

CHARLES STARK DRAPER LABORATORY

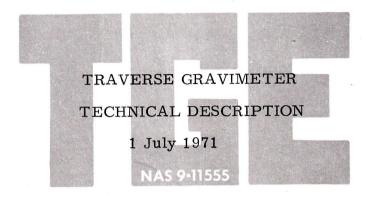
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PRELIMINARY



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PRELIMINARY

ERRATA SHEET

The following errors to this technical description should be corrected as stated:

LOCATION	CHANG	E
	From	То
page 2.2, last sentence	handles	handle
page 2.3, Figure 2-1	9.50 (REF) 10.25	9.00 (REF) 9.75
page 4.3, step 5	travers	traverse
page 4.5, step 4	paragraph 4.4	paragraph 4.3
page 5.3, last para., line 4	mods	mode
page 5.3, last para., line 6	diredtly	directly
page 5.6, last para., line 3	signal	signals
page 5.7, line 4	comparatpr	comparator
page 5.7, 3rd para., last line	immersion	inversion
page 5.10, line 9	detectro	detector

PREFACE

This document has been prepared to provide general information relative to the configuration and design concepts and operation of the Traverse Gravimeter as of 1 July 1971. The material contained herein is identified as "preliminary" and is intended to serve the prime function of providing information for potential Critical Design Review (CDR) attendees.

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SECTION 1

INTRODUCTION

1.1 TRAVERSE GRAVIMETER EXPERIMENT

The purpose of the Traverse Gravimeter Experiment (TGE) is to measure gravity at various points on the lunar surface to obtain a gravity profile. The profile will be used to reveal subsurface information related to ridges, mascons, craters, rills, scarps, thickness variations in the regoliths and lava flows, and density variations in the basement and maria highland borders. The gravity measurements will be made at predetermined stops along the route of a Lunar Rover Vehicle. Results of each measurement will be displayed to the Astronaut who will, in turn, transfer the measurement to earth by way of voice communication.

1.2 MISSION REQUIREMENTS

The Traverse Gravimeter (TG) is self-contained, light weight and essentially automatic in operation. Power is supplied by an internal 7.5 volt battery and there are no requirements for external power, recording devices or telemetry.

The TG will be transported to the lunar surface on the Lunar Module (LM) descent stage of Apollo 17. After LM landing the TG will be deployed on the lunar surface and initial measurements will be made in the vicinity of the LM. The TG will then be placed on the Lunar Rover Vehicle (LRV) and gravitational measurements will be made at various stations where the LRV is stopped for geological examinations. The TG will then either remain on the LRV or be removed to the lunar surface where a gravitational measurement will be initiated by the Astronaut. Upon initiation, the TG will automatically level, make a gravity measurement and be prepared to display this to the Astronaut. Additional information about the status of the TG temperature will also be available for display to the Astronaut.

SECTION 2

PHYSICAL DESCRIPTION

2.1 GENERAL SPECIFICATIONS

Table 2.1 lists general specifications for the TG.

CHARACTERISTIC	DATA
sht.	20.0 inches

TABLE 2.1 TG, GEN	ERAL SPECIFICATIONS
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CHARACTERISTIC	DATA
Height:	20.0 inches
Width:	11.0 inches
Depth:	9.75 inches
Weight:	25 pounds
Number of Controls:	One toggle switch (ON/STBY) and three pushbuttons (BIAS, GRAV and READ)
Number of Displays:	One nine digit numerical display, of which the first seven digits are for GRAVITY/BIAS informa- tion and the last two are for temp- erature
Selectable modes:	Primary:
	ON STBY (standby)
	Secondary:
	GRAV (gravity measuring) BIAS (bias measuring) READ (display)
Automatic submodes:	GRAV mode:
	Normal level Normal measure
	BIAS mode:
	Normal level, bias mode Normal exit, bias mode Bias measure Bias exit

2.2 EXTERIOR CHARACTERISTICS

The TG, shown in Figure 2.1, is enclosed in a multilayered insulating blanket approximately 3/8-inch thick which provides thermal protection for the internal components. The blanket covers all portions of the unit with the exception of the carrying handle and the three feet at the bottom of the unit. A hole is cut in the blanket through which the gravity/bias and temp display can be read.

A heat radiator located at the top of the unit provides the primary means of heat expulsion. The radiator as well as the display panel are protected from the lunar environment by hinged metal covers over each.

There is a folding handle on the top of the TG for hand carrying and for mounting the unit on the Lunar Rover Vehicle. Cam latches on the sides of the handles secure the TG to the LRV when the handles is pressed down toward the rear of the unit.

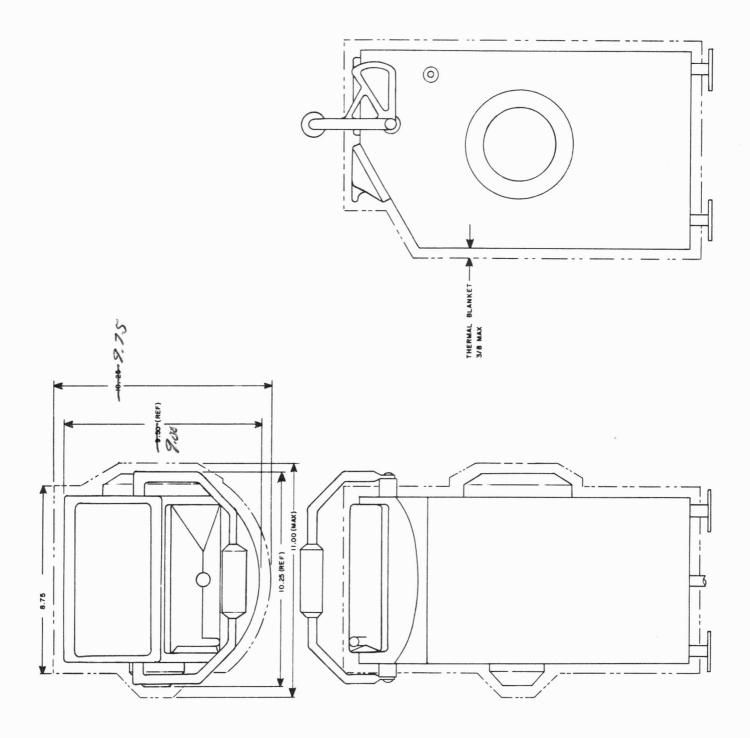


Figure 2-1. Traverse Gravimeter, Outline Drawing

SECTION 3

CONTROLS AND DISPLAYS

3.1 CONTROLS

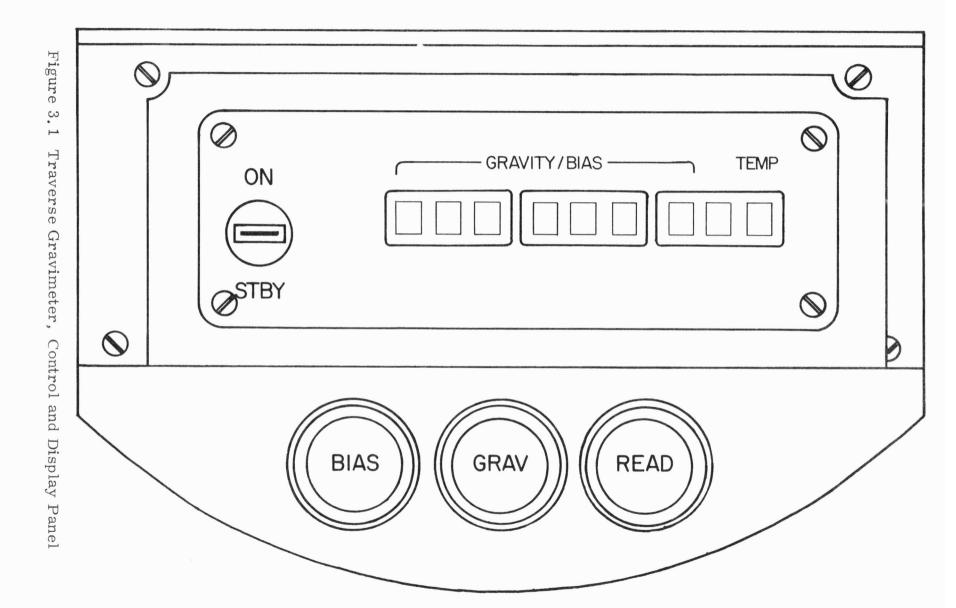
The TG controls, consisting of one toggle switch and three pushbuttons, are shown in Figure 3.1 and described in the following paragraphs.

3.1.1 ON/STBY SWITCH. - This switch applies power to select a standby (STBY) or operate (ON) mode. In the STBY position, used from launch up to TG deployment on the lunar surface, power is supplied only to the oven temperature controls and VSA oscillator-amplifiers to maintain a constant thermal environment for the VSA. With the switch in the ON position, power is also applied to the crystal oscillator and part of the mode control logic to enable operation of the TG.

3.1.2 BIAS PUSHBUTTON. - This control is a momentary contact pushbutton which initiates a bias gravity measurement. When pressed, VSA assembly is automatically inverted 180[°] for the measurement. The VSA assembly is then leveled and a gravity measurement is made. On completion of the measurement cycle, the VSA assembly is returned to its normal orientation automatically.

3.1.3 GRAV PUSHBUTTON. - This control is a momentary contact pushbutton which initiates a gravity measurement. When the switch is pressed, the TG leveling loops go into operation and a gravity measurement is made.

An additional function of the GRAV pushbutton is to work in conjunction with the READ pushbutton to enable a phase lock loop bypass mode of operation. This mode is initiated by depressing the GRAV and READ pushbuttons simultaneously. Conversely, to return to the phase lock mode, both pushbuttons must be pressed simultaneously or the ON/STBY must be toggled.



3.2

3.1.4 READ PUSHBUTTON. - This control is a momentary contact pushbutton which enables the GRAVITY/BIAS and TEMP displays. The enable is only held for fifteen seconds but may be reinitiated by pressing the pushbutton again. As stated in paragraph 3.1.3, an additional function of this switch is to enable the phase lock loop bypass mode.

3.2 DISPLAYS

The TG displays consist of an incandescent indicator located on the TG display panel cover and a nine digit display located on the display panel, under the cover.

3.2.1 LEVEL/MEASURE INDICATOR. - This indicator displays the status of the TG when in the ON mode of operation. The indicator flashes while the TG is levelling and illuminates steadily until a measurement is complete.

3.2.2 GRAVITY/BIAS DISPLAY. - This display indicates a seven digit number which represents the measured lunar gravity value. The display will be active for fifteen seconds each time the READ pushbutton is pressed. The display value will be relayed to earth, via the astronaut, where it will be interpreted. The gravity display will nominally be 870XXXX for a normal gravity measurement and 310XXXX for a bias measurement.

3.2.3 TEMPERATURE DISPLAYS. - The temperature displays consist of the two last (eighth and ninth) digits of the nine digit display. The displays will be activated along with the bias or gravity reading, when the READ pushbutton is pressed.

3.2.3.1 Temperature Alarm Status - This indicator, the eighth digit of the nine digit display, indicates a number from 0 to 7 which represents the status of the VSA temperature alarm. The displayed number is interpreted as follows:

VSA temp. -, No alarm
 VSA temp. +, No alarm

2	VSA temp, Cold alarm
3	VSA temp. +, Cold alarm
4	VSA temp, Hot alarm
5	VSA temp. +, Hot alarm
6	VSA temp, Very hot alarm
7	VSA temp. +, Very hot alarm

3.2.3.2 VSA Temperature. - This indicator, the ninth digit of the display, indicates a number from 0 to 7 which represents deviation of the VSA temperature from normal. The 0 to 7 digits represent .01 to .07 degrees centigrade.

SECTION 4

LUNAR OPERATION

4.1 GENERAL

The two basic modes of operation of the TG are determined by the ON/STBY toggle switch on the display panel. In the standby mode (STBY position), used from launch until lunar traverse, power is supplied only to the oven temperature controls and VSA oscillatoramplifiers, maintaining a constant thermal environment for the VSA. At least 90 seconds before the gravity measurements are to be made, the system is placed in the operate mode (ON position of switch). Power is then supplied to a crystal oscillator and to a small part of the mode control logic.

To initiate a gravity measurement, the GRAV pushbutton is depressed, supplying power to all system elements except the GRAVITY/ BIAS and TEMP displays. The Level/Measure indicator will then flash, indicating that the levelling loops are in operation. When the VSA assembly is within 7 arc minutes of the correct orientation with repsect to gravity, the Level/Measure indicator will illuminate steadily and, after a delay of 15 to 20 seconds, the gravity measurement cycle will begin. If for any reason the instrument goes off level more than 7 arc minutes during the delay before the measurement begins, the levelling and delay will be automatically recycled. Should a loss of phase lock occur during measurement cycle, the three most significant digits of the GRAVITY/BIAS display will be zero when the operator activates the display. The levelling and measurement sequence must then be restarted as described above. If no level disturbance occurs, after about 25 seconds the gravity measurement will be complete. At this time, the system automatically returns to the operate mode. Depressing the READ pushbutton activates the GRAVITY/BIAS and TEMP displays. To conserve power, the displays go off after fifteen seconds, but may be reactivated for fifteen seconds by again depresssing READ.

To initiate a bias measurement, the BIAS pushbutton is depressed. The VSA assembly then is automatically leveled and inverted before the measurement is carried out. On completion of the measurement cycle, the VSA assembly is returned to its normal orientation automatically. The displays are activated as described previously.

Operational procedures for the TG on the lunar surface include: deployment on the lunar surface, installation of the TG on the Lunar Rover Vehicle (LRV), initial gravity and bias measurements in the vicinity of the LM, and lunar traverse operations. The following paragraphs provide step by step procedures for these operations.

4.2 INITIAL DEPLOYMENT

Proceed as follows to remove the pallet containing the TG from the LM, install it on the LRV and place the TG on the lunar surface.

CAUTION

The TG should remain in the quadrant II equipment bay no longer than 16 hours as overheating of the TG circuits may occur.

Step 1. Remove the pallet from the quadrant III equipment bay and install it on the LRV.

<u>Step 2.</u> Remove and dispose of launch latches from the display and radiator covers.

<u>Step 3.</u> Place the ON/STBY switch (located under the TG display panel protective cover) to the ON position.

CAUTION

Ensure that the display panel protective cover is closed.

NOTE

Approximately 90 seconds warm up time should be allowed before continuing to a measurement cycle.

Step 4. Remove TG from flight position on the pallet.

Step 5. Place the TG on the lunar surface, oriented so that it is shaded from the sun until immediately prior to travers.

4.3 INITIAL MEASUREMENTS

Proceed as follows to make the required measurements in the vicinity of the LM:

<u>Step 1.</u> Press the READ pushbutton and lift the display panel protective cover to check the readings of temperature indicators. (It should be noted that the GRAVITY/BIAS display will indicate the last reading taken prior to launch, and not that of a new measurement.)

NOTE

If the temperature alarm display (eighth digit) indicates a hot condition, the TG should be cooled by placing the unit in a shaded area and/or opening the radiator cover located at the top of the unit. Conversely, if the display indicates a cold condition, the TG should be placed in more direct sunlight.

Step 2. Take a bias measurement by performing steps 2a through 2d following:

Step 2a. Press the BIAS pushbutton to initiate the measurement cycle.

<u>Step 2b.</u> Check that the level/measure indicator flashes for between 0 to 10 seconds, indicating that the TG is in a levelling cycle.

NOTE

If the LEVEL indicator remains flashing, the TG base is positioned more than 15° from the horizontal and the levelling loops cannot properly level the VSA assembly. If this is the case, the TG should be realigned.

Step 2c. Check that the MEAS indicator illuminates steadily, indicating that the levelling cycle is complete and the TG is in a measuring cycle.

NOTE

The operator should not touch the TG while the level/measure indicator is illuminated as a vibration may cause the GRAVITY display to output a reading of 000 as the first three digits when the READ pushbutton is pressed.

<u>Step 2d.</u> Press READ pushbutton to initiate display of the bias gravity measurement and the temperature information.

NOTE

If seven zeroes are displayed in the GRAVITY/ BIAS display, the TG base is positioned more than 15° from the horizontal and must be realigned.

NOTE

The GRAVITY/BIAS and TEMP displays will illuminate for fifteen seconds. The displays may be reactivated by pressing READ again.

Step 3. After the bias measurement data is relayed to the earth, via voice communication, initiate the gravity measurement by pressing the GRAV pushbutton.

Step 4. Repeat steps 2b through 2d above.

Step 5. Install the TG in the traverse position on the pallet immediately prior to launch.

4.4 NORMAL TRAVERSE OPERATIONS

Proceed as follows to operate the TG during lunar traverse.

Step 1. Prior to each traverse, press the READ pushbutton to check temperature displays and take a bias and a gravity measurement in the vicinity of the LM.

Step 2. Take gravity measurements at each LRV stop according to the following requirements:

a. The number of measurements shall be a total of approximately 60. There will be 20 to 30 measurements per traverse depending on whether 3 or 2 traverses are made. The minimum number of measurements per traverse is 5.

b. The horizontal position accuracy in two coordinates shall be ± 10 meters near the LM to $\pm~25$ meters at the furthest position from the LM.

c. The elevation control must be accurate to ± 14 meters relative to the LM datum plane over the entire traverse. A goal for interstation elevation is ± 2 meters.

d. Along the straight line projection from the LM to the furthest station, the desired station spacing is: 0.5 Km minimum;1.0 Km maximum.

e. Elapsed time between each measurement must be known to within 7.0 minutes.

Step 3. Upon return to the LM at the end of each traverse, remove the TG from the LRV and place the unit in the LM shade.

Step 4. Take a bias and gravity measurement as specified in paragraph 4.4, steps 2, 3 and 4, and relay the results back to Earth.

NOTE

Bias measurements shall normally only be taken at the beginning and end of each traverse. However, should an unexpected event happen to the TG such as dropping it, banging it, or insulation damage, a bias measurement may have to be made after this event to determine TG performance.

Step 5. Place the ON/STBY switch, located under the display panel cover, to the STBY position during the traverse recovery period.

Step 6. Prior to the next traverse, place the TG ON/STBY switch to ON.

4.5 ALTERNATE TRAVERSE OPERATIONS.

If excessive vibration of the LRV degrades TG performance, use the following procedure during stops of each traverse.

Step 1. Remove the TG from the LRV.

Step 2. Place the TG on the lunar surface in a stable position so that the base of the unit is less than 15 degrees from the horizontal.

CAUTION

Care should be taken not to raise lunar dust near the TG as the dust could block the radiator and cause the TG to overheat.

Step 3. Take a gravity measurement and relay the results to earth.

Step 4. Place and secure the TG on the LRV.

SECTION 5

FUNCTIONAL DESCRIPTION

5.1 GENERAL

The TG measures and displays gravity by processing signals from a vibrating string accelerometer (VSA) which is encased along with oscillator-amplifiers in a low heat loss, preciselycontrolled oven.

The two basic modes of operation are determined by a toggle switch on the control panel. In the Standby mode, used from launch until lunar traverse, power is supplied only to the oven temperature controls and VSA oscillator-amplifiers, maintaining a constant thermal environment for the VSA. Some time before the gravity measurements are to be made, the system is placed in the Operate mode. Power is then supplied to the crystal oscilator and to a small part of the mode control logic.

The major functional sections of the TG include: control, temperature control and monitoring, leveling and inversion, measurement, and display. These functional sections are described in the following paragraphs. Figure 5.2, a block diagram, shows the relationship of each functional section to the overall function of the TG.

5.2 CONTROL SECTION

The control section, shown on sheet 1 of Figure 5.1 controls the distribution of power and selects the operating modes for the TG. The TG has two primary modes of operation, STBY (standby) and ON. In the STBY mode battery power is supplied only to two 5 volt dc power supplies (+ and -) and a 4 KHz ac power supply. The 5 volt supplies provide power for the VSA and oscillatoramplifiers and the temperature control and monitor circuits. The 4 KHz supply provides excitation and a demodulator reference for the temperature control and monitor circuits.

When the TG is placed in the ON mode two additional 5 volt power supplies are energized as well as a +12 volt supply. The 5 volt supplies provide power to the control switching logic and the phase lock loop logic. The +12 volt supply energizes the 4MHz crystal oscillator. Once the oscillator is energized, a warm up period of 90 seconds should be allowed before proceeding to a BIAS or GRAV mode. This is to insure stability of the oscillator outputs prior to a measurement cycle.

When a GRAV or BIAS mode is initiated by pressing the appropriate pushbutton, power is supplied to all sections of the TG except the displays. At the completion of a leveling and measurement cycle for the selected mode, the TG reverts back to the ON mode to conserve power.

Selection of the display function (READ pushbutton pressed) energizes K3 for a period of 15 seconds. During this time, VRDIS (+5 volts) is energized as well as the +4 volt power supply for the gravity/bias and temperature display. At the completion of the 15 second hold the display will be disabled. The READ pushbutton may be pressed again, however, to enable the displays without loss of the stored information.

The +5 OPER voltage applied to the switching logic enables the selection of the BIAS or GRAV mode. When either pushbutton is pressed, the +5V OPER voltage is gated to produce the 5 volt VLON signal. This signal is inverted and used to drive relays K1 and K2 which in turn energize a -5 volt power supply for the control logic and a +28 volt power

supply for the stepper motors. Relay K2 also switches the +5V OPER to produce a +5 V LOGIC voltage for the control logic.

In addition to driving the relays, VLON is also supplied to the temperature data strobe circuit of the leveling and inversion section.

A command delay pulse (VLDLY) of approximately 15 msec duration is initiated by the switching through K1 of the -5V LOGIC voltage. This signal is used to initialize the flip-flops in the leveling and measurement sections to a known state.

The switching logic controls the selection and sequencing of the various TG modes. When the GRAV pushbutton is pressed, the GRAV MODE SELECTED and GRAVOR BIAS SELECTED signals are both enabled. These signals are supplied to the leveling and inversion section, and enable stepper motor response to the normal X and Y pendulum outputs. The NORMAL CONTROL signal is also enabled and supplied to the phase lock loop and the display section

When the BIAS pushbutton is pressed, the BIAS MODE SELECTED and GRAV OR BIAS SELECTED signals are generated. These signals automatically sequence the TG through the four submodes of the BIAS mods. The first of these submodes is the same as a normal level mode. where the X and Y gimbals are leveled in response to pendulum outputs. At the completion of the leveling the TG goes directly into a normal exit submode. In this submode, the BIAS CONTROL signal is supplied to the phase lock loop to disable the counting function and the CAM SWITCH RESET supplied from the leveling section is inhibited by the BIAS MODE SELECTED. The bias submode enables the Y gimbal to be inverted 180[°] under control of the BIAS COUNTER CONTROL. The END OF COUNT signal informs the switching logic that the gimbal has been inverted and the leveling section is ready for a measurement. At the completion of the measurement, the Y gimbal is rotated back 180° and the mode is terminated by the MODE RESET signal. The COUNT DOWN signal extinguishes the level/measure indicator when the Y gimbal is being rotated back.

The PLL BYPASS signal is enabled when the GRAV and READ pushbuttons are pressed simultaneously. In this condition the NORMAL CONTROL to the phase lock loop is inhibited and the unfiltered difference frequency is selected for readout.

5.3 TEMPERATURE CONTROL AND MONITORING SECTION

This section, shown on sheet 1 of Figure 5.1, provides precision temperature regulation and monitoring for the inner (precision) and outer ovens. The section consists of : a precision oven temperature control and monitor circuit, an outer oven thermostat and heater circuit, and an outer oven temperature monitor circuit.

The VSA and oscillator-amplifiers are encased in the precision oven which is maintained at a temperature near 120° F to within $.018^{\circ}$ F by the temperature control and monitor circuit. The precision oven in turn is encased in an outer oven and is protected from external thermal dsiturbance by this oven. Under normal conditions the outer oven is quiescent and only extended exposure of the TG to lunar shade or sunlight could be expected to slowly change its temperature.

The precision oven temperature circuit is a proportional plus rate-feedback, loop employing a resistance thermometer element for a sensor, and an electrical heater. The complete temperature sensor is an ac excited bridge, two arms of which are thermisters; the other two arms are standard resistors. Excitation voltage for the bridge is supplied by a 1.6 volt center tap from a balanced and shielded transformer in the control section. Output of the bridge at 1.6 volts is 18 mv per degree F.

The bridge output is amplified and supplied to a diode ring demodulator. Reference voltage for the demodulator is 3.75 volts at 4 kHz which will produce an output of about $32.4 \text{ V/}^{\circ}\text{F}$. The amplifier that receives the demodulator output is a derivitive-plus-proportional amplifier. Output of this amplifier is supplied through a DC amplifier to the control drivers. The precision heaters react to the drivers to maintain the temperature of the oven to a tolerance of $\pm .018^{\circ}$ F.

A tap from the demodulator output is amplified and supplied to the leveling and inversion section as the TEMPERATURE DATA. The signal is multiplexed and converted to digital form by that section and then supplied to the display section. The temperature data is decoded by the displays to drive the VSA TEMP display (digit 9). Displayed readings will be from +7 to +0 and from -0 to -7, which are interpreted as \pm . 07 degrees C from the nominal value.

The outer oven temperature monitor circuit consists of thermostat switches which provide switch closure signals to indicate temperature changes in the outer oven. The signals represent the status of the outer oven and indicate a cold, hot or very hot condition. The signals are supplied directly to decoders in the display section where they are used to drive the eighth digit of the nine digit display. Output of the display is a number from 0 to 7 which is interpreted as: 0 or 1 no alarm, 2 or 3 cold alarm, 4 or 5 hot alarm, and 6 or 7 very hot alarm.

The outer oven thermostat and heater circuit merely reacts to temperature changes to control the power supplied to a heater.

5.4 LEVELING AND INVERSION SECTION

The leveling and inversion section is shown on sheet 2 of Figure 5.1. The purpose of this section is to level the normal and bias pendulums for normal gravity and bias measurements and to inform the measurement section when a level condition exists.

Control of the section is initiated by selection of the gravity or bias mode of operation at the TG control panel. When a mode is selected, a discrete indicating the selected mode is supplied to the multiplexer drive logic. The drive logic controls the switching through the multiplexer of normal and bias pendulum outputs and temperature data. At any one time that the normal or bias modes are active, the multiplexer will pass signals from a Y-axis pendulum (normal or bias), an X-axis pendulum (normal or bias), and temperature data. Timing for the multiplexer is generated from the 4 kHz clock fed to the counter. The counter is a two-stage ripple counter, the last stage of which generates all phases of the 1 kHz output of the first stage.

After data has been selected and switched by the multiplexer, it is fed to the analog to digital converter and read into the converter by the ENCODE COMMAND from the timing logic. The data is converted to digital form and supplied to the storage registers by the X-, Y-, and temperature data-strobes. The strobe pulses follow the encode pulse of a particular channel; that is, a Y pendulum strobe pulse follows a Y encode multiplexer control pulse. The X and Y strobes are generated by outputs from the counter in this section. Strobing of the temperature data, however, is controlled by the VSA readout logic in the measurement section.

The temperature data which is supplied through the converter is stored in a 4-bit register. Since the temperature will be read only during the display mode, the register is driven by the +5 VOPER voltage so that the data will remain after the leveling and inversion section has been de-energized. The temperature register is strobed by the synchronization of the TEMP MEASUREMENT GATE as a slow clock and the temperature strobe as a fast clock. This synchronization will generate one pulse which is started by the first temperature strobe pulse after the gate has been enabled, and is turned off by the second temperature strobe pulse which occurs during this period. This means that the temperature data is being recorded at the end of each measurement sampling period.

The leveling logic, consisting of the high range analog comparator and the low range digital comparator, determines the positions (from null) of the pendulums and generates signal to control rotation of the pendulums either clockwise, counterclockwise, rapidly, slowly or stopped. The high range comparator upon sensing that either pendulum is greater than 32 arc minutes from null (+ or -) will command that pendulum to slew fast (either FAST X, FAST Y, or both). Conversely if the comparator senses that the pendulums are within ± 32 arc minutes of null, SLOW X and SLOW Y commands are generated.

The low range digital comparator provides the slewing commands for input to the X and Y storage registers. When the comparator senses that a pendulum is greater than 3 arc minutes from null, SLEW X and/or SLEW Y commands are generated and supplied to the storage registers. When the pundulums are within the 3 arc minute range, the slew commands are disabled and the READ X and READ Y commands are enabled by the comparator.

The COUNT UP (clockwise) and COUNT DOWN (counterclockwise) commands determine the direction of slewing for the stepper motors. These commands are determined by the polarity of the SIGN BIT.

The motors control logic processes the information received from the X and Y storage registers to drive the X and Y stepper motors in the required direction and at the speed determined by the comparators. Other inputs to this logic include a fast and slow clock, a mode selected signal, and 15° cam switch signals. The clocks are gated in the control logic to provide the fast (61 Hz) and slow (6.7 Hz) clock signals for slewing the motors. The cam switches are located at the + and -15° positions of the X and Y gimbals. Signals from these switches provide for reset of a slewing function in the event a gimbal is being slewed in the wrong direction. For instance if the stepper motor counter was trying to slew up (COUNT UP) and the $+15^{\circ}$ Y position was reached, then a CAM SWITCH RESET would be enabled which would reset the leveling and immersion section.

Control of the motors drive logic is determined by the mode selected (normal or bias). When the normal mode is selected (GRAV pushbutton pressed), the leveling section looks at the normal X and Y pendulum outputs and drives the stepper motors as per the pendulum information. The bias mode however, consists of a series of four submodes which are automatically sequenced when the BIAS pushbutton is pressed.

The first submode in the sequence is the normal level, bias mode. In this the system is leveled as in a normal mode but instead of proceding to take the data, the drive control logic enters the next submode in the bias sequence. This is the normal exit, bias mode which disables the reset signal that originates from the + and -15° cam switches, the COUNT UP Y and COUNT DOWN Y signals and the SLEW Y signal. The SLEW Y signal is disabled in such a way that the Y register will continue to count regardless of the SLEW Y signal. An internal slew fast Y is also generated which works independent of the SLEW Y. This mode also disables the READ so that no reading of the data counter can occur and the SLEW X signal so that the X stepper motor cannot operate. At this point the BIAS COUNTER CONTROL signal is enabled which in turn enables the motor counter to count through a total of 5400 pulses. These pulses are equivalent through gear reduction to a 180 degree swing of the Y gimbal. When the last pulse is counted the counter generates an END OF COUNT which places the leveling section in a bias submode. This mode reacts similarly to a normal mode except that $\pm 15^{\circ}$ X and Y signals are disregarded and leveling data is taken from the bias pendulums instead of the normal pendulums through control of the multiplexer.

After leveling and data acquisition in the bias submode, the bias exit mode is selected. This mode is similar to the normal exit mode except that the Y gimbal is first inverted back 180[°] to a normal position, then the bias mode is terminated.

5.5 MEASUREMENT SECTION

The measurement section, shown on sheets 3 and 4 of Figure 5.1, consists of the VSA and oscillator amplifiers, the phase lock loop, and the readout logic. The VSA and oscillator-amplifiers are encased in the inner (precision) oven and are energized in all of the TG modes. The oven is maintained at a temperature near 120° F to within 0.18°F by the oven temperature control circuit.

The VSA is a high-sensitivity accelerometer consisting of two single vibrating strings back to back. The strings, when energized, each generate continuous vibrations which are amplified by the oscillator-amplifiers. Output of the amplifiers is a sine wave of a frequency between 9.3 and 9.7 KHz. Since the VSA and oscillator-amplifiers are energized in all modes, the VSA output frequency signals are always available at the inputs to the phase lock loop module. The phase lock loop module, however, is energized only when the gravity submode is selected at the control panel (GRAV pushbutton pressed).

The purpose of the phase lock loop module is to determine the difference frequency between the two **outputs** of the oscillator-amplifiers and to filter the frequency to remove any undesirable vibrations. The VSA oscillator-amplifiers outputs are supplied to a mixer consisting of a ring demodulator and a filter-integrator circuit. The difference frequency output of the mixer is a square wave whose frequency is that of the sine wave produced by the ring demodulator.

Any vibration on the TG will appear as a frequency modulation component on the VSA frequency. Since the main components of this noise will be at very low frequencies, a very narrow-band filter is used in the phase lock loop. For stability, a narrow bandwidth requires a low loop gain, hence a small lock-on range. The variation between different VSA's, and the wide range of possible biases, dictates that the exquisition range be much larger than the hold-in range for the phase lock loop. Therefore, a two-mode filter system is employed. A fast loop, consisting of a wide band phase detector and filter is provided for rapid lock-on to bring the voltage-controlled oscillator close to the desired operating frequency. The slow loop is essentially in parallel with the fast loop and consists of a narrow band phase detector and a low pass filter.

When the phase lock loop is initially energized, outputs of both the fast and slow loops are summed by a capacitor summing network to drive the voltage controlled oscillator (VCO). Approximately ten seconds after the TG is in a level condition, the HOLD command causes the fast loop input to the VCO to be sampled and held. The wide band filter of the fast loop is then switched out and the narrow-band filter of the slow loop controls the input to the VCO. Output of the VCO is then counted to determine the difference frequency and supplied to the VSA readout Logic.

Should any vibrations cause the input frequency from the VSA to exceed the limit of the slow loop once the fast loop is switched out, the rate detectro circuit will generate a PL RATE ALARM (out-of-lock discrete). If a large amount of vibration continually causes a rate alarm during the measure cycle, a phase lock loop by-pass mode can be initiated, in which the unfiltered difference frequency is taken directly from the mixer.

The VSA readout logic receives both the unfiltered and the filtered outputs of the phase lock loop. A phase lock loop/by-pass circuit selects the desired frequency dependent upon the mode selected by the control section. If a phase lock loop by-pass mode was selected by pressing the GRAV and READ pushbuttons simultaneously, the PLL BYPASS signal will inhibit the NORMAL CONTROL signal and cause the selection of the unfiltered difference frequency. The filtered difference frequency is selected if only the GRAV phsubutton is pressed (NORMAL CONTROL signal enabled).

A timing diagram of the measurement function is shown in Figure 5.2. The readout section is initialized by the VLDLY signal (15 msec delay pulse) which sets the timing flip-flops to a known state and gates the READ command. Timing for the section is provided by the counted down difference frequency of the ripple counter (20 Hz nominal).

When the TG is within ± 3 arc minutes of a level condition, the READ command is supplied to the readout section. This is gated with the VLDLY signal to produce the GATED READ command for the gate generator and delay circuit. Primary output of this circuit is the HOLD command for the phase lock loop. The HOLD output will be

delayed from 2 to 4 cycles (ripple counter cycles) after the circuit is enabled by the GATED READ command.

Once the HOLD is enabled, there is a total of four cycles before reading of the VSA data commences. This delay (approximately 13 sec) is to insure stability of the phase lock loop output prior to a read cycle. Reading occurs when the 125 KHz clock, counted down from the 4MHz crystal oscillator, is gated under control of the ripple counter output to produce the GRAVITY COUNT. The count is enabled for a total of six cycles, which at a period of 3.2 seconds means the data is read for 19.2 seconds. Synchronous with this count gate is the TEMP MEASUREMENT GATE which is supplied to the leveling and inversion section to enable transfer of the VSA TEMPERATURE DATA to the displays. The GRAVITY COUNT is fed the input of a seven stage decade counter in the display section. One cycle after the reading has been completed and the data set out, a MODE RESET is generated which removes power from the VSA readout section.

In the event the phase lock loop drops out of lock during a measurement, the rate alarm will generate a LACK LOCK signal. This signal will clear the three most significant digits of the BCD counter and the display will show zeroes in the first three digit position. If the TG is in a phase lock loop by-pass mode, the PLL BYPASS Signal will cause the first significant digit of the display to be zeroed

5.6 DISPLAY SECTION

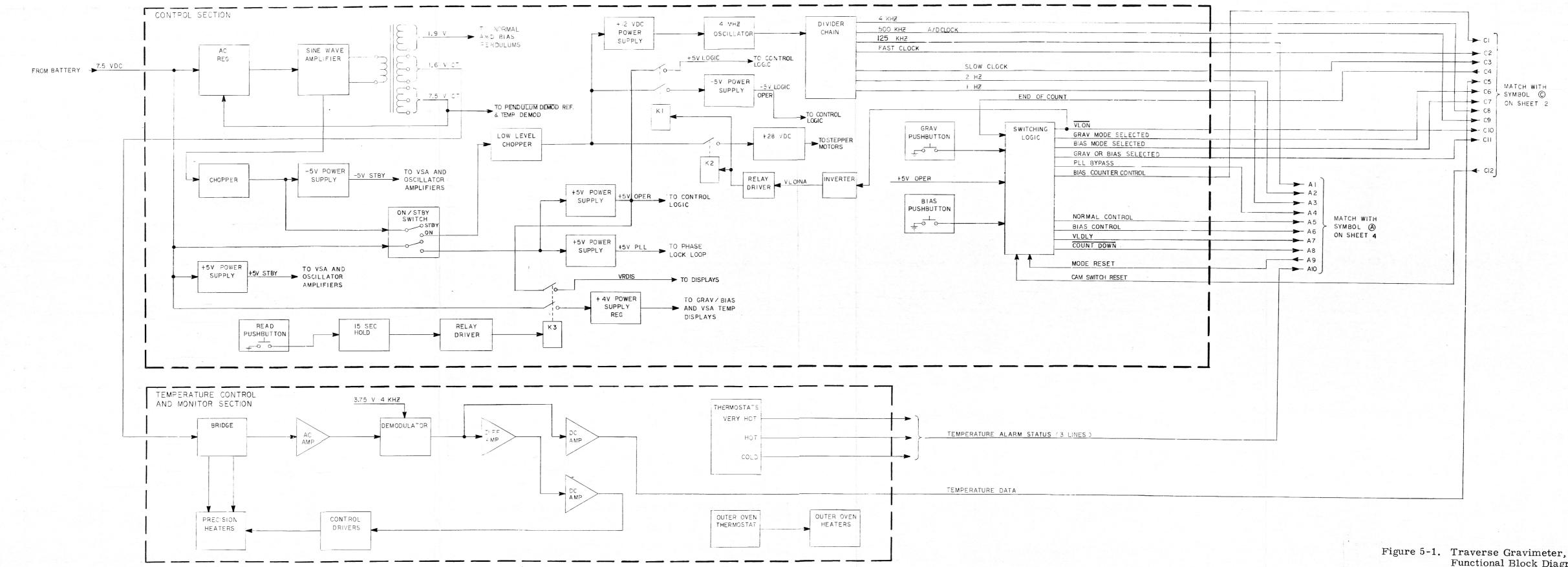
The display section, shown on sheet 4 of Figure 5.1, processes the gravity, temperature and mode status information to drive the nine digit display and the level/measure indicator.

The numerical display, when activated, presents the gravity or bias measurement in the first seven digits, the outer oven temperature in the eighth digit and the VSA temperature in the ninth digit. The gravity or bias data is received from the measurement section and held in the seven stage decade counter. The counter holds the data until the display is activated or a new measurement cycle is initiated. The temperature data is held in readout gates until the display is activated.

When the READ pushbutton is pressed +4 volts and +5 VRDIS is supplied to the display section to activate the numerical display and enable the data transfer from the counter and the temperature readout gates. The display is only activated for 15 seconds but may be reactivated (without loss of information) by pressing the READ pushbutton again.

If a loss of phase lock occurred during the measurement cycle, the LACK LOCK signal will cause the first three significant digits of the counter to be reset. This in turn will cause zeroes to be displayed in the first three digits when the display is activated. A zero in only the first digit of the display indicates that the TG is in a phase lock loop, bypass mode. This is accomplished by the PLL BYPASS RESET signal resetting the most significant digit of the counter.

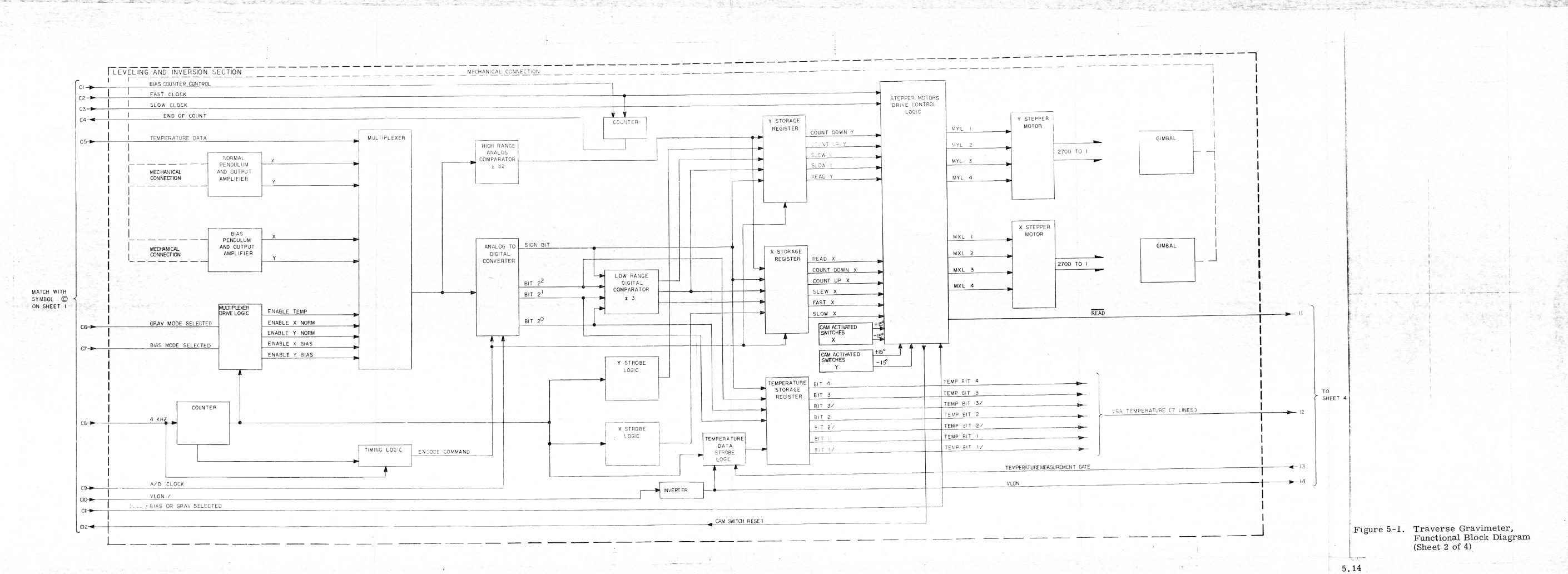
The level/measure indicator displays the status of the level and measure cycles and is only activated during the GRAV or BIAS modes. When the TG is in a leveling cycle, a 1 Hz clock, counted down from the 4MHz crystal oscillator, will cause the indicator to flash. The indicator will continue to flash until the TG is within ± 3 arc minutes of level. The READ signal from the leveling and inversion section will then cause the indicator to illuminate steadily until the measurement cycle is complete. The COUNT DOWN signal will extinguish the indicator when the TG is in a bias exit mode and the Y gimbal is being inverted.

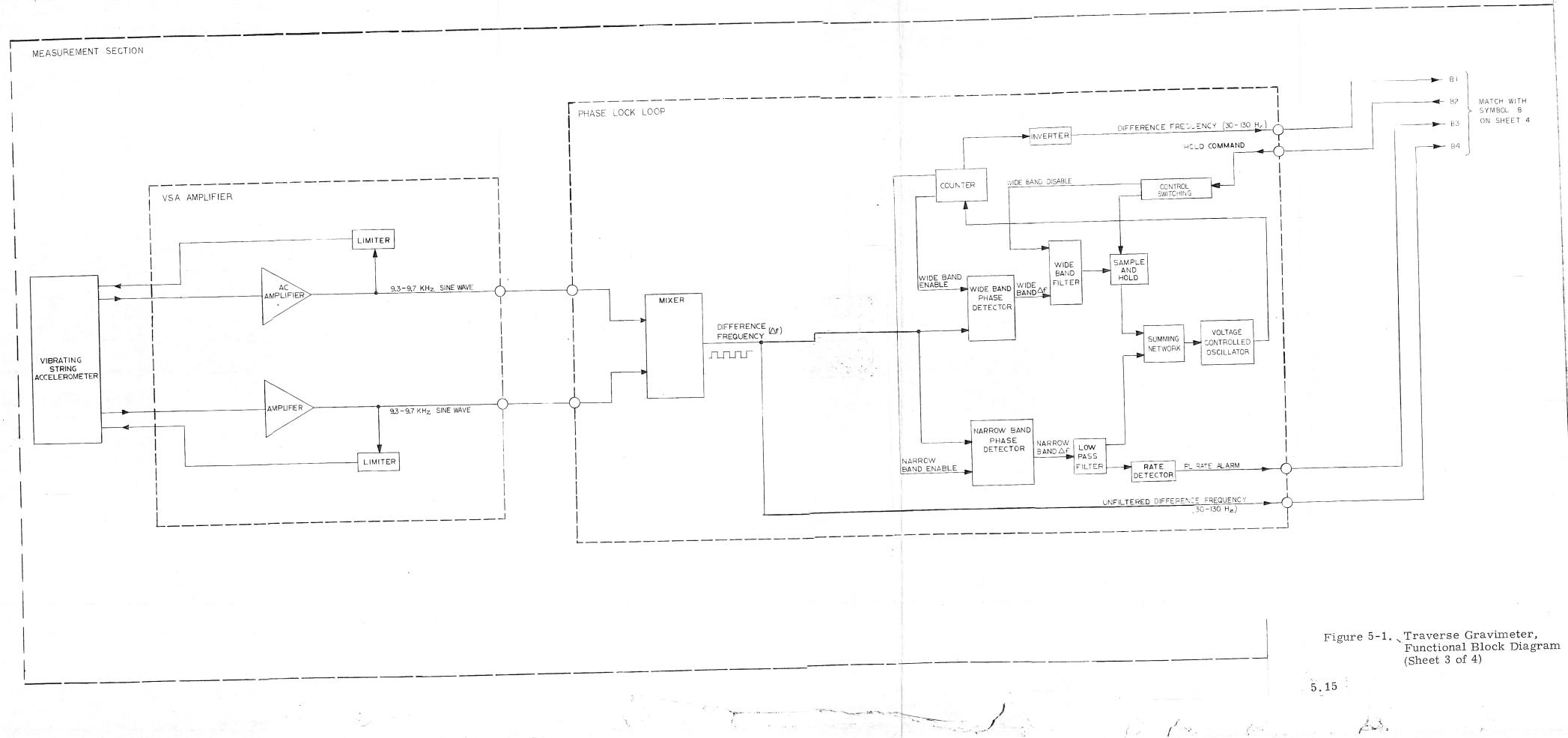


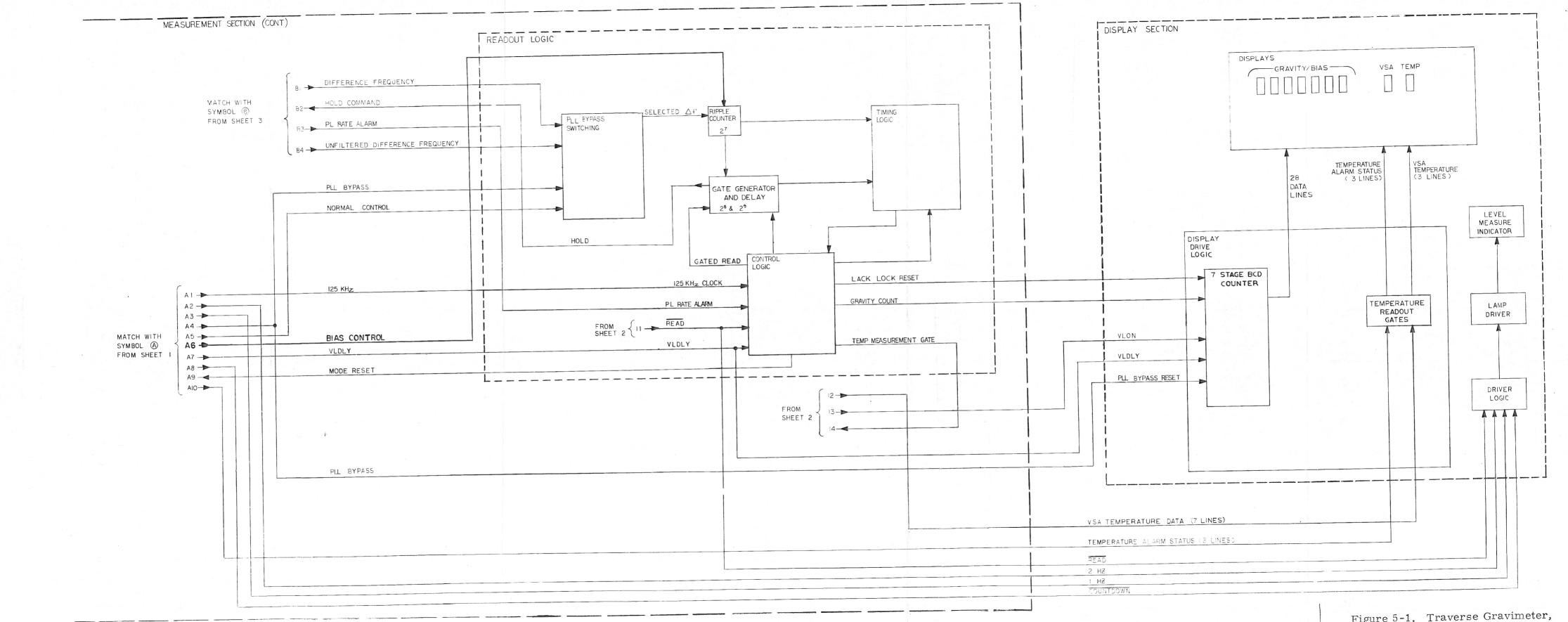
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5.13

Functional Block Diagram (Sheet 1 of 4)







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Figure 5-1. Traverse Gravimeter, Functional Block Diagram (Sheet 4 of 4)

5.16

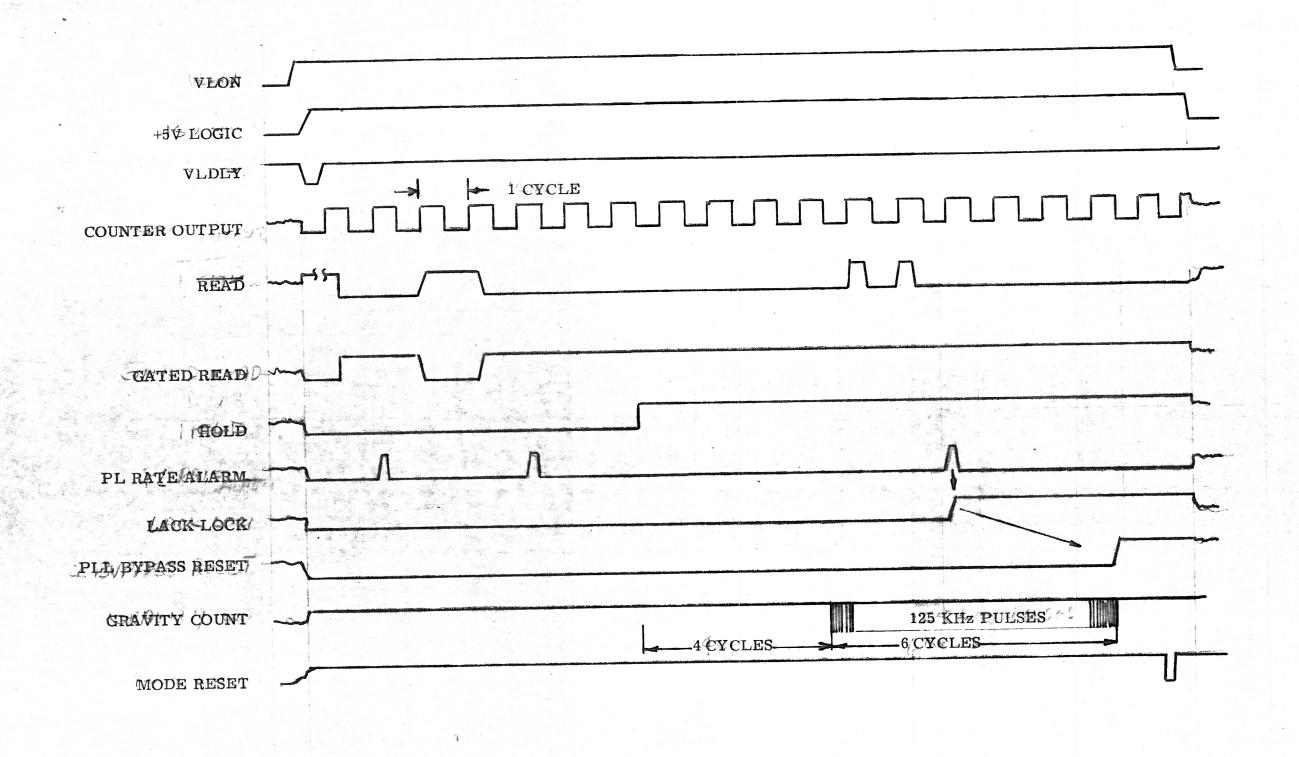


Figure 5.2 Measurement Function, Timing Diagram

APPENDIX A

TRAVERSE GRAVIMETER SPECIFICATIONS

This appendix contains the end item specification for the Traverse Gravimeter.

CONTRACT END ITEM DETAIL SPECIFICATION

PART I

PERFORMANCE/DESIGN AND QUALIFICATION REQUIREMENTS

TRAVERSE GRAVIMETER EXPERIMENT

CEI 2025000

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CONTRACT END ITEM DETAIL SPECIFICATION (Prime Equipment)

PART I

PERFORMANCE AND DESIGN REQUIREMENTS

(2025000)

TRAVERSE GRAVIMETER EXPERIMENT

Approved by ______ (Preparing Activity)

Approved by_____(NASA Office)

Approval Date_____

Date

Contract Number_____

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END ITEM CONFIGURATION CHART

Specification Issue	ECPs	Production Effectivity
)		

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SPECIFICATION CHANGE LOG

SPECIFICATION NO. 2025000

SCN NO.	ECP NO.	SCN DATE	PAGES AFFECTED	ITEM AFFECTED
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1.0 SCOPE

This part of this specification establishes the requirements for performance, design, test and qualification of one type-modelseries of equipment identified as CEI 2025000, Traverse Gravimeter, hereinafter referred to as TG. The primary function of the TG shall be to measure gravity on the lunar surface. In addition, the TG shall be capable of a transfer gravity measurement to determine the absolute value of lunar gravity.

The information obtained should reveal density differences below the lunar surface. These differences may be due to the contrast between lunar dust and rocks or to the contrast between different kinds of rocks.

The TG shall be a light weight, self-contained portable instrument. The TG shall be automatic in operation and require manual mode control inputs by the astronaut. The TG shall be transported to the lunar surface aboard the Lunar Module Descent stage, mounted on a stowage pallet in the Scientific Equipment Bay, Quad III.

After lunar landing, the TG shall be deployed on the lunar surface in the vicinity of the Lunar Module by one astronaut. Initial operational and check out procedures shall be performed, after which time the TG shall be placed on the Lunar Rover Vehicle (LRV). Gravity measurements shall be obtained at various scientific stations along the Lunar Rover Vehicle and astronaut traverses. The TG shall indicate visually that a gravity measurement has been completed. The astronaut will then manually energize the display and by voice transmission to MSC Control Center, relay the display information.

This information shall be a coded nine digit number that represents the difference in VSA string frequencies, internal temperatures and mode status of the instrument.

1.0 The Principal Investigator can then interpret and analyze this data to determine the lunar gravity profile.

2.0 APPLICABLE DOCUMENTS

The following documents, of exact issue shown, form a part of this specification to the extent specified herein. In the event of conflict between documents referenced here and other detail contents of Sections 3, 4, 5, and 10, the detail requirements of Sections 3, 4, 5, and 10 shall be considered a superseding requirement.

2.1 Project and System Documents

2.1.1 Standards

Document	Title	Date
MIL-STD-130C	Identification Marking of U. S. Military Property	29 Sept. 67
MIL-STD-454A	Standard General Requirement for Electronic Equipment	5 Jan. 65
MIL-STD-1472	Human Engineering Design Criteria for Aerospace Systems and Equipment	9 Feb. 68
LM-STD-LSP 530-001		
ND 1002019	Marking, General Specification for	13 Mar. 70
ND 1002023	Serialization, Procedure for serialization of components, subassemblies and assemblies for Apollo G & N Equipment	17 Feb. 65

2.1.2 Drawings

NumberTitleDate2025000Traverse Gravimeter
Experiment Top Assembly

2.1.3 Other Publications

Document	Title	Date
QOP-15	Reliability Program Plan for Traverse Gravimeter Experiment	Mar. 71
LIS 360-22700	Installation and Prelaunch Service Requirements of the Lunar Module SEQ	
LIS 360-22314	Environmental Conditions Induced by the Lunar Module on the Scientific Equipment Located on the Quad III Pallet	
LID 360-22844	Traverse Gravimeter Experiment, Lunar Module Pallet Stowage, Descent Stage	

3.0 REQUIREMENTS

3.1 Performance

- 3.1.1 Primary Performance Characteristics
- 3.1.1.1 General The primary function of the TG is to accurately measure gravity on the lunar surface.

The TG shall be a lightweight, self-contained low powered instrument.

Thermal control of the TG shall be optimized by a thermal blanket over the outer structure. An external surface radiator with a moveable shield shall provide for heat dissipation of the instrument. In addition, internal temperature control circuitry shall produce electrical heat as required.

3.1.1.1 The TG shall have four front panel mode control switches and a nine digit visual display with moveable cover. The nine digit coded number shall indicate the difference in VSA string frequencies, internal temperature and mode status.

A visual indicator on the outer surface of the TG shall indicate the level and measuring status of the instrument in either gravity mode.

The TG shall have the capability of measuring gravity while mounted on the Lunar Rover Vehicle pallet or on the lunar surface.

- 3.1.1.2 Measurement Accuracy and Range -
- 3.1.1.2.1 Measurement Accuracy The TG shall be capable of measuring lunar gravity within the accuracy of \pm 1.2 milligals when the base of the instrument is within \pm 15 degrees of the horizontal.
- 3.1.1.2.2 Measurement Range The full scale range shall be equal to or greater than 10^3 gal.
- 3.1.1.2.3 Measurement Time The lunar gravity measurement cycle shall be equal to or less than 2.5 minutes.
- 3.1.1.3 Environment The TG shall be capable of performing mission and functional requirements constrained by the conditions specified in Table 1, "TGE SYSTEM ENVIRONMENTS and CONSTRAINTS".
- 3.1.1.4 Physical The TG shall interface mechanically with the stowage pallet meeting all requirements of practical utilization and structure integrity under all environmental conditions as specified in paragraph 3.2.1, "Interface Requirements".
- 3.1.2 Secondary Performance Characteristics
- 3.1.2.1 General The TG shall be designed to be carried and deployed by a one man operation.
- 3.1.2.2 A battery pack shall be integral to the TG providing no less than 300 watt hours for all modes of operation over a 15 day period.

ENVIRONMENT	STORAGE UNPACKED	TRANSPORT'N & STORAGE PACKAGED	MOVEMENT TO PAD	FACTORY & ASSY BLDG CHECKOUT	LAUNCH PAD ENVIRONMENT	FLIGHT	LUNAR OPERATIONS
HUMIDITY	15 to 50% relative	0 to 30% relative Par. 3.1.3.4	0 to 30% relative Par. 3.1.3.4	50% maximum	50% maximum	N/A	N/A
SAND & DUST	N/A	N/A	N/A	N/A	N/A	N/A	Dust Brush Par. 3.1.3.4
ACCELERATION	1.0 g through axis	2.67 g vertical with 1 g lateral	1.0 g vertical	N/A	N/A	5.0 g direction of launch 1.0 g all other directions	1/6th g
VIBRATION	N/A	Par. 3.1.3.8	Par. 3.1.3.8	N/A	N/A	Par. 3.1.3.8	Par. 3.1.3.8
SHOCK	8 g any direction	8 g any direction	8 g any direction	N/A	N/A	8g any direction	12 inch free fall onto a hard surface under lunar gravity
TEMPERATURE	65 ⁰ to 85 ⁰ F	65 ⁰ to 100 ⁰ F	65° to 100° F	65° to 85° F	65° to 85° F	-20° to 85° F	Par. 3.1.3.4
RADIATION	N/A	N/A	N/A				Par. 3.1.3.4
SOLAR RADIATION	360 BTU/ft ² / hr 2 hr/day	N/A	N/A	N/A	N/A	N/A	Par. 3.1.3.4
PRESSURE	Ambient	Sea level to 50,000 ft	Ambient	Ambient	Ambient	<1 x 10 ⁻⁸	$<1 \times 10^{-8} torr$
ACOUSTICS	N/A	N/A	N/A	N/A	N/A	Par. 3.1.3.4	N/A
OTHER	Par. 3.1.3.4	Par. 3.1.3.4	Par. 3.1.3.4	Par. 3.1.3.4	Par. 3.1.3.4	Par. 3.1.3.4	Par. 3.1.3.4

TGE SYSTEM ENVIRONMENTS & CONSTRAINTS

- 3.1.2.3 The TG shall provide a hierarchy of operating modes with automatic controls, while maintaining a constant thermal environment for the inner structure, enabling accurate measurement, data display and calibration.
- 3.1.2.4 The TG shall provide a coded nine digit display:
 - a. Gravity Binary Coded Decimal (7 digit)
 - b. Precision oven temperature deviation from controlled null. (1 octal digit)
 - c. Inner structure temperatures low, normal, warm, hot. (1 octal digit)
 - d. Level/measure indicator (front panel incandescent light)
- 3.1.3 Operability
- 3.1.3.1 Reliability There are no quantitative reliability goals established for the TG. MIT/CSDL generated NASA Experiments R & QA Plan shall be imposed to the extent specified in the Reliability Program Plan for the TG, March 1971.
- 3.1.3.2 Maintainability The TG shall be so designed to facilitate maintenance via replacement of modules or parts whichever is economically feasible during all phases of instrument life span up to and including operation during acceptance and qualification testing. Failure occurrences subsequent to TG acceptance shall be maintained by total replacement of the TG, with exception of components identified in Paragraph 3.2.2.3 "Logistics Critical Components List".
- 3.1.3.3 Useful Life The useful life of the TG shall include time required for all testing and flight operations as well as a reasonable margin for TG reliability.

- 3.1.3.4 Natural Environment The TG shall be designed to accomplish its mission withstanding the environmental parameters specified herein and in Table I. "TGE System Environment and Constraints."
- 3.1.3.4.1 Transportation and Storage Environmental specifications indicate maximum levels inside the shipping container experienced directly by TG.
- 3.1.3.4.2 Lunar Operations Radiator surfaces and radiator cover to be dusted whenever opened. Display panel to be dusted whenever opened.
- 3.1.3.4.3 Lunar Temperature Operations Pallet, Rover and Surrounding Equipment assumed @ Local Lunar Temperature with Alpha = 0.9
- 3.1.3.4.4 Radiation -

	2
Solar Flux	$442 \text{ BTU/ft}^2/\text{hr}$
Earth Emission	$73 \text{ BTU/ft}^2/\text{hr}$
Lunar Emission (Sub Solar Point)	419 BTU/ft ² /hr
Lunar Emission (Dark Side)	2.2 BTU/ft ² /hr
Earth Albedo Entire Solar Spectrum Over Visible Spectrum	0.35 0.40
Lunar Normal Albedo Entire Solar Spectrum Over Visible Spectrum	0.047 0.098
Lunar Spherical Albedo Over Visible Spectrum	0.073
Space Sink Temperature	-460°F

3.1.3.4.5 Lunar Solar Radiation - 442 BTU/ft²/hr Pallet, Rover and Surrounding Equipment assumed @ Local Lunar Temperature with Alpha = 0.9

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3.1.3.4.6 Flight Acoustics - REF. .0002 DYNES/CM²

Octave Band Center Frequency Hz	Sound Pressure Level DB
16 32	106 125
63 125	$\begin{array}{c} 135\\ 139\end{array}$
250	134
500 1000	126 122
$2000 \\ 4000$	$\begin{array}{c} 117\\112\end{array}$
8000	108
Overall	141

- 3.1.3.4.7 Other Environments Rain, Salt Spray, Fungus, Ozone, Hazardous Gases, EMI, Meteroids Not applicable.
- 3.1.3.5 Transportability The TG shall be designed as a portable instrument in accordance with this specification and shall be hand carried to KSC and protected from adverse environment during transport.
- 3.1.3.6 Human Performance The TG hardware shall permit efficient use of the capabilities of ground and flight personnel in the applicable natural and induced environments. Controls shall be readily accessible, suitably arranged, properly identified and of such size and construction as to permit convenience and ease of operation. All controls shall operate freely, smoothly, and easily without excessive binding, play, or backlash. Switches, levers, and other controls which are manipulated during operation of the equipment, shall be of such rugged design and construction that they will not be damaged when repeatedly operated. The TG hardware shall comply with the design criteria of MIL-STD-1472, 9 Feb. 1968.

3.1.3.7 Safety -

- The safety of the flight and ground personnel shall be a a. prime consideration in the design of the TG. Sharp edges, burrs, corners, and protuberances are not permitted. The TG shall be designed to prevent personnel contact with high temperature surfaces and hazardous electrical power.
- b. The TG shall have adequate safeguards to prevent hazardous conditions and inadvertent operation. Normal operations, malfunctions, failures, and component replacement shall not cause damage to other equipment or injury to personnel. Minimum hazards will be the criteria used in selecting TG subsystems and component parts that will permit accomplishment of experiment objectives.
- The TG shall be designed to operate in environments (including с. ionizing radiation) involved in development, testing and flight without exposing ground or flight personnel to hazards.

Power

- Induced Environment The requirements specified herein and in 3.1.3.8 Table I define the environmental parameters to which the TG shall be designed.
- 3.1.3.8.1 Flight Vibration -

RANDOM - 1.0 MINUTE PER AXIS

Frequency Hz	Spectral Density
20 to 40	+12DB/Octave
40 to 85	0.03 g^2/Hz
85 to 110	+6 DB/Octave
110 to 400	0.05 g^2/Hz
400 to 450	-6 DB/Octave
450 to 1100	0.04 g^2/Hz
1100 to 2000	-12 DB/Octave

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3.1.3.8.1	SINUSOIDAL SWEEP
(Cont.)	3 OCTAVE/MINUTE

Frequency Hz

Level

 5 to
 12
 0.2 in. DA

 12 to
 100
 1.4 g

SINUSOIDAL DWELL

10.0 sec per axis 1.5 g @ 6 Hz

3.1.3.8.2 Lunar Vibration -

Vertical

0.2 0.5 Hz 0.2 1.0 Hz 1.0 10.0 Hz 0.2 10.0 Hz RMS Horizontal 0.2 0.5 Hz

0.5 10.0 Hz

1.0 10.0 Hz

0.2 10.0 Hz RMS

Octave Increase

+9 DB/Octave Rise 0.21 g²/Hz -6 DB/Octave Rise 0.56 g Octave Increase +9 DB/Octave Rise 0.042 g²/Hz

-6 DB/Octave Rise 0.25 g

3.2 TG Definition

3.2.1 Interface Requirements

3.2.1.1 Schematic Arrangement - The relationship of the TG to the stowage pallet is shown in Figure 1, TG Mechanical Interface Diagram.

- 3.2.1.2 Detailed Interface Definition The TG shall meet all interface requirements of practical utilization and structural integrity under all environmental conditions. Detailed interface requirements between the TG and other equipment shall be governed by the Contracting Officer.
- 3.2.1.3 Functional -
- 3.2.1.3.1 Pre Launch and Translunar Flight The TG shall be installed in the Scientific Equipment Bay, Quad III of the Lunar Module Descent Stage. The TG shall be mounted on the pallet in the "transport" position. The TG shall be placed in an OFF standby mode, that provides temperature control to the inner structure during translunar flight.
- 3.2.1.3.2 Lunar Surface Operations The TG shall be removed from the Scientific Equipment Bay, and deployed on the lunar surface by one astronaut. The TG shall be capable of complete functional operations on the lunar surface and on the Lunar Rover Vehicle pallet mounted in the "traverse" position.
- 3.2.1.3.3 Lunar Surface Transportation The TG shall be capable of being transported to the point of emplacement by hand carry and by transport on the Lunar Rover Vehicle pallet.
- 3.2.1.3.4 The gravity measurement cycle shall be as follows:
 - a. The base of the instrument shall be levelled to within \pm 15 degrees of horizontal.
 - b. The ON/STBY front panel toggle switch shall be placed in the "ON" position.
 - c. The normal (GRAV) or bias (BIAS) gravity pushbutton switches shall be depressed.
 - d. The level/measure light will indicate level and measurement status.

3.2.1.3.4
 e. A gravity measurement will automatically be sampled after the inner structure has levelled to zero degrees of vertical ± 7 arc minutes.

- f. The measurement cycle shall not exceed 2.5 minutes.
- 3.2.1.3.5 Data Quantization the TG shall provide two gravity measurement modes; normal and bias. The quantization in each mode shall be as follows:
 - a. Less than or equal to 0.1 milligal in the normal gravity mode.
 - b. Less than or equal to 0.3 milligal in the bias gravity mode.
- 3.2.1.4 The following list of interface control drawings are referenced to specify the interface requirements of the TG with other equipment.

Number	Title
LIS 360-22700	Installation and Prelaunch Service Requirements of the Lunar Module SEQ
LIS 360-22314	Environmental Conditions Induced by the Lunar Module on the Scientific Equipment located on the Quad III pallet.
LID 360-22844	Traverse Gravimeter Experiment, Lunar Module Pallet Stowage, Descent Stage

- 3.2.2 Component Identification
- 3.2.2.1 Government Furnished Property List The TG shall be designed to incorporate the following Government Furnished Property.

NOMENCLATURE		PART NUMBER
	Vibrating String Accelerometer	Ambac Lot D4e
3.2.2.2	Engineering Critical Components - NOT	APPLICABLE.

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TO BE DEFINED

Figure 1. TG Mechanical Interface Diagram, (TRANSPORT MODE)

3.2.2.3 Logistics Critical Components List - The following list of critical components within the TG require individual specifications.

NOMENCLATURE	PART NUMBER
Battery Pack Assembly	2025021
Thermal Blanket Assembly	SCD No.

3.2.3 Technical Manuals

Technical manuals for the operation and maintenance of the TG are listed in Section 6, Part II of this specification.

3.3 Design and Construction

The TG shall be designed and constructed in accordance with NASA Drawing 2025000.

3.3.1 General Design Features

The TG shall consist of the following major assemblies:

Outer Structure Assemblies

Base Housing Thermal Insulation Blanket Battery Pack Power Supply Module Phase Lock Loop Module Crystal Oscillator Control and Display Panel Surface Radiator

Inner Structure Assemblies

Precision Oven Intermediate Oven Electronics Frame Middle Gimbal

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3.3.1.1 Outer Structure - The outer structure of the TG shall be rectangular in shape, with a flat rear surface for pallet attachment. The outer surface shall be covered with a multi-layer insulation blanket. A folding handle on the top shall be designed for hand carry and for attaching the TG to the stowage pallet. Three feet mounted on the bottom of the TG shall accommodate lunar surface operation. The two rear feet shall be placed in a cradle on the stowage pallet and, with the carrying handle folded, secure the TG to the pallet. Pip-pins and a lanyard will be used to secure the TG to the stowage pallet during the translunar phase of the mission.

A heat radiator shall be on the top surface. A manually operated cover on the radiator allows the astronaut to protect the radiator during traverses and to expose the radiator during rest periods.

A control panel consisting of four manually operated switches shall initiate all modes of operation. The TG shall have two primary modes, and three sub-modes of operation.

A nine digit display panel shall indicate an index number for gravity measurement and internal temperature and temperature alarm status. A light mounted on the display cover exterior, shall indicate level and measure mode status.

The VSA string frequencies shall be filtered in the phase lock loop module to eliminate any externally induced vibrations.

The temperature of the battery pack assembly shall be thermostatically controlled by an electrical heater.

The outer structure shall house the assemblies and associated subassemblies listed in paragraph 3.3 "Design and Construction".

3.3.1.2 Inner Structure - The inner structure of the TG shall be a two axis gimbal system that contains a VSA housed in a thermally protected and evacuated two stage oven assembly. The oven assembly shall be enclosed in a Electronic frame assembly of

3.3.1.2 similar structural design. The Electronic frame shall be pivoted (Cont.) similar structural design. The Electronic frame shall be pivoted about its axis and supported by a middle gimbal assembly. The middle gimbal shall control the vertical positioning of the inner gimbal over a 30 degree range. The middle gimbal assembly shall be attached through bearings to the base housing and shall rotate 210 degrees. Stepper motors and gear trains shall provide the drive and positioning of the gimbal assemblies.

A proportional controlled temperature system shall supply electrical heat for thermal protection of the precision oven.

The intermediate oven shall be thermally protected by a preset on-off thermostatically controlled electrical heater system.

The Electronic frame shall include associated electronics and a multiplexer. The signals from the inner gimbal must be multiplexed to minimize wires brought out of the middle gimbal.

- 3.3.1.3 The TG shall be designed to provide accessibility, replaceability and serviceability consistent with efficient servicing, testing and maintenance requirements.
- 3.3.1.4 Nominal Physical Characteristics -

a.	Height	20.0 inches
b.	Width	11.0 inches
с.	Depth	9.75 inches
d.	Weight	27 earth pounds

- 3.3.1.5 Engineering Drawings The top assembly drawing number 2025000 shall establish the basic design and construction.
- 3.3.2 Selection of Specifications and Standards

Specifications and standards necessary for the design and development of the TG, in addition to those referenced in this specification shall be selected in the following order of preference except as otherwise defined in this specification.

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- 3.3.2 a. NASA specifications and standards
 - b. Federal specifications and standards
 - c. Military specifications and standards (MIL, JAN or MS)
 - d. Other

(Cont.)

- 3.3.3 Materials, Parts and Processes
- 3.3.3.1 Materials During the design of the TG, the selection of materials shall be based on engineering evaluation and qualification for best performance under environmental constraints listed in Table 1, "TGE System Environment and Constraints".
- 3.3.3.2 Parts Suitable specifications shall be referenced in the appropriate component procurement specifications, SCDs or drawings.
- 3.3.3.3 Processes Suitable specifications shall be referenced in the appropriate procurement specification, SCDs or drawings.
- 3.3.4 Standards and Commercial Parts

The use of qualified parts shall receive prime consideration in fulfilling the TG design objectives, and shall be in accordance with QOP-15.

- 3.3.5 Moisture and Fungus Resistance Not applicable.
- 3.3.6 Corrosion of Metal Parts

The TG parts, including spares, shall be protected against corrosion as applicable.

3.3.7 Interchangeability and Replaceability

The TG shall be designed to make all numbered like parts interchangeable. The objective during development shall be to achieve interchangeability of integrated parts in accordance with MIL-STD-454, Requirement 7.

3.3.8 Workmanship

The TG including all parts and assemblies shall be constructed and finished in accordance with MIL-STD-454, Requirement 9.

3.3.9 Electromagnetic Interference

The TG design shall consider EMI requirements as specified in LM STD LSP 530-001.

3.3.10 Identification and Marking

The TG shall be marked for identification in accordance with the following documents:

NUMBER	TITLE
ND 1002019	Marking, General Specification for
ND 1002023	Serialization, Procedure for Serialization of components subassemblies and assemblies for Apollo G & N Equipment
MIL STD 130C	Identification Marking of U.S. Military Property

Conspicuous markings or labels shall be affixed to the TG to warn ground support personnel and astronauts of the presence of hazardous conditions.

3.3.11 Storage

The TG shall be capable of storage without degradation for a period of 5 years with VSA and battery removed.

- 4.0 QUALITY ASSURANCE PROVISIONS
- 4.1 Phase I. Test/Verification

4.1.1 Engineering Test and Evaluation

Development tests shall be performed in accordance with the requirements to be established under the direction of the contracting agency. These tests will enable evaluation of the design in the breadboard stages, establish functional capabilities for parts and design, and allow for the incorporation of desired changes or corrections into prototype and production hardware.

4.1.2 Preliminary Qualification Tests

Not applicable.

4.1.3 Formal Qualification Tests

The following sections specify the methods of formally verifying that each requirement in Section 3 has been satisfied. These tests are to be performed to evaluate the final design and reliability and to determine compliance with performance and environmental requirements.

- 4.1.3.1 Requirement/Quality Cross-Reference Index See Table II.
- 4.1.3.2 Inspection The following requirements of Section 3 shall be verified by an inspection of the TG equipment and/or documentation at the time and place of the qualification testing.

3.1.3.2	Maintainability
3.1.3.5	Transport a bility
3.2.1	Interface Requirements
3.2.2	Component Identification
3.3.1	General Design Features
3.3.2	Selection of Specifications & Standards
3.3.3	Materials, Parts & Processes
3.3.4	Standards & Commercial Parts
3.3.6	Corrosion of Metal Parts

4.1.3.2	3.3.7	Interchangeability & Replaceability
(Cont.)	3.3.8	Workmanship
	3.3.10	Identification & Marking
	3.1.3.7	Safety

- 4.1.3.3 Analysis Not applicable.
- 4.1.3.4 Demonstrations The following requirements of Section 3 shall be verified by demonstrations.

3.1.1	Functional Characteristics
3.1.3.5	Transportability
3.1.3.6	Human Performance

4.1.3.5 Qualification Tests - The following requirements of Section 3 shall be verified during the formal qualification test program.

cesses
ference

4.1.3.6 Acceptance Tests - The following requirements of Section 3 shall be verified during the acceptance test program.

3.1.1 Functional Characteristics

- 4.1.4 Reliability Tests and Analyses
 MIT/CSDL generated Reliability Program Plan for the TG, March 1971 shall be imposed to the extent specified therein.
- 4.1.5 Engineering Critical Component Qualification Not applicable.

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TABLE II

Requirement/Quality Cross-Reference Index

Requirements	Req Para	Test Para	Test Method
Functional Characteristics	3.1.1	4.1.3.4, 4.1.3.6	
Reliability	3.1.3.1	N/A	
Maintainability	3.1.3.2	4.1.3.2, 4.1.3.4	
Useful Life	3.1.3.3	N/A	
Natural Environment	3.1.3.4	4.1.3.5	
Transportability	3.1.3.5	4.1.3.2	
Human Performance	3.1.3.6	4.1.3.4,	
Safety		4.1.3.2,	
Induced Environment	3.1.3.8	4.1.3.5	
Interface Requirements	3.2.1	4.1.3.2	
Component Identification	3.2.2	4.1.3.2	
General Design Features	3.3.1	4.1.3.2	
Selection of Specifications and Standards	3.3.2	4.1.3.2	
Material Parts and Processes	3.3.3	4.1.3.2, 4.1.3.5	
Standard and Commercial Parts	3.3.4	4.1.3.2	
Moisture and Fungus Resistance	3.3.5	N/A	
Corrosion of Metal Parts	3.3.6	4.1.3.2	
Interchangeability and Replaceability	3.3.7	4.1.3.2	
Workmanship	3.3.8	4.1.3.2	
Electro-Magnetic Inter- ference (EMI)	3.3.9	4.1.3.5	
Identification and Marking	3.3.10	4.1.3.2	
Storage	3.3.11	N/A	

4.2 Phase II, Integrated Test Requirements

Pallet Interface Requirements: The stowage pallet interface test requirements shall comply with documents as specified in Paragraph 3.2.1, "Interface Requirements".

5.0 PREPARATION FOR DELIVERY

Not applicable.

6.0 NOTES

Not applicable.

10.0 APPENDIX

Not applicable.

APPENDIX B

GROUND SUPPORT EQUIPMENT SPECIFICATIONS

This appendix contains the end item specification for the Ground Support Equipment required for the Traverse Gravimeter.

CONTRACT END ITEM DETAIL SPECIFICATION

PART I

PERFORMANCE/DESIGN AND QUALIFICATION REQUIREMENTS

GROUND SUPPORT EQUIPMENT

CEI 2025900

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CONTRACT END ITEM DETAIL SPECIFICATION (PRIME EQUIPMENT)

PERFORMANCE AND DESIGN REQUIREMENTS

(2025900)

GROUND SUPPORT EQUIPMENT

(Preparing Activity)

Approved by _____ Approved by _____

(NASA Office)

Date_____

Approval Date_____

Contract Number_____

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END ITEM CONFIGURATION CHART

Specification Issue	ECPs	Production Effectivity
		•

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SPECIFICATION CHANGE LOG

SPECIFICATION NO.

SCN NO.	ECP NO.	SCN DATE	PAGES AFFECTED	ITEM AFFECTED

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1.0 SCOPE.

This specification establishes the requirements for performance, design test and qualification of the Ground Support Equipment (GSE) required to support the Traverse Gravimeter (TG), Contract End Item Number 2025000.

The GSE primary purposes are as follows:

- a. Final Acceptance Testing
- b. Field support

The following are classified as GSE:

- a. TG Shipping Container
- b. TG Blanket Container
- c. TG Rotary Tilt Fixture
- d. Breakout Box Assembly
- e. Special Tool Set

2.0 APPLICABLE DOCUMENTS

2.1 Specifications

2.1.1 Federal

2.1.2

Number	Title	Date
MSC-GSE-MEIS- 2A Type 2	Ground Support Equipment Master End Item Specification	March 1967
Military		
MIL-STD-1472	Human Engineering Design Criteria for Aerospace Sys. & Equipment	9 Feb. 1968
MS 24123A (USAF)	Plate Identification	21 Jan. 1960

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2.1.2 (Cont.)	Number	Title	Date
	AFETRM 127.1	Range Safety Manual Air Force Eastern Test Range	1 Jan. 1969
	MIL-STD-810A	Environmental Test Methods for Aerospace and Ground Equipment	23 June 1964
	MIL-STD-454A	Standard General Requirements for Electronic Equipment	5 Jan. 1965
2.1.3	Standards		
	Number	Title	Date
	MIL-STD-803A-1 (USAF)	Human Engineering Design Criteria for Aerospace Sys. & Equipment Part 1 Aerospace System Ground Equipment	27 Jan. 1964
	MIL-STD-130B with Notice 1 dated 2-7-64	Identification Marking of U. S. Military Property	24 April 1962

- 3.0 REQUIREMENTS
- 3.1 Performance
- 3.1.1 Primary Performance Characteristics
- 3.1.1.1 General Ground Support Equipment is required for servicing, testing, handling, maintaining and transporting experiment hardware.The functions of the GSE are as follows:
 - a. Performance verification of the TG instrument package.
 - b. Provide TG instrument calibration capability.

- 3.1.1.2 TG Shipping Container The TG Shipping Container shall be a small lightweight shipping container designed for hand transporting the TG hardware and any necessary accessories. The container may also be used for storing the TG hardware and accessories. The container shall keep the TG clean and dry during hand transportation, and shall afford some measure of environmental isolation.
- 3.1.1.3 TG Blanket Container The TG Blanket Container shall be a small lightweight container designed for hand transporting the TG Blanket. The container shall keep the Thermal Blanket clean and dry during hand transportation. The container shall keep the thermal blanket from being depressed in order to maintain its integrity and keep it in the proper form that it will be in when placed on the gravimeter.
- 3.1.1.4 TG Rotary Tilt Fixture The TG Rotary Tilt Fixture shall provide the mechanical mounting capability such that the TG is capable of measuring gravity to the required accuracy at any orientation up to 15[°] tilt.
- 3.1.1.5 Breakout Box Assembly The Breakout Box shall be designed to interrupt appropriate circuits to enable performance of the following:
 - a. Monitoring the string frequency lines input to the Phase Lock Loop circuitry.
 - b. Introducing test frequencies to the Phase Lock Loop circuitry.
 - c. Measurement of Battery Voltage and Current.
- 3.1.1.6 Special Tool Set (Blanket Wrenches, Adapters, Mandrils, etc.) The Special Tool Set shall be used for the following functions:
 - a. Support installation and removal of the blanket halves.
 - b. Servicing of the Precision and Intermediate ovens.
 - c. Removal and replacement of the battery.

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- 3.1.2 Secondary Performance Characteristics
- 3.1.2.1 General The GSE shall have the capability of operationally testing the TG instrument. The GSE will be used for ambient functional checkout only. Special test setups required for complete acceptance and qualification testing are considered to be non deliverable items.
- 3.1.2.2 TG Shipping Container The TG Shipping Container should have the capability of keeping the TG from being exposed to environments outside the range of 65°F to 100°F for one hour. The outside ambient atmospheric pressure range is 10psia 14.7psia. The Shipping Container shall be capable of closing without touching the TG. The Shipping Container itself shall not weigh more than 50 lbs. with the TG hardware and The Container shall weigh less than 20 lbs. with no hardware.

The TG Shipping Container shall provide a replaceable dessicant capability to protect the TG from effects of humidity during transit.

The Shipping Container shall not exceed the size, weight, and volume as specified in paragraph 3.3, "Design and Construction."

3.1.2.3 TG Blanket Container - The TG Blanket Container shall provide a two way pressure relief valve and a purging valve. The Blanket Container itself shall not weigh more than 30 lbs. with the thermal blanket.

Suitable handles shall be provided to enable one man to transport the container.

3.1.2.4 TG Rotary Tilt Fixture - The TG Rotary Tilt Fixture shall be capable of accepting and holding the TG, of leveling the TG to an accuracy of \pm 7 minutes, and of providing 360° rotation of the TG mounting surface at an angle of 15° 15' \pm 15'. Provide for the capability of being locked in any rotary position.

- 3.1.2.5 Breakout Box Assembly The Breakout Box Assembly performance requirements are a function of the design and construction to be implemented.
- 3.1.2.6 Special Tool Set The Special Tool Set requirements are a function of the design and construction to be implemented.
- 3.1.3 Operability
- 3.1.3.1 Reliability The design, materials, and manufacturing shall be such that failure of the GSE shall not affect the launch schedule or cause damage to the TG.
- 3.1.3.2 Maintainability Design should be such to provide accessibility, replaceability, and serviceability consistent with efficient servicing, testing, and maintenance requirements.
- 3.1.3.3 Useful Life The useful life of the GSE shall include time required for all testing and flight operations.
- 3.1.3.4 Natural Environment The GSE shall be designed to withstand the natural environmental parameters specified in Table 1.
- 3.1.3.5 Transportability The GSE may be protected by suitable packaging for transportation and storage if the environment exceeds that specified in Table 1. The GSE shall be capable of meeting the operating requirements of the applicable performance specification after exposure, while protected by its normal packaging, to these environments. Wherever possible, GSE shall be designed to withstand handling and transportation environments without the necessity of special containers or the necessity of monitoring critical environments to verify that design limits have not been exceeded
- 3.1.3.6 Human Performance The GSE hardware shall be designed to permit efficient use of the capabilities of ground and flight personnel in the applicable natural and induced environments. Controls shall be readily accessible, suitably arranged, properly identified and of

- 3.1.3.6 (Cont.) such size and construction as to permit convenience and ease of operation. All controls shall operate freely, smoothly, and easily without excessive binding, play, or backlash. Switches, levers and other controls which are manipulated during operation of the equipment, shall be of such rugged design and construction that they will not be damaged when repeatedly operated. GSE shall comply with design criteria of MIL-STD-803A-1 and MIL-STD-1472 respectively.
- 3.1.3.7 Safety The safety of the flight and ground personnel shall be a prime consideration in the design of the GSE. Sharp edges, burrs, corners and protuberances are not permitted. The GSE hardware shall be designed to prevent personnel contact with high temperature surfaces and hazardous electrical points.

The GSE hardware shall have adequate safeguards to prevent hazardous conditions and inadvertent operation. Normal operations, component replacement, malfunctions, or failures shall not cause damage to other equipment, the flight vehicle, or injury to personnel.

The GSE shall be designed to meet the requirements of AFETRM 127.1.

3.1.3.8 Induced Environment - The GSE shall be protected from all adverse conditions and shall be capable of experiencing normal shocks and vibrations while being transported on a commercial airplane. The TG Shipping Container and TG Blanket Container shall not be exposed to normal airline handling and transportation procedures.

3.2 GSE Definition

- 3.2.1 Interface Requirements
- 3.2.1.1 Schematic Arrangement Not applicable.

3.2.1.2 Detailed Interface Definition - The GSE shall meet the following interface requirement:

Test equipment shall be designed so that failure within the equipment or loss of power will not cause failure or damage to the equipment being tested and failure of the equipment being tested will not cause failure or damage to the test equipment.

The following interface control drawings and engineering documentation are referenced to specify the electrical, mechanical, functional and procedural interface requirements of the GSE with other equipments.

Engineering Documentation -

TG Assembly Drawing - 2025000

- 3.2.2 Component Identification
- 3.2.2.1 Government Furnished Property List The GSE shall be designed to incorporate the following Government Furnished Property.

None.

3.2.2.2 Engineering Critical Components List -

None.

3.2.2.3 Logistics Critical Components List -

None.

3.2.3 Technical Manuals

A GSE Instruction Manual shall be prepared to define the operation procedures and functional requirements which will be required during the use of the GSE in testing TGE equipments. A section of the manual will describe the calibration and verification procedures for the GSE.

3.3 Design and Construction

3.3.1 General Design Features

The contractor shall perform the engineering tasks required for developing the detailed design for the GSE required for the TGE. The GSE shall be designed and developed in accordance with the requirements of Ground Support Equipment Master End Item Specification MSC-GSE-MEIS-2A, Type 2.

The physical characteristics of the TG Shipping Container shall approximate the following:

a. Height	25	inches
-----------	----	--------

	b.	Width	18 inches
--	----	-------	-----------

c. Depth 17 inches

- d. Weight Less than 20 lbs.
- e. Thickness 0.125 ABS plastic
- 3.3.1.1 The physical dimensions of the TG Rotary Tilt Fixture shall approximate the following:
 - a. Height 4.00 inches
 - b. Length 25.00 inches
 - c. Width 28.00 inches
- 3.3.1.2 The physical characteristics of the TG Blanket Container shall approximate the following:
 - a. Height 25 inches
 - b. Width 18 inches
 - c. Depth 17 inches
 - d. Weight Less than 30 lbs.
- 3.3.2 Selection of Specifications and Standards

Specifications and standards necessary for the design and development of the GSE, in addition to those referenced in this specification,

3.3.2 shall be selected in the following order of preference except as otherwise defined in this specification.

- a. NASA specifications and standards.
- b. Federal specifications and standards.
- c. Military specifications and standards (MIL, JAN or MS)
- d. Other
- 3.3.3 Materials, Parts and Processes Not applicable.
- 3.3.4 Standards and Commercial Parts Not applicable.
- 3.3.5 Moisture and Fungus Resistance

The GSE shall be designed to resist moisture and fungus in accordance with MIL-STD-810.

- 3.3.6 Corrosion of Metal Parts Not applicable.
- 3.3.7 Interchangeability and Replaceability

The GSE shall be designed to make all numbered life parts interchangeable. The design objective during development shall be to achieve interchangeability of integrated parts in accordance with MIL-STD-454 Requirement 9.

3.3.8 Workmanship

The GSE including all parts and assemblies shall be constructed and finished in accordance with commercial standards.

3.3.9 Electromagnetic Interference

The GSE shall not induce EMI in other equipments, nor be susceptible to interference within the limits specified in LM-STD-LSP-530-001.

3.3.10 Identification and Marking

The GSE shall be marked for identification in accordance with MIL-STD-130. Nameplates shall conform to MS24123. Conspicuous markings or labels shall be affixed to the GSE to warn ground support personnel and astronauts of the presence of hazardous conditions. GSE hardware which could accidentally be substituted for flight hardware or backup hardware shall be red striped with material compatible red paint to prevent such substitution.

The GSE wires and cables for experiment shall not be identified by hot stamping directly onto primary or secondary insulation.

3.3.11 Storage

The GSE shall have a storage life of 5 years. Control shall be maintained on all parts and materials which are sensitive to age or the storage environments.

These parts and materials shall be identified, and if deterioration is a factor during storage or after installation for use, the maintenance procedures shall indicate a replacement cycle or the necessary retesting.

4.0 QUALITY ASSURANCE PROVISIONS

- 4.1 Phase I, Test/Verification
- 4.1.1 Engineering Test and Evaluation (or Development Test) Not applicable.

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4.1.2 Preliminary Qualification Tests Not applicable.

4.1.3 Formal Qualification Tests

The following sections specify the methods of formally verifying that each requirement in Section 3 has been satisfied. These tests are to be performed to evaluate the final design and reliability and to determine compliance with performance and environmental requirements.

- 4.1.3.1 Requirement/Quality Cross Reference Index See Table 2.
- 4.1.3.2 Analysis Verification by analysis shall be used in lieu of testing whenever it can be shown by generally accepted analytical techniques that an article will meet the applicable technical requirements. A report of each such analysis shall be submitted.
- 4.1.3.3 Inspection Verification by inspection shall be used whenever it can be shown that inspection techniques are adequate to assure that the article will meet the applicable technical requirements. Inspection will be used to verify the construction features, compliance with drawings, workmanship and physical condition of the article.
- 4.1.3.4 Demonstration Verification by demonstration shall be used whenever it can be shown that demonstration is adequate to assure that the article will meet the applicable technical requirements. Demonstration will be used to verify such requirements as service and access, handling, convenience, and ease of operation.
- 4.1.3.5 Test Verification by test shall be used whenever none of the above verification methods can be applied.

- 4.1.4 Reliability Tests and Analyses Not applicable.
- 4.1.5 Engineering Critical Component Qualification Not applicable.
- 4.2 Phase II, Integrated Test Requirement

Integrated systems tests when applicable will be conducted to verify that the GSE, when integrated with mating systems hardware, is functionally and operationally compatible.

5.0 PREPARATION FOR DELIVERY

Not applicable.

- 6.0 NOTES
- 6.1 Supplemental Information

There is also a need for the following equipments which will be required to support the TG at KSC.

- a. Vacuum Pump
- b. Battery Charger and Constant Current
- c. Variable Power Supply 7.5 Volts, 6 amps
- d. Voltage and Current Meters
- e. Counter and Printer with Precount Capabilities.
- 10.0 APPENDIX

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TABLE 1. GSE NATURAL ENVIRONMENT PARAMETERS

a) Temperature

Air Transportation Ground Transportation Storage

b) Pressure Air Transportation

Ground Transportation and Storage

- c) Humidity
- d) Sunshine
- e) Rain

g) Fungus

f) Sand and Dust

 -45° F to $+140^{\circ}$ F for 8 hours -20° F to $+145^{\circ}$ F for 2 weeks $+25^{\circ}$ F to $+105^{\circ}$ F for 3 years

Minimum of 3.47 psia for 8 hours (35,000 - foot altitude)

Minimum of 11.78 psia for 3 years (6,000 - foot altitude)

0-100 percent relative humidity, including conditions wherein condensation takes place in the form of water or frost for at least 30 days

Solar radiation of 360 BTU per square foot per hour for 6 hours per day for 2 weeks.

Up to 0.6 inch per hour for 12 hours, 2.5 inches per hour for 1 hour.

As encountered in desert and ocean beach areas, equivalent to 140-mesh silica flour with particle velocity up to 500 feet per minute and a particle density of 0.25 gram per cubic foot.

As experienced in Florida climate. Materials will not be used which will support or be damaged by Fungi.

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TABLE 1. (Continued)

h) Salt Spray

Salt atmosphere as encountered in coastal areas, the effect of which is simulated by exposure to a 5 percent salt solution by weight for 48 hours.

i) Ozone

3 years exposure, including 72 hours at 0.5 ppm, 3 months at 0.25 ppm, and the remainder at 0.05 ppm concentration.

TABLE 2. REQUIREMENT/QUALITY CROSS-REFERENCE INDEX

Requirements	Req Para	Test Para	Test Method
TG Shipping Container	3.1.1.2	4.1.3.3	
TG Blanket Container	3.1.1.3	4.1.3.3	
TG Rotary Tilt Fixture	3.1.1.4	4.1.3.3 4.1.3.5	
TG Shipping Container	3.1.2.2	4.1.3.3	
TG Blanket Container	3.1.2.3	4.1.3.3	
TG Rotary Tilt Fixture	3.1.2.4	4.1.3.5	
Reliability	3.1.3.1	4.1.3.3	
Maintainability	3.1.3.2	4.1.3.3	
Useful Life	3.1.3.3	4.1.3.3	
Natural Environment	3.1.3.4	4.1.3.3	
Transportability	3.1.3.5	4.1.3.4	
Human Performance	3.1.3.6	4.1.3.4	
Safety	3.1.3.7	4.1.3.3	
Detailed Interface Definition	3.2.1.2	4.1.3.5	
Technical Manual	3.2.3	4.1.3.3	
Moisture and Fungus Resistance	3.3.5	4.1.3.3	
Interchangeability and Replaceability	3.3.7	4.1.3.3	
Workmanship	3.3.8	4.1.3.3	
Electromagnetic Interference	3.3.9	4.1.3.3	
Identification and Marking	3.3.10	4.1.3.3	
Storage	3.3.11	4.1.3.3	

APOLLO 17 TRAVERSE GRAVIMETER EXPERIMENT

Building 45 - Preliminary Report

December 14, 1972

I. INT ODUCTION

The Traverse Gravimeter Experiment (TGE) data are presented in this report. All headings are shown in table I. A total of 26 realings were obtained, including three temperature readings, two bias realings and 21 gravity readings. Most readings were taken on the Rover. At the LM site, all readings except reading No. 1 were taken on the surface in accordance with mission rules. A: sempral science stops, readings were repeated on the surface.

II.

COLVERSION OF DISPLAYED NUMBERS

The displayed number is a nine digit number consisting of seven gravity digits followed by the temperature digits at the beginning of each traverse, readings 1, 10 and 18 on table I; the display was read upon turning the STBY/ON switch to ON. For these readings only, the eighth digit is meaningful; the others are meaningless. The eighth digit indicates the status of various temperature alarms. The ninth digit is valued only during a gravity or bias measurement. A displayed number less than seven indicates the VSA temperature is in control. The conversion of the displayed number to gravity in milligals is performed as follows: (In computing $K_2 g^2$ and $K_3 g^3$ a value of 0.167g is assumed for g .)

Where:

 $D_N \equiv$ Displayed value for gravity measurement $D_r =$ Displayed value for bias measurement $K_0 =$ Bias $K_1 =$ VSA scale factor $K_2 =$ VSA second order term $K_3 =$ VSA third order term

For the purposes of these preliminary calculation, the following values are used based on laboratory and prelaunch testing.

$\mathbf{K}^{\mathbf{X}}$	V0:2	.00034 Hz/g^2		
К3	a	0.00300 Hz/g ³		
K ₁	-	129.14549 Hz/g	840	EVA 1
	∎**** ₽ 781 ⁻¹	129.14550 Hz/g	***	EVA 2
	ge nas Reserve	129.14551 Hz/g	Reine	EVA 3

Also, the gravity values computed are based on computing bias from TG display readings 3 and 4 of table I. This is done for the purposes of this report only. Further analysis of the data by the P.I. may result in using some other value of bias.

III. DISCUSSION OF RESULTS

The TCE functioned throughout all three EVA's. The last two digits were 0 and 1 for every gravity and bias measurement, indicating excellent temperature control and that at no time during the EVA's did any of the temperature alarms actuate. . 2

The value of bias computed at the beginning of EVA-1 was 7.2159 Hz. A predicted value of bias based on laboratory test data was 7.2144 Hz. Total shift during the translunar phase was .0015 Hz. Total shift during the translunar phase was .0015 Hz. This corresponds to about an ll mgal bias shift which is considered reasonable as compared to typical bias shifts experienced during acceptance and vibration testing. During EVA-1 small changes in gravity wore experienced as expected due to the relatively flat terrain. The largest shift observed, occurred while taking the TGE on an off the Rover at the LM site. A 4.5 mgal shift was obtained. At this time, it was suspected a shock due to handling caused this shift. At the end of EVA-1, the first displayed reading (reading #8) was OOOXXXX, indicating loss of lock in the phase-lock loop. In order to induce this (especially on the surface), the TGE must have been bumped rather severely during a measurement. The measurement (as repeated and a reasonable reading was obtained.

This reading at the LM site was 1.4 mg lower than reading Nc. 3 indicating a reasonable agreement.

During EVA-2, a large gravity change was found at station 2. This caused the P.I. to request an additional reading on the way to station 3. This reading is indicated in table I as station 2A. The closeout reading at the end of EVA-2 (reading No. 17) was close to the closeout of EVA-1 (reading No. 9) or 0.7 mgal difference.

During EVA-3, no reading was taken at station 7, probably because of timeline considerations. At stations 8 and 9, readings were taken both on and off the Rover. The differences off the Rover

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were 6.9 and 6.2 mgal less than on the Rover for stations 8 and 9 respectively. This is not much different from the 4.5 mgal difference obtained at readings 2 and 3 at the beginning of EVA-1. The fact that the changes were of the same magnitude and in the same direction suggests that some type of Rover motion, astronaut handling or surface phenomenon may have induced this. On the way from station 9 to the LM site, the palate on which the TG was mounted swung open. Previous experience indicates that the shock effect that may have resulted from this could cause a bias shift. At the LM site at the end of EVA-3, both a gravity and bias measurement were obtained on the surface (readings 25 and 26). The bias computed from these values was 7.2153 Hz or .0006 Hz different from the initial bias computed at the beginning of EVA-1. This is equivalent to about a 4.2 mgal bias shift. This could well have been caused by the swirging of the palate on the way to the LM site or by other mechanically induced shock effects such as taking the instrument on or off the Rover several times.

IV. CONCLUSIONS

The TGE performed well throughout all three EVA's. Temperature performance was excellent. There is no reason to believe that there were any electronic problems. Performance, however, was not as good as was hoped for based on tests of the instrument and Rover rides during various simulations such as at Flagstaff and Black-Hawk. Just impressions based on the data indicate that the major error source was shock or rough handling. The sensor in the TGE (the vibrating string accelerometer) is known to be sinsitive to shock. Experience has also shown that the bias

of the VSA is affected much more than the scale factor. The differences obtained at stations where readings were taken both on and off the Rover were larger than expected. Despite these error sources (particularly during EVA-3), the instrument appeared to be functioning well.

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TABLE I

APOLLO 17 TRAVERSE GRAVIMETER EXPERIMENT DATA

Reading Number	EVA	Site	TG Display	Gravity	Type of Reading
1	1	LM	XXXXXXX-0Y	N/A	Temperature
2]	LM	6700031-01	162,699.0	Grav-On Rover
3	1	LM	6700172-01	162,694.5	Grav-On Surface
	1	LM	3374540-01	N/A	Bias-On Surface
4.	1		6700026-01		
5		Alsep		162,699.2	
6	1	Station 1.	6700129-01	162,695.9	Grav-On Rover
7	1	SEP site	6700101-01	162,696.8	Grav-On Rover
8	1	ΓW	0001330-01	N/A	Grav-On Surface
9].	LM	6700215-01	162,693.1	
10	2	ΓW	XXXXXXXXXX	N/N	Temperature
11	2	IM	6700177-01	162,694.3	Grav-On Surface
15	2	Station 2 .	6701552-01	162,649.7	Grav-On Rove
13	2	Station 2A	6701235-01	162,660.0	Grav-On Rover
14	2	Station 3	6700497-01.	162,683.9	Grav-On Rover
15	2	Station 4	6700125-01	162,696.0	Grav-On Rova
16	2	Station 5	6700314-01	162,689.8	Grav-On Rover
17	5	LM	6700235-01	162,692.4	Grav-On Surface
18	3	LM	xxxxxxx- <u>0</u> 7	N/A	Temperature
19	3	L.14	6700270-0.L	162,691.3	Grav-On Surface
20	3	Station 6	6701098-01	162,664.4	Grav-On Surface
21	3	Station 8	6700960-01	162,668.9	Grav-On Rover
22	3	Station 8	6701173-01	162,652.0	Grav-On Surface
23	3	Station 9	6700378-0.L	162,687.7	Grav-On Rover
24	3	Station 9	6700571-01	162,681.5	Grav-On Surface
25	3	IM	6700107-01	162,696.5	Grav-On Surface
26	3	. IM	3374171-01	N/A	Bias-On Surface