. The next figure shows a plot of the error obtained at different frequencies:

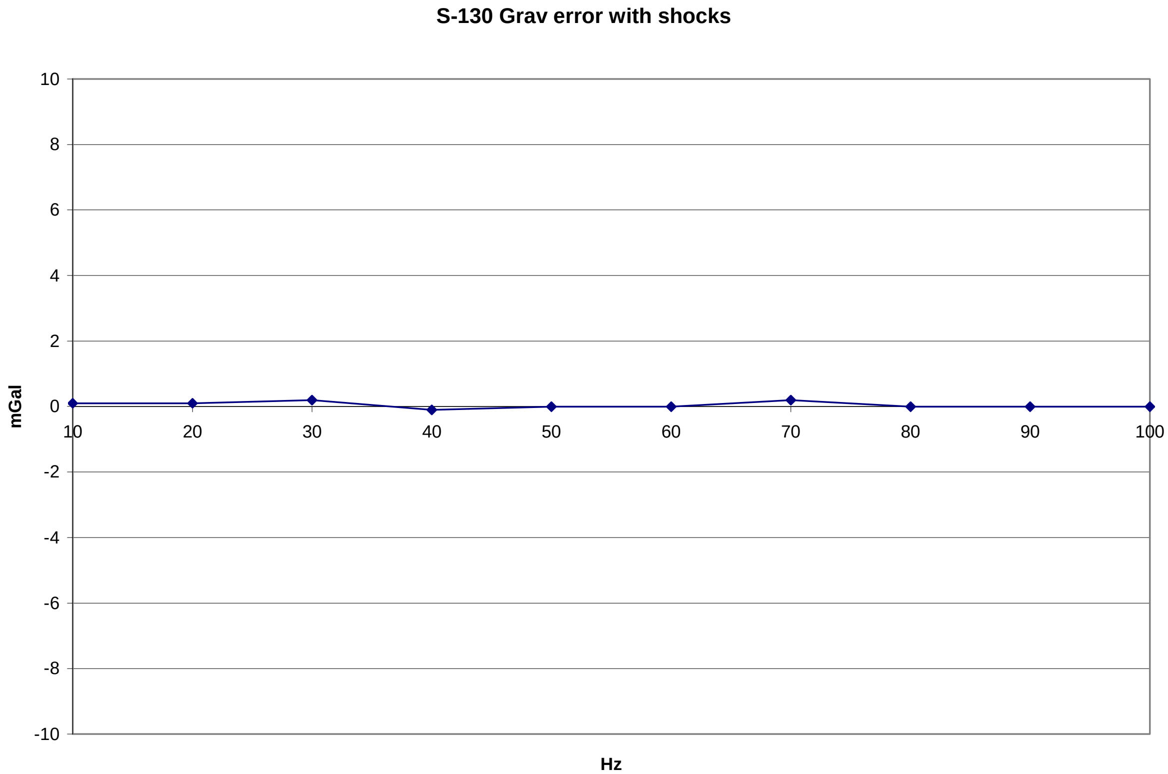


Figure 4 Gravity error when optimized air shocks are used .

Micro-g LaCoste Air – Sea meter suspension model:

The inner suspension model.

The Micro-g LaCoste meter gimbal to frame suspension can be modeled as a single degree of freedom spring, mass, and damper system.

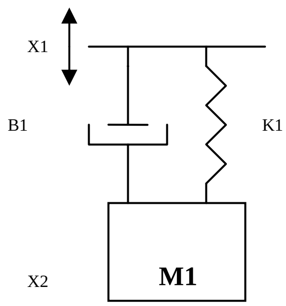


Fig1 Single degree of freedom gimbal suspension equivalent model

Approximate measured values for the L& R meter :

M1=57.6 Kg (mass of gimbal plus sensor)

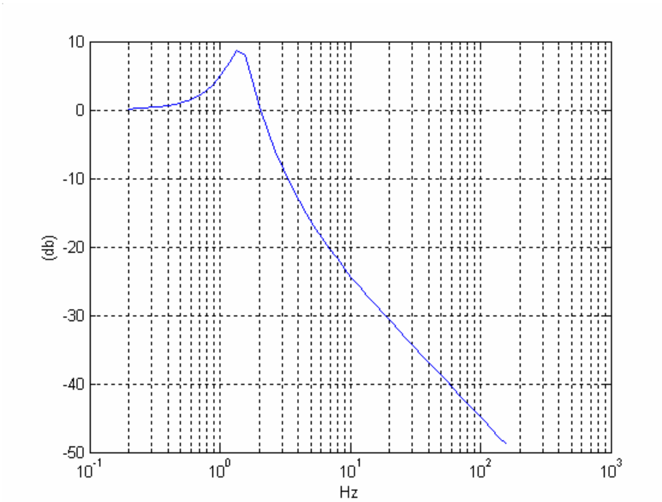
K1=4826.4 N/m

B1=206 N Sec/m

The model of figure 1 has can be represented by the next transference function:

$$\frac{X_2(s)}{X_1(s)} = \frac{\frac{B}{M1}\cdot S + \frac{K1}{M1}}{S^2 + \frac{B1}{M1}S + \frac{K1}{M1}} = \frac{3.576\cdot S + 83.79}{S^2 + 3.576\cdot S + 83.79}$$

Figure 2 Transfer function of the Micro-g LaCoste suspension



The air shock absorbers (outer suspension model)

The current air shock absorbers present a transmissibility response shown in the next figure

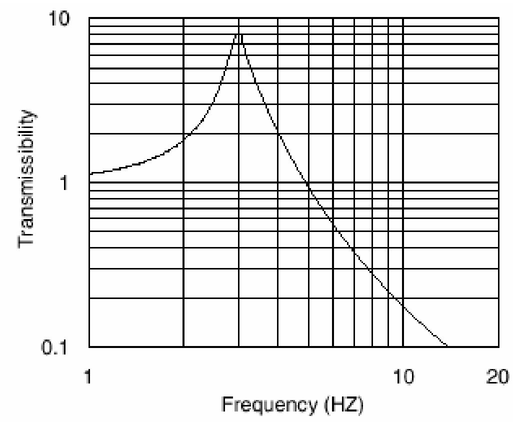


Figure 3 Transmissibility of the shock absorber at is nominal load

The Transmissibility function of the system of the frame and shock absorber can be modeled as

$$\frac{X_3}{X_2} = \frac{5.345 \cdot S + 355.3}{S^2 + 5.345 \cdot S + 355.3}$$

Transfer function of full system.

The total transfer function from base plate to sensor can be modeled as

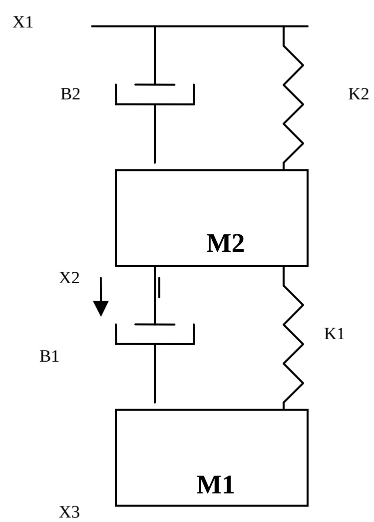


Fig 4. Block diagram of the gimbal plus shocks

For the outer (second) stage:

K2=26500 N/m (air shocks)

B2= 1000 N-sec/m

M2=17.23 Kg (mass of frame)

The total transmissibility from base plate to the sensor for vibration applied in the vertical axis of the gravity meter is given by the next transfer function:

$$\frac{X_3}{X_1} = \frac{210.4 \cdot S^2 + 10518.8 \cdot S + 131025}{S^4 + 74.5 \cdot S^3 + 2141.5 \cdot S^2 + 10518.8 \cdot S + 131025.3}$$

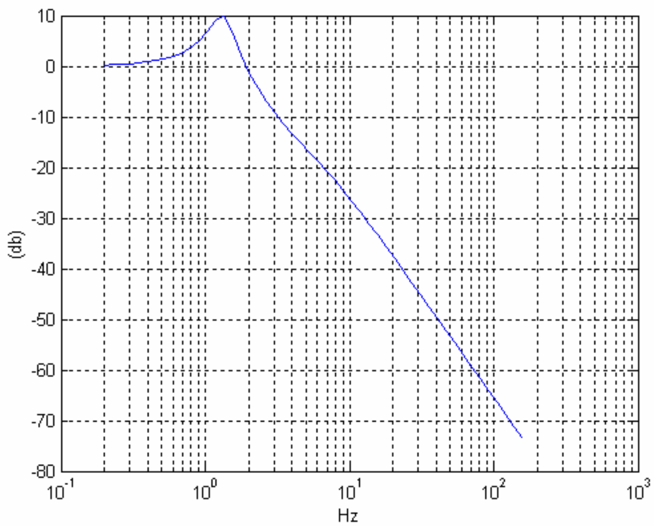


Figure 4. Transmissibility of the signal from base plate to sensor

As we can see, the suspended gimbal plus the shock absorbers form a 4th order low pass filter. This system attenuates vibration in a range from 30 dB to 80 dB at all the frequencies that can affect the meter.

Conclusion

With proper pressure in the air shocks, Micro-g LaCoste Air-Sea gravity meters (air damped) show negligible errors in gravity due to vibration in the 0-100 Hz range at any amplitude reasonably expected in the field. The meter must be treated and used as a system and must be properly set-up in order to obtain the best results. It is possible that a poorly tuned gravimeter can respond with inferior results but this is not a problem if the system is set up correctly. However, our tests make it clear that the Micro-g LaCoste gravity meter systems are an excellent gravity meter for dynamic applications.

13.3.4 FINAL CALIBRATION CHECK

A quick check of the system calibration is done at City Park in Austin, Texas.

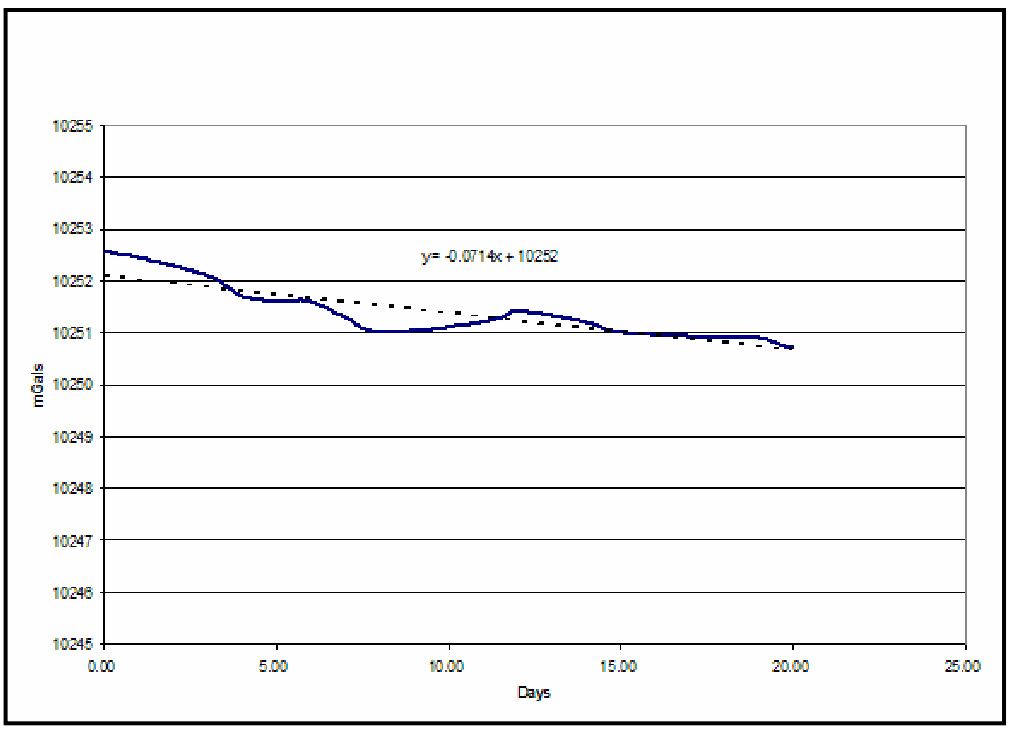
The meter is placed in the back of a van and driven between the top and bottom stations of a known 17.1 mGal test range.

<u>Example:</u>

Bottom Average:	10261.30	CU
Top Average:	10244.22	CU
Observed Difference:	17.08	CU
Known Difference:	17.11	mGal

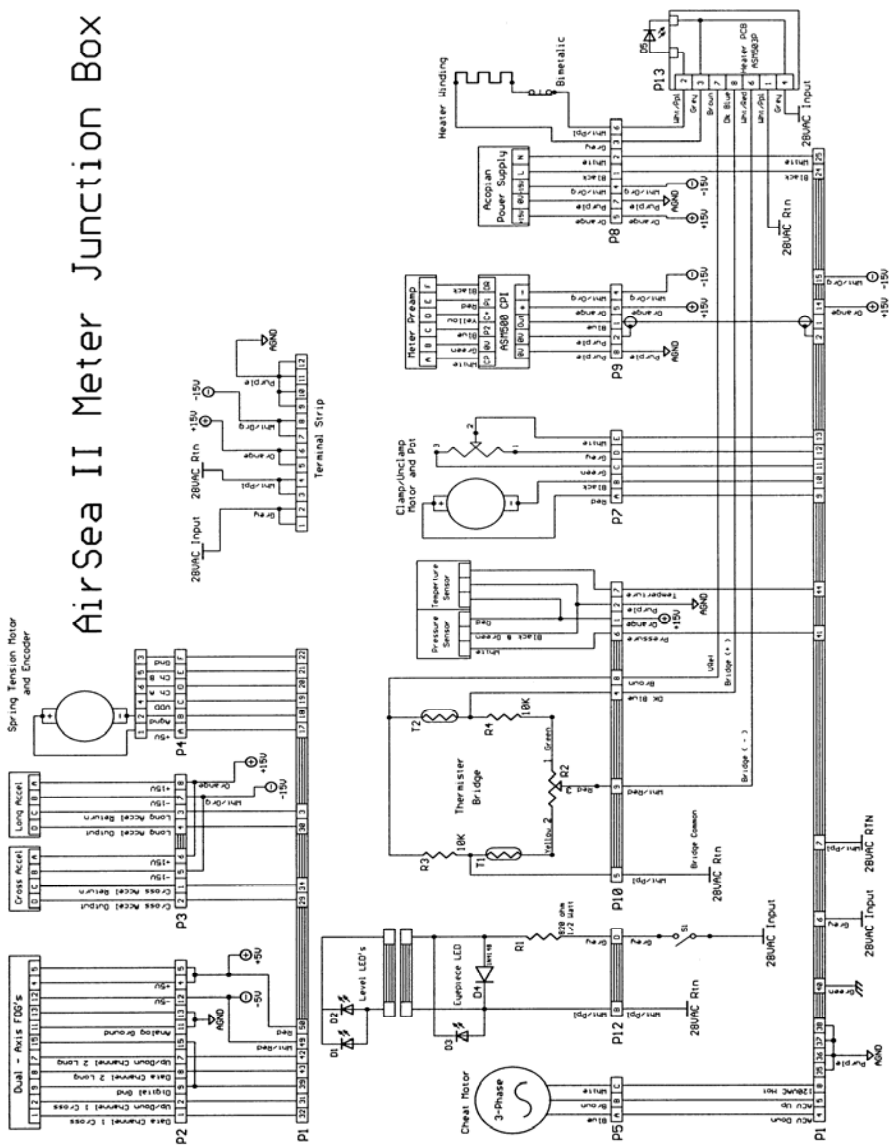
13.3.5 STATIC DRIFT TEST

The meter is monitored to determine the drift rate, which is typically < 3 mGal / month.

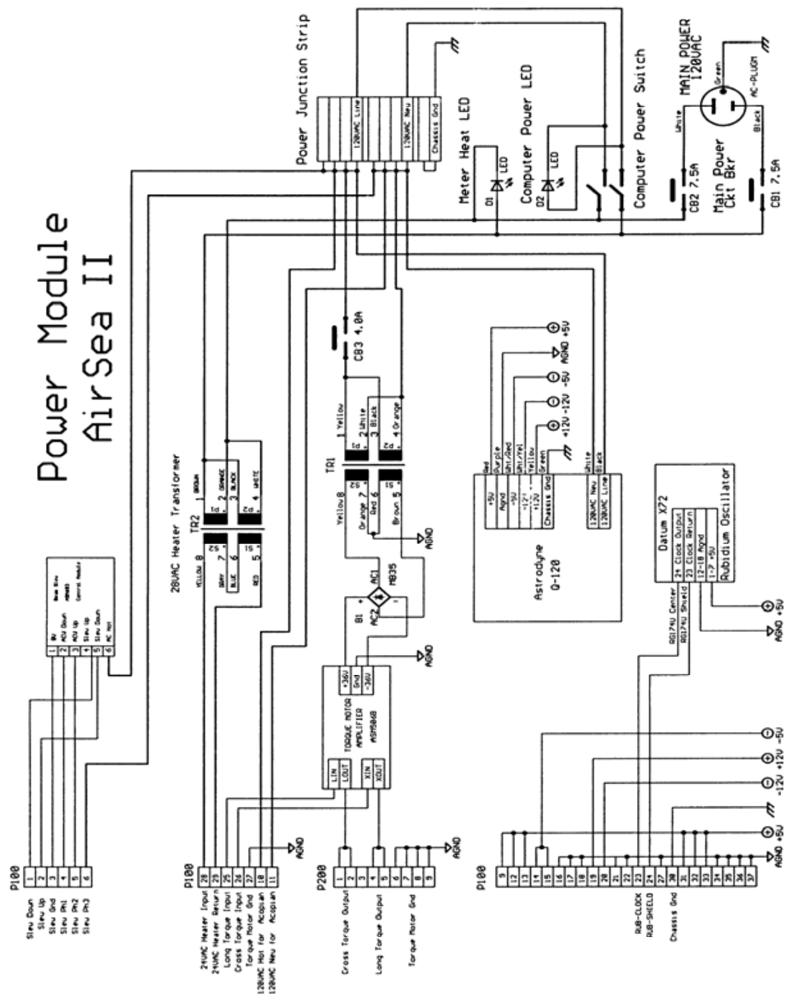


14 WIRING DIAGRAMS

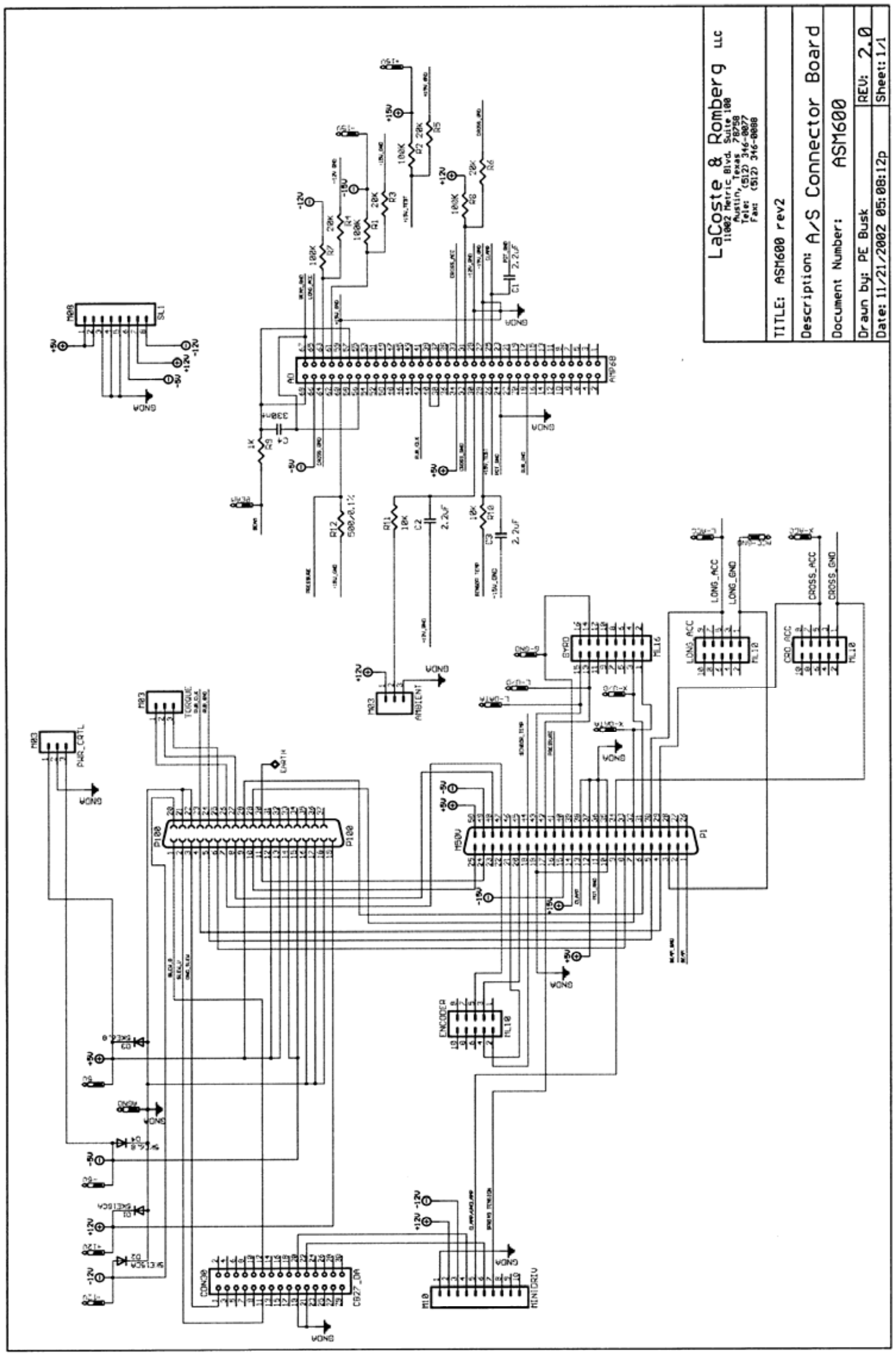
14.1 METER JUNCTION BOX



14.2 POWER MODULE



14.3 CONTROL MODULE CONNECTOR BOARD



15 BIBLIOGRAPHY

15.1 GENERAL GRAVITY and MAGNETICS

Garland, G., 1965, The Earth's Shape and Gravity, Pergamon press

Guion, D., Herring, A., and Ruder, M., 1998, GP601 - Gravity and Magnetics: Field Work, Processing, and Interpretation, 223 pages, part of IHRDC Video Library for Exploration and Production Specialists, ihrdc.com.

Nettleton, L., 1971, Elementary Gravity and Magnetics for Geologists and Seismologists, Society of Exploration Geophysicists, Monograph Series Number 1, 121 pages.

Nettleton, L., 1976, Geophysical Prospecting for Oil, McGraw-Hill.

Torge, W., 1989, Gravimetry, Walter de Gruyter, ISBN 3-11-010702-3

15.2 AIR-SEA GRAVITY METER THEORY

LaCoste, L., 1967, Measurement of Gravity at Sea and in the Air, *Reviews of Geophysics*, v. 5, no. 4, p. 477-526.

LaCoste, L., Clarkson, N., and Hamilton, G., 1967, LaCoste & Romberg Stabilized Platform Shipboard Gravity Meter, *Geophysics*, v. 32, p. 99-109.

LaFehr, T., and Nettleton, L., 1967, Quantitative Evaluation of a Stabilized Platform Shipboard Gravity Meter, *Geophysics*, v. 32, p. 110-118.

LaCoste, L., 1973, Cross Correlation Method for Evaluating and Correcting Shipboard Gravity Data, Geophysics, v. 38, no. 4, p. 701-709.

Valliant, H., and LaCoste, L., 1976, Theory and evaluation of the LaCoste & Romberg three-axis inertial platform for marine gravimetry, *Geophysics*, v. 41, p. 459-467.

Valliant, H., 1983, Field Trials with the LaCoste and Romberg Straight Line Gravimeter, Geophysics, v. 48, p. 606-610.

Valliant, H., 1991, Gravity Meter Calibration at LaCoste & Romberg, *Geophysics*, v. 56, p. 705-711.

Valliant, H., 1992, The LaCoste & Romberg Air/Sea Gravity Meter: An overview, *in Handbook of Geophysical Exploration at Sea*, 2nd Edition, Hydrocarbons: CRC Press, p. 141-176.

15.3 MARINE GRAVITY SURVEYING

Dehlinger, P., 1978, Marine Gravity, 322 pages, Elsevier Publishing, ISBN 0444-41680.

Graterol, V., and Cobos, C., 1994, Gravity and Magnetic Interpretation, Guarumen: Asociacion Mexicana de Geofisicos de Exploracion, A.C., AMGE, 6th Symposium Proceedings.

Hall, M., and Herring, A., 1991, Improved Control System for the LaCoste and Romberg Shipborne Gravity Meter, Expanded Abstracts, 61st Annual SEG convention, p. 622-625.

Herring, A., 1985, Increased resolution of shipborne gravity measurements using GPS, Expanded Abstracts, 55th Annual SEG convention, p. 218-219.

Zumberge, M., Ridgway, J., and Hildebrand, J., 1997, A towed marine gravity meter for near-bottom surveys, Geophysics, v. 62, no. 5, p. 1386-1393.

Yalamanchili, S., and Van Nieuwenhuise, R., 2002, Regional gravity and magnetic data usage for seismic survey planning and the integration of 3-D gravity and seismic data in The Santos and Campos Basins, Brazil, SEG 72nd Ann. Mtg., Expanded Abs., Salt Lake City, Utah.

Van Nieuwenhuise, R., 2000, Oceanic, transitional, and continental crustal boundaries defined by potential fields data with examples from the North Sea, Gulf of Mexico and New Zealand, SEG 70th Ann. Mtg., Calgary, Alberta.

15.4 AIRBORNE GRAVITY SURVEYING

Bell, R., Coackley, B., and Stemp, R., 1991, Airborne Gravimetry from a Small Twin Engine Aircraft over the Long Island Sound, Geophysics, v. 6, no. 9, p. 1486-1493.

Bell, R., Childers, V., Arko, R., Blankenship, D., and Brozena, J., 1999, Airborne gravity and precise positioning for geological applications, JGR, v. 104, no. B7, p. 15281-15292.

Bower, D., Kouba, J., and Beach, R., 1990, The spectrum of GPS measurement errors and the accuracy of airborne gravity measurements, Geophysics, v. 55, no. 8, p. 1101-1104.

Brozena, J., 1984, A Preliminary Analysis of the NRL Airborne Gravimetry System, 1984, Geophysics, v. 49, no. 7, p. 1060-1069.

Brozena, J., and Peters, M., 1988, An Airborne Gravity Study of eastern North Carolina, Geophysics, v. 53, no. 2, p. 245-253.

Brozena, J., Mader, G., and Peters, M., 1989, Interferometric Global Positioning System: Three-dimensional Positioning Source for Airborne Gravimetry, v. 94, p. 12153-12162.

Brozena, J., 1992, The Greenland Aerogeophysics Project: Airborne gravity, topographic, and magnetic mapping of an entire continent, in: O. Colombo (Ed.): From Mars to Greenland, Proc. IAG symposia 110, Vienna 1991, Springer-Verlag, p. 203-214.

Brozena, J., 1991, Airborne Gravimetry, in *Handbook of Geophysical Exploration at Sea*, 2nd Edition, Hard Minerals, ed. Geyer, R., CRC Press.

Childers, V., Bell, R., and Brozena, J., 1999, Airborne gravimetry: An investigation of filtering, Geophysics, v.64, no. 1, p. 61-69.

Gumert, W., 1991, Airborne Gravity Measurements: in *Handbook of Geophysical Exploration at Sea*, 2nd Edition, Hydrocarbons: CRC Press.

Gumert, W., 1997, Aerogravity Surveying System: A Highly Effective Exploration Tool, in: Proceedings of the Workshop on Airborne Geophysics, ed. Colin Reeves, International Institute for Aerospace Survey and Earth Sciences, p. 41-49.

Halpenny, J., and Darbha, D., 1995, Airborne gravity tests over Lake Ontario, Geophysics, v. 60, no. 1, p. 61-65.

Hammer, S., 1983, Airborne gravity is here! , Geophysics, v.48, no. 2, p. 213-223.

Harlan, R.B., 1968, Eotvos Corrections for Airborne Gravimetry, JGR, v. 73, no. 14, p. 4675-4679

Klingele, E., Cocard, M., and Kahle, H-G., 1997, Kinematic GPS as a source for airborne gravity reduction in the airborne gravity survey of Switzerland, *JGR*, v. 102, p. 7705--7715.

Klingele, E., Bagnaschi, L., Halliday, M., Cocard, M., and Kahle, H-G., 1993, Airborne Gravimetric Survey of Switzerland: First Results, Institute of Geodesy and Photogrammetry, IGP-Publication number 226, ISBN 3-906513-59-9, ETH Zurich, Switzerland.

Klingele, E., Cocard, M., Halliday, M., and Kahle, H-G., 1996, Airborne Gravimetric Survey of Switzerland: Swiss Geophysical Commission, Report Number 31, 104 pages.

LaCoste, L., Ford, J., Bowless, R., and Archer, K., 1982, Gravity Measurements in an Airplane Using State-of-the-Art Navigation and Altimetry, Geophysics, v. 47, no. 5, p. 832-838.

Nettleton, L., LaCoste, L., and Harrison, C., 1960, Tests of an Airborne Gravity Meter, Geophysics, v. 25, no. 1, p. 181-202.

Nettleton, L., LaCoste, L., and Glicken, M., 1962, Quantitative Evaluation of Precision of Airborne Gravity Meter, JGR, v. 67, no. 11, p. 4395-4410.

Schwarz, K., and Li, Y., 1996, What can airborne gravimetry contribute to geoid determination? , JGR v. 101, p. 17873-17881.

Swain, C., XXXX, Horizontal acceleration corrections in airborne gravimetry, Geophysics, v. xx, no. xx, p. xxx-xxx

Thompson, L., and LaCoste, L., 1960, Aerial Gravity Measurements, *JGR*, v. 65, no. 1, p. 305-322.

Verdun, J., Bayer, R., Klingele, E., Cocard, M., Geiger, A., and Halliday, M., 2002, Airborne Gravity Measurements over Mountainous Areas by using a LaCoste & Romberg Air-Sea Gravity Meter, *Geophysics*, v. 67, p. 807-816.

Verdun, J., Klingele, E., Bayer, R., Cocard, M., Geiger, A., and Kahle, H., 2002, The alpine Swiss-French airborne gravity survey, Geophysical Journal International, v. 151, p. 1-12.

Washcalus, G., Kratochwill, J., and Gumert, W., 1991, Precise Airborne Gravity Measurements For Geophysical Exploration, Institute of Navigation and Exploration, 4th annual meeting, Williamsburg, VA., 25 pages.

Wilson, W., Van Nieuwenhuise, R., Steuer, M., and Ojeda, G., 1996, Identifying Structural Styles in Colombia, AAPG Annual Convention, San Diego, Calif.