OPERATING MANUAL

MODEL GR-310

GAMMA RAY SPECTROMETER

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geoMetrics

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WARRANTY

geoMetrics guarantees this instrument to be in perfect operating condition, fully tested, and complete as described for one full year beginning with the date of receipt but not to exceed fifteen months from the shipping date.

geoMetrics guarantees that all equipment offered for sale is free from defects in materials and workmanship, carefully tested, and in first class operating condition. In the event of malfunction, geoMetrics, at its own expense, will repair or replace any materials, equipment, work, or parts which prove defective or deficient under normal operating conditions. Unless altered by contract, the warranty period shall extend for one calendar year beginning with the date of acceptance, but will not exceed fifteen (15) months from the date of shipment.

Every effort has been made to ruggedize and protect the Gamma Ray Detectors for their intended use. Due to the fragile nature of the crystal detector assembly and difficult operating environments, geoMetrics' warranty does not include breakage of the crystal for whatever reason. geoMetrics does, however, warrant the detectors to be complete and fully operational to their published specifications at the time of delivery and to maintain the stated minimum resolution and performance for a period of one year.

geoMetrics reserves the right to perform warranty services FOB Sunnyvale or at the customer's installation site. geoMetrics is not responsible for delays or defects in the quality of results from misuse, mishandling, unauthorized modifications, installation, or other operation conditions outside its control.

WARRANTY SERVICE

If warranty service is necessary, or if technical advice is required contact GeoMetrics.

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If any part of this instrument is returned to the factory for any reason, please include this completed form with the complete instrument or any individual part returned for repair.
SHIP TO:

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395 Java Drive
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Name ______________________________

Company ______________________________

Address ______________________________

City, State, Zip. Country ______________________________

Telephone Number ______________________________

Please describe symptoms of trouble as completely as possible or detailed reason for return (use additional paper if required):

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CAUTION

The high voltage power supply in the Model GR-310 generates from 750 to 1200 volts. It can deliver painful shocks which may be hazardous. Only competent personnel should attempt to service the electronic circuitry.

Whenever the instrument cover is to be removed, as when the battery pack is to be replaced, be certain that the FUNCTION switch in the upper left hand corner of the instrument panel is in the OFF position.

Although the crystal in the GR-310 is insulated, the package should not be subjected to a rapid temperature change of more than 20° ambient.

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ruggedized console cabinet. Power for approximately fifty hours of operation is provided by a battery pack comprised of twelve alkaline flashlight "D" cells. No special operating skills are required. Controls are designed for simple operation, and displays are easily read.

1.3 SPECIFICATIONS

Detector: Thallium doped sodium iodide crystal 2 inch diameter by 2 inch thick (5.1 cm by 5.1 cm) optically coupled and hermetically sealed to a high gain photomultiplier tube that is shock mounted in a special housing within the spectrometer cabinet. Crystal volume: 6.3 in.^{3} (104 cm^3).

Data Accumulate: Data accumulation periods of 1, 10, 100, or 1000 seconds may be selected by a panel switch. Letter "A" is continuously displayed on a readout panel during an accumulation period.

Data Functions: A panel switch selects the data to be displayed: total gamma ray counts (TC) or counts in the energy windows for potassium (K), uranium (U), and thorium (TH). The switch also permits calibration of the instrument with an internal reference isotope.

Data Outputs: Visual: Total count is indicated on a five digit light emitting diode (LED) display with the decimal point automatically positioned for direct readout in

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1.0 GENERAL INFORMATION

1.1 INTRODUCTION

Information necessary for proper operation and maintenance of geoMetrics' Model GR-310 Gamma Ray Spectrometer is included in this manual along with brief descriptions of radiometric survey techniques that provide optimum results in the field.

It is emphasized that the Model GR-310 is a precision instrument and should be protected from sudden temperature changes and be handled gently. Special precautions should be observed in the field to avoid contamination of the instrument by radioactive dust.

1.2 GENERAL DESCRIPTION

The geoMetrics Model GR-310 is a high resolution, differential type spectrometer that has been expressly designed for uranium prospecting, geologic mapping, and reconnaissance surveys. It is a completely self-contained, portable system equipped with a 6.3 in.^{3} (104 cm^3) thallium doped sodium iodide [NaI(Tl)] detector and an internal calibration reference isotope. The GR-310 provides independent, switch-selectable measurements for total gamma ray count and the diagnostic gamma radiation for potassium (^{40}K), uranium (^{214}Bi), and thorium (^{208}Tl). Data outputs in counts per second are available on a digital readout or on a 250 degree full view analog rate meter. An audio signal (ticking sound) can be set to start at a given gamma ray threshold with a pulse rate that varies with the real time count rate. The spectrometer incorporates reliable, solid-state electronic components installed compactly in a lighweight, ruggedized console cabinet. Power for approximately fifty hours of operation is provided by a battery pack comprised of twelve alkaline flashlight "D" cells. No special operating skills are required. Controls are designed for simple operation, and displays are easily read.

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Data Outputs: Visual: Total count is indicated on a five digit light emitting diode (LED) display with the decimal point automatically positioned for direct readout in counts per second. Count rate also is continuously displayed on the 10 to 10,000 cps logarithmic scale of a full view, 250 degree meter. No range switching is required, and electronic circuitry provides smooth meter movement throughout the entire range.

Audio: A ticking sound proportional to the count rate is generated when a selected gamma ray background count rate is exceeded. The threshold for the audible signal is adjusted by a calibrated AUDIO THRESH knob on the instrument panel.

Operating Modes:

Continuous: After counts have been accumulated for either 1 or 10 seconds, the count rate value is displayed for 2 seconds. Count rate measurement is automatically repeated after display.

Manual: START ACCUM pushbutton activates the count rate measurement cycle for the 100 or 1000 second data accumulation periods. A 3 second audible "ready" signal denotes end of the accumulation period. The DISPLAY pushbutton recalls accumulated data at any time prior to the next measurement cycle.

Energy Discrimination:

Switch selectable, independent measurement of three differential window settings (factory adjusted) and one total count channel:

Potassium (^{40}K):	Window peak — 1.46 MeV Window width — 200 keV
Uranium (^{214}Bi):	Window peak — 1.76 MeV Window width — 200 keV
Thorium (^{208}Tl):	Window peak — 2.62 MeV Window width — 400 keV
Total Count (T/C):	All gamma ray energy between 0.4 and 4.0 MeV

Calibration: Reference isotope (^{133}Ba) mounted inside console and the front panel potentiometer adjustment for "peak count" on digital display and rate meter. Calibration window: 0.34 to 0.37 MeV.

Power Requirements: Twelve "D" type replaceable flashlight cells. Battery status indicated on meter. Approximately fifty hours of continuous rate meter operation from alkaline cells.

Temperature Range: $-10°C$ to $+60°C$ ($+14°F$ to $+140°F$); maximum rate of temperature change: 20°C per hour.

Size: Electronics console with internal detector: 3-1/2 x 7 x 11 in. (9 x 18 x 28 cm).

Weight: Console with internal detector and battery pack: 7.5 lb (3.4kg).

1.4 INVENTORY INSPECTION

When received from the manufacturer, the Portable Gamma Ray Spectrometer, Model GR-310, should include the following items:

a)	Console	1 each
b)	Calibration source (^{133}Ba)	1 each
c)	Adjustable shoulder harness	1 each
d)	Battery pack — "D" type cells	2 sets (24)
e)	Shipping/carrying container	1 each
f)	Operator's Manual	1 each
g)	Applications Manual	1 each
h)	Small tube of glue	1 each

2.0 INSTALLATION

2.1 INTRODUCTION

The geoMetrics Model GR-310 Gamma Ray Spectrometer is ready for field operation as shipped from the factory. It will be necessary to install the batteries and the reference source, however. For ease of communication, the batteries are collectively referred to as a "battery pack" in this manual.

2.2 BATTERY TYPES

Nearly any 1.5 volt "D" cell can be used for the battery pack of the GR-310 spectrometer, but alkaline or premium type carbon zinc cells have been found to provide significantly longer operation than standard carbon zinc flashlight cells. Operating temperatures have a pronounced effect on the life of the battery pack, as is indicated in the following table. Alkaline cells should be used whenever possible and especially for operation at low temperatures.

"D" CELL TYPE	BRAND NAMES	CONTINUOUS OPERATION (approx. hours)			
		25° C	0° C	-20° C	-30° C
Alkaline	Eveready, E-95 Mallory, M 1300 Mallory, CSR 356	50	35	10	5
Standard carbon zinc (flashlight)	Burgess Eveready Ray-O-Vac	10	1	0	0
Premium carbon zinc (industrial)	Burgess, 1200	25	3	0	0

2.3 BATTERY PACK INSTALLATION

Following is the procedure for installation or replacement of the battery pack in the Model GR-310 spectrometer:

1. Be sure the FUNCTION switch in the upper left hand corner of the instrument panel is in the OFF position.

2. Unsnap the plastic side latches and remove the instrument cover.

3. Remove the four cell retaining tubes from their holders.

4. Place three fresh "D" cells in each retaining tube.

   NOTE: Be sure all cells face the same direction in each retaining tube. Note which end of the series combination of cells is positive.

5. Note polarities indicated by labels fastened to each cell retaining tube holder. Insert the positive end of a retaining tube into the positive terminal of a holder (positive terminal has red insulation), and then push the negative end in place. Repeat this operation until all retaining tubes have been installed.

6. Replace the instrument cover gently and secure it in place with the side latches.

7. Turn the FUNCTION switch to the CAL position and the ACCUM PERIOD switch to the BAT position. The rate meter needle should be over the highest part of the white BAT band located on the inner diameter of the meter face, indicating fresh batteries. Note the position of the needle.

If the needle is not at a maximum indication and it is known that the batteries are fresh, repeat steps 1 through 5 of this section, this time being absolutely certain that each cell is lined up + to - and that the battery tubes are installed properly. Then, gently replace the instrument cover, latch the cover, and repeat the first part of this step.

2.4 REFERENCE SOURCE INSTALLATION

The Model GR-310 requires a permanently mounted internal reference source (^{133}Ba) for proper operation. The radiation level of the source is very low. To comply with U.S. Nuclear Regulatory Commission (NRC) requirements, this isotope must be shipped external to the electronics console and installed at the point of ultimate destination. This isotope is exempt from NRC or agreement state licensing requirements. It is not for human use, introduction into foods, beverages, cosmetics, drugs or medicinals, or into products manufactured for commercial distribution. Such exempt quantities should not be combined.

1. Be sure the FUNCTION switch is OFF.
2. Unsnap the plastic side latches and carefully remove the instrument cover.
3. Remove the ^{133}Ba reference source from its plastic container.
4. Place the reference source directly on the colored dot located inside the instrument cover on the left hand bottom corner and press in place to anchor it firmly using some of the "lock tight" glue supplied with the instrument.

5. Note the "Calibration Point" indicated on the plastic sheet covering the solder side of the GR-310 circuit board. This value is the approximate setting of the CAL SET potentiometer to be used later to calibrate the GR-310 (see paragraph 3.4).

6. Replace the instrument cover gently and secure it in place with the side latches,

3.0 OPERATION

3.1 INTRODUCTION

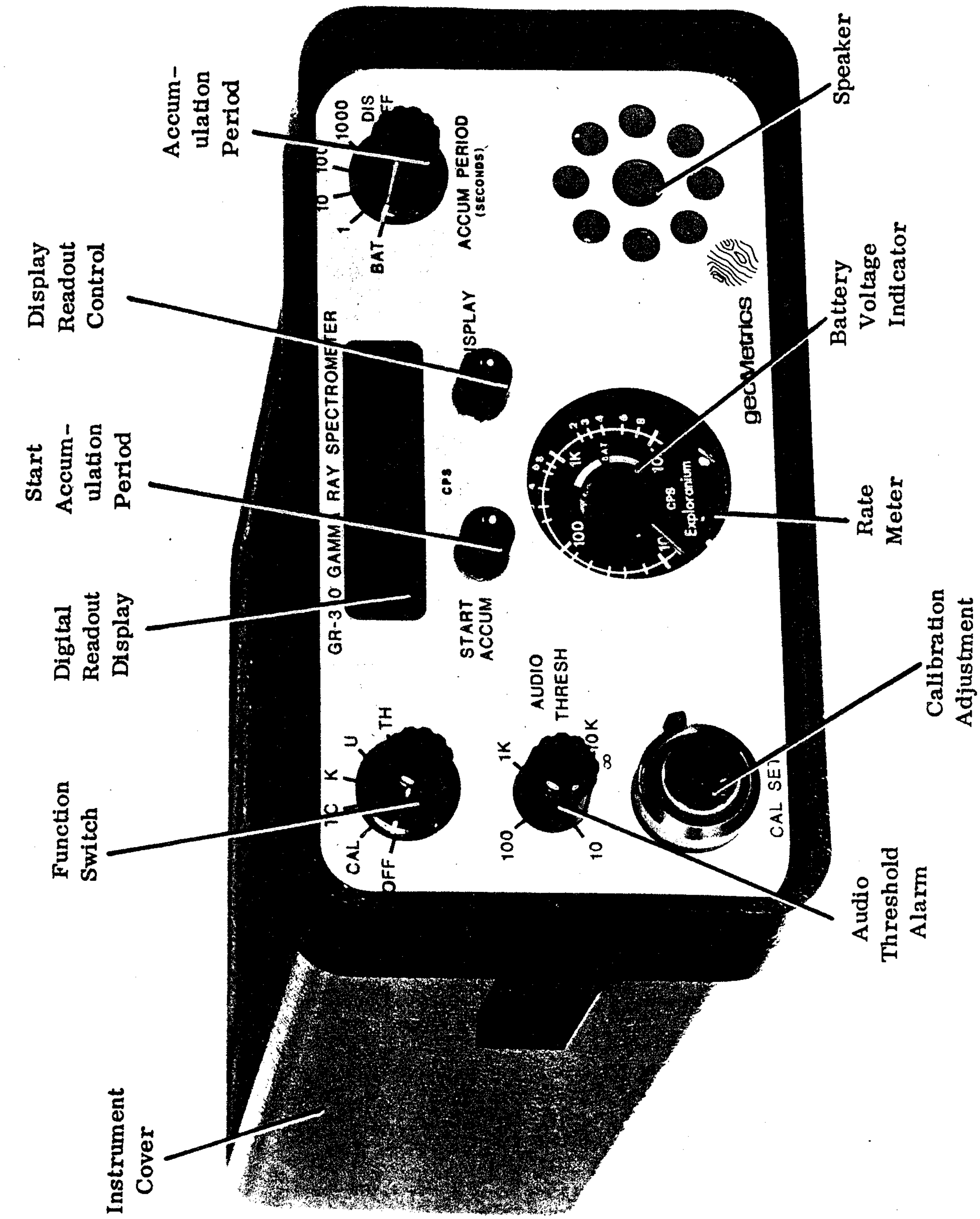
The geoMetrics Model GR-310 spectrometer is arranged so that all operating controls, switches, meters, and displays are in full view and are easily accessible from the front panel. Since the spectrometer comes complete and ready for use (except for the installation of the battery pack and reference source described in Section 2), the operator need only become familiar with the functions of the various controls and then follow a typical operating sequence.

3.2 CONTROLS AND INDICATORS

The functions of the various controls and indicators on the GR-310 spectrometer are described below. Figure 3-1 indicates the locations of the various items on the front panel of the instrument.

CONTROLS	DESCRIPTION
FUNCTION SELECTOR	Rotary Switch - 5 position OFF - Battery disconnected CAL - Calibration channel activated TC - Total counts displayed K - Potassium channel counts displayed U - Uranium channel counts displayed TH - Thorium channel counts displayed
ACCUM PERIOD	Rotary Switch - 6 position BAT - Displays battery pack voltage on rate meter

	SAMPLE TIME - 1, 10, 100, 1,000 seconds in the accumulation period.
	DIS OFF - Digital circuitry disabled to conserve the battery. The rate meter and audio signal are still functional.
AUDIO THRESH	Potentiometer: Marked values correspond approximately to meter scale values of 10, 100, 1000, 10000 and ∞ counts per second (∞ = off). Audio alarm will be activated when the indicated counts per second is exceeded.
CAL SET	Potentiometer: 10 turn, locking. Used to calibrate the instrument gain with an internal ^{133}Ba reference source.
START ACCUM	Pushbutton: Momentary contact. Activates 100 or 1000 second data accumulation periods.
DISPLAY	Pushbutton: Momentary contact. Activates visual display at end of 100 or 1000 second accumulation period.



CONTROLS AND INDICATORS
Figure 3-1

INDICATORS	DESCRIPTION
DIGITAL READOUT	LED 5 digit display; provides numerical values of count rates directly as counts per second. The letter "A" is displayed during accumulation time periods.
RATE METER	A wide scale, 250 degree meter movement; electronically driven to provide a smooth, 3 decade logarithmic readout of 10 to 10,000 counts per second. The rate meter operates continuously.
AUDIO OUTPUT	A speaker emits a signal when accumulation periods are over and also provides a variable frequency ticking sound proportional to count rate.

3.3 REFERENCE SOURCE

The reference source used in the Model GR-310 is ^{133}Ba. The isotope has a half-life of about seven years and emits a variety of gamma ray photons, as indicated in Figure 3-2. The calibration window is set to count gamma ray photons with energies in the interval of 0.34 to 0.37 MeV. The resolution of a thallium doped sodium iodide detector of the type used in the Model GR-310 is such that the 0.356 and the 0.380 MeV gamma ray photons shown in Figure 3-2 are lumped into one major photo peak with a maximum located near 0.356 MeV. The reference photo peak is relatively free from spectral interference of the ^{232}Th and ^{238}U decay series, except for ^{214}Pb, which emits at 0.350 MeV.

4000 cps Ba133

REFERENCE ISOTOPE

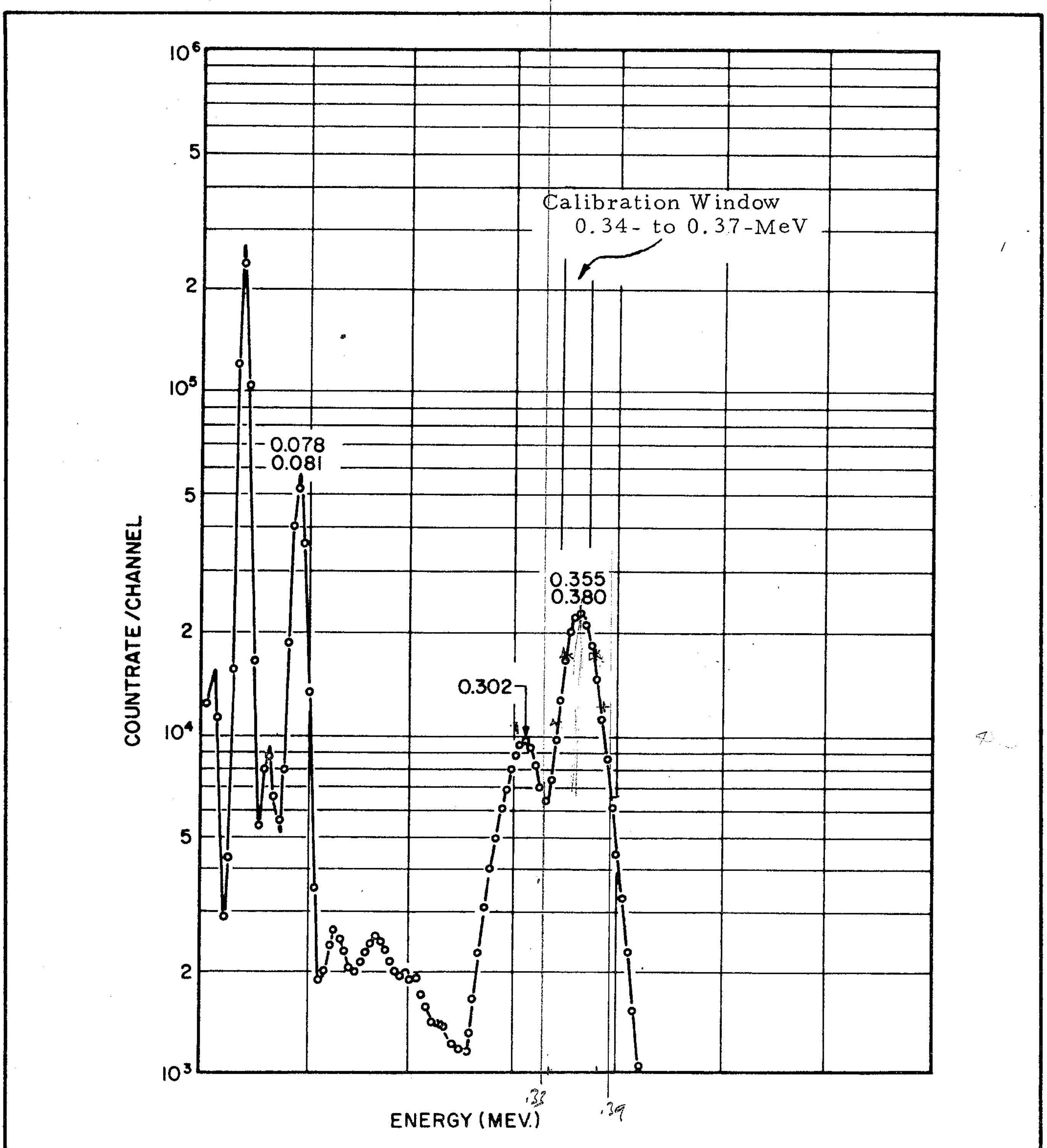


Figure 3-2 Gamma Spectrum for ^{133}Ba Reference Isotope

$\int_{\Delta E} dn = 4000$

Naturally, the ^{133}Ba photo peak is subject to interference from the Compton effect and back scatter; thus, if calibration is attempted in the presence of high activity, Compton radiation from ^{238}U-decay series will cause some interference. When high activity (>500 counts per second total count) is suspected of interfering with calibration, the GR - 310 should be removed to a region of low background.

3.4 INITIAL CALIBRATION PROCEDURE

When the instrument is first received from the factory, the reference source (^{133}Ba) must be mounted within the instrument case. For the initial calibration, it is assumed that the user has followed the steps in Section 2.4 and is now ready to perform the following additional steps:

1. Turn the FUNCTION switch to the CAL position.
2. Set the ACCUM PERIOD switch to the "1" position (i.e., the 1 second period).
3. Unlock the CAL SET potentiometer and adjust it to the value of the "Calibration Point" noted in Section 2.4, step 5.
4. Slowly rotate the CAL SET potentiometer a small amount in either direction until a maximum reading (counts per second) is obtained on the digital readout or the rate meter. When properly calibrated, the count rate should peak in the range of 125 to 175 counts per second.
5. If a maximum reading within the range of 125 to 175 counts per second cannot be obtained with small excursions of the CAL SET potentiometer, it may be necessary to search a wider range of

CAL SET values.

a. Start by moving the potentiometer one full turn lower than the "Calibration Point" and slowly move upward to one turn past "Calibration Point."

b. This procedure should result in a peak counting rate in the desired range. If a peak cannot be found or if its rate is higher or lower than the 125 to 175 counts per second range, recheck the source position within the case of the unit (see Section 2.4).

NOTE: Although the GR-310 is internally temperature compensated, temperature variations will produce some changes in the CAL SET values.

The CAL SET potentiometer shifts the gain of the photomultiplier so that the 355 KeV peak falls within the 0.34 to 0.37 MeV window. When this occurs the other peaks from ^{40}K, ^{214}Bi, and ^{208}Tl will also be within their proper windows.

3.5 OPERATION PROCEDURE

The state of the battery pack should be ascertained before each field trip. Ordinarily the voltage of the battery pack in the Model GR-310 is an indication of the remaining life, because the initially high voltage gradually decays to a low value just before complete collapse. However, certain types of dry cells may show an unusually high voltage after a brief period of inactivity, even though their useful life is spent. The battery check should be performed after a short period of operation (about ten minutes) as well as when first turned on. A sharp drop in voltage indicates the need to change the battery pack.

Since the readout display and digital circuitry use significant amounts of battery power, the ACCUM PERIOD switch should be set at DIS OFF whenever the display is not needed.

Battery Check: The following procedure may be used at any time to monitor the battery condition. (Also see Sections 2.2 and 2.3)

1. Set FUNCTION switch to CAL.
2. Set ACCUM PERIOD switch to BAT.
3. Note the position of the rate meter needle on the white BAT band located on the inner diameter of the meter face. The approximate remaining life of the battery pack can be estimated from the relative position of the needle on the white BAT band.

Calibration: For normal operation of the Model GR-310, it is customary to make occasional recalibrations during field operations. The detector at the bottom of the instrument case should not be near strong radioactive sources that interfere with the calibration source (^{133}Ba). Follow the procedure as given in Section 3.3.

Operation: When the battery check and the calibration adjustment have been completed, the GR-310 spectrometer is ready for use in the field. The following procedure is recommended for normal field operation:

1. Turn the FUNCTION switch to the desired position [i.e., TC for total count, K for potassium (^{40}K), U for uranium (^{214}Bi), or TH for thorium (^{208}Tl)]. Usually, TC is selected for initial search.

2. Turn the AUDIO THRESH potentiometer completely clockwise to the "∞" position to prevent activation of the variable frequency ticking feature of the audio signal system.

3. Turn the ACCUM PERIOD switch to the desired sampling time period (1, 10, 100 or 1,000 seconds).

NOTE: Radioactive decay of natural elements is a random process, hence the gamma radiation released varies in intensity over any given time period. Generally, the shorter the sampling time period the less gamma radiation is measured and the statistical error (E) is greater. Specifically, the percentage of statistical error incurred varies with the number of counts collected, or:

$$E\ (\%) = \frac{100}{\sqrt{N}}$$

Where N = number of counts collected in any given time.

Thus, for

10 counts,	E = 32%
100 counts	E = 10%
1,000 counts	E = 3%
10,000 counts,	E = 1%

For typical assay needs, 1000 counts (or 3%) is accurate enough, and the sample time represented by 1000 counts is measured in minutes for typical U and TH bearing rock types.

"1" and "10" positions:

These positions accumulate data for 1 or 10 seconds, display the counts per second on the LED digital readout for two seconds, and then recycle with a new accumulation period, etc. The decimal point on the digital readout is automatically positioned to permit direct reading of count rate (counts per second).

"100" and "1000" positions:

These positions accumulate data for 100 or 1000 seconds. When the ACCUM PERIOD switch is first rotated to either position, the measurement cycle will be activated and the letter "A" will appear in the readout display during the accumulation period. At the end of the selected accumulation period, the letter "A" will disappear and the decimal point will appear in the readout simultaneously, an audio signal will be produced. To display data, it is necessary to depress the DISPLAY pushbutton. Data may be recalled as often as desired. However, to obtain new values, it is necessary to depress the START ACCUM pushbutton, whereupon a new accumulation period is initiated (signified by the displayed letter "A"). As before, new data can be observed when the DISPLAY button is depressed.

3.6 AUDIO OUTPUT AND THRESHOLD ALARM

A variable frequency "ticking" output is provided in the Model GR-310 to enable rapid location of areas of high radioactivity. At high count rates, the ticking sounds blend into a tone that has a pitch proportional to the activity of the gamma ray source. The circuitry that produces the audio output is always in operation, unless the FUNCTION switch is in the OFF position.

The audio output is triggered whenever a predetermined count rate is exceeded. Thus, it is possible to find anomalous gamma radiation levels above a selected background level or count rate threshold. The following procedure may be used to set the audio signal threshold:

1. Determine the average background level by taking several total count readings over a representative survey area.

2. While the detector is situated over an area that is considered to represent the average background level, rotate the AUDIO THRESH potentiometer completely counterclockwise and then slowly clockwise until the sound stops. The AUDIO THRESH potentiometer is now set at the background threshold for the immediate area. A slightly higher setting allows the instrument to act as an "anomaly" indicator.

3.7 ANALOG RATE METER

The analog rate meter operates continuously when the instrument is "on." The meter has an approximate logarithmic scale and may be used in place of the digital readout, especially when battery power is to be conserved.

In general, the digital readout and the analog rate meter will indicate readings that are similar, but slight differences may often be noted. These differences occur because the averaging period for the rate meter and the digital accumulation period are not necessarily the same. In general, highest accuracy will be obtained from the digital output where counting times of 100 or 1,000 seconds have been used.

In spite of the accuracy of the accumulated readout for a given time interval, the random nature of gamma ray arrival at the detector will produce successive digital readouts that show variations, for just as the fluctuations of the rate meter needle demonstrate the random arrival of gamma ray photons, there will be variations in the total accumulated count received by the digital circuitry. It is possible to observe real time digital circuitry counting by depressing and holding down the DISPLAY pushbutton during any accumulating period. The digital readout will increment sporadically in response to the random rate of arrival of gamma rays at the detector.

3.8 OTHER OPERATIONAL FEATURES AND CONSIDERATIONS

The LED display indicates the number of counts obtained during an accumulation period within the energy range set by the FUNCTION switch. However, the readout is normalized to counts per second by automatic interposition of the decimal point (as determined by selected settings on the ACCUM PERIOD switch). For example, if the digital display showed a reading of 123.45 for an ACCUM PERIOD of "100", the display indicates a reading of 123 counts per second, but is is obvious that 12,345 counts were accumulated over a 100 second interval.

NOTE: Depressing the DISPLAY button whenever the ACCUM PERIOD switch is in BAT or DIS OFF position will cause a zero to appear randomly in the digital readout. Using the DISPLAY button in this manner is not recommended, for the LED's in the digital readout may be damaged.

It is possible to interrupt and restart the data accumulating period by depressing and releasing the START ACCUM pushbutton.

To conserve battery power during audio or rate meter surveys, the ACCUM PERIOD switch is switched to DIS OFF. The setting deactivates the digital multiplexing circuitry as well as the LED digital readout, and is especially useful for surveys where the Model GR-310 is carried in a backpack or shoulder harness and visual presentation of data is not necessary.

4.0 THEORY OF OPERATION

4.1 INTRODUCTION

This section contains a brief explanation of the overall operation of the geoMetrics Model GR-310 Gamma Ray Spectrometer and detailed descriptions of each major segment of the electronic functions. Also included are a complete parts list, diagrams of the main circuit board and the voltage divider assembly board, and a complete circuit diagram. With the exception of the photomultiplier detector assembly, which is a hermetically sealed unit that must be returned to the factory if it is damaged, all components can be obtained from geoMetrics, should there be need for emergency repair of the Model GR-310.

CAUTION

The high voltage power supply generates from 750 to 1200 volts. Please refer to Section 5.5 for safe service procedures.

4.2 OVERALL OPERATION

The major circuit segments in the Model GR-310 spectrometer are shown in their entirety in the circuit diagram following Chapter 7. The crystal detector (XTAL) transforms incident gamma rays into tiny flashes of light that are converted into electrical current pulses by the photomultiplier tube (PMT). The current pulses vary in amplitude, but the amplitude of each pulse is directly proportional to the gamma ray energy deposited in the crystal by an incident ray. The current pulses are extremely narrow (typically 300 nsec). A pulse shaping network is used to convert them into single cycle bipolar voltage pulses that are readily processed. Following is a brief introductory description of the circuits in the GR-310, more detailed discussion will be given later.

a. Battery/Pack Voltage Regulator. The battery pack supplies 12 to 18 volts for operation of displays and noncritical components. Regulators supply +5 and +10 volts for other circuits.

b. High Voltage Power Supply. Power for operation of the photomultiplier is obtained from an inverter operating at battery pack voltage. A fraction of the high voltage is compared to a 10V temperature compensated precision reference. The error is amplified and fed to a high gain feedback loop in order to maintain the output at the voltage level selected by the calibration potentiometer R2 to within ±1 part per hundred.

c. High Voltage Divider and Pulse Shaper. The controlled output of the high voltage power supply is routed to a voltage divider or "string" that supplies the dynodes of the photomultiplier with the proper accelerating voltage. The current pulses issued by the photomultiplier anode have a variable peak current and pulse width, depending on the way the gamma ray interacted with the crystal, but the total charge is constant for a given energy level of interaction. The pulse shaper circuit stretches short duration unipolar current pulses to about four microseconds and converts them into smooth single bipolar pulses.

d. Pulse Amplifier and Windows. The voltage output of the pulse amplifier is proportional to the gamma ray energy that initiated the pulse. The bipolar pulses from the pulse shaper are amplified so that they can be used to drive two voltage comparators simultaneously. One comparator determines whether the pulse voltage achieves a lower value, while the other determines whether it is less than a higher value. Pulse voltages that fall between the lower and higher vales of the voltage "window" are to be counted. The FUNCTION control sets the voltage levels at which the comparators operate and thus the control permits counting of radiations from ^{40}K, ^{214}Bi, ^{208}Tl, etc. When both comparators have indicated a pulse voltage falling within the selected window, logic circuitry causes a pulse signal to be issued and the signal is further processed by the remaining circuits.

e. Rate Meter Circuits. Signal pulses issued by the window logic circuitry are amplified, rectified, and filtered by the rate meter circuits. The filtered pulses provide a dc level that is proportional to the pulse rate, that is, the rate at which gamma rays interact with the detector. In order to compress pulse rates to that they can be observed continuously on a meter, the filtered output is processed by a diode resistor network so that the meter indications are approximately logarithmic over a range of 10 to 10000 counts per second.

f. Audio Circuits. Signal pulses issued by the window logic circuitry also are used to provide audible indication at the rate of gamma ray arrival at the detector. The signal pulses are processed to provide a tone whose pitch varies with the count rate. The AUDIO THRESH control can be set to suppress the audio tone below a certain count rate.

g. Counter and Display Decoder. Signal pulses from the window comparators are individually counted by the associated circuitry. Each pulse is registered by a 5 decade multiplexing counter. On signal from the timing circuits, the count is started, stopped, and then decoded to drive five 7 segment LED numerical displays. The circuit also blanks the five digits and illuminates an "A" on a sixth LED during the interval of time that counts are being accumulated.

h. Accumulator and Timing Circuits. The circuits in this portion of the GR-310 provide the timing functions needed to obtain accurate count rates. An oscillator timer provides a 1,024 Hz output for LED display renewal and a 1 Hz output for timing accumulation intervals. The 1 Hz output is processed by decade counters to provide the additional 10, 100, and 1,000 second accumulation periods used in the GR-310. On command from pushbutton START ACCUM, the count accumulation period selected by the ACCUM PERIOD control is begun, and count signals are passed to the counter circuits. At the close of the time interval, counting stops and an audible signal is emitted by the speaker. On depressing the DISPLAY button, the counter readout on the LED display is enabled.

4.3 POWER SUPPLY

All power for the Model GR-310 is derived from a battery pack consisting of twelve size "D" dry cells connected in series. The battery voltage varies considerably as function of load, temperature, and age. Nominally, the voltage ranges from 12 to 18 volts. The battery pack is completely disconnected when the FUNCTION switch is off. At all other positions, the battery pack supplies power as required. A capacitor C 39 removes switching transients. Battery voltage is made available to noncritical circuits via terminal BAT+, and is also supplied to the two voltage regulators that supply fixed potential for operation of voltage sensitive circuits.

All circuits in the GR-310 have been designed to keep battery drain at a minimum. Logic and timing functions employ CMOS elements for low power drain. Only two wide band linear IC's are used in the signal processing circuits. The divider string for the photomultiplier draws low current because Zener regulators are used for supplying the last three dynodes with voltage. An efficient, nonsaturating transformer is used in the high voltage supply circuit. The LED display consumes the majority of the power supplied by the battery pack.

CAUTION
The high voltage power supply can deliver shocks. Only competent personnel should attempt to service the Model GR-310.

The high voltage power supply circuit is comprised of an amplitude controlled inverter, a nonsaturating type step up transformer, a voltage divider, a reference voltage source, and a high gain amplifier. The inverter changes battery voltage to ac. For this purpose, an LM 555 C (U 3) timer is operated as a variable frequency oscillator with a basic frequency of about 360 Hz at a 14 % duty cycle. The output of the oscillator provides base drive for Q 1 through current limiting resistor R 8. The load for Q 1 is the primary of the step up transformer T 1, a diode, CR 3, bypasses inductive transient current generated in the transformer primary and prevents momentary reverse biases from appearing across Q 1. The ac generated at the secondary of T 1 is half wave rectified by CR 4 and smoothed by a capacitative input R-C filter to provide the high voltage power required for operation of the photomultiplier. The R-C filter consists of R 9 and R 10 with high voltage capacitors C 6, C 7 and C 8. The output requirement is about 1,000 volts at a load of approximately 75 μA.

The voltage divider consisting of R 11 and R 12 is across the entire high voltage dc output. Both resistors are selected and matched so that they maintain a constant ratio (±50 ppm) over a temperature range of 0 to 50° C. The voltage across R 12 is monitored and maintained constant by the high gain amplifier U 2. Nominally, the ratio of the divider is 0.0078. Accordingly, with a 10 volt reference supply, the maximum output is of the order of 1200 volts.

The voltage across R 12 is applied to the noninverting terminal (+) of the differential amplifier U 2 while the inverting terminal (-) of the amplifier is connected to the calibration potentiometer R 2. This potentiometer R 78 is part of a resistor network connected to a highly stable 10 volt reference source U 1, that receives power directly from the battery pack. The combination of resistors R 1 and R 2 permits the CAL SET potentiometer to operate over an approximately 4.5 volt span and supply reference voltages to the differential amplifier. With the range of reference voltages available to the calibration potentiometer R 2, the high voltage power supply can be varied from 700 to 1200 volts.

The fraction of the high voltage output appearing across R 12 is compared with the R 2 reference voltage. At the inverting input terminal of the differential amplifier U 2, voltage differences are amplified, and the output of the differential amplifier is applied through CR 1 and R 5 to oscillator U 3, thus changing the voltage appearing between the discharge terminal 7 and the threshold terminal 6 of U 3. The altered voltage causes the basic oscillator frequency and duty cycle of the U 3 oscillator to change. As a result, the "energize" cycle of the oscillator is altered and the energy stored in the step up transformer is varied in such a way as to make the voltage across R 12 become equal to the reference voltage selected by CAL SET. When transistor Q 1 is "on", battery voltage is applied across T 1 and flux builds up in the core until the required energy is stored. When Q 1 is turned off, the voltage reverses and CR 4 becomes conductive. Since the time required to dump stored energy into the filter capacitors is fairly constant, this portion of the duty cycle is determined by C 4 and R 7. The maximum energizing period is set by R 6, to avoid saturating the transformer T 1.

The resistor network, comprised of R 1 and R 2 and the CAL SET potentiometer R78 also includes R75, R76, and R77 (a thermistor) to improve gain stability with temperature changes. As is evident from inspection of the resistor network, the voltage applied to the CAL SET potentiometer and the magnitude of the reference voltage (above ground) selected by CAL SET are a function of the resistance of the thermistor and hence a function of the temperature inside the GR-310 enclosure.

4.4 PHOTOMULTIPLIER DETECTOR

Photomultiplier action initially depends on the emission of electrons from a surface illuminated by electromagnetic radiation. Usually, highly energetic illumination is needed to cause emission of electrons from ordinary metals, but the alkali metals readily release electrons when illuminated by visible or ultraviolet light. The photosensitive surface in a phototube of the type used in the Model GR-310 is a coating of cesium or a mixture of alkali metals that includes cesium.

The device consists of a large photosensitive cathode at ground potential, a focusing grid structure, ten auxiliary dynodes arranged in a circle, and an anode. When a photon impinges on the large surfaced cathode, the emitted primary electrons are drawn toward the positively charged grid or focusing element and then further accelerated toward a small area on the first dynode. When the electrons collide with the first dynode they cause ejection of secondary electrons which in turn are accelerated toward the positively charged second dynode, there to cause ejection of still more electrons. The process of acceleration and ejection of an ever increasing number of secondary electrons continues until an avalanche of electrons finally impinges on the last photomultiplier element, the anode (plate).

Thus a single photon causes a large pulse of electrons to pass through the anode circuit, and if it is assumed that four secondary electrons are liberated for each impinging electron at each dynode, the current amplification (or gain) for a 10 stage photomultiplier is 4^{10} or approximately one million.

The gamma ray detector used in the Model GR-310 is comprised of a crystal of thallium doped sodium iodide [NaI (Tl)] that is in the form of a right cylinder 2 inches in diameter by 2 inches high (5.1 x 5.1 cm). The scintillation phosphor converts the energy of an impinging gamma ray into a pulse of light of a wavelength that falls within the sensitivity of the photomultiplier cathode. The scintillation phosphor is characterized by a high atomic number, which results in good gamma ray stopping power. It also has a high luminescent efficiency, that is, large pulse heights are obtained for low energy gamma ray interactions.

When a gamma ray enters the crystal and collides with any orbital electron of the constituent atoms, it may impart a portion of its energy to the electron, and the gamma ray is brought down to a lower energy level which then has a correspondingly higher probability for collision (this phenomenon is identified as Compton scatter). However, the scatter phenomenon produces a more or less random variety of energy pulses, implying that a monoenergetic gamma ray will be associated with a distribution of lower energy radiations.

Sodium iodide is extremely hygroscopic and fragile and therefore is sealed in a moisture proof housing.

NOTE: Sudden temperature changes should be avoided to prevent cracking from thermal shock. As a rule, temperature changes at the crystal should not be greater than 10° C per hour.

The detector crystal is bonded to the face of the photomultiplier to minimize interface reflections. The photomultiplier crystal combination is shielded and supported by foamed polymer within a light tight hermetic enclosure in order to minimize mechanical and thermal shocks.

In the detector, incident gamma ray energy is converted to a light pulse, and the intensity of the emitted light is proportional to the incident energy of the gamma ray. The resolution of the crystal in the Model GR-310 at 662 KeV is typically 9%, which results in sufficient discrimination for separation of the peaks of interest at 1.46, 1.76 and 2.62 MeV (K, U, Th).

The overall detector system gain must be maintained within ±2% to ensure reliable assays. In general, the gain is affected by the following:

(1) temperature induced gain drift of PMT and electronics

(2) high voltage drift

(3) aging

The photomultiplier itself is sensitive to temperature changes. Typically, the gain coefficient is -0.5% per degree C, but the actual value is a function of the particular tube. In the Model GR-310, shifts in phototube detector gains are of little concern because the calibration procedure compensates for the drifting gain of the photomultiplier and because the high voltage power supply has temperature compensating elements.

The gain of the photomultiplier is subject to long term drift because of aging effects.

At very high count rates, photomultipliers often show a change of gain, but this is caused by shifts in dynode voltages owing to the high resistance components used in the voltage divider. Lower resistance values will eliminate this problem, but the increased power consumption is not warranted for field type instrumentation. The last three dynodes are held at constant voltage by Zener diodes, and pulses are bypassed with capacitors. These circuit features minimize the shift in gain at high count rates. Thus, the GR-310 can operate at rates of 50,000 cps or more.

The high voltage divider for the photomultiplier dynodes is on a separate circuit board located inside the PMT housing.

The network C11, C12, L1, L2, R13 convert the anode current pulse from the PMT to a bipolar pulse. This technique avoids the long tail or undershoot that is produced when a unipolar pulse is passed through a coupling capacitor. As a result, all pulses in the GR-310 are cleanly separated from their neighbors, making possible high count rates.

4.5 PULSE AMPLIFIER AND WINDOWS

The pulses issued by the pulse shaping circuits are amplified by a simple inverting operational amplifier U 4. The amplifier has a gain of 4 and it provides the low impedance required for driving the dual comparator U 5. When the high voltage power supply is properly set, the peak pulse amplitude at the output of U 4 will be 1 volt for 1 MeV of gamma ray energy impinging the crystal detector.

The noninverting input (+) of U 4 is referenced to 5 volts obtained across R 29 at the bottom of the window resistance divider. The inverting input (-) receives pulses from the pulse shaper. The purpose of potentiometer R 18 "offset" will be described later.

The window resistance divider and the FUNCTION switch provide precision reference voltages for the comparators U 5. In essence, the amplitude of the voltage pulse issuing from the photomultiplier is compared against the voltage references supplied by the window resistance divider. Only pulses which are greater than the low side of the energy window but less than the high side of the energy window are counted. Each window must be broad enough to encompass the statistical spread in pulse heights emanating from the detector, but narrow enough to eliminate pulses of the wrong energy.

As an example of the operation of the windows, consider that the window marked Ba (the calibration window) is at position 2 of FUNCTION switch S 2 (position 1 is OFF), and that the range or width of the Ba window is being defined as the voltage across R 27 with the lower energy side corresponding to the voltage across R 28 (note that the upper end of R 29 is the base level for comparison of voltages at amplifier U 4). With a 10 volt regulated power supply across the window resistance divider, the computed potential drop across R 28 is 0.34 V and that across R 27, 0.03 V.

Since 1 volt equals 1 MeV, it follows that the low side of the Ba window is at 0.34 MeV, and that the calibration window (Ba) range is 0.34 to 0.37 MeV, as was noted in Section 1.3. The middle of the Ba window corresponds to 0.355 MeV, which is essentially the peak of the combined 0.355 and 0.380 MeV, gamma ray emissions of the calibration source since the 0.380 MeV is of low relative intensity.

The dual comparator, U 5, receives amplified pulses from U 4 at its inverting inputs (-) and its noninverting inputs are connected across selected resistors in the window resistance divider. For example, with FUNCTION switch at position 2, the low energy end of the Ba calibration window is connected to U 5 pin 9 and the high energy end to U 5 pin 4. Now, let us assume that a pulse corresponding to 0.355 MeV were to be issued by U 4, that is, the pulse voltage would peak at 0.355 volt. Since the pulse voltage is greater than the low end voltage of the window (0.34 V), the lower U 5 comparator would become "active" because the pulse signal is greater than its low end voltage reference. However, because the pulse voltage is less than the high end voltage of the window (0.37 V), the other U 5 would not become active. Both comparators respond only when the pulse voltage exceeds their reference voltage.

Now, let us examine what happens when a comparator detects that the pulse voltage exceeds its reference voltage. Note that the output of each comparator is connected to one of the one shot multivibrators of U 6. The multivibrator connected to the low end comparator delivers a one microsecond positive logic pulse when activated and the high end comparator delivers a five microsecond downward pulse on a normally high line. But the five microsecond one shot is triggered by the leading slope of the incoming pulse from the pulse amplifier, and the one microsecond one shot is triggered by the trailing slope of the peak. Moreover, the one microsecond pulse is used to drive all the following circuits and thus constitutes a valid count. The outputs of the one shot multivibrators are passed to an AND (both inputs must be high for a high output) gate U 16 and whenever the five microsecond "0" pulse is coincident with the "1" pulse of the one microsecond one shot, the gate is disabled, and Q 2 does not pass one microsecond pulses to the counting circuits. On the other hand, if the pulse from the pulse amplifier exceeds the low end of the window, but not the high end, then a one microsecond pulse is gated through for counting. Transistor Q 2 acts as a power amplifier for the one microsecond pulse. As will be described in succeeding sections, Q 2 is connected as a driver for a current source and as an emitter follower for the rate meter circuits and for the audio section.

Although the dual comparator, U 5, has low offsets and fast response, a pulse is at or near its peak value only for an extremely short amount of time, and thus it is necessary to surpass the dc comparison threshold by several millivolts in order to produce a valid output. The offset control R 18 (factory set) and resistor R 16 provide the required few millivolts. Only one control is sufficient because both comparators are integrated on the same chip and thus require the same amount of overdrive. The offset control is adjusted so that when the gain is properly set for the reference source (Ba), it will also be properly set for all other windows.

Potentiometer R73 is factory set and varies the width of the nominally 1 microsecond pulse issued by U6. The adjustment is used to set the full scale reading of the rate meter.

4.6 RATE METER CIRCUIT

Amplified 1 microsecond pulses issuing from Q2 enter the rate meter circuit via CR6. The pulses are rectified by CR6 and used to charge an R-C filter comprised of R35 and C23. The load on the filter, which also determines the gain, consists of six resistances that are progressively switched in by six diodes as the voltage increases. In essence, the meter scale is broken up into six equal segments of progressively decreasing gain. Amplifier U7 is used to drive the meter to avoid overloading the filter. As noted in the previous section, the full scale output of the meter is adjusted by R73.

Potentiometer R79 picks off a fraction of the rate meter output and this is used to set the threshold for activation of the audio alarm system. The potentiometer control is designated AUDIO THRESH. Also, the entire output voltage of U7 is used by a comparator in the audio circuit, as will be explained in the following section.

4.7 AUDIO CIRCUIT

The audio circuit provides two kinds of signals: one announces the end of an accumulation period by a 3 second note, and the other signals that a preset background count has been exceeded by emitting a tone that varies in pitch as a function of count rate. The variable pitch is produced by a succession of clicks that blend into a tone at high rates.

The 1 microsecond count pulse initiated by window comparator U 5 and further processed by Q 2 is introduced to the audio circuit as a pulse of emitter current flowing through R 50 and R 51. The potential drop across R 51 drives the base of Q 3 (a current source), which charges an R-C filter consisting of C 25, R 53, C 26, and R 54. This two pole filter smooths random variations in the spacing of the pulses that originate at the crystal detector. Without the filter, the sound produced by the audio circuit would not have a recognizable pitch.

The output of the filter drives transistors Q 4 and Q 5. Thus, the output is reflected by a current mirror comprised of these two transistors and, as a result, C 27 is charged. However, R 56, Q 5, R 57, and C 27 are part of the timing circuit of the U 9 oscillator timer, and the oscillator frequency is proportional to the mirrored current. During the "off" portions of the output of the U 9 oscillator, Q 6 allows C 29 to charge through R 58, and during the "on" portions (short, fixed intervals), the energy stored in C 29 is delivered to the potentiometer R 59, which constitutes the speaker volume control (factory set). The discharge of C 29 produces a "click" at the speaker. At higher count rates, C 29 cannot charge fully between cycles, but this is desirable to prevent excessive power output at high frequencies.

The AUDIO THRESH control described in the previous section is provided to prevent audio output below a certain count rate. The oscillator U 9 can be stopped by application of a positive signal to the reset terminal (pin 4). Comparator U 8 supplies the stop signal. The comparator receives two inputs, one is the output of U 7 corresponding to the smoothed 1 microsecond voltage count pulses initiated by the low end window comparator U 5 and the other is a reference voltage selected by AUDIO THRESH. Whenever the output of the meter driver U 7 goes below the voltage selected by AUDIO THRESH, comparator U 8 supplies the necessary positive voltage to squelch oscillator U 9. Feed-back resistor R 48 applies a small amount of hysteresis to prevent erratic operation near threshold.

An operational amplifier, U 10, is arranged to act as an audio power amplifier and oscillator when zero voltage is applied at the inverting input. Normally, however, amplifier U 10 is inoperative because the inverting input is kept high by the accumulator circuitry described in the next section. As required, the accumulator circuitry activates amplifier U 10 for 3 seconds. When enabled, the amplifier oscillates because of positive feedback, and the oscillations are transferred to the speaker.

4.8 ACCUMULATOR CIRCUITS

The accumulator circuits described in this section utilize CMOS for low battery drain. An oscillator timer, U 11, supplies two outputs: a 1,024 Hz square wave from the internal RC oscillator pulsed by C 32 and the combination of R 63 and R 64, and a divided down output of 1 Hz (obtained from internal division circuits). Since the Model GR-310 also requires timing intervals of 10, 100, and 1,000 seconds, three decade counters U 12, U 13, and U 14 count the 1 Hz output of the oscillator timer and provide pulse signals corresponding to the required timing intervals. The 1,024 Hz pulses from the oscillator timer are used by the counting circuits as a scan clock for multiplexing the L E D display, as will be described in the following section.

The ACCUM PERIOD switch permits selection of one of four timing intervals (1, 10, 100, and 1,000 seconds). The operation of the 1 and 10 second accumulation circuits are similar. For simplicity, let us assume a 1 second accumulation period has been selected. When the START ACCUM pushbutton is depressed, voltage is removed from terminal 9 of the AND gate U 16 and simultaneously from terminal 5 of NOR gate U 17. The resulting increase in potential of the NOR gate output applied at the base of Q 9 momentarily grounds the collector circuit, thereby pulsing the digit select disable pin 15 of the 5 decade counter U 20, and simultaneously interrupting the count input to the counter, which is obtained via NOR gate U 15. The pulse from NOR gate U 17 also is applied to flip-flop U 18 which sets the 3 second one shot monostable U 19. The Q terminal output pulse of flip-flop U 18 (pin 15) is also applied to reset pin 2 of the five decade counter U 20, thus clearing the counter resisters. However, the same pulse is also transferred to the oscillator timer (U 11) and decade counters, whereby the U 11 oscillator timer is reset along with the timing decade counters U 12, U 13, and U 14. As a result of the U 18 flip-flop action, all counters and timers are reset and the Q terminal potential of the one shot multivibrator U 19 via AND gate U 16 enables NOR gate U 15 to pass counts to the five decade counter U 20.

When flip-flop U 18 returns to its stable state, all counters and timers are enabled and the timer starts passing 1 Hz pulses to gate U 16 or to the counters.

When the one second accumulation period has terminated, the 1 Hz clock pulse is passed through U 16 to U 17 and the resulting output pulse appears at pin 5, the clock input of U 19. The pulse triggers U 19 into its three second action, whereupon the display is unblanked and the "A" that was there is removed. When the U 19 one shot runs down, flip-flop U 18 is clocked into action, which generates a master reset for a few milliseconds and then resets itself through R70 and C36. The active state of the 3 second one shot also stops the count by disabling gate U 15. The reset clears the counter and starts the timer counter as has been described above. If a 10 second accumulation period were to be selected, the circuit action would be the same, except that the AND gate, U 16, will be involved. Note that once started, the 1 and 10 second accumulation periods proceed automatically, taking measurements and displaying accumulated data.

Accumulation periods of 100 and 1,000 seconds perform similarly to the 1 and 10 second periods, except that the end of the accumulation period is announced by a 3 second audible signal and that the operator must press the DISPLAY button to obtain a digital readout. When the ACCUM PERIOD switch has been set at 100 or 1,000 seconds, the initial pulses from U 17 activates flip-flop U 18 and the 3 second one shot multivibrator, as has been explained above. However, note that the second half of U 18 is reset by the first half, and that the second half of U 19 is also reset by its first half. Moreover, note that the 100 and

1,000 second counter pulses are delivered to the U 15 NOR gates and that the processed pulses are passed directly to the second half of the U 18 flip-flop. Thus, the timing signal for the longer accumulation periods stops the counting via the U 16. The flip-flop action also triggers the U 19 three second one shot multivibrator which applies a zero level voltage to the annunciator line that leads to an audio power amplifier U 10. Normally, the audio amplifier is biased to saturation and held inoperative by U19. After 3 seconds, U 19 returns to its normal state.

The DISPLAY pushbutton must be depressed to illuminate the digital readout, inasmuch as the readout display is not automatically activated as was described for the 1 and 10 second accumulation periods. When the DISPLAY button is depressed, terminal 8 is grounded to enable display of digits U 20 (pin 15), and the one in seven decoder U 21 is enabled (high at pin 4). The readout display can be illuminated repeatedly. However, a new measurement can only be obtained by depressing the START ACCUM button.

4.9 COUNTER-DISPLAY CIRCUITS

The principal active device in the counter display circuits is U 20, a five decade counter. The counter has multiplexed outputs and drives the five digit display, illuminating each digit one-fifth of the time on command from the digit control lines. The output, in BCD format, appears sequentially for each digit at pins 17, 18, 19, and 20 and it is further decoded by U 21 (one in seven decoder) into the 7 segment format required by the display LED's. The outputs of decoder U 21 are applied to the bases of an array of seven emitter followers, QN 1, that have current limiting resistors provided by an array, RN3. The amplified output drives the LED's, supplying about 24 milliamperes to each segment. The sequence of the digits is indicated by the digit control pins 7, 8, 14, 16, and 11 of U 20 and is decoded by the array of seven Darlingtons, U 22. Decimal point position is determined by a section of the FUNCTION switch as indicated, Q 8 provides power.

The 5-digit LED display can be unblanked on command via pin 4 of U 21 and as long as the digit select disable pin 15 of the U 20 five decade counter is active, Q7 supplies power to a transistor array QN 2 (connected as diodes). The transistor diode array is configured to illuminate an "A" on the sixth position of the LED display. Enabling the digit select pin 15 turns off the "A" and the decimal point position is enabled, but no digits will appear on the display until U 21, the one-in-seven decoder, is unblanked at pin 4. The scan clock for the U 20 five decade counter is the 1,024 Hz timing signal generated by U 11.

5.0 MAINTENANCE

5.1 CALIBRATION

The GR-310 spectrometer is easily calibrated. When the FUNCTION switch is set to CAL, the ACCUM PERIOD switch is set to 1, and a maximum reading can be obtained by small excursions of the CAL SET potentiometer, the instrument is calibrated and all energy windows are properly set.

If the instrument has been dropped or shocked in a way that may suggest damage to internal circuits, and the usual CAL SET potentiometer reading (see Section 2.4) can not be used to obtain a maximum reading on calibration, it is first necessary to see whether the ^{133}Ba calibration source has been dislodged. First re-establish the proper position of the reference source by following the procedures given in Sections 2.4 and 3.4. Of course, if the source has been installed for a number of years, the intensity of its gamma ray emission will have decreased somewhat but the maximum reading will be obtained near the "Calibration Point" setting of the CAL SET potentiometer and very closely to the setting observed at the last calibration. Instrument malfunction is to be suspected whenever the CAL SET setting required to peak the emission of the reference source differs greatly from its usual position.

5.2 BATTERY PACK

When the batteries are drained, they may be replaced by following the procedure given in Section 2.3. The battery pack in the Model GR-310 has an active life that is governed mainly by the way the instrument is used, the length of time the instrument has been operated, and the actual age of the cells in the battery pack at the time of installation. Another important parameter is the temperature of operation (see Section 2.2). It is impossible, therefore, to state the length of time which a battery pack will operate, only experience with the instrument under user's conditions can provide useful estimation of the life of a battery pack.

Long battery life can be obtained if certain rules are observed:

(1) The LED digital display draws large amounts of power. Do not operate the display if only audio is being used.

(2) The audio output also consumes power. Set the AUDIO THRESH potentiometer high enough so that background ticking is infrequent.

The age of a dry cell determines the total power obtainable from it. Because the shelf life of a modern cell is long, there is great tendency to store quantities of cells for years. Also, since most dry cells are not marked with the date of manufacture, it is highly possible to have old as well as freshly manufactured cells in a given lot. For optimum service, the cells should be of recent vintage.

5.3 STORAGE

The Model GR-310 may be stored at temperature in the range of -30° to 60° C. To prevent damage to the detector, the storage locale should be such that sudden temperature changes do not take place. If it is necessary to store the GR-310 under conditions where temperatures are known to vary rapidly, it is best to surround the storage case with insulation before packaging in a sealed box. For any period of storage or inactivity greater than about six months, the instrument may be housed in its storage case, but the battery pack should be removed in order to prevent damage by electrolyte leakage from deteriorated dry cells. Ideally, after the battery pack has been removed, a package of silica gel desiccant should be placed in the position normally occupied by a battery tube. The desiccant will protect the circuit boards from condensation.

5.4 CLEANING

It is necessary to be aware that the background count registered by the GR-310 spectrometer can originate in the radioactive dust deposited on its surface as well as in the source being examined at the time of a measurement. In spite of great care, radioactive dust impinges on instrument surfaces and remains attached. The operator who normally handles radioactive specimens inadvertently may transfer radioactivity to the instrument itself or to objects near it or in contact with it. For example, the padded shoulder harness may easily become impregnated with radioactive dust, and the clothing of the operator often is the deliberate as well as the inadvertent carrier of radioactive mineral samples or dusts.

The outside of the instrument case should be periodically wiped with a clean, damp cloth or paper towel. When it is necessary to change the battery pack, the operation should be performed in a dust free location of low radioactivity.

5.5 TROUBLESHOOTING

The Model GR-310 is neatly packaged in a relatively small container and most circuit elements are spaced closely on a compact circuit board. Moreover, there are sections of the circuit board that generate high voltage (750 to 1,200 volts), and the main circuit board is very close to an auxiliary circuit board that supports the high voltage divider for the photomultiplier. As a result, servicing of the Model GR-310 may be hazardous and should only be attempted by experienced personnel.

However, there are some tests and emergency repairs which the average electronics technician may undertake provided directions are followed completely. It must be realized that procedural errors may cause high voltages to damage low voltage circuits. In general, the following rules should be observed:

(a) Do not use uninsulated conductors as probes, whenever possible use a plastic or insulated device.

(b) Keep the FUNCTION switch at OFF position as much as possible when the circuit boards are exposed.

(c) Perform all preliminary tests with a voltmeter that has an input impedance of at least 10 meg ohms and one grounded probe. Higher impedance instruments are needed to measure the high voltage generated in the GR-310.

Removal of the main board is a complicated procedure and too involved for simple troubleshooting, therefore, all voltage tests will be performed on the solder side. It is emphasized that both sides of the circuit board have been spray coated with a thin layer of fungus retarding insulation and that it will be necessary to use a sharp pointed voltmeter probe to penetrate the insulating layer. Any of the screws that hold the circuit board in place are at ground potential and may be used as a fastening point for the ground lead of the voltmeter.

The following table lists common troubles, their probable cause, and remedies and tests that can readily be performed. In general, the most probable causes are listed first. If the remedies given in the table do not remove the malfunction, it will be necessary to return the instrument to the factory with the instrument return form in the front of this manual.

Malfunction	Probable Cause	Remedy - Tests
1. Low BAT indication	(a) Spent battery pack	(a) Change battery pack
	(b) One or more cells inserted incorrectly	(b) Check position of cells
	(c) One or more cells weak	(c) Test each cell separately (min. 1.5V)
2. No BAT indication; instrument inoperative	(a) Spent battery pack	(a) Change battery pack
	(b) No contact at one cell	(b) Check to see that protective insulation has been removed from cells
		(c) CAUTION: High voltage will be on during this test. Check for BAT voltage at test point A on circuit board (Fig. 5-2). Place voltmeter probe at test point B and set FUNCTION switch to CAL; proper BAT voltage indicates switch is operative
3. No BAT indication; digital display and audio section operative	(a) Rate meter movement inoperative	(a) First be sure FUNCTION switch is OFF. Check contacts at J-3, Fig. 5-2
		(b) CAUTION: High voltage will be on during this test. Set ACCUM PERIOD to BAT, place voltmeter probe at test point C. Switch FUNCTION to CAL. Voltmeter should read BAT voltage (see 2-(c) above). Place voltmeter probe at test point D. Voltmeter should indicate a very low voltage. Switch FUNCTION to CAL. If voltages are present, meter must be replaced.

	Malfunction	Probable Cause	Remedy - Tests
4.	Digital display operative but audio section inoperative; BAT indication is normal, but rate meter is immobile	(a) Rate meter circuit I. C.	(a) Remove and replace U-7 (LM308)
			(b) Remove and replace U-8 (CA3140AS)
5.	Audio section inoperative	(a) Damaged speaker cone	(a) CAUTION: High voltage. Set AUDIO THRESH fully counterclockwise. Check for ac or voltage pulses at pin 3, J-3; test point E on Fig. 5-2
		(b) Amplifier	(b) Remove and replace U-8 (CA3140AS)
		(c) Oscillator	(c) Remove and replace U-9 (LM555C)
6.	Audio and rate meter operative LED display completely inoperative	(a) Indeterminate	Return to Factory
7.	BAT indication is proper; digital display illuminates but does not read counts; rate meter and audio sections inoperative	(a) 10 V power supply	(a) CAUTION: High voltage. Check for 10 volts at test point F on Fig. 5-2
		(b) 5 V power supply	(b) CAUTION: High voltage. Check for 5 volts at test point G on Fig. 5-2
		(c) High voltage inoperative	(c) CAUTION: Check for high voltage with a 1000-megohm input voltmeter (1500 volt range) at test point H on Fig. 5-2. If less than 700 volts, test 10 V reference supply output at test point F, Fig. 5-2. If O, K., remove and replace U-2 (LM-308N) and/or U-3 (LM555C)

Malfunction	Probable Cause	Remedy - Tests
	(d) Pulse amplifier	(d) Remove and replace U-4 (LM318N)
	(e) Comparators	(e) Remove and replace U-5 (LM319)
	(f) Pulse amplifiers	(f) Remove and replace U-6 (CD4098)
	(g) Count gate	(g) Remove and replace U-16 (CD4081)
8. Audio operates as a background alarm, but the 3 sec signal is not obtained at end of 100 and 1000 sec ACCUM PERIOD	(a) Audio amplifier	(a) Remove and replace U-10 (LM380N)
	(b) Multivibrator timer	(b) Remove and replace U-18 (CD4027)

6.0 SURVEY GUIDELINES

6.1 INTRODUCTION

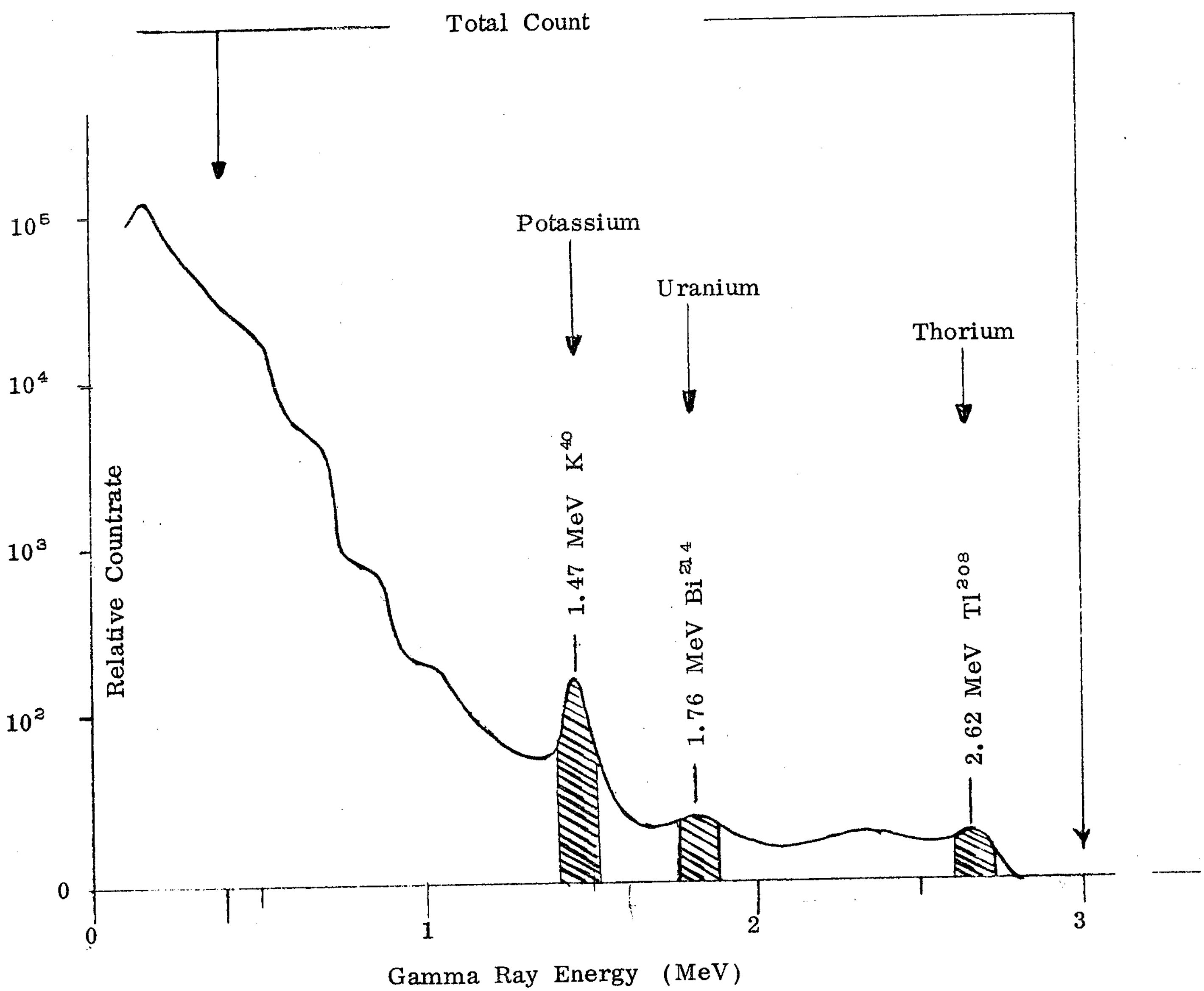
All soils and rocks emit gamma rays because of the presence of trace amounts of radioactive elements. Among the most intense radiations are those of potassium-40 (^{40}K), bismuth-214 (^{214}Bi), and thallium-208 (^{208}Tl). The radiation from potassium-40 is useful for geological surveys inasmuch as potassium distribution is indicative of a variety of rock types. On the other hand, bismuth-214 and thallium-208 are the radioactive decay products of uranium-238 and thorium-232, respectively, and as such are highly diagnostic of the presence of economically valuable radioactive ores. For simplicity in geological surveys, the gamma ray energies emitted by bismuth-214 and thallium-208 and potassium-40 are referred to as uranium (U), thorium (TH), and potassium (K); the FUNCTION switch markings on the GR-310 reflect this simplification.

Figure 6-1 shows a typical gamma ray spectrum in the energy range covered by the GR-310, that is, the region 0.4 to 4.0 MeV. The spectrogram includes the scattering caused by the Compton effect as well as contributions from cosmic rays and the gamma rays emitted by other elements in the natural radiation environment. Note that gamma ray activity is greater at low energies, but this comes about mainly because Compton scatter converts penetrative high energy gamma rays to the more absorptive low energy varieties. Thus, for example, the highly energetic primary gamma ray energy emitted at 2.62 MeV by the thorium disintegration product, thallium-208, is scattered into indistinguishable varieties of lower energy levels.

GAMMA RAY SPECTROGRAM

The shaded areas represent the analyzer window widths; the "total count" is the sum of all counts between 0.4 and 3 MeV, and represents the output typically obtained from a spectrometer.

FIGURE 6-1



As a result, thorium disintegrations contribute to the observed intensities of the uranium and potassium primary gamma ray emissions. In turn, the 1.76 MeV uranium primary emission from bismuth-214 contributes to the observed potassium-40 energy peak. Cosmic rays contribute scattered energy over the whole energy range, but the intensity of cosmic radiations is low and quite constant, and so it becomes part of the background radiation and does not confuse measurements made with the GR-310.

For accurate determinations of the amounts of thorium, uranium, and potassium, it is necessary to correct the readings observed at the TH, U, and K peaks indicated in Figure 6-1 for contributions from more energetic gamma rays. Although correction factors can often be computed from theoretical considerations, ordinarily they are obtained empirically from observations made at test pads specifically constructed to contain known concentrations of the three radioactive materials of interest (potassium, uranium, and thorium). The correction factors are often called "stripping ratios" when they are used in mathematical equations for computing radioactive element concentrations (see Section 6.3).

The Model GR-310 instrument is a differential type of gamma ray spectrometer, for it scales counts from particular energy "windows." For this purpose, the pulse height outputs of the crystal detector are separated into voltage groups centered about the voltages corresponding to the energies of the primary gamma rays emitted by K, U, or TH species. As indicated in Figure 6-1, the width of the energy regions is 0.2 MeV for the K and U peaks and 0.4 MeV for the TH peak. Also, Figure 6-1 indicates that the K window is centered at 1.46 MeV, the U window at

1.76 MeV, and the TH window at 2.62 MeV. In general, a window width is adjusted to capture the entire peak area, and so the window at the TH peak is necessarily wider than at the K peak. The window widths in the GR-310 include approximately 90% of the peak area.

Figure 6-1 also indicates the energy range included in the TC, or total count window. Note that total count rates will be high since the window width includes all gamma ray energies between 0.4 and 4.0 MeV.

6.2 GUIDELINES

Count rates at any of the four windows indicated in Figure 6-1 can be easily obtained with the operating instructions given in Section 3.0. As a rule, the GR-310 is used to obtain profiles of count rates in a given geographic area. The idea is to localize regions of high (or low) count rate. For this purpose, there is obtained a reference reading that corresponds to the background gamma ray emission of the area in general, so that a locale of high gamma ray emission (or low) can be distinguished and circumscribed. An area with gamma ray activity higher than background (or lower) is called an anomaly.

In principle, if the AUDIO THRESH control of the GR-310 is set properly, that is, at a setting slightly greater than the average maximum background reading, the audio output is silent and the operator can simply walk around in a given area and locate the anomaly. For example, with the AUDIO THRESH control set properly, the audio signal is activated whenever the operator is over the anomaly. Conversely, if the audio signal is set so that it is activated continuously by the background, then a lack of audio output indicates an area of activity significantly lower than background.

For expediency, readings in a ground survey are obtained systematically, and the area being examined is traversed along readily identifiable lines spaced twenty-five to one hundred feet (ten to thirty-five meters) according to the typical formation thickness, the expected width of geological or anomalous features, and the desired resolution of the survey. Generally, readings are obtained along a traverse at stations that are as far apart as the spacing between traverse lines. In other words, the area is traversed along a systematic grid and stations are located at intersections of traverse lines. Ordinarily, the reading stations are spaced closely for initial measurements. The spacing is made wider when successive measurements show little variations, and the area appears geologically uniform. In areas of interest, very closely spaced stations may be used.

The actual locations of stations and traverse lines should be noted on an aerial photograph or a map, using dominant topographical features as the principal points of reference. All data should be systematically recorded in a field notebook, but in many instances a tape recording of data and observations is adequate.

For the mapping of vein type uranium, acidic igneous rock, and other geological explorations, TC (total count) is the principal measurement used to locate significant features. For this type of mapping, only TC is observed at each station. When significant variations in count rates are noted between the readings obtained at successive stations, then the count rates for the other three energy windows are measured and the additional data are used to assist delineation of the anomalous area. The Model GR-310 spectrometer permits making rapid TC measurements with the rate meter. Of course, more accurate measurements can be obtained by accumulating counts and reading the digital display, but this procedure may be found inordinately lengthy and it often may not improve the significance of the data. The audio mode of operation is particularly attractive for mapping because it eliminates the need to look at the instrument and it does not impose a high drainage rate on the battery pack.

More detailed and complete sets of observations at all four windows are required for certain types of mapping and explorations, (e.g., localizing sedimentary formations, geological mapping in general, identification of subtle sedimentary uranium type anomalies, observations of possible "halo" effects around certain mineral or oil deposits). Prolonged sampling, compared with the few seconds needed for total count at the same station, is necessary in order to obtain satisfactory statistics. For example, the thorium count is extremely small in most cases, and the operator may need to sample thorium for one hundred seconds or longer, in order to localize thorium concentration with certainty. Since the GR-310 normalizes all measurements to counts per second, there is no need to convert data obtained over different sampling times.

In many instances, there is need to examine the gamma ray activity of individual samples to determine the geological structure that is contributing to an observed anomaly. For this purpose, the instrument is placed on an outcrop of low background radioactivity or on another convenient surface and several readings are taken of each of the four variables (TC, K, U, T) with the instrument in this position. Then a large sample is brought into contact with the bottom center of the instrument, after which readings at the four variables are obtained. Long counting periods will be required for this type of work. Note that readings obtained without the sample (background) must be subtracted from readings obtained when the sample is at the instrument. The size of the various samples should also be noted when comparing readings. Several samples of the same type may also be measured to assure the significance of the results.

6.3 ASSAY EQUATIONS

The sensitivity and stripping coefficients are calibration constants that express the relationship between count rate and the abundance of a radioactive element in a source. The radioactive element concentrations are computed with the aid of the following equations:

$$K = \Delta_{kk} \; (R_k - S_{ku} R_u - S_{kt} R_t)$$
$$U = \Delta_{uu} \; (R_u - S_{ut} R_t)$$
$$T = \Delta_{tt} \; (R_t - S_{tu} R_u)$$

The symbols T, U, and K represent concetrations of thorium, uranium, and potassium, respectively. The symobls R_k, R_u, R_t represent the observed count rate in a window in counts per second, corrected for the corresponding background rate. For example, R_t implies subtraction of the background rate observed at the thorium window from the count rate observed at the thorium window when the spectrometer receives gamma rays from the source being measured. Quite often, the background rate at a window is small in comparison to the count rate observed over a radioactive source, and it may be ignored.

The symbols Δ_{kk}, etc. are the sensitivity constants and S_{ku}, etc. are the stripping constants. For the Model GR-310, the constants have been determined empirically by measurements at the Department of Energy test pads in Grand Junction, Colorado.

The following equations are used to compute the concentrations of potassium, uranium, and thorium as determined by the GR-310 spectrometer, when count rate measurements are expressed as counts per second.

$$\text{(percent)} \quad K = 0.96\ (R_k - 1.32\,R_u - 0.1\,R_t)$$
$$\text{(parts per million)} \quad U = 13.0\ (K_u - 0.83\,R_t)$$
$$\text{(parts per million)} \quad T = 28.0\ (R_t - 0.089\,R_u)$$

See also Appendix II - "Radioelement Assay with Portable Gamma Spectrometer"

$\%U_{4a} = .1(R_u - .83\,R_t)$

$\%U_{oo} = .0013(R_u - .83\,R_t)$

7.0 TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	GeoMetrics Part No.	Dwg No.
C-1	Capacitor: 0.1 μF	15-114-104	4-2
C-2	Capacitor: 330 pF	15-201-331	4-2
C-3	Capacitor: 1 μF 35V	15-604-105	4-2
C-4	Capacitor: 0.047 μF	15-405-473	4-2
C-5	Same as C-1		4-2
C-6	Capacitor: 0.02 μF 1.4 kV	15-120-203	4-2
C-7	Same as C-6		4-2
C-8	Same as C-6		4-2
C-9	Capacitor: 510 pF	15-201-511	4-2
C-10	Capacitor: 0.01 μF	15-109-103	4-3
C-11	Capacitor: 150 pF	15-201-151	4-3
C-12	Capacitor: 150 pF	15-201-102	4-3
C-13	Capacitor: 24 pF	15-201-240	4-4
C-14	Same as C-1		4-4
C-15	Capacitor: 1.5 pF	15-106-015	4-4
C-16	Same as C-1		4-4
C-17	Same as C-1		4-4
C-18	Same as C-1		4-4
C-19	Same as C-1		4-4
C-20	Same as C-1		4-4
C-21	Capacitor: 240 pF	15-201-241	4-4
C-22	Capacitor: 50 pF	15-201-500	4-4
C-23	Capacitor: 1 μF Mylar, 50V	15-411-105	4-5
C-24	Capacitor: 100 pF	15-201-101	4-5
C-25	Same as C-23		4-6
C-26	Same as C-23		4-6
C-27	Capacitor: 0.01 PACER	15-401-103	4-6
C-28	Same as C-1		4-6
C-29	Capacitor: 2.2 μF 35V	15-605-225	4-6
C-30	Same as C-29		4-6
C-31	Same as C-9		4-6
C-32	Capacitor: 0.0082 μF	15-401-822	4-7
C-33	Capacitor: 10 μF	15-601-106	4-7
C-34	Same as C-33		4-7
C-35	Same as C-33		4-7
C-36	Same as C-1		4-7
C-37	Same as C-33		4-2
C-38	Same as C-33		4-2
C-39	Capacitor: 22 μF	15-604-226	4-2
CR-1	Diode 1N914	48-400-914	4-2
CR-2	Same as CR-1		4-2
CR-3	Diode SF4	48-500-002	4-2
CR-4	Diode SF M-30	48-500-030	4-2
CR-5	Diode 1N4135	48-404-135	4-3

7.0 TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	GeoMetrics Part No.	Dwg No.
CR-6	Same as CR-1		4-5
CR-7	Same as CR-1		4-5
CR-8	Same as CR-1		4-5
CR-9	Same as CR-1		4-5
CR-10	Same as CR-1		4-5
CR-11	Same as CR-1		4-5
CR-12	Same as CR-1		4-5
CR-13	Same as CR-1		4-5
CR-14	Same as CR-1		4-2
DS-1	Display: DL 44M	39-202-001	4-8
DS-2	Same as DS-1		4-8
DS-3	Same as DS-1		4-8
J-1	Connector: 2-pin AMP 350209-1	21-230-003	4-2
J-2	Connector: 4-pin AMP 350211-1	2-1230-011	4-3
J-3	Connector: 4-pin AMP 9-305255-1	21-230-015	4-5, 4-6
J-4	Connector: 14-pin socket	31-604-014	4-5, 4-7
L-1	Inductor: 2.7 mH	18-204-054	4-3
L-2	Inductor: 5.6 mH	18-204-058	4-3
L-3	Inductor: 220 μH	18-204-041	4-4
Q-1	Transistor: 2N3440	48-103-440	4-2
Q-2	Transistor: 2N2484	48-102-484	4-4
Q-3	Transistor: 2N2369A	48-202-369	4-6
Q-4	Transistor: 2N3906	48-103-906	4-6
Q-5	Same as Q-4		4-6
Q-6	Transistor: 2N5194	48-105-194	4-6
Q-7	Transistor: MPS-A13	48-200-013	4-8
Q-8	Same as Q-7		4-8
Q-9	Same as Q-3		4-7
QN-1	Transistor Array: CA 3082	48-303-082	4-8
QN-2	Same as QN-1		4-8
R-1	Resistor: 3.83 K, 1/4 watt, 1%	47-314-249	4-2
R-2	Resistor: 4.53 K, 1/4 watt, 1%	47-314-256	4-2
R-3	Resistor: 680 K, 1/4 watt, 5%	47-102-684	4-2
R-4	Resistor: 10 K, 1/4 watt, 5%	47-102-103	4-2

7.0 TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	GeoMetrics Part No.	Dwg No.
R-5	Resistor: 8.2 K, 1/4 watt, 5%	47-102-822	4-2
R-6	Resistor: 62K, 1/4 watt, 5%	47-102-623	4-2
R-7	Same as R-4		4-2
R-8	Resistor: 100 Ohms, 1/4 watt, 5%	47-102-101	4-2
R-9	Resistor: 300 K, 1/4 watt, 5%	47-102-304	4-2
R-10	Same as R-9		4-2
R-11	Matched Resistor: 87.25 M (50 ppm), 1%	47-328-001	4-2
R-12	Matched Resistor: 688 K (50 ppm), 1%	47-328-001	4-2
R-13	Resistor: 4.3 K, 1/4 watt, 5%	47-102-432	4-3
R-14	Same as R-4		4-4
R-15	Resistor: 43K, 1/4 watt, 5%	47-102-433	4-4
R-16	Resistor: 1.6 M, 1/4 watt, 5%	47-102-165	4-4
R-17	Same as R-15		4-4
R-18	Resistor, Variable: 50 K, Beckman 68WR50K	47-420-503	4-4
R-19	Resistor: 2.21 K, 1/4 watt, 1%	47-315-226	4-4
R-20	Resistor: 402 ohms, 1/4 watt, 1%	47-315-155	4-4
R-21	Resistor: 536 ohms, 1/4 watt, 1%	47-315-167	4-4
R-22	Resistor: 200 ohms, 1/4 watt, 1%	47-315-126	4-4
R-23	Resistor: 100 ohms, 1/4 watt, 1%	47-315-097	4-4
R-24	Same as R-22		4-4
R-25	Resistor: 953 ohms, 1/4 watt, 1%	47-315-191	4-4
R-26	Resistor: 30.1 ohms, 1/4 watt, 1%	47-315-047	4-4
R-27	Same as R-26		4-4
R-28	Resistor: 340 ohms, 1/4 watt, 1%	47-315-148	4-4
R-29	Resistor: 4.99 K, 1/4 watt, 1%	47-315-260	4-4
R-30	Resistor: 2 K, 1/4 watt, 5%	47-102-202	4-4
R-31	Same as R-4		4-4
R-32	Same as R-4		4-4
R-33	Same as R-4		4-4
R-34	Same as R-13		4-4
R-35	Resistor: 360 ohms, 1/4 watt, 5%	47-102-361	4-5
R-36	Resistor: 270 K, 1/4 watt, 5%	41-102-274	4-5
R-37	Resistor: 15K, 1/4 watt, 5%	47-102-153	4-5
R-38	Resistor: 33 K, 1/4 watt, 5%	47-102-333	4-5
R-39	Resistor: 100K, 1/4 watt, 5%	47-102-104	4-5
R-40	Resistor: 330 K, 1/4 watt, 5%	47-102-334	4-5
R-41	Resistor: 1 M, 1/4 watt, 5%	47-102-105	4-5
R-42	Resistor: 2.2 M, 1/4 watt, 5%	47-102-225	4-5
R-43	Resistor: 4.3 M, 1/4 watt, 5%	47-102-435	4-5
R-44	Resistor: 22 M, 1/4 watt, 5%	47-102-226	4-5
R-45	Resistor: 2.7 K, 1/4 watt, 5%	47-102-272	4-5
R-46	Resistor: 13 K, 1/4 watt, 5%	47-102-133	4-6
R-47	Resistor: 200 K, 1/4 watt, 5%	47-102-204	4-6
R-48	Resistor: 6.2 M, 1/4 watt, 5%	47-102-625	4-6
R-49	Same as R-39		4-7
R-50	Same as R-30		4-6

7.0 TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	GeoMetrics Part No.	Dwg No.
R-51	Same as R-30		4-6
R-52	Resistor: 1.5 K, 1/4 watt, 5%	47-102-152	4-6
R-53	Same as R-39		4-6
R-54	Same as R-39		4-6
R-55	Same as R-30		4-6
R-56	Same as R-30		4-6
R-57	Same as R-4		4-6
R-58	Same as R-52		4-6
R-59	Resistor, Variable; 50 ohms, Beckman 68WR50	47-420-500	4-6
R-60	Same as R-59		4-6
R-61	Resistor: 510 K, 1/4 watt, 5%	47-102-514	4-6
R-62	Resistor: 120 K, 1/4 watt, 5%	47-102-124	4-7
R-63	Resistor: 30 K, 1/4 watt, 5%	47-102-303	4-7
R-64	Same as R-18		4-7
R-65	Resistor: 1 K, 1/4 watt, 5%	47-102-102	4-7
R-66	Resistor: 680 K, 1/4 watt, 5%	47-102-684	4-7
R-67	Same as R-66		4-7
R-68	Same as R-39		4-7
R-69	Same as R-39		4-7
R-70	Same as R-9		4-7
R-71	Resistor: 330 ohms, 1/4 watt, 5%	47-102-331	4-8
R-72	Resistor: 130 ohms, 1/4 watt, 5%	47-102-131	4-8
R-73	Resistor, Variable: 10 K, Beckman 68WR10K	47-420-103	4-4
R-74	Resistor: 75.0 K, 1/4 watt, 1%	47-315-373	4-5
R-75	Resistor: 270 ohms, 1/4 watt, 5%	47-102-271	4-2
R-76	Resistor: 6.2 K, 1/4 watt, 5%	47-102-622	4-2
R-77	Thermistor: 5 K (5%) @ 25° KA35J1	53-401-003	4-2
R-78	Resistor, Variable: 100 K, ten-turn	47-501-104	4-2
R-79	Resistor, Variable: 500 K	47-403-504	4-5
RN-1	Resistor Pack: 470-ohm W. L.	47-113-471	4-5
RN-2	Resistor Pack: 10,000-ohm S. L. 1 comm.	47-100-103	4-7
RN-3	Resistor Pack: 330-ohm D. I. L.	47-121-331	4-8
S-1	Switch, Rotary: 4-pole, 6-pos. Grayhill 71ASF30-02-0GN	51-210-030	4-4, 4-5, 4-6, 4-7
S-2	Same as S-1		
S-3	Switch, Pushbutton: Alco MPE-206R	51-308-004	4-7
S-4	Same as S-3		4-7
T-1	Transformer: Microtran, M8050	18-308-050	4-2

7.0 TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	GeoMetrics Part No.	Dwg No.
U-1	Voltage Ref: PMI Ref-01, 10-volt	31-300-001	4-2
U-2	Integrated Circuit: LM308N, op. amp.	31-400-308	4-2
U-3	Integrated Circuit: LM555CN, timer	31-410-555	4-2
U-4	Integrated Circuit: LM318N, high-speed op. amp.	31-400-318	4-4
U-5	Integrated Circuit: National LM319D, high speed dual comp.	31-204-098	4-4
U-6	Integrated Circuit: CD4098	31-204-098	4-4
U-7	Same as U-2		4-5
U-8	Integrated Circuit: CA3140AS, op. amp.	31-203-140	4-6
U-9	Same as U-3		4-6
U-10	Integrated Circuit: LM380M, audio power amp.	31-400-380	4-6
U-11	Integrated Circuit: MC14541BP, osc., timer	31-204-541	4-7
U-12	Integrated Circuit: CD4017, decade counter/divider	31-204-017	4-7
U-13	Same as U-12		4-7
U-14	Same as U-12		4-7
U-15	Integrated Circuit: CD4011, quad. 2-input NAND gate	31-204-011	4-7
U-16	Integrated Circuit: CD4081, quad 2-input AND gate	31-204-081	4-4, 4-7
U-17	Integrated Circuit: CD4002, dual 4-input NOR gate	31-204-002	4-7
U-18	Integrated Circuit: CD4027, dual J-K master/slave flip-flop	31-204-027	4-7
U-19	Same as U-6		4-7
U-20	Integrated Circuit: MC14534BP, five-decade counter	31-204-534	4-8
U-21	Integrated Circuit: CD4511B or MC14511CP, BCD to 7-segment latch, decoder, driver	31-204-511	4-8
U-22	Integrated Circuit: MC1416, 7 Darlingtons	31-401-416	4-8
VR-1	Voltage Regulator: LM340 LAH10, 10 volts	31-410-340	4-2
VR-2	Voltage Regulator: LM309H, 5 volts	31-300-309	4-2
	Components of Divider PCB		
	Resistors: 1.6 M, 1/4 watt, 5%	47-102-165	4-3
	Capacitors: 0.01 μF, 500 volts	15-109-103	4-3
	Diodes: 1N4135	48-404-135	4-3
	Miscellaneous		
	Harness and Holder	16002-03	
	Carrying Case	16003-01	
	Barium Calibration Source	84286-01	

APPENDIX II

RADIOELEMENT ASSAY WITH PORTABLE GAMMA SPECTROMETERS

JUNE, 1977

Introduction

Often the concentrations of uranium, thorium, or potassium of a mineralized area are desired. In geologic mapping the subsurface* and nonobvious surface boundaries of differing rock types can sometimes be located by radiometric assay. In either case a portable gamma spectrometer can save time and effort. For example, a 3" x 3" cylindrical detector can measure in a few minutes 10 parts per million levels of uranium to about 10% accuracy. Larger crystals are used for both search and assay modes where high sensitivities are required.

The counting rates in the spectrometer over specific energy windows can be made proportional to each of the three radioelement concentrations K, U, and T. Unfortunately, each energy window is somewhat influenced by one or both of the other elements. To correct for this effect, each window count rate is first "stripped" of the interference effects of the other elements before being multiplied by the proportionality constant which gives concentrations. This is illustrated by the general equations given below.

Procedures

The GR-310 and GR-410 spectrometers in the digital accumulate mode can obtain accurate count rates for the elements K, U, and T if the detector is placed over a large, flat outcrop or uniform soil area. The spectrometer should be placed approximately 25 cm above the surface. Careful calibration using the internal reference isotope should be performed just before taking data for highest accuracy.

Concentrations in K %, U in parts per million, and T in parts per million are obtained from the following formula:

$$K = \Delta_{KK} (R_K - S_{KU} R_U - S_{KT} R_T)$$

$$U = \Delta_{UU} (R_U - S_{UT} R_T)$$

$$T = \Delta_{TT} (R_T - S_{TU} R_U)$$

* Although gamma rays can penetrate only a foot or so of soil, the soil itself is often characteristic of the subsurface rock type.

The quantities R_K, R_U, and R_T are the count rates in counts per minute corrected for instrument background* for potassium, uranium, and thorium respectively, and the other quantities are constants given below for the various crystals which can be used with the GR-410, and the internal 2" x 2" crystal of the GR-310. The Δ values are the sensitivities and the S_{IJ} values are stripping constants.

Assay Equations (Also see notes a through d - pages 4 and 5)

GR-310 (INTERNAL 2" X 2" CRYSTAL)

$$K\% = 0.016 \quad (R_K - 1.32\,R_U - 0.1\,R_T)$$

$$U_{ppm} = 0.217 \quad (R_U - 0.83\,R_T)$$

$$T_{ppm} = 0.467 \quad (R_T - 0.089\,R_U)$$

GR-410 AND GPX-21 (3" X 3" CRYSTAL)

$$K = 0.00632 \quad (R_K - 0.846\,R_U - 0.57\,R_T)$$

$$U = 0.0591 \quad (R_U - 0.682\,R_T)$$

$$T = 0.163 \quad (R_T - 0.033\,R_U)$$

GR-410 AND GPX-112 (4" X 4" X 7" CRYSTAL)

$$K = 0.00133 \quad (R_K - 0.745\,R_U - 0.31\,R_T)$$

$$U = 0.0139 \quad (R_U - 0.61\,R_T)$$

$$T = 0.0376 \quad (R_T - 0.03\,R_U)$$

GR-410 AND GHX-256 (4" X 4" X 16" CRYSTAL

$$K\% = 0.000467 \quad (R_K - 0.648\,R_U - 0.086\,R_T)$$

$$U = 0.00510 \quad (R_U - 0.378\,R_T) - \quad \beta - \gamma\alpha$$

$$T = 0.00974 \quad (R_T - 0.05\,R_U)$$

$\gamma\alpha = .244$ $\alpha = 1.378$ $\beta = .330$ $\gamma = .648$

* Instrument background can be obtained by taking data over water or other low background medium. See "Geological Applications Manual for Portable Gamma Ray Spectrometers."

All counting rates are in counts per minute. If counts per second are used multiply the constant in front of the bracket by 60 for each equation.

The constants were determined at near ground level over the Energy Research and Development Administration (ERDA) test pads in Grand Junction, Colorado. Four pads of differing concentrations were used to establish a "best fit" set of sensitivities and stripping constants. The fresh, wet concrete samples of each pad were used by ERDA to determine the "standard" pad concentrations. Pad dimensions are 30 feet x 40 feet. A fifth "matrix" pad was also used to remove all effects of air, instrument, and concrete background.

Sources of Error

The errors in the radiometric assay method described are mainly due to the following factors (in approximate order of most significant first):

1) Spatial geometry not quite similar in size and shape to test pad configuration. Typical error ± 10%.

2) Surface moisture variations give errors of ± 10%, but may sometimes cause as much as ± 20%.

3) Nonprecise setting of windows in spectrometer or lack of accurate gain calibration. Typical error ± 5%.

4) Errors in the determination of the sensitivity and stripping constants. Typical error ± 5% for stripping constants, and ± 1% for the sensitivity values.

5) Incomplete instrument background removed. (Significant only for lowest ppm ranges 1 to 2 ppm U.) Typical error at 10 ppm, + 5%.

6) Gamma counting statistical error of the counting rates R_K, R_U, R_T. These errors can be made as small as ± 1% by obtaining 10,000 counts or more to determine the rate numbers. For example, at 600 cpm in a given channel approximately 20 minutes of counting time results in 12,000 counts or better than 1% accuracy. The errors in K, U, and T concentrations will depend on the propagation of error from each of the counting rate errors ΔR_K, U, T.

7) At high counting rates, greater than 60,000 cpm, system deadtime corrections should be made to determine the true counting rates by dividing the observed rate by $(1 - D R_0)$ where D is the deadtime for the spectrometer; 10 μs for the GR-410; 3μs for the GR-310. Thus, for R_0 = 10,000 cps (600,000 cpm) the observed rate gives a corrected rate of 11,110 counts in the case of the GR-410, and 10,309 counts corrected in the GR-310.

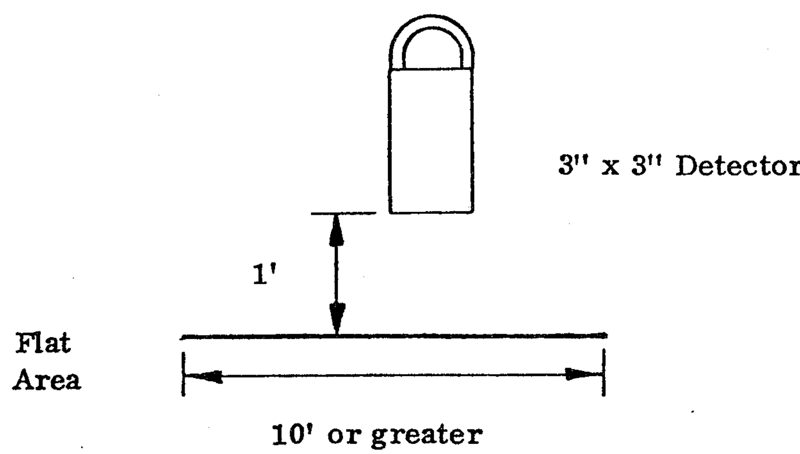
Notes

a) In most cases it is not necessary to remove the small counting rates introduced by background sources in the instrument and surrounding air.

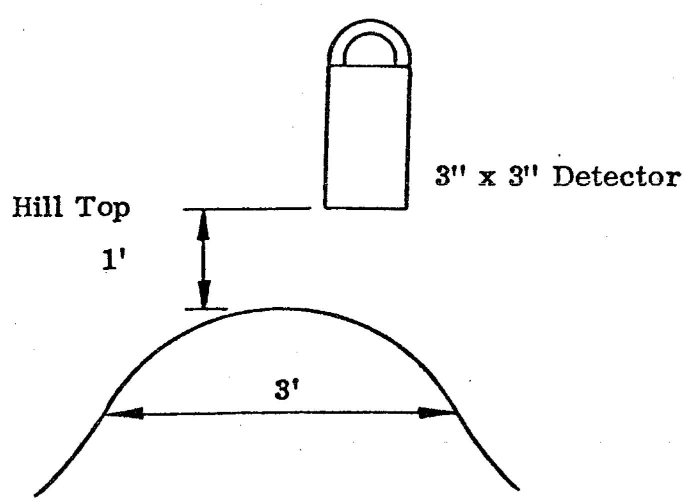
b) Notes taken or small drawing of the instrumental geometry can be used to make partial corrections for non standard geometry.

c) Approximate corrections for various geometries:

Solid Angle
2π Steradian



Use constants as given.

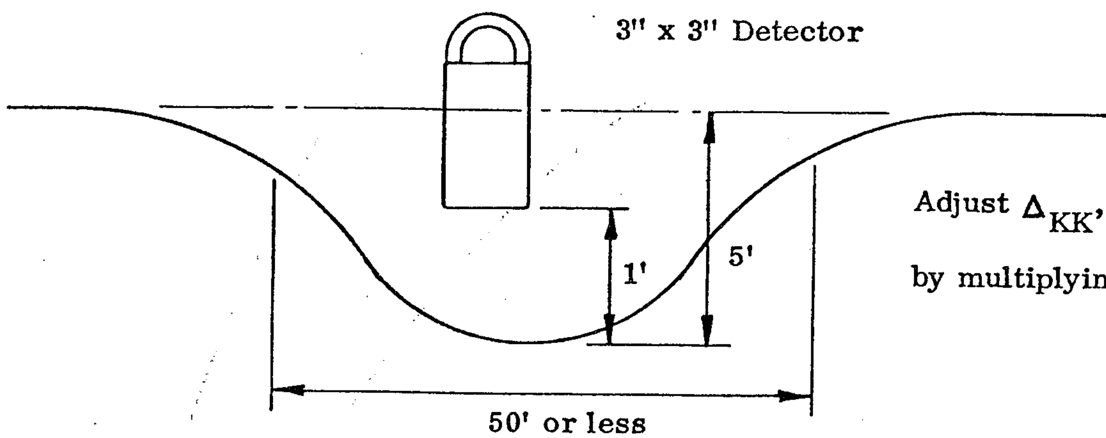


$2/3\,(2\pi) = \frac{4\pi}{3}$ Steradian

Adjust Δ_{KK}, Δ_{UU}, Δ_{TT} constants by multiplying by 1.5

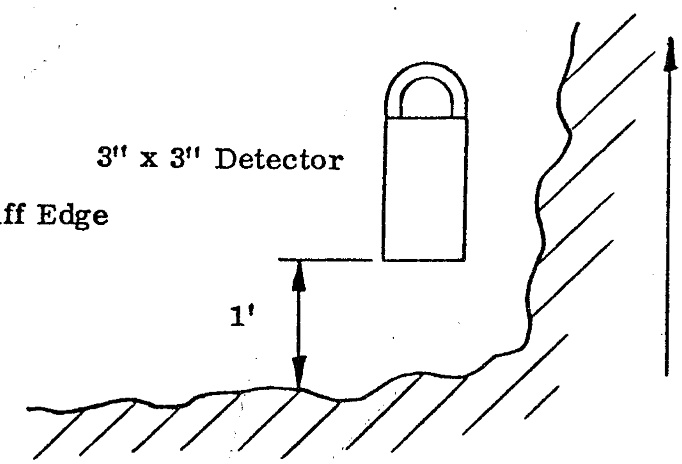
Valley

4/3 (2π)



Adjust Δ_{KK}, Δ_{UU}, Δ_{TT} by multiplying by 0.75

Cliff Edge



5' or greater

Solid Angle
3/2 (2π)

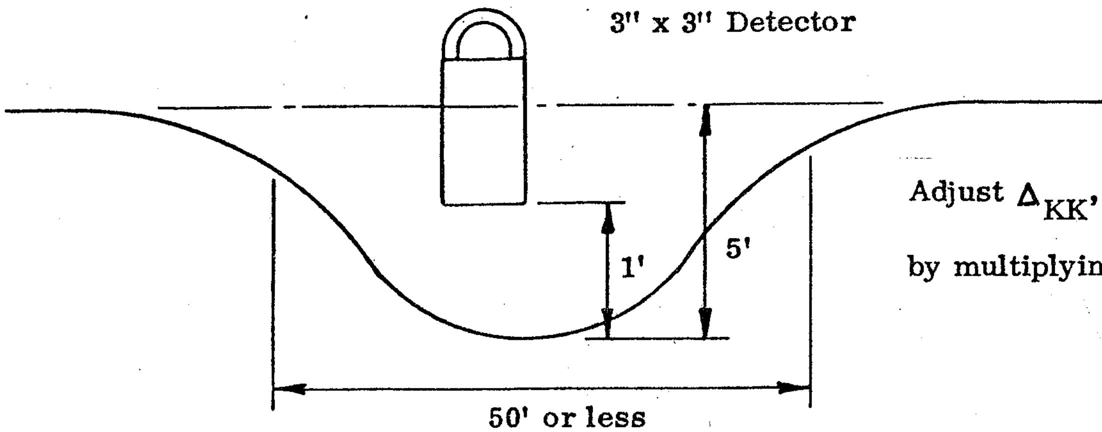
Adjust Δ_{KK}, Δ_{UU}, Δ_{TT} by multiplying by 0.666

d) All parameters in the assay equations are given for the standard windows of the GR-310 and GR-410.

These are:

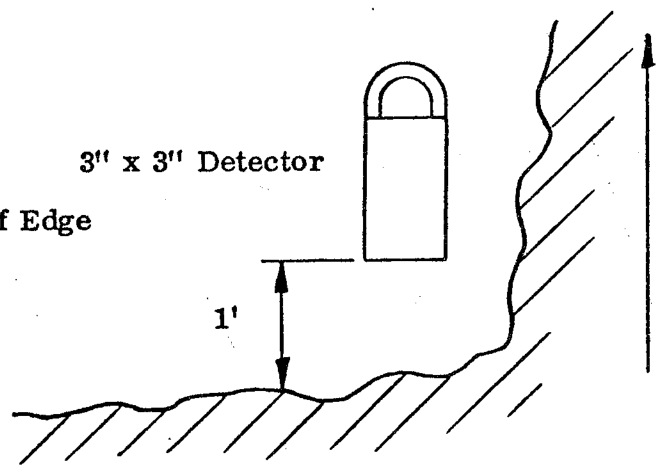
	K	1.36 to 1.56 MeV
	U	1.66 to 1.86 MeV
	T	2.42 to 2.82 MeV

Valley $\qquad$ 4/3 (2π)



Adjust Δ_{KK}, Δ_{UU}, Δ_{TT}
by multiplying by 0.75

Cliff Edge



Solid Angle
3/2 (2π)

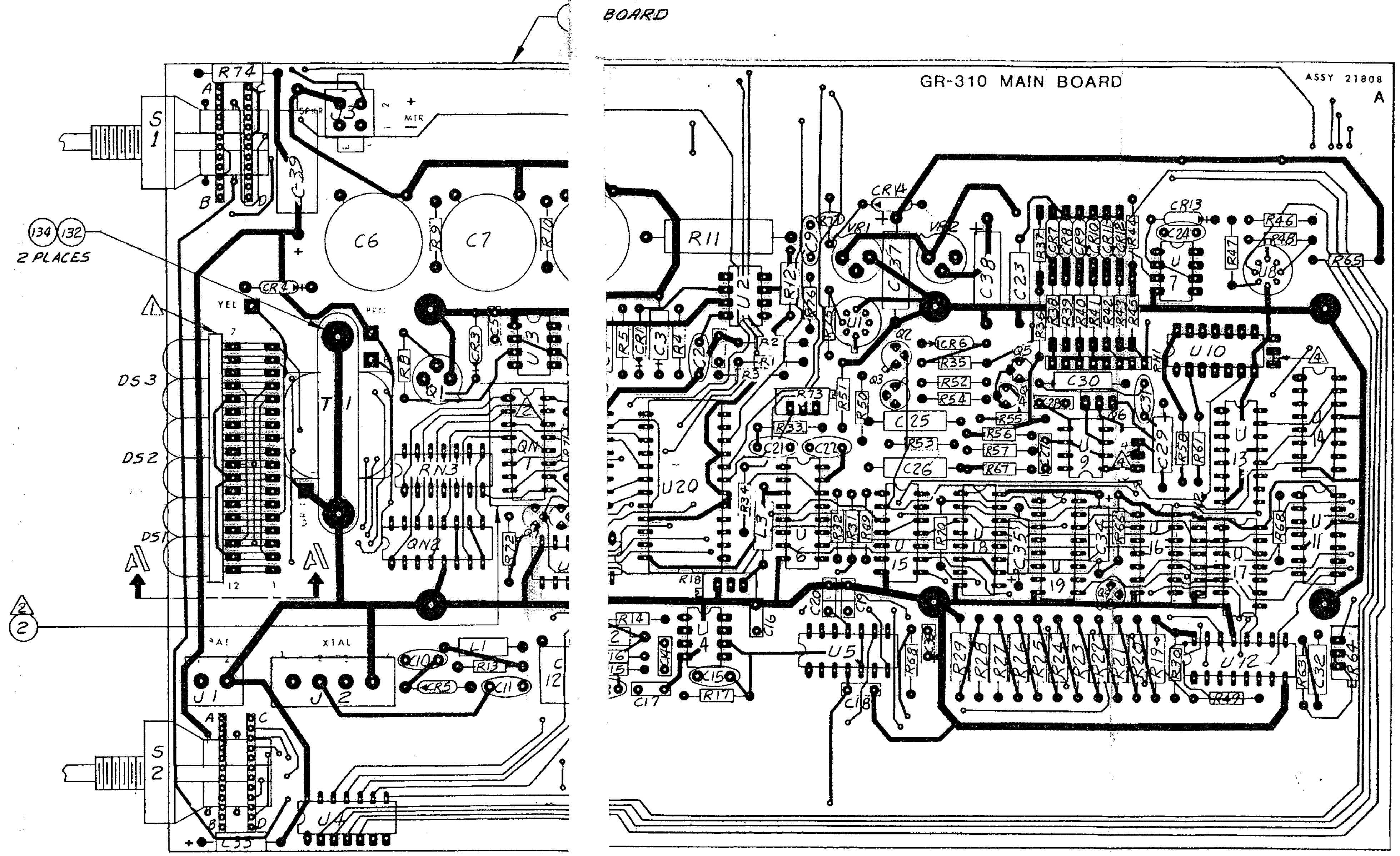
Adjust Δ_{KK}, Δ_{UU}, Δ_{TT}
by multiplying by 0.666

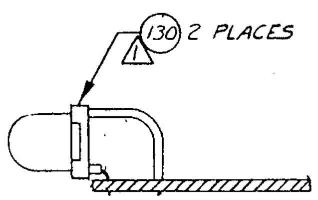
d) All parameters in the assay equations are given for the standard windows of the GR-310 and GR-410.

These are:	K	1.36 to 1.56 MeV
	U	1.66 to 1.86 MeV
	T	2.42 to 2.82 MeV

LTR	E.O. NO.	DESCRIPTION	DATE	APP'D
A		PRODUCTION RELEASE # 58	3.23.78	B.S.
B	600	REV PER ECO	7.19.78	B.S.

REVISIONS





SECTION A-A

NOTES:

1. SIDES OF SOCKETS TO BE SHAVED OFF 1/32" SO THAT SOCKET ASSEMBLES AS SHOWN (BOTH ENDS OF EACH SOCKET). DISPLAYS TO BE INSTALLED SO THAT THE 5 PIN SIDE OF THE DISPLAY IS AWAY FROM THE P.C. BOARD.
2. CEMENT HEATSINK (ITEM 2) TO TOP OF QN1 USING LOCTITE # 430 OR EQUIV. JOINED SURFACES TO BE THROUGHLY CLEANED WITH ACETONE BEFORE CEMENTING.
3. REF SCHEMATIC 21802.

4. JUMPER AS SHOWN

NEXT ASSEMBLY: 21806	USED ON: 310	APPLICATION
UNLESS OTHERWISE NOTED: 2 PLC ± / 3 PLC ± / ANGLE ±	REMOVE BURRS & SHARP EDGES	SURFACE FIN ✓
MATERIAL: SEE MAT'L LIST	FINISH:	DO NOT SCALE THIS DRAWING
SIGNATURE DFT: RB	DATE: 4/20/7?	CHECK / APP'D / APP'D

geoMetrics, Sunnyvale, California

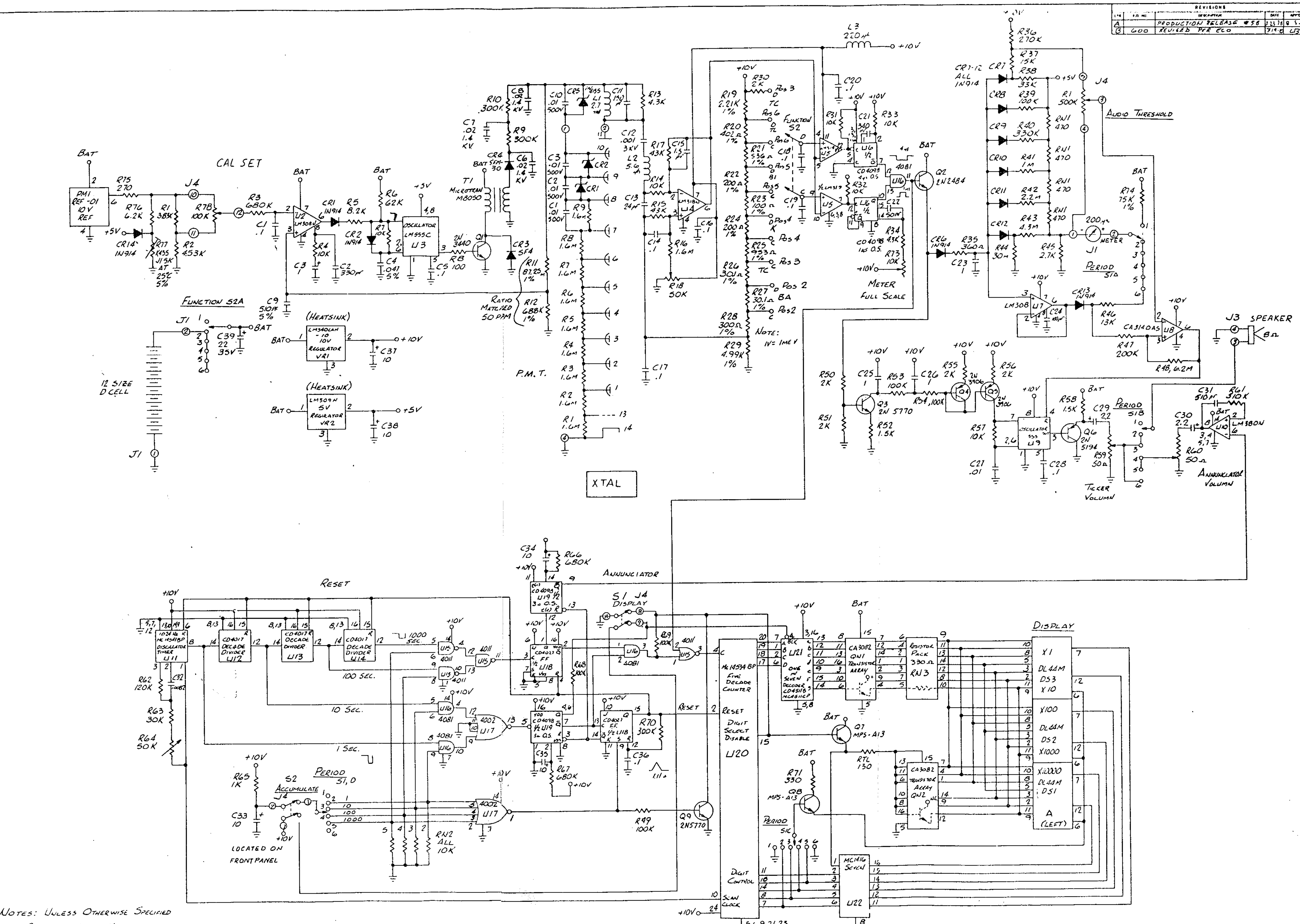
PCB ASSY MAIN BOARD

SIZE	CODE IDENT NO.	DRAWING NUMBER	REV.
D	GR 310	21808	B

SCALE 2/1 SHEET 1 OF 1

21808

LTR	ECO NO.	DESCRIPTION	DATE	APPD
A		PRODUCTION RELEASE #58		
B	600	REVISED PER ECO		



Notes: Unless Otherwise Specified

1. Resistors 1/4W 5%.
2. Capacitors Are In Microfads.
3. Referance Assy's 21808, 21810.

Ref: 21808
Main P.C. BD. Assy.

geoMetrics

SCHEMATIC SPECTROMETER

Size: E | Code Ident No.: GR310 | Drawing Number: 21802 | Rev: B

Material: See LM.